THE INDIAN JOURNAL OF TECHNICAL EDUCATION

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Editorial

Sustainable Development: In today's fast-changing world, engineering and sustainable development are inextricably connected. This combination has the potential to bring about innumerable remarkable transformations in the entire world. We should focus our efforts on identifying and implementing sustainability targets that require immediate and focused attention. Recognizing the importance of sustainability and its components, making meaningful success on this front will be extremely useful and enriching for humanity as a whole. Sustainable development has many components that must be understood in terms of engineering and applications. Many technical applications can be efficiently used to achieve sustainability goals.

Engineering research is vital for achieving ambitious objectives and aspirations for the future. Governments, scientific and educational institutions, corporate entities, civic society, and individuals worldwide must all work together to bring about major progress. We need to evaluate the overall impact of attaining sustainability across all stakeholders.

The response to these projects indicates academics' and researchers' commitment to sustainable development and ensuring that everyone lives in a fair and clean future. Ensure that, the eminent scientists, engineers, educators, and business leaders are committed to sustainable development. In order to attain global sustainable development, it is necessary to take into the account of numerous obstacles, situations, and choices that affect the opportunities and prosperity for everyone, everywhere.

The United Nations' efforts on Sustainable Development have been recognized and embraced by many organizations in their daily operations. Research on sustainability aims to take a holistic approach to the financial, environmental, and social aspects of sustainable development, empowering and equipping future generations to meet their requirements. Several discourses have arisen around the concept of sustainable development, each promoting distinct sociopolitical objectives. Researchers investigating global environmental governance discovered that public discourses primarily represent four sustainability frames: radical sustainability, constraints discourse, mainstream sustainability, and progressive sustainability. We must work to make the Earth sustainable and habitable for everyone.

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A Survey on Design and Implementation of Quantum Computing Circuit Optimization using Qiskit

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ABSTRACT

Recent interest has been gained by the field of quantum computing, which is a groundbreaking discipline derived from quantum mechanics and computer science, thanks to its potential to bring a new way of computing. This survey is an attempt to show how a field like Quantum Computing (QC) came into being, besides its utility in the field for those who want to go into it. Firstly, we would like to throw light on the very fundamental principles of quantum computing; based on that we shall conduct the readers through the main concepts of qubits, the concepts of power of interference, superposition, entanglement, noise, and of course, the quantum noise. We deal with the introduction of quantum hardware and quantum gates for this research work. In this research work, in a particular, deals with the present phases of QC includes (NISQ) focuses on to solve real-life problems. Apart from this, we assure you to gain insight into the design of quantum methodology and their realization in the applications area. We place emphasis on methods like Shor's algorithm and Grover's algorithm. Furthermore, we also provide an explanation of the impact of QC on different fields such as Material Science, Machine Learning (ML), encryption, and optimization concerns. Reading this paper would enable people to learn the fundamentals and implement them in a practical context along with the process of quantum circuit development. We are striving to become an irresistible source of information for folks who want to attract updates on this fast-changing subject and for new explorers of quantum computing.

KEYWORDS : Quantum computing, Quantum methodology, Quantum gates, Qiskit, etc.

INTRODUCTION

QC is expected to be a next-order change in the computational power, hitherto not found by classical computers, to find the solution of an ultrahard problem—it can even create new unknown worlds. Primarily founded on quantum mechanics and QC uses advanced phenomena like superposition and entanglement to deploy data in very peculiar ways that no classical computer can do the same. This evolution also means laying the stage for areas such as cryptography, pharmaceuticals, artificial intelligence, and material science. At its core, QC influences the ethics of quantum mechanics—specifically, entanglement and superposition—to procedure data in such different ways rather than classical computers which cannot be replicate. To understand QC, it is essential to grasp the concepts of superposition and entanglement. In classical computing, bits are the fundamental units of data, and they can exist in one of two states: 0 or 1. QC,

however, uses quantum bits or qubits. Thanks to the phenomenon of qubits and superposition can occur in a combination of both 0 and 1 states simultaneously. This permits QC to perform many calculations in parallel, vastly increasing their processing power.

Qiskit is a quantum-information science kit developed by IBM and can be considered a standard in quantum computation. This open-framework provides researchers and developers with virtual design tools for process simulation and the execution of quantum circuits. Use of Qiskit in the practice allows students to learn the theory related to laboratory research work and quantum computing practice. It also supports the integration of high-level quantum hardware into hardware platforms. It provides a platform for researchers, developers, and students to design, simulate, and execute quantum circuits. As one of the most widely used frameworks in the quantum computing community, Qiskit is essential for those looking to explore and develop quantum algorithms.

In the current research, we are tending to discuss how the design and implement using Qiskit for quantum algorithms, to make errors. We explain salient features of quantum computing from basics to the features and architecture of the Qiskit. More specifically, we explain concrete applications of quantum computing—especially when illustrating quantum methodology, like the Grover search algorithm and the Shor factoring algorithm.
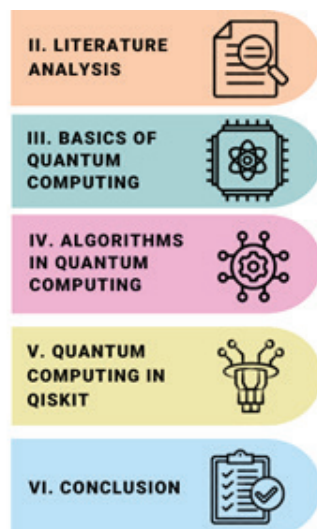
Fig. 1. Section of this Paper

This paper, whether you are a scientist, teacher, or developer, must become a quite useful tool of exploration of the quantum computer along with its scope through Qiskit. To illustrate further what Qiskit is capable of, we implement a few different quantum algorithms: Grover's search algorithm, an specimen of the power of quantum parallelism, and Shor's factoring algorithm, pointing out the possible of quantum computers to breakdown classical cryptographic systems. This will further show the real-life applications of quantum computing and what part Qiskit plays in opening this up to a wider audience.

LITERATURE ANALYSIS

Quantum computing is one of the interdisciplinary areas of study basically compiling its fundamental principles from quantum mechanics, computer science, and information theory in constructing a new model of computation. Researchers and practitioners alike have

From the different aspects of quantum computing, ranging from foundational principles and algorithmic advancements

from theoretical explanation to practical implementation within quantum technologies. Whereas in classical computing the bits can take only 0 or 1 values, in quantum computing qubits may assume a superposition-taking both states 0 and 1 simultaneously. The contributions to quantum computing, from theoretical foundations to practical implementations, have profoundly shaped the research landscape. Today, QC is a vibrant and quickly growing field, with significant investments from academia, industry, and government agencies. Research is increasingly interdisciplinary, drawing on expertise from physics, computer science, mathematics, and engineering to solve complex challenges.

This section highlights some of the key contributions in the area, with particular emphasis on how these evolved and contributed to shaping the quantum computing research landscape as depicted in Table 1. Typically provide a summary of key contributions, categorized by their impact on the field. It might include landmark papers, significant algorithmic advancements, major hardware developments, and milestones in quantum error correction. Also, a tabular summary would highlight how each contribution has influenced subsequent research and helped shape the existing state of quantum computing.

Table 1. Literature Work

References	Basic Concepts	Keywords	Claim by Authors
Muhammad Ali Shafique, Arslan Munir, Imran Latif [1] [2024]	Quantum computing uses the concept of quantum bits (qubits), principles of entanglement and superposition to achieve the complex calculations which more efficiently than classical computers.	Quantum computing, entanglement, interference, quantum circuits, quantum algorithms, quantum applications.	It provides a comprehensive guide to QC, covering important principles, key technologies, and applications, to serve as a valuable resource for both beginners and experts in the field.
Prateek Singh, Ritangshu Dasgupta, Anushka Singh, Harsh Pandey, Vikas Hassija, Vinay Chamola, Biplab Sikdar [2] [2024]	Quantum computing influences the principles of quantum mechanics to perform complex computations at unprecedented speeds, enabling advances in fields like cryptography, materials science, and artificial intelligence.	Quantum revolution, quantum algorithm, quantum gates, quantum programming language, quantum simulators	In recent improvements in quantum computing tools and technologies have transformed the field from theoretical concepts into practical applications, driving significant research and innovation.
Brijesh Kumar Awasthi [3] [2024]	Quantum computing explores the potential of quantum mechanics to revolutionize data processing, using qubits and principles like entanglement and superposition to solve complex problems more efficiently than classical computers.	Qubits, Superposition, Entanglement, Quantum Algorithms, Quantum Hardware, Quantum Error Correction, Quantum Programming Languages, Quantum Mechanics	Quantum computing as a transformative field that has the potential to revolutionize computation and offers a comprehensive guide to understanding its fundamental principles, technologies, and applications, making it accessible to both enthusiasts and professionals.
Kawino Charles [4] [2024]	Quantum computing, integrating quantum mechanics with computer science and engineering, offers new approaches to mathematical optimization, comparing classical and quantum optimization algorithms and discussing their potential for achieving quantum speedup	Mathematical Optimization, Quantum Annealing, Quantum Approximate Optimization Algorithm (QAOA), Classical Algorithms, Global Optimization, Variation Algorithms, NISQ Computers.	No general quantum algorithm currently provides a speedup for all global optimization problems, quantum approaches show transformative potential for certain classes of optimization problems.
Mr. Pradeep Nayak, Sudeep Rathod, Surabhi, Sukanya [5] [2024]	Quantum computing integrates principles from quantum mechanics with computer science to solve complex problems using qubits and quantum algorithms, offering potential breakthroughs in computation and practical applications.	Quantum Computing, Qubits, Quantum circuits, Noise Measurement.	It provides a comprehensive guide to quantum computing, covering foundational concepts, key technologies, and practical applications, to attend as a valued resource for both newcomers and those seeking to stay updated in the rapidly evolving field.

Our work [2024-2025]	Current Survey based on recent design and implementation of combinations of algorithms or a single algorithm by analysis optimize circuit to solve either complex problem as well as simple by taking frequency of Quantum Circuit under Qiskit	Quantum Computing, Quantum Circuits, Quantum Algorithms, Quantum Gates, Qiskit, etc.	Creating Combinational Algorithms under a new optimalization quantum circuit by taken as particular frequency to solve a particular problem under Qiskit

The literature is replete with many review papers, which have registered a considerable contribution in quantum computing. Such papers have made an in-depth investigation of many technical topics like quantum neural networks, quantum machine learning, quantum algorithms, quantum distributed networks, lots of the related topics. The major drawback concerning most of the papers that have taken up this topic is that they are, without a doubt, very indeed technically and complexly difficult or most of the papers do not discuss the most involved topic part. new advances. Also, most of the literature available on this subject is written mainly for readers who either belong to the field of the physics or computer engineering department. This leaves a gap for readers. This survey has taken into consideration the above points and thus will cover topics from basics with the use of figures and tables to understand better. No prerequisites are required for reading this paper. It gives an overview of the different tools and technologies enabling quantum computing and its applications. This paper tries to highlight some important advances in quantum computing while providing helpful hints on where to go next for the interested reader.

BASICS OF QUANTUM COMPUTING

The present section introduces the elementary principles of quantum mechanics necessary to understand QC. It addresses very briefly some basic principles like superposition, entanglement, and quantum interference that confer upon quantum systems their peculiar properties. One should discuss here properties of the qubit, quantum gates and circuits, quantum algorithms and qubit technologies. FIGURE II illustrates the multi-layered process architecture of a quantum computer.

Conceptual Architecture of Quantum Computing

Conceptual architecture in the theory of quantum computing is designed to include the problems and possibilities brought in by quantum mechanics. This, in turn, enables quantum computers to perform such computations that, if attempted on a classical computer, would result in inefficiency. This architecture can be further divided into a number of key layers responsible for various things with respect to quantum computation:

Physical Layer

i)   Qubits: The quantum bits (information units), qubits, are the building blocks of quantum information and can exist in superpositions of states (Both 0 and 1 simultaneously) as well as be entangled with other qubits.

ii) Quantum Gates: These are operations that manipulate the state of qubits in a similar way to classical computing's logic gates. The quantum gates that are the basic operations of a quantum computer are the Pauli-X, CNOT, Hadamard gate and others. This makes it possible for the implementation of quantum algorithms.

iii) Control and Readout: This part involves the physical means by which we can control qubits (e.g. applying microwaves in superconductor qubits) and also read out their states, which usually needs advanced quantum-limited amplifiers.
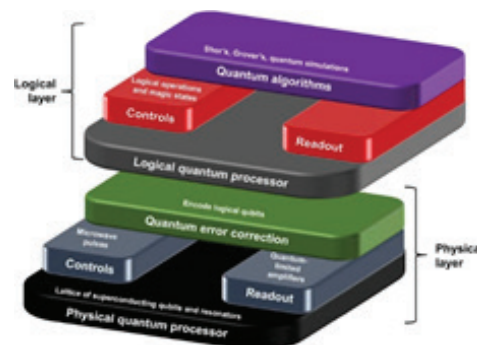
Fig. 2. Conceptual Architecture Of Quantum Computing

iv) Quantum Error Correction Layer:

1) Error Correction Codes: Quantum systems are prone to errors because of decoherence and noise. Therefore, such systems should have error correction circuits in place as a countermeasure. The first part of this layer encodes logical qubits into physical qubits by using error-correcting codes such as the surface code to protect against quantum noise.

2) Fault-Tolerant Operations: It is assured that quantum computations are resilient to errors and quantum algorithms are mitigated from noise impacts by a mechanism known as the error correction circuit.

Logical Quantum Processor Layer

i) Logical Qubits: They are qubits that are corrected by error correction, and are that way used for quantum computation with higher comfort than previously. Logical qubits make up the primary constructs for realizing greater level quantum operations at us.

ii) Logical Operations: This covers the processing of quantum gates and circuits using logical qubits. These processes are engineered to be able to cope even during the exposure to certain level of noise and errors that are inherent in operating systems.

iii) Quantum Circuits: Quantum circuits are a sequence of quantum gates similar to those of classical logic circuits. They specify the manner in which qubits interact and transform throughout the quantum computation process.

iv) Quantum Algorithms Layer:

1) Quantum Algorithms: These are the algorithms explicitly formulated to run on quantum computers, taking the benefit of quantum superposition, entanglement, and interference. Besides these, there are quantum simulation algorithms for modeling quantum systems.

2) Quantum Simulation: QC can be used to simulate quantum systems, which are very hard to model using classical computers, and so the applications are in chemistry, material science, and physics.

ALGORITHMS IN QUANTUM COMPUTING

Quantum algorithms are specific sets of commands tailored for execution on quantum computers. Quantum algorithms rely on the development principles regarding quantum gates and circuits, which allow the manipulation of quantum information residing in qubits. Shor's algorithm, one of the most well-known quantum algorithms, efficiently solves the factorization problem. Since most common encryption schemes, like RSA, rely for their security on the hardness of this factorization problem for large integers, this problem is of crucial importance in cryptography. Shor's algorithm can factor large integers exponentially faster than the best-known classical algorithms, hence a quantum computer running Shor's algorithm would be able to break many current cryptosystems.

Another instance is Grover's algorithm, which offers a two-fold increase in speed for searching unsorted databases. This algorithm exhibits potential uses in various fields like optimization and data analysis. Many researchers are committed to leveraging the powers of quantum algorithms in devising ways of assessing their implications in various problem domains. Few examples of quantum algorithms together with the sort of problems they are intended to solve, are presented in Table 2.

Table 2. Quantum Algorithms

Quantum Algorithm	Description	Type Of Problem	Key Applications	Quantum Advantage
Shor's Algorithm	Efficiently factors large integers, which is classically hard (e.g., RSA).	Factoring, Integer Factorization	Cryptography, particularly breaking RSA encryption	Exponential speedup over classical factoring algorithms.

Grover's Algorithm	Provides a quadratic speedup for unstructured search problems.	Unstructured Search	Database search, optimization problems	Quadratic speedup: Finds a target item in $O(\sqrt{N})$ time.
Quantum Fourier Transform (QFT)	Converts a quantum state to its frequency domain representation.	Signal Processing, Period Finding	Basis for many quantum algorithms, including Shor's	Exponential speedup in Fourier transforms operations.
Quantum Phase Estimation (QPE)	Estimates the eigenvalue of a unitary operator.	Eigenvalue Estimation	Finding eigenvalues, quantum simulation	Essential for many quantum algorithms, including Shor's.
Quantum Approximate Optimization Algorithm (QAOA)	Approximates solutions for combinatorial optimization problems.	Combinatorial Optimization	Optimization, machine learning	Provides good approximations with fewer qubits.
Quantum Simulations	Simulates quantum systems to study their properties and dynamics.	Quantum System Simulation	Quantum chemistry, material science	Exponential speedup in simulating quantum systems.

QISKIT IN QUANTUM COMPUTING

Quantum computing, with Qiskit, provides a set of full, open-source tools for manipulating quantum computers. Target users for Qiskit include novice and advanced users who want to develop and run quantum programs at different levels of abstraction. Qiskit, developed by IBM, is a quantum computing framework that is open-source and enables users to design, test, and execute quantum circuits on both simulators and real quantum devices. It consists of a range of parts that will enable users to engage with quantum algorithms, quantum circuits, and quantum hardware.

COMPONENTS OF QISKIT

i) Qiskit Terra: This provides the foundation for Qiskit-Terra. Users are allowed to create quantum circuits, define their custom gates, and manage quantum programs. It provides the necessary tools to compile and optimize circuits for different quantum hardware.

ii) Qiskit Aer: An efficient emulator of quantum circuits operating in a traditional setting. It enables the user to simulate noise models for testing and seeing how circuits would behave on real quantum devices. These simulators could model ideal quantum devices but also realistic noisy and erroneous quantum devices, which users can use

to optimize the performance of their circuits and inform them as to how noise may affect results..

Fig 4. Components of Qiskit

iii) Qiskit Ignis: This package focuses on quantum error correction and noise characterization. It has tools that allow the understanding, mitigation, and correction of errors in quantum computations.

iv) Qiskit Aqua: A collection of quantum algorithms and applications for chemistry, optimization, machine learning, and finance. Such a library makes it easy to apply quantum algorithms toward solving real-world problems.

v) Qiskit IBM Quantum: This now grants access via the cloud to quantum hardware by IBM to run one's quantum circuits on real quantum devices.
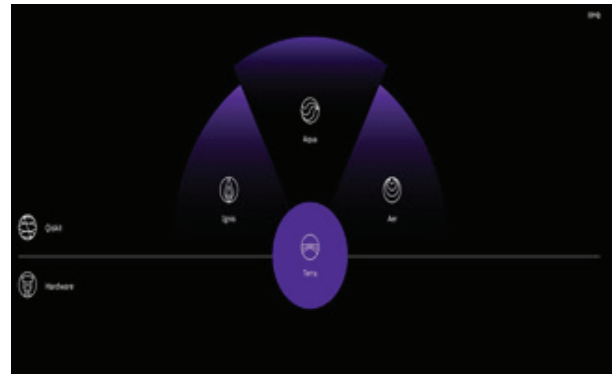
CONCLUSION

In conclusion, this survey paper provides an overview of technology that is still in the experimental phase but it has the potential to be transforming to the various fields. These fields include cryptography, materials science, optimization, and artificial intelligence. Using the Qiskit, the researcher and developer can find, simulate, and instantiate the quantum algorithms. Many of the obstacles which are naturally there in quantum computing can be bypassed with quantum computing. Meanwhile, there are big challenges, especially in the areas of quantum error correction, scalability, and noise management which are not to be neglected. Finding solutions to these issues will demand multiple actions including quick thinking in the realm of quantum computing, a task that cannot be achieved without advances in both quantum hardware and software, as well as the development of new quantum algorithms that can effectively utilize actual quantum processors.

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Equation-Centric Paradigms: Mathematical Models for Advanced System Dynamics and Control

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ABSTRACT

This comprehensive exploration delves into the forefront of control systems engineering, examining equation-centric approaches with a focus on Sliding Mode Control (SMC) and Proportional-Integral-Derivative (PID) control. The analysis involves a meticulous evaluation of their robustness, tracking accuracy, adaptability, and implementation complexity. SMC's inherent robustness, particularly in handling uncertainties and disturbances, contrasts with PID's adaptability and simplicity. Domain-specific comparative studies across aerospace, robotics, industrial automation, power systems, and biomedical engineering illuminate the nuanced advantages and challenges of each approach. Identifying optimal strategies necessitates a holistic view, considering system dynamics, disturbance characteristics, and implementation constraints. The analysis explores hybrid approaches, advanced PID variants, and the integration of machine learning techniques, such as reinforcement learning, into control strategies. Model Predictive Control (MPC) and the evolving landscape of equation-based techniques contribute to the ongoing quest for optimal control solutions. The findings emphasize the importance of tailoring control strategies to specific requirements, prompting continual advancements in the field. As technology evolves, the integration of innovative techniques is anticipated, further shaping the landscape of optimal control in diverse applications.

KEYWORDS : *Model Predictive Control, PID, Sliding mode control, Equation-Centric.*

EQUATION-CENTRIC APPROACHES

Equation-centric approaches play a pivotal role in the field of control systems and system dynamics, providing a rigorous and structured framework for modeling, analysis, and control. This overview delves into the significance of equation-centric paradigms, focusing on their fundamental principles, applications, and the integration of SMC & PID control. [1]

Equation-Centric Foundations

At the core of equation-centric approaches lies a mathematical description of the system dynamics. These equations encapsulate the relationships between different variables, offering a concise and precise representation of the underlying processes. Whether describing the motion of a robotic arm or the temperature dynamics of a chemical reactor, equations serve as the language through which control strategies are formulated and analyzed.

The fundamental element of equation-centric modeling focuses on dynamic equations that describe the behavior of a system. These equations may be expressed in a general form as:

$$F(x,u,t) = 0$$

Here, x represents the state variables, u denotes the control input, and t is time. F encapsulates the dynamic relationships governing the system.

Sliding Mode Control (SMC)

One prominent equation-centric paradigm is Sliding Mode Control (SMC), renowned for its robustness

in the face of uncertainties and disturbances. The fundamental concept of SMC involves creating a sliding surface, representing the deviation between the desired and actual states. The control law is formulated to drive the system along this sliding surface, ensuring that it remains robust to disturbances. The key equation governing SMC is the control law, where the control input is a combination of proportional and derivative terms. This equation encapsulates the essence of SMC and forms the basis for its successful application in diverse fields, from aerospace to manufacturing. [2-3]

The core equation of SMC is the control law, expressed as:

$$u_{\text{SMC}} = -k \cdot \text{sign}(s) + kd \cdot s$$

In this equation, u is the control input, k is the sliding mode control gain, s is the sliding surface, and kd is the derivative gain.

Proportional-Integral-Derivative (PID) Control

Another cornerstone of equation-centric control is PID control. The PID controller is defined by three parameters – proportional, integral, and derivative gains – each contributing to the overall control action. The PID equation captures the dynamic interplay between the error, its integral, and derivative, allowing for the fine-tuning of the controller's response. PID control finds widespread use due to its simplicity, effectiveness, and versatility. The equation-driven nature of PID control facilitates its implementation in various systems, from household thermostats to complex industrial processes.

The PID control equation is given by:

$$u_{\text{PID}} = K_p \cdot e + K_i \cdot \int e\,dt + K_d \cdot \frac{de}{dt}$$

Here, e represents the error, Kp, Ki, and Kd are the proportional, integral, and derivative gains, respectively.

Integration of SMC and PID

Recognizing the strengths of both SMC and PID, researchers have explored the integration of these two approaches. The equation that results from this fusion combines the sliding mode control law with the proportional, integral, and derivative terms of PID control. This integrated equation-centric strategy

aims to leverage the robustness of SMC along with the stability properties provided by PID, offering an enhanced control paradigm that can adapt to a wide range of scenarios. [4]

Combining SMC and PID involves merging their control laws:

$$u_{\text{total}} = -k \cdot \text{sign}(s) + kd \cdot s + K_p \cdot e + K_i \cdot \int e\,dt + K_d \cdot \frac{de}{dt}$$

This integrated equation incorporates the robustness of SMC and the stability features of PID.

Significance of Mathematical Models in System Dynamics

The significance of mathematical models in system dynamics is intimately tied to their ability to formulate complex relationships through equations, providing a quantitative framework that enhances our understanding, prediction, and control of dynamic systems.

Formulation of System Equations: The core significance lies in the translation of real-world phenomena into mathematical equations. Consider the general form of a dynamic system equation:

F(x,u,t)=0

Here, F encapsulates the intricate relationships between state variables x, control inputs u, and time t. This equation succinctly represents the essence of a system's behavior, enabling a deeper understanding of its dynamics.

Prediction and Analysis through Equations: The power of mathematical models lies in their ability to predict system behavior under varying conditions. Equations facilitate simulations, allowing us to analyze and anticipate how a system will evolve over time. For instance, in a control system, the equation governing the system dynamics enables the prediction of the system's response to different control inputs. [5]

Control Design Guided by Equations: Mathematical models provide the basis for designing control strategies, with control laws often expressed as equations. In a PID controller, for example, the equation defines the control

input u in terms of the error e and its derivatives. These equations guide the design and tuning of controllers for effective regulation and stabilization of systems.

$$U = K_p \cdot e + K_i \cdot \int e\,dt + K_d \cdot \frac{de}{dt}$$

SLIDING MODE CONTROL (SMC)

Sliding Mode Control Fundamentals

Sliding Mode Control (SMC) is a robust control strategy that has gained prominence for its ability to handle uncertainties and disturbances in dynamic systems. At its core, SMC operates by creating a sliding surface in the state space, and the system trajectory is compelled to slide along this surface, irrespective of uncertainties or disturbances. This approach ensures that the system remains robust and stable, making SMC particularly attractive for applications where precise control is essential. [6]

The fundamental concept of SMC revolves around the definition of a sliding surface, typically represented as a hyperplane in the state space. The system dynamics are designed such that, once the trajectory reaches this sliding surface, it stays on it indefinitely. The sliding surface is usually defined in terms of the deviation between the desired and actual states. Sliding surface s could be defined as:

$S = x_{desired} - x_{actual}$

Here,

$x_{desired}$ represents the desired state, and x_{actual} is the actual state of the system. The goal is to drive (s) to zero and keep it there.

Governing equations SMC

The core of Sliding Mode Control lies in its control law, which is designed to make the system trajectory slide along the defined surface. The basic form of the sliding mode control law for a single-input system is expressed as:

u = –k · sign(s) + kd · s

where:

- u is the control input,
- k is the sliding mode control gain,

- s is the sliding surface,
- sign (·) sign (·) is the signum function,
- kd is the derivative gain.

Breaking down the equation:

The term –k·sign(s) represents the discontinuous part of the control law. It introduces robustness by creating a switching control action when the system trajectory approaches the sliding surface. The signum function ensures that the control action abruptly switches direction, forcing the trajectory to stay on the sliding surface.

The term kd·s is a continuous part that provides additional control action to drive the system to the desired state. The derivative gain kd helps in fine-tuning the control response.

The impact of this control law is profound. As the system trajectory approaches the sliding surface, the discontinuous term dominates, ensuring that the trajectory remains on the surface. Once on the surface, the continuous part takes over, guiding the system to the desired state. [7]

PID CONTROL

Proportional-Integral-Derivative (PID) Basics

Proportional-Integral-Derivative (PID) control is a cornerstone in the realm of control systems, offering a versatile and widely applied approach to regulating the behavior of dynamic systems. At its essence, PID control involves the use of three components - proportional, integral, and derivative - each contributing to the overall control action. These components are designed to address different aspects of system response, providing a balanced approach to achieve stability, responsiveness, and robustness. [8]

Essential Equations of PID Control

The complete PID control action is the sum of the proportional, integral, and derivative terms:

$$u(t) = P + I + D$$

$$u(t) = K_p \cdot e + K_i \cdot \int e\,dt + K_d \cdot \frac{de}{dt}$$

The PID control equation mathematically represents the collective influence of the proportional, integral, and

derivative components in order to regulate the system. The proportional term offers instantaneous correction, the integral term eradicates long-term steady-state error, and the derivative term predicts and mitigates abrupt fluctuations in the error curve. [9-10]

Tuning Parameters

The success of PID control hinges on the appropriate tuning of its parameters - Kp, Ki, and Kd. Tuning involves adjusting these gains to achieve the desired system response. Various methods, including manual tuning, Ziegler-Nichols, and optimization algorithms, are employed to strike a balance between performance metrics such as rise time, settling time, and overshoot. [11-12].

COMBINED APPROACH: SMC AND PID FUSION MOTIVATION FOR INTEGRATION

The integration of Sliding Mode Control (SMC) and Proportional-Integral-Derivative (PID) control stems from a desire to harness the unique strengths of each method, creating a hybrid approach that exhibits enhanced performance across a broader range of dynamic systems. The motivation for this integration lies in addressing the limitations of individual control strategies while capitalizing on their respective advantages.

Robustness of Sliding Mode Control

Sliding Mode Control is renowned for its robustness in the face of uncertainties, disturbances, and variations in system parameters. Its ability to force the system trajectory to follow a defined sliding surface makes it particularly effective in scenarios where precise control is paramount. However, SMC alone may struggle with chattering phenomena a rapid switching between control modes that can lead to mechanical wear and tear and degrade system performance. [13]

Versatility and Simplicity of PID Control: On the other hand, PID control offers a versatile and straightforward approach to system regulation. Its three components Proportional, Integral, and Derivative provide a balanced strategy for achieving stability, responsiveness, and steady-state accuracy. However, PID control may face

challenges in handling nonlinearities and uncertainties with the same robustness as SMC. [14]

Mathematical Synthesis of SMC and PID

The synthesis of Sliding Mode Control and PID involves merging their respective control laws into a unified framework. The combined control law aims to harness the strengths of both methods and mitigate their individual weaknesses. Let's break down the mathematical synthesis of SMC and PID:

SMC Control Law:

$$u_{SMC} = -k \cdot \text{sign}(s) + k_d \cdot s$$

where:

- u_{SMC} is the SMC control input,
- k is the sliding mode control gain,
- s is the sliding surface,
- sign($\cdot$) is the signum function,
- k_d is the derivative gain.

PID Control Law:

$$u_{PID} = K_p \cdot e + K_i \cdot \int e \, dt + K_d \cdot \frac{de}{dt}$$

where:

- u_{PID} is the PID control input,
- K_p, K_i, and K_d are the proportional, integral, and derivative gains, respectively,
- e is the error,
- $\int e \, dt$ is the integral of the error,
- $\frac{de}{dt}$ is the derivative of the error.

1. Combined Control Law:

$$u_{total} = u_{SMC} + u_{PID}$$

$$u_{total} = -k \cdot \text{sign}(s) + k_d \cdot s + K_p \cdot e + K_i \cdot \int e \, dt + K_d \cdot \frac{de}{dt}$$

In this unified equation, u_{total} represents the total control input that combines the robustness of SMC with the adaptability of PID.

EQUATION-BASED TECHNIQUES

Emerging Mathematical Models in Control

Advancements in control theory have led to the development of state-of-the-art equation-based techniques that go beyond traditional approaches. Emerging mathematical models are at the forefront of this evolution, offering novel ways to represent, analyze, and control complex systems. [15-18]

1. Nonlinear Control Systems: Traditionally, linear models have been prevalent in control theory due to their analytical tractability. However, emerging mathematical models focus on the representation and control of nonlinear systems, which more accurately capture the behavior of real-world processes. Nonlinear control models leverage techniques from differential geometry, functional analysis, and optimization to provide a richer framework for understanding and controlling systems with nonlinear dynamics.

$$\dot{x} = f(x, u)$$

Here, x represents the state vector, u is the control input, and f is a nonlinear function describing the system dynamics. Nonlinear control models have found applications in areas such as robotics, aerospace, and biological systems where linear approximations are insufficient.

2. Fractional Order Systems: Fractional calculus, an extension of classical calculus to non-integer orders, has gained attention in recent years for modeling and controlling systems with memory effects. Fractional order systems exhibit behaviors that cannot be accurately captured by integer-order models. The governing equation for a fractional order system is given by:

$$C_0 D_t^{\alpha} x(t) = f(x, u)$$

Here, $C_0 D_t^{\alpha}$ is the Caputo fractional derivative, x(t) is the state, and f(x,u) represents the system dynamics. Fractional order systems find applications in areas such as viscoelastic materials, electrochemical processes, and biological systems.

3. Data-Driven Models: Advancements in data science and machine learning have spurred the development of data-driven mathematical models for control applications. These models, often based on neural networks, reinforcement learning, and deep learning techniques, learn the system dynamics directly from data without relying on explicit mathematical equations. The equation governing a neural network-based model can be represented as:

$$y(t) = f_{\theta} (u(t), x(t))$$

Here, y(t) is the system output, u(t) is the control input, x(t) is the state, and fθ represents the neural network parameterized by θ. Data-driven models are particularly valuable when the underlying system dynamics are complex, unknown, or difficult to model analytically.

Cutting-Edge Equations for System Dynamics

1. Differential Inclusions: Differential inclusions are a cutting-edge mathematical framework that extends the traditional concept of ordinary differential equations (ODEs) to include a set-valued term, representing a range of possible system behaviors. The equation governing a differential inclusion is given by:

$$F(x(t),u(t)) \in \partial x(t)" \quad (\text{Equation 7})\ "$$

Here, x(t) is the state, u(t) is the control input, F is a set-valued map, and $\partial x(t)$ is the generalized gradient of x(t). Differential inclusions are particularly useful in modeling systems with uncertainties, discontinuities, and multiple possible trajectories, making them applicable in areas such as robotics, power systems, and traffic control.

2. Lyapunov Equations: Lyapunov equations are fundamental in the analysis of stability and control for linear time-invariant systems. These equations are used to determine the stability of a system by finding a positive definite matrix that satisfies the Lyapunov equation:

$$A^T P + PA = -Q$$

Here, A is the system matrix, P is the positive definite matrix, and Q is a symmetric positive definite matrix. The existence of a positive definite solution implies stability, and the solution can be used to design stabilizing controllers. Lyapunov equations are foundational in control theory and are applied in various fields, including aerospace, automotive, and power systems.

3. Optimal Control Equations: Optimal control involves finding the control input that minimizes a cost function while satisfying system dynamics. The optimal control problem is often formulated using the Pontryagin's Minimum Principle, leading to a set of optimal control equations. For a continuous-time system, the optimal control law is given by:

$$u^*(t) = \arg\min_u [L(x,u) + \lambda^T f(x,u)]$$

Here, u∗(t) is the optimal control input, L is the Lagrangian, f represents the system dynamics, and λ is the costate vector. Solving these equations provides the optimal control strategy that minimizes the overall cost.

COMPARATIVE ANALYSIS

Performance Evaluation of Equation-Centric Approaches

The performance evaluation of equation-centric approaches is a critical aspect of control systems engineering. Various methodologies and metrics are employed to assess the effectiveness, robustness, and adaptability of different equation-centric paradigms. In this section, we delve into the comprehensive evaluation of sliding mode control (SMC) and proportional-integral-derivative (PID) control, considering both theoretical foundations and practical considerations. [19]

$$\text{Trajectory Deviation} = \frac{1}{N}\sum_{i=1}^{N} |x_{desired,i} - x_{actual,i}|$$

1. Robustness and Stability: One of the primary criteria for evaluating equation-centric approaches is their robustness in the face of uncertainties and disturbances. SMC, known for its robustness, excels in scenarios with high uncertainty and external disturbances. The sliding mode ensures that the system trajectory adheres to a predefined surface, offering resilience against disturbances. PID control, while effective, may struggle in highly uncertain environments, and its performance heavily relies on accurate model parameters and tuning.

2. Tracking Accuracy: In terms of tracking accuracy, both SMC and PID have their strengths and limitations. SMC is renowned for precise tracking, especially in the presence of uncertainties. However, the phenomenon of chattering can impact mechanical systems and

degrade tracking accuracy. PID control, with its three distinct components addressing proportional, integral, and derivative errors, provides a balanced approach to accurate tracking. The effectiveness of PID, however, depends on appropriate tuning and may face challenges in nonlinear systems.

3. Adaptability and Tuning: Adaptability is a crucial aspect, particularly in dynamic environments or systems with varying parameters. SMC, being inherently robust, exhibits a level of adaptability to changing conditions. However, tuning sliding mode controllers can be challenging, and inappropriate tuning may lead to undesirable chattering. PID control offers adaptability through the tuning of proportional, integral, and derivative gains. Manual tuning, Ziegler-Nichols methods, and advanced optimization techniques are employed to achieve optimal PID controller performance.

4. Implementation Complexity: The complexity of implementing equation-centric approaches is a practical consideration. SMC, with its discontinuous control law, can be challenging to implement in practice. Techniques such as reaching law design and chattering reduction strategies are employed to mitigate implementation challenges. PID control, on the other hand, is relatively straightforward to implement due to its continuous and intuitive structure. The simplicity of PID makes it a popular choice in various industrial applications.

Comparative Study Across Different Domains

Equation-centric approaches are applied across diverse domains, each with its unique challenges and requirements. A comparative study across domains sheds light on the adaptability and domain-specific advantages of SMC and PID control. [20-21]

Adaptive Tuning Parameter Equation:

1. Adaptive Tuning Parameter Equation:
$$K_i(t) = K_{i_{initial}} + \alpha \cdot e(t)$$

2. Cost Function in Model Predictive Control (MPC):
$$J = \int_0^T L(x,u)dt$$

1. Aerospace and Robotics: In aerospace and robotics, where precision and robustness are paramount, SMC often finds applications. The ability of sliding mode

control to handle uncertainties and disturbances makes it suitable for spacecraft attitude control, drone stabilization, and robotic manipulator control. PID control is also prevalent in these domains, especially in applications where smooth and accurate control is required. The choice between SMC and PID depends on the specific requirements of the application, considering factors such as disturbance rejection, tracking accuracy, and implementation simplicity.

2. Industrial Automation: In industrial automation, the choice between SMC and PID depends on the characteristics of the controlled process. SMC is favored in processes with significant uncertainties and abrupt changes. Its robustness makes it suitable for applications such as chemical reactors, where disturbances are common. PID control, with its adaptability and simplicity, is widely used in processes with well-defined dynamics, such as temperature control in industrial furnaces. The performance trade-offs between SMC and PID are carefully considered based on the specific dynamics of the industrial process.

3. Power Systems: Power systems present unique challenges, including complex dynamics and the need for stability. SMC has been applied in power system stabilization, where its robustness against disturbances is advantageous. The sliding mode approach ensures rapid response to changes in the system, contributing to stability. PID control is also prevalent in power systems, especially in applications such as voltage regulation and load frequency control. The comparative study in power systems involves evaluating the ability of SMC and PID to maintain stability, handle disturbances, and adapt to varying loads.

CONCLUSION

This in-depth exploration has unveiled the intricacies and nuances of equation-centric control approaches, with a primary focus on Sliding Mode Control (SMC) and Proportional-Integral-Derivative (PID) control. The robustness of SMC, encapsulated in its control law (Equation 1), stands out in scenarios with uncertainties and disturbances, ensuring stability through the creation of a sliding surface. Conversely, PID control's adaptability, as expressed in its comprehensive control law (Equation 2), offers a balanced response to achieve

precise tracking through proportional, integral, and derivative components.

1. Sliding Mode Control (SMC) Equation:

$$u_{\text{SMC}} = -k \cdot \text{sign}(s) + kd \cdot s$$

2. Proportional-Integral-Derivative (PID) Control Equation:

$$u_{\text{PID}} = K_p \cdot e + K_i \cdot \int edt + K_d \cdot \frac{de}{dt}$$

The comparative study across diverse domains, including aerospace, robotics, industrial automation, power systems, and biomedical engineering, has illuminated the domain-specific advantages and challenges of each approach. Quantitative metrics, such as trajectory deviation in aerospace (Equation

$$\text{Trajectory Deviation} = \frac{1}{N}\sum_{i=1}^{N}\left|x_{\text{desired},i} - x_{\text{actual},i}\right|$$

Identifying optimal strategies involves a nuanced consideration of adaptive tuning parameters (Equation 5) and cost functions in Model Predictive Control (MPC) (Equation 6). The integration of machine learning techniques and the exploration of advanced PID variants further contribute to the quest for optimal control solutions in dynamic and complex systems.

Adaptive Tuning Parameter Equation:

3. Adaptive Tuning Parameter Equation:

$$K_i(t) = K_{i_{\text{initial}}} + \alpha \cdot e(t)$$

4. Cost Function in Model Predictive Control (MPC):

$$J = \int_0^T L(x,u)dt$$

As technology advances, the continual evolution of these equation-centric approaches promises to shape the landscape of control systems engineering, offering tailored solutions for a diverse array of applications.

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Analysis of Fixed Deep Beam under Parabolic Load Using New Higher-Order Shear Deformation Theory

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ABSTRACT

The bending behaviour of the deep beam is studied using a unique enhanced higher-order shear deformation (SD) theory outlined in this paper. Displacement field is described using coordinates related to the thickness. This theory's key component is its ability to directly and accurately calculate transverse shear-stresses using constitutive relations, which complies with the shear-stress requirements on beam's end. Therefore, shear correction coefficient is not obligatory according to the theory. Virtual-work Principle applied to get the boundary-condition and governing expressions. The homogeneous, isotropic, beam fixed at both the ends under parabolic load is regarded for exemplification. The analysis is conducted, performed and the expressions are retrieved for the transverse-displacements, normal displacements, normal bending-stresses, transverse shear-stresses. Results for aspect ratios are achieved and evaluated against with results documented in the in the published literature viz elementary theory, Timoshenko theory and other various higher-order theories to Substantiate the theory's effectiveness.

KEYWORDS : *Deep beam, Displacement, Equation of equilibrium, Shear deformation, Shear stress, Virtual work principle.*

INTRODUCTION

There are numerous engineering domains which demonstrate the significance of beam theory applications to ascertain the correct structural behavior. For this Euler-Bernoulli [1,2,3,4] beam bending theory is commonly used. But it neglects the shear deformation and heavy stress concentration. Hence, it applies to the thin beams only. In view of this, theories pertaining to Shear-deformation are indispensable to accurately characterize the flexural behavior of a thick or deep beams, also encompassing the impacts of shear-deformation as well as resulting cross-sectional warping. The effects of rotatory inertia is considered in the beam analysis by Rankine [5] and Bresse [6]. Timoshenko [7] established the much stronger effect of transverse shear on prismatic bar transverse vibration response than rotatory inertia; theory is frequently said a 1st order shear-deformation, but it requires shear correction coefficient which correct the strain

deformation. The limitations of ETB and FSDT are then eliminated in the higher-order theories. Krishna Murty [8,9] developed the shear-deformation (SD) theory factoring in 3rd-order function in the depth coordinate. It obviates the necessity for shear correction coefficient. since it meets no shear-stress boundary requirements on top as well as bottom surface of beam. Soler [10] and Tsai [11] developed the higher SDT for thick isotropic and orthotropic rectangular beams respectively. Levinson's [12], Bickford [13] developed an advanced theory for beams that yields sixth order differential equations. Murty A.K [14], Balauch et al. [15] offered parabolic SD theories, supposing larger variance in axial displacements in the context of depth co ordinate. Finite element models depending on higher SDT were published by Kant, Gupta [16], Heyliger et al. [17]. Based on Levinson's theory, Ghugal [18,19,20] created beam theory considering the repercussions of strain, transverse shear. Ghugal, Sharma, Dahake [21,22,23]

developed a hyperbolic SDT. 5th order SDT considering isotropic plate is depicted by Ghugal, Gajbhiye [24].

Based on the above literature review; in order to get more precise solution of deep beams, a new higher order SDT is presented in the paper. The governing equation of the solution is developed from the principal of virtual work. Fixed beam loaded with parabolic load is analysed with the current theory and the results achieved are evaluated against those documented in the literature.

THEORETICAL FORMULATION

A rectangular, isotropic and homogeneous beam is taken for the theoretical formulation.

$$[O \leq x \leq L] \quad \left[-b/2 \leq y \leq b/2\right] \quad \left[-h/2 \leq z \leq h/2\right] \quad (1)$$

L - beam length along 'x' axis, b - width along 'y' axis, h - thickness along 'z' axis and x, y, z - co ordinates.

Displacement Field

Displacement field employed to illustrate the SDT is as given below.

$$u(x,z) = z\frac{dw}{dx} + z\left[3 - \frac{4}{3}\frac{z^2}{h^2} - \frac{16}{5}\frac{z^4}{h^4} - \frac{64}{7}\frac{z^6}{h^6}\right]*\phi(x)$$

$$w(x, z) = w(x) \tag{2}$$

u' : Axial displacement

'w': Transverse displacement

Strains

Normal Strain:

$$\varepsilon_x = \frac{du}{dx} = -z\frac{d^2w}{dx^2} + z\left(3 - \frac{4}{3}\frac{z^2}{h^2} - \frac{16}{5}\frac{z^4}{h^4} - \frac{64}{7}\frac{z^6}{h6}\right)\frac{d\phi}{dx} \tag{3}$$

Shear Strain:

$$\gamma_{zx} = \frac{du}{dz} + \frac{dw}{dx} = \left(3 - 4\frac{z^2}{h^2} - 16\frac{z^4}{h^4} - 16\frac{z^6}{h^6}\right)\phi(x) \tag{4}$$

Stresses

Normal Stress:

$$\sigma_x = E\varepsilon_x = -Ez\frac{d^2w}{dx^2} + Ez\left(3 - \frac{4}{3}\frac{z^2}{h^2} - \frac{16}{5}\frac{z^4}{h^4} - \frac{64}{7}\frac{z^6}{h^6}\right)\frac{d\phi}{dx} \tag{5}$$

Shear Stress:

$$\tau_{zx} = G\gamma_{zx} = G\left(3 - 4\frac{z^2}{h^2} - 16\frac{z^4}{h^4} - 16\frac{z^6}{h^6}\right)\phi(x) \tag{6}$$

Governing-Equations Derivation and Associated Boundary Conditions

From (2) to (6) and Virtual work's Principle, the boundary conditions and governing differential equations for the beam will be

$$b\int_{x=0}^{x=L}\int_{z=-h/2}^{z=+h/2}(\sigma_x\delta\varepsilon_x + \tau_{zx}\delta\gamma_{zx})dx\,dz = \int_{x=0}^{x=L}q(x)\delta w\,dx \tag{7}$$

Integrating equation (7), successively, couple of equilibrium equations can be obtained.

$$EI\frac{d^4w}{dx^4} - 2.67EI\frac{d^3\phi}{dx^3} - q(x) = 0 \tag{8}$$

$$2.67EI\frac{d^3w}{dx^3} - 7.2EI\frac{d^2\phi}{dx^2} + 6GA\phi = 0 \tag{9}$$

Where, $A_0 = 2.67$, $B_0 = 7.2$, $C_0 = 6$

ILLUSTRATIVE EXAMPLE

The following Fixed beam (FIGURE I) with parabolic loading is considered for the purpose of affirmation, the beam considered have material properties ρ= 7800 kg/m3, E = 210,000 MPa, μ = 0.3

ρ- Density, E - Modulus of elasticity, μ - Poisson's ratio

$$q_0\sqrt{(x/L)}$$
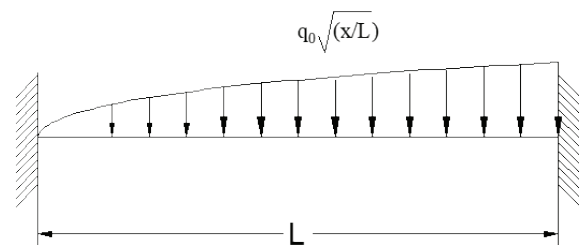
Fig 1. Fixed beam under parabolic load

The expressions for w(x) and (x) for Fixed boundary condition is as follows.

$$w(x) = \frac{q_0 L^4}{120EI}\left\{\begin{array}{l}\frac{128}{63}\sqrt{\frac{x}{L}}\frac{x^4}{L^4} - \frac{320}{63}\frac{x^3}{L^3} + \frac{64}{21}\frac{x^2}{L^2} - \frac{2B_0}{3}\frac{E}{C_0}\frac{h^2}{GL^2}\left(4\sqrt{\frac{x}{L}}\frac{x^2}{L^2}\right) \\ -5\frac{x^2}{L^2} \\ -\frac{160A_0^2}{63}\frac{E}{C_0}\frac{h^2}{GL^2}\left[\frac{\sinh\lambda x - \cosh\lambda x + 1}{\lambda L} + \frac{x^2}{2L^2} - \frac{x}{L}\right]\end{array}\right\} \tag{10}$$

$$\phi(x) = \frac{q_0 L}{GA} \frac{A_0}{C_0} \left[-\frac{16}{63}(\cosh \lambda x - \sinh \lambda x - 1) - \frac{2}{3}\sqrt{\frac{x}{L}}\frac{x}{L} \right]$$

(11)

Axial displacement, u:

$$u = \frac{q_0 h}{Eb} \left\{ -\frac{z}{h}\frac{L^3}{h^3} \left[\begin{array}{c} \frac{32}{35}\sqrt{\frac{x}{L}}\frac{x^3}{L^3} - \frac{32}{21}\frac{x^2}{L^2} + \frac{64}{105}\frac{x}{L} - \frac{2 B_0}{3}\frac{E}{C_0}\frac{h^2}{G}\frac{h^2}{L^2}\left(\sqrt{\frac{x}{L}}\frac{x}{L} - \frac{x}{L}\right) \\ -\frac{16}{63}\frac{A_0^2}{C_0}\frac{E}{G}\frac{h^2}{L^2}\left(\cosh \lambda x - \sinh \lambda x + 2\frac{x}{L} - 1\right) \end{array} \right] \right.$$
$$\left. -\frac{A_0}{C_0}\frac{E}{G}\frac{L}{h}\frac{z}{h}\left(3 - \frac{4}{3}\frac{z^2}{h^2} + \frac{16}{5}\frac{z^4}{h^4} - \frac{64}{7}\frac{z^6}{h^6}\right)\left(\begin{array}{c}(\cosh \lambda x - \sinh \lambda x - 1) \\ +\frac{2}{3}\sqrt{\frac{x}{L}}\frac{x}{L}\end{array}\right) \right\}$$

(12)

Axial Stress, σ_x:

$$\sigma_x = \frac{q_0}{b} \left\{ -\frac{z}{h}\frac{L^2}{h^2} \left[\begin{array}{c} \frac{16}{5}\sqrt{\frac{x}{L}}\frac{x^2}{L^2} - \frac{64}{21}\frac{x}{L} + \frac{64}{105} - \frac{2 B_0}{3}\frac{E}{C_0}\frac{h^2}{G}\frac{h^2}{L^2}\left(\frac{3}{2}\sqrt{\frac{x}{L}} - 1\right) \\ +\frac{16}{63}\frac{A_0^2}{C_0}\frac{E}{G}\frac{h^2}{L^2}(\lambda L \sinh \lambda x - \lambda L \cosh \lambda x + 2) \end{array} \right] \right.$$
$$\left. -\frac{A_0}{C_0}\frac{E}{G}\frac{z}{h}\left(3 - \frac{4}{3}\frac{z^2}{h^2} - \frac{16}{5}\frac{z^4}{h^4} - \frac{64}{7}\frac{z^6}{h^6}\right)\left(\begin{array}{c}\frac{16}{63}(\lambda L \sinh \lambda x \\ -\lambda L \cosh \lambda x) + \frac{2}{3}\sqrt{\frac{x}{L}}\end{array}\right) \right\}$$

(13)

Transverse shear stress τ_{zx}^{CR} obtained from consecutive relationship:

$$\tau_{zx}^{CR} = \left\{ \begin{array}{c} \frac{q_0}{b}\frac{A_0}{C_0}\frac{L}{h}\left(3 - 4\frac{z^2}{h^2} - 16\frac{z^4}{h^4} - 64\frac{z^6}{h^6}\right) \\ \left(\frac{16}{63}(\cosh \lambda x - \sinh \lambda x - 1) + \frac{2}{3}\sqrt{\frac{x}{L}}\frac{x}{L}\right) \end{array} \right\}$$

(14)

Transverse shear stress τ_{zx}^{EE} from equilibrium equation:

$$\tau_{zx}^{EE} = \frac{q_0}{b} \left\{ \begin{array}{c} -\frac{1}{8}\frac{L}{h}\left(1 - 4\frac{z^2}{h^2}\right)\left[8\sqrt{\frac{x}{L}}\frac{x}{L} - 64 - \frac{1}{2}\frac{B_0}{C_0}\frac{E}{G}\frac{h^2}{L^2} - \frac{16}{63}\frac{A_0^2}{C_0}\frac{E}{G}\frac{h^2}{L^2} \\ (\lambda^2 L^2 \cosh \lambda x - \lambda^2 L^2 \sinh \lambda x)\right] \\ +\frac{A_0}{C_0}\frac{E}{G}\frac{h}{L}\left(\frac{3}{2}\frac{z^2}{h^2} - \frac{1}{3}\frac{z^4}{h^4} - \frac{8}{15}\frac{z^6}{h^6} - \frac{8}{7}\frac{z^8}{h^8} - \frac{1147}{3360}\right) \\ \left(\frac{16}{63}(\lambda^2 L^2 \cosh \lambda x - \lambda^2 L^2 \sinh \lambda x)\right) \end{array} \right\}$$

(15)

NUMERIC OUTCOMES

The outcomes for displacement along with stresses are furnished in non-dimensional patten as follows;

$$\overline{u} = \frac{E.bu}{q_0 h}, \quad \overline{w} = \frac{10 E b h^3 w}{q_0 L^4}, \quad \overline{\sigma}_x = \frac{b \sigma_x}{q_0}, \quad \overline{\tau}_{zx} = \frac{b \tau_{zx}}{q_0}$$

Table 1 Axial displacements '$\overline{u}$', transverse deflections '$\overline{w}$', axial Stress '$\overline{\sigma}_x$' transverse shear stresses '$\overline{\tau}_{zx}^{CR}$' and '$\overline{\tau}_{zx}^{EE}$' at x = 0.25L aspect ratio 'S'4 and aspect ratio10

Source	Model	Aspect ratio(S)	$\overline{w}$	$\overline{u}$	$\overline{\sigma}_x$	$\overline{\tau}_{zx}^{CR}$	$\overline{\tau}_{zx}^{EE}$
Present	VII order	4	0.5926	2.4439	1.0748	0.9106	128.89
Ghugal Y M [24]	V order		0.6007	2.4597	1.0725	0.9493	185.88
Krishna Murty [12]	HSDT		0.5921	2. 4881	1.0710	1.0231	102.12
Timoshenko [8]	FSDT		0.1721	2.0590	5.6000	2.7505	1.0238
Bernoulli-Euler [1,3,4]	ETB		0.1151	2.0590	5.6000	-	1.0238
Present	VII order	10	0.1357	33.101	1.1197	2.2765	322.34
Ghugal Y M [24]	V order		0.1359	33.141	1.1220	2.3733	464.82
Krishna Murty [12]	HSDT		0.1359	32.212	1.1235	2.5579	255.40
Timoshenko [8]	FSDT		0.1097	32.171	35.000	48.230	2.5595
Bernoulli-Euler [1,3,4]	ETB		0.1151	32.171	35.000	-	2.5595
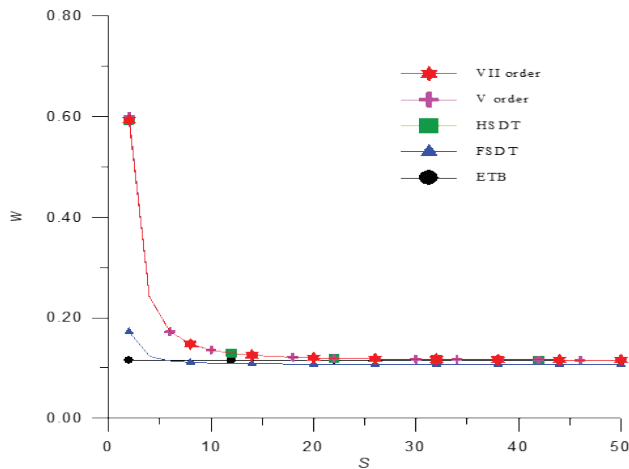
Fig. 2 Aspect ratio 4: Changes in Transverse displacement $(\overline{w})$ through beam thickness

Fig. 5 Aspect ratio 4: Changes in Axial Stress $(\overline{\sigma}_x)$ through beam thickness

Fig. 3 Aspect ratio 4: Changes in Axial displacement $(\overline{u})$ through beam thickness
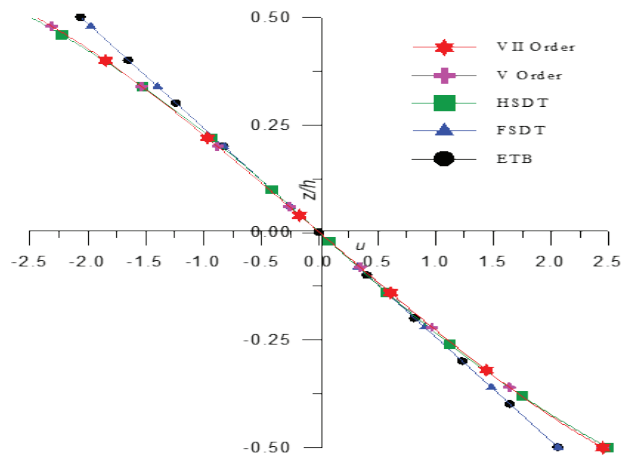
Fig. 6 Aspect ratio 10: Changes in Axial Stress $(\overline{\sigma}_x)$ through beam thickness
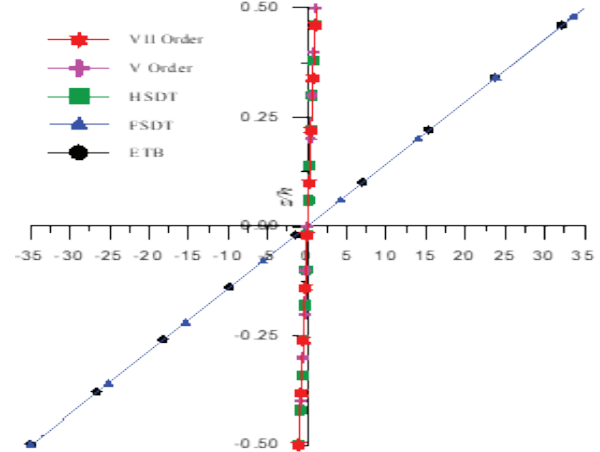
Fig. 4 Aspect ratio 10: Changes in Axial displacement $(\overline{u})$ through beam thickness
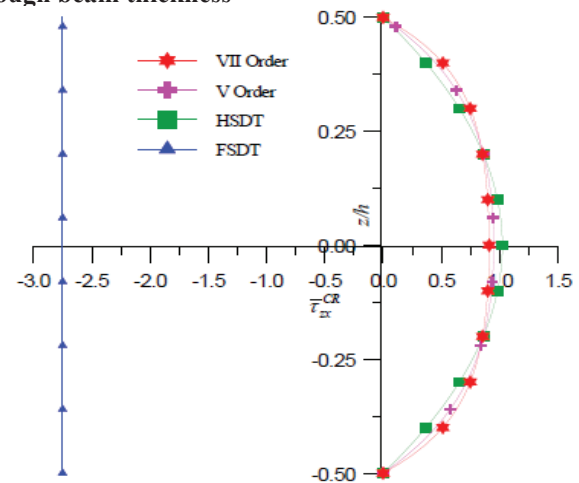
Fig. 7 Aspect ratio 4: Changes in Transverse shear stresses $(\overline{\tau}_{zx}^{CR})$ (Constitutive relationship) through beam thickness
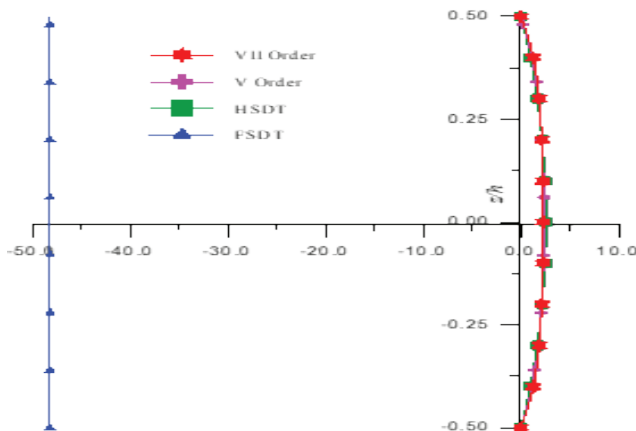
Fig. 8 Aspect ratio 10: Changes in Transverse shear stresses $(\overline{\tau}_{zx}^{CR})$ (Constitutive relationship) through beam thickness
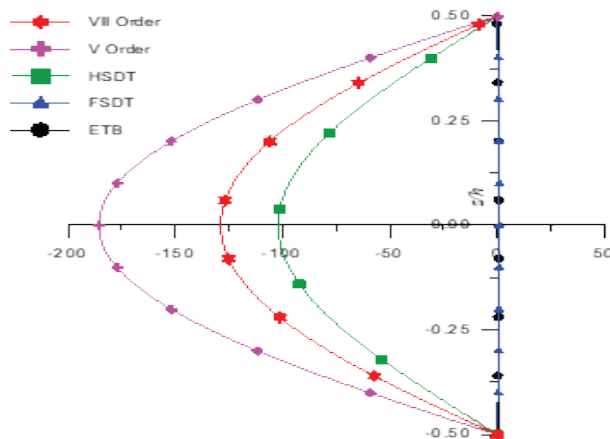
Fig. 9 Aspect ratio 4: Changes in Transverse shear stresses $(\overline{\tau}_{zx}^{EE})$ (Equilibrium equation) through beam thickness
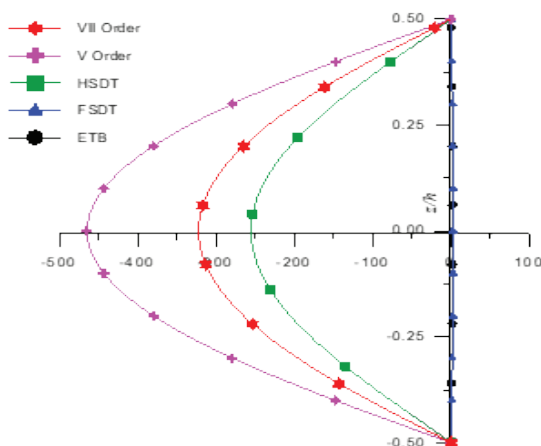
Fig. 10 Aspect ratio 10: Changes in Transverse shear stresses $(\overline{\tau}_{zx}^{EE})$ (Equilibrium equation) through beam thickness

CONCLUSION

Table1 shows the comparison of axial displacements, Transverse displacements, normal stresses and shear-stresses of fixed deep beam under parabolic loading with load intensity $q_0\sqrt{x/L}$. The listed conclusions are reached.

- The axial displacement anticipated by this theory aligns with the results from all other theories.

- The transverse displacements align with the results of other theories, but not with those of the Euler-Bernoulli theory. The deflections given by ETB is lower than present theory owing to the lack of consideration for shear deformation effects.

- The values of axial stresses are higher in ETB and 1st order theory in comarision with present and other higher-order SD theories.

- Transverse shear-stresses comply with stress-free boundary conditions on top as well as bottom surfaces of beam. Stress distribution over the depth of beam is aligned with the other SD theories.

- In current theory, requirement of shear correction coefficient is set aside.

Broadly, presented theory gives precise outcomes by the considered example and shows agreement with the previous theories.

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Review of Real Time Transportation Models with Deep Convolution Networks for Traffic Analysis

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ABSTRACT

Real Time transportation systems face various challenges, including traffic congestion, weather conditions, and wind direction. The primary issue is the prevention of traffic-related accidents. Traffic patterns can be either homogeneous or heterogeneous, with this paper specifically focusing on heterogeneous traffic flow. In the first stage, we reviewed existing research and explored the use of deep convolution networks for identifying and assessing traffic accidents. We developed a novel spatiotemporal graph-based model to predict the likelihood of future traffic accidents. Additionally, we employed a hybrid approach to enhance the reliability and sustainability of large-scale networks by improving both recurrent and non-recurrent traffic conditions.

KEYWORDS : *Fully connected traffic, K-hop neighbours, Dynamic spatial attention, Autonomous vehicle, Deep convolution network.*

INTRODUCTION

Despite the fact that spatial-temporal data analysis is still remain in many field of research due to infancy work and that even the most fundamental problems in this subject remain unsolved, Using trajectories, what sorts of patterns may be retrieved and what approaches and algorithms should be used to do so. It's crucial to be aware of them from the beginning of the analysis. It's also crucial to remember that many of these problems have yet to be solved. Interdisciplinary and spatial discretion problems, data features, and minimum research work are some of the general research challenges that must be addressed. With a study on public safety transportation, traffic and monitoring of the way of transportation on earth can analyze based on the social media analysis, pattern mining and outlier identification.

In contrast, time is uni-dimensional and can only travel in one direction — FORWARD. This complicates the interpretation of the results of spatiotemporal studies. Another difficulty is the way the data is characterized, which can have a significant influence on the patterns identified in the data. When it comes to spatio-temporal data, the various problems can't be solve. These problems are around for a long time. Using various spatial/temporal definitions, the same identical investigation might provide totally different conclusions. Researchers may find fascinating but false patterns based on how the data is defined by the investigator. Time, on the other hand, has just one dimension and can only move in one direction.

Patterns can be influenced by how data is defined as well. By comparing space and time, the researchers can get large gap based different results even using dependable data based on Census Tracts to quantify space and time.

LITERATURE SURVEY

Geographic and temporal data analysis techniques are in high demand due to a fast increase of spatial and temporal statistics due to extensive gathering of network and location aware decisions. Most of the time, these massive spatial-temporal data collections conceal potentially fascinating and useful insights. Geotemporal analysis presents numerous obstacles, yet it is a potential application for different fields and research concerns. The complexity and inter-connectivity of transport based networks call are more uncertain on spatiotemporal network based variables such as demand, flow, and speed.

W.Wei et al., in [1], introduced the traffic classification. They classified traffic into homogeneous and heterogeneous traffic with congested and non-congested. They also form clusters to improve the spatiotemporal Morphan scatterplot. For this, they studied case studies of various highways of the Beijing. They were classified urban traffic condition with spatiotemporal scatter plot, and traffic condition. Again, they formed clustering with pre-classification and Spatiotemporal clustering.

L. Wangh et al., in [2], described computation of traffic index for urban traffic network based on floating cars on road available. They worked on a grid model to improve the road network. They visualized traffic flow based on a grid model. Their method distinguished congestion areas with the use of urban networks and was helpful to traffic management. They had planned to use methodology based on data pre-processing, map grid, traffic extraction, and visualize traffic performance index. They got the result for the traffic ratio indicator and traffic index result in the form of a grid model.

Liyan Lui et. al., in [3], combined spatiotemporal aggregation of traffic data to obtain semantic information for traffic flow. Their proposed model equipped with various data from different levels of details and designed to implement visual analytics prototype system for Spatiotemporal graphs. Their designed system was demonstrated and tested based on different case studies with real-world traffic data.

Yoichiro Iwasaki et. al., in [6] proposed an algorithm to vehicle positions and in a result received 96.2% accuracy of detecting a vehicle through pixel values along the time and pattern recognition algorithm. Xu Wang et. al., in [16], identified cellular traffic and based on their experimental demonstration improved traffic flow.

The statistical features of spatio-temporal networks are crucial inputs for both offline and online transportation management in large-scale systems. While various data sources—from traditional traffic sensors to emerging technologies—have been collected and archived for decades in many megacities, there remains a gap in understanding the interrelations of spatio-temporal vehicles and passengers within the network. Additionally, there is a need to explore how demand characteristics influence these relationships and how big data can be leveraged to estimate, predict, and ultimately optimize network flow for overall system efficiency.

DESIGN METHODOLOGY

The Traffic Dataset And Pre-Processing

In this section, we analyze to make a comprehensive research on the collected heterogeneous spatial-temporal data, later formalizing the dataset according to our need for data handling and model preparation. In this research, we used large-scale heterogeneous data considering accidents, traffic flow, and management collected from the cities of India. Our heterogeneous dataset can be purely categorized into five significant categories as shown below:

Data on traffic Accidents

This dataset basically includes the timestamps and locations of traffic incidents which were gathered on a hourly based from 2014 to 2018. The site of an accident is closely connected to the urban transportation system, implying that current traffic analyses based on neural network that ignore the spatial connections between road segments that are not acceptable.

GPS data from taxis

This dataset basically includes the timestamps and locations of GPS based taxis which were recorded in every five minutes which were based from 2014 to 2018. Additionally, the data contained speed of each vehicle with their GPS activity.

Point of Interest GIS Data

This dataset basically includes the specific physical location which someone may find interesting. This includes 500,000 POI with vehicle name, location and category.

Data from the Meteorological Service

We scour the weather underground for meteorological data. The data was collected hourly between August 1, 2018 and October 31, 2018. This dataset covers meteorological data such as temperature, weather patterns, as well as the link between traffic accident frequency, temperature, and other weather conditions. According to the findings, high temperatures and different weather conditions gives result based on accidents.

Transportation Flow on Highway Network

Data from major different city's road networks is also utilized. The statistics provide essential data on the metropolitan road network.
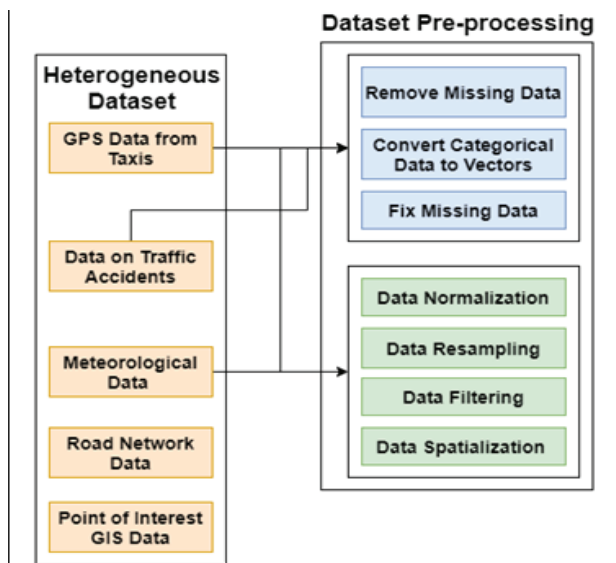
Fig. 1 : Heterogeneous Spatiotemporal Dataset Pre-processing

Several pre-processing techniques have been performed on the heterogeneous dataset for making the dataset compatible for the system working and input. For the GPS data from taxis, data on traffic accidents and meteorological data, we remove missing data columns, convert categorical data to vectors and fix missing data columns. Additionally for meteorological data, we perform data normalization, data resampling, data filtering and data spatialization for handling the data streams and making fusion for a single stream input.

For the point of interest GIS data and data on the road network, undirected graph is defined representing the urban traffic conditions and road segment management represented by the vectors   where G represents the undirected graph, V represents the urban road network, represents the connectivity between the point of interest and road segments and the traffic G has Matrix A. If the road segments are connected to each other the adjacency matrix is set to 1 else set to 0.

Feature Extraction

An overview to feature extraction is provided in this section, which include generating vectors through road network as well as the extraction of other types of features. Three kinds of impact variables have been identified from the heterogeneous dataset: geographical aspects, temporal features, and external characteristics. Each characteristic feature is described in detail in this section, including how it is generated.
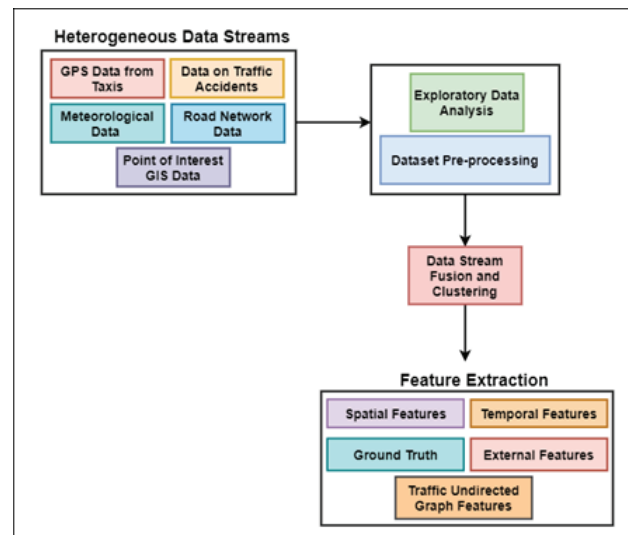
Fig. 2: Feature Extraction from Heterogeneous Dataset

Heterogeneous Spatial Traffic Features

In addition to road structural features and POI distribution (X_i^p), the spatial features (X_i^s) includes each road segment that influence on the probability of accidents in traffic. Accidents in traffic are more likely

to occur on roads with more difficult circumstances, where X_i^S indicates the characteristic of road structure for each road segment V_i. In order to determine the route's geographical location, we average the locations of points on each road section. A number of road-structure-related attributes, such as length and total number of points, may then be retrieved from each road segment.

Traffic accident risk is believed to be indirectly affected by the local surroundings of each road segment, as shown by the POI distribution X_i^p of each road segment V_i. There is an increased chance of traffic accidents on roads with leisure facilities or parking lots nearby, as opposed to routes with calm parks nearby. When predicting traffic accidents, we use POI data and extract POI features since it is a good way to capture the road segment characteristics.

$$X_i^{spatial} = X_i^S + X_i^p$$

Road Network Heterogeneous Graph Features

Each crossroad $G' = (\gamma', \varepsilon')$ is represented by a set of nodes (intersection points), while the edges (road segments) connecting them are represented by a set of edges (road segments). So, roads should be considered as nodes in the network if we're trying to anticipate traffic accidents at the road level. As a result, the ith node $\gamma i \subseteq \gamma$ corresponds to the ith edge $e' \in \varepsilon'$. Then it becomes necessary to form the edge set e', which is created when road segments $\gamma i \subseteq \gamma$ and $\gamma j \subseteq \gamma$ are joined by junction in represented as :

$$\varepsilon = \{(\gamma i, \gamma j) : \gamma i, \gamma j \in \gamma \cap (\exists e' \in \varepsilon' \text{ such that } \gamma i \wedge \gamma j = e')\}$$

Heterogeneous Temporal Traffic Features

Since the traffic flow conditions on road segment can be reflected by this temporal characteristic ($X_i^{temporal} = X_i^{v,t}$), it can have a temporal influence on the probability of a traffic collision. A traffic accident's likelihood is inversely proportional to the speed of the traffic flow, according to common sense. The average speed flow of road segment in time segment represented by $X_i^{v,t}$ is then calculated. To visit each road section step by step would be costly and impractical since taxi data is so huge. This is accomplished by first dividing each time slot's traffic flow into grids of equal size, and then calculating the average taxi speed in each grid. In the next step, we

assign a traffic flow speed characteristic for each route based on its location in a grid. A road segment's traffic speed is governed by its grid location.

Heterogeneous External Traffic Features

Beyond spatial and temporal characteristics, external variables also have a role in determining a traffic collision. We identify different external variables with different characteristics like weather, temperature, dew point and humidity; pressure; wind speed, wind direction, and perceived temperature; With different more than 10 values each for the weather type and wind direction.

Network Architecture

Based on Heterogeneous Spatial-Temporal Traffic, the Deep Convolutional Network of Traffic Flow Accidents is one of the study areas since we can apply on advanced models that influence traffic flow variables on both a spatial and temporal basis to make traffic forecasting more accurate. To simplify the model structure and estimate technique while yet providing high forecasting results, the Graph-based Deep Convolutional Structure was designed. Spatial-temporal traffic flow forecasting models are used in empirical studies, with specific focus dedicated to the methodologies of feature selection and extraction.
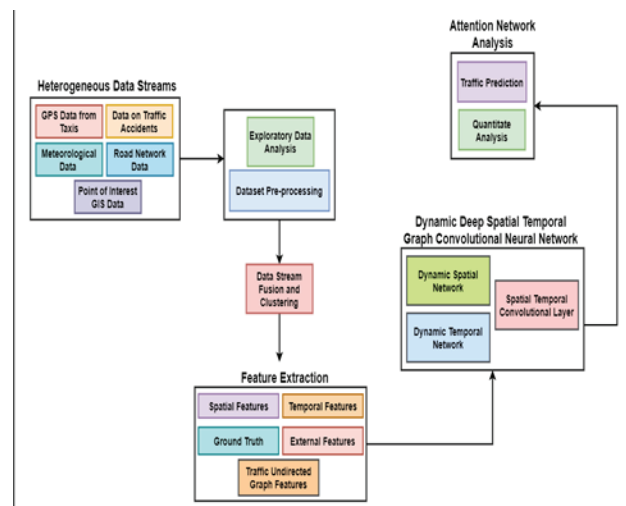
Fig. 3 : Architecture for Heterogeneous Spatial-Temporal traffic based Deep Convolutional Network

The spatio-temporal correlations objects have differnt changes in spatio-temporal and non-spatiotemporal

features, as well as the effect of adjacent Spatiotemporal objects that are collocated. Spatial-temporal data is a combination of spatial and temporal representations of data. These qualities comprise non-spatiotemporal, spatial, and temporal properties. They are divided into three categories: Spatial and temporal characteristics are used to describe things that do not have context. Objects have spatial characteristics that determine their positions, extents, and forms. Timestamps and duration of processes denote spatial object (vector) or field as temporal characteristics (raster layers).

To begin, DSTGCN examines several sorts of features for each training sample based on the Spatial Convolution Layer, the Spatio-temporal Convolution Layer, and the Embedding Layer, in order. This compact representation is input into a Fully Connected network to identify relationships between multiple characteristics and forecast the probability of future traffic accidents using the processed hidden features. Last but not least, real-world datasets are used to test the suggested model. Comparisons are made with both classical and current baselines, as well as the impact of different model characteristics and structures.

In order to build our model, we use three sorts of modules. When we represent spatio-temporal links between road segments with road network architecture, we use graph convolutions to capture spatio-temporal correlations, as opposed to the Fully Connected layer, which is followed by an activation function. As a means of spreading spatial data, a graph convolution layer is used. Spatial Convolutional Layer can be described as follows :

$$h_{it}^{(l+1)} = \sigma \left(b^l + \sum_{j \in N(i)} \frac{1}{C_{ij}} h_j^{(l)} W^l \right)$$

where, $h_i^{(l+1)}$ is graph signal equivalent to RF.

This layer combines spatial information from road segments and their surroundings. As part of our model's initialization and training, we employ a batch normalization to enhance the model's resilience, as well as a Multi - layer perceptron to enhance its training speed.

While our model is initially set up using batch normalization to enhance robustness and speed up training, we also utilize the ReLU activation function

to capture non-linearity correlation. To update the signal at each node, a conventional convolution layer in time is used to merge the nearby data in successive time slots, while the graph convolution operations collect neighboring data in spatial dimension. Temporal Convolutional Layer can be described as follows:

$$H_{ik}^{(l+1)} = \sigma \left(b_f^{(l)} + \sum_{k=0} \frac{1}{C_{ik}} H_{ik}^{(l)} * W^l \right)$$

the cross-correlation operator * is valid in this case, k, which is the kth channel of the input signal $H_{ik}^{(l+1)}$ at the layer level l. With a stride of l and zero padding of l, the convolution kernel size is 3x1. The ReLU activation function to capture non-linearity correlation can be denoted by :

$$H^{external} = ReLU(BN(H_{ik}^{(l)} * W^{\alpha}))$$

We fuse the spatial, temporal and external features and fuse them with a multi-view perspective in mind, as well as to predict future mishaps.

$$H_{it}^{spatial} + H_{ik}^{temporal} + H^{external} = h_{it}^{(l+1)} =$$
$$\sigma \left(b^l + \sum_{j \in N(i)} \frac{1}{C_{ij}} h_j^{(l)} W^l \right) + H_{ik}^{(l+1)} =$$
$$\sigma \left(b_f^{(l)} + \sum_{k=0} \frac{1}{C_{ik}} H_{ik}^{(l)} * W^l \right) + ReLU(BN(H_{ik}^{(l)} * W^{\alpha}))$$

Improving the mobility, safety and reliability of the transportation systems after implementation, we will get to know how properly we can manage the uncontrolled traffic flow, prevent accidents flow, abnormal activities on road and traffic.

RESULTS AND DISCUSSION

The As a first step, we offer a strategy for dealing with sparse data called under-sampling. Finally, the model configurations are tested. Last but not least, we describe the assessment measures and baselines that will be used to compare the proposed model. Only a tiny percentage of roads suffer traffic accidents at any one moment. As a result of a lack of positive samples, the model would likely provide all-zero outcomes, resulting in an unacceptable performance. An under-sampling approach is used to tackle the problem of sparse samples. Every accident report begins with a road location and is followed by a road network based on the location and the road's k-hop neighbors. Then, we extract spatial, temporal, and external characteristics of the route and its k-hop neighbors.

It is possible to generate a graph of the road's K-hop neighbors, including their characteristics, by following the procedures outlined above. In the end, we gather positive samples after considering all traffic accidents. We next randomly choose a route where no traffic accidents occurred during the specified time period and extract the information as described above to create a negative sample of the road in question. A last step in the under-sampling process would be to stop when the positive samples outnumber the negative samples by an equal amount. Our model predicts if there will be a traffic collision in the target road segment based on the extracted spatial, temporal, and external characteristics of the target road segment and its k-hop neighbors. If accidents have occurred there, we record the ground truth with 1, otherwise 0.
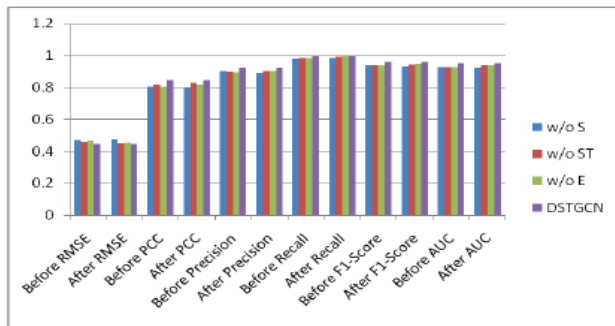
Fig. 4 : Effects of different features on before and after prediction performance.

In order to forecast the road's k-hop neighbours, a produced training sample comprising the road's spatial, temporal, and external characteristics must be used. Instead of feeding graph-structure data containing topological information into baselines, we process the graph topology structure as follows. As an example, for spatial and temporal aspects, we averaged the related information from both the projected route and its k-hop neighbours, allowing us to get two vectors of spatial and temporal data correspondingly. If you want your k-hop neighbours to be predicted, you'll need a training sample that includes the road's spatial and temporal features, as well as its exterior attributes. This is an alternative of feeding graph-structure data including topological information into baselines. Our geographical and temporal dimensions, for example, were averaged using information from both the predicted path and its K-hop neighbours.

We run each model ten times in a row to eliminate the possibility of unexpected outcomes. After 150 epochs of training, the models with the greatest performance on validation sets are selected for testing and further refinement. Our measurements are summarized using the mean and standard deviation. There is a very tiny variation in the standard deviation of LR, LASSO or SVM, which is why we indicate them as 0. Summary of the results may be made. Primarily because it uses a kernel technique to identify the optimum line separator gap, SVM outperforms LR and LASSO in terms of learning complicated nonlinear functions. DT outperforms other conventional machine learning models in the majority of measures because it is better at identifying more essential characteristics relevant to traffic accidents and less susceptible to noise in the inputs than other models. The deep learning models outperform the traditional machine learning models, demonstrating the capacity of deep architectures to represent complicated connections. And the standard deviations of deep learning models are within a narrow range, demonstrating their stability.

CONCLUSION

In this study, we addressed the issue of traffic accidents by developing a novel spatiotemporal graph-based model for predicting the probability of future traffic incidents. A significant amount of data was collected, and key features were extracted. The model comprises three main components: a spatio-temporal layer to capture both spatial connections and temporal dependencies, an embedding layer to learn dense and meaningful representations of external factors, and a comparative analysis against existing methods using real-world datasets. The proposed model can be used to alert individuals to potential risks in advance, helping them choose safer travel routes.

We are further refining the results by analyzing the latest models, enhancing model accuracy, and conducting comparative analyses of algorithms to boost performance. This research is implemented on a foreign dataset, enabling us to better understand uncontrolled traffic flow, prevent accidents, predict traffic jams, and ensure accurate navigation. Our hybrid approach enhances the reliability and sustainability of large-scale networks by improving both recurrent and non-recurrent traffic conditions. Additionally, the model

detects abnormal events on the road, contributing to accident prevention, traffic management, structural management, and traffic flow prediction.

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Review of Soft Computing Technique to Find the Steady State Temperature in a Reactor

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ABSTRACT

A chemical reactor is typically the most significant unit operation in a chemical process. Chemical processes can be classified as endothermic, requiring energy input, or exothermic, which releases energy. Therefore, in order to maintain a constant temperature, energy must either be withdrawn from or provided to the reactor. The rate constant of a reaction must be considered while designing controllers to control the concentration of a continuous stirred tank reactor (CSTR). Effect of initial guesses of concentration and temperature in the reactor on their steady state values has been examined in this simulation. If equations are not coupled, then the single equation can be solved by itself. Here equations mass balance and energy balance equations are simultaneous algebraic, nonlinear coupled equations. To solve this nonlinear problem solve function in MATLAB has been explored. Three sets of initial guesses are given and final steady state concentration and temperature values calculated. The guesses are in the fairly large range, concentration from 1 to 9 kilomol per meter cube and temperature from 27 to 177 degree centigrade. It is demonstrated that final steady state values are different for individual guess values in one case and are same for one different guess values.

KEYWORDS : *CSTR, Coupled equations, Steady state reactor.*

INTRODUCTION

A chemical reactor is typically the most significant unit operation in a chemical process. Since chemical processes are either exothermic, releasing energy or endothermic, requiring energy input maintaining a steady temperature necessitates the removal or addition of energy from the reactor. The most fascinating systems to study are exothermic reactions due to their potential for exotic behavior, such as multiple steady-states (many possible values of the output variable for a given input value), and potential safety issues (rapid temperature increases, sometimes referred to as "ignition" behavior).

As seen in figure 1, it is regarded as a perfectly mixed, continuously stirred tank reactor (CSTR) in this work. We study the example of a single, first-order, irreversible exothermic reaction, A→B. It is evident from figure 1, that one fluid stream is continuously added to the reactor and another is continuously taken out of it. The reactor fluid's concentration and temperature are identical to those of the exit stream because the reactor is perfectly mixed. Observe that there are feed and exit streams on a jacket that wraps around the reactor. It is assumed that the jacket is perfectly mixed and that its temperature is lower than that of the reactor. The heat produced by the reaction is subsequently removed from the reactor by energy that enters the jacket through the reactor walls [1].

In this work, following is considered for Continuous stirred reactor (CSTR) equipped with heating/cooling jacket such that

The transients that is inherent disturbances in the system are neglected

The operation is diabetic that is the exchange of energy is carried out with the help of the jacket

A single first order reaction takes place in the reactor
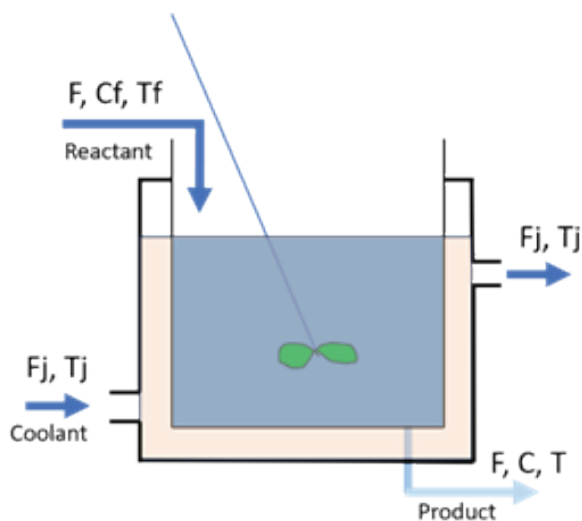
Fig. 1: Schematic diagram of CSTR

A CSTR wherein an A→B irreversible exothermic reaction occurs. Figure 1 [2] illustrates how a coolant medium that circulates via a jacket encircling the reactor removes reaction heat. The heat generated by the reaction and the heat absorbed by the coolant should be equivalent while the CSTR is at steady state.

PRELIMINARIES

The rate constant of a reaction must be considered in the design of controllers for controlling the concentration of a continuous stirred tank reactor. In reference [5], a series reaction A→B→C is taken into consideration. With regard to the concentration of species A and rate constant k1, the reaction A→B is first-order, and the reaction B→C is second-order with regard to the concentration of species B and rate constant k2. A detailed study of the CSTR's dynamics is conducted.

An overview of CSTR

The system is a jacketed CSTR. It is equipped with heating or cooling jacket. CSTR is equipped with a stirrer. In an ideal CSTR it is assumed that there is perfect mixing and no gradient in concentration of reaction volume. With time temperature of reaction mixture may change. For an endothermic reaction temperature will be falling down and for exothermic reaction temperature will be increasing. The temperature is need to maintained constant. The transients in the

system are neglected. Inherent disturbances in the system which may lead to change in system variables. So, control system is required to maintain the system variables. At steady state these system variables should not change. Before the steady state is reached, the system would be dynamic in nature. During shut down phase also transient and dynamic behaviour of system is encountered. Diabetic operation refers to energy. In a CSTR there is an inflow and outflow, so mass flow is there. Regarding energy exchange, that is input of energy and removal of energy. Exchange of energy is carried out via a convection processes.

Inlets have reactants, outlets have products and unreacted reactants. F is the inlet reactant flow rate and outlet product flow rate. As far as a steady state operation with respect to flow of mass is concerned, the system is already at steady state with respect to flow of mass is concerned. The overall mass within the system is not changing with time. Inside the tank, concentration is C. V is the volume of the reaction mixture. r is the rate of reaction. There are quantities associated with the jacket. The purpose of the jacket primarily is for heat transfer. Temperature of the jacket at the outlet and inlet is assumed the same. The flow is in a steady state so inlet and outlet flow rates are the same. ΔH is the heat of reaction. Its sign depends on whether the reaction is endothermic or exothermic. It's again important to know the magnitude of heat of reaction because it is going to change the temperature of a reaction mixture. For endothermic [Large Δ H] there is a large drop in the temperature so steam needs to be provided.

Mass Balance and Energy Balance Equation

There are two balance equations

Mass balance

$$\frac{F}{V}(C_f - C) - r = 0 \qquad (1)$$

Time rate of inflow of the species is given by (F/V)*C$_f$ and the outflow is given by (F/V)*C. Then time rate of change of concentration of species in the reaction mixture specifically due to reaction. At steady state, these two need to balance out. Additional dynamical term at the right side if a system is transient. As no term at the right side in equation (1), it is considered that the system is at steady state. The Inflow to the reactor

contains some reactants. The concentration of species in the feed is given as C_f and at the outlet, the concentration is C. The concentration at the outlet C is not equal to the concentration at the feed/inlet. If the concentration is changing, it is happening in the reaction chamber.

Energy balance

$$\frac{F}{V}(T_f - T) + \left(\frac{-\Delta H}{\rho C_p}\right)r - \frac{VA}{V\rho C_p}(T - T_j) = 0 \tag{2}$$

Here there are three terms. Mass which is coming in, is bringing energy into the system. The energy exchange is the heat transfer or heat exchange that takes place between the jacket fluid and reaction mixture contents. The quantification of this energy certainly depends on the difference between jacket temperature and mixture temperature. Second term has the Heat transfer coefficient and the area of heat transfer is there.

Sign of the ΔH depends on two things-

What is the rate of reaction? And What is the magnitude of energy of reaction? Larger energy of reaction will take large energy. These equations are certainly not differential equations. These equations need to be solved for T and C. These are nonlinear algebraic equations.

If the equations are not coupled, then the single equation can be solved by itself. The rate of reaction r in equation (1), is a function of concentration as shown in equation (2). But the rate of reaction is also a function of temperature. Therefore, the first equation is not implicit. Here equations are simultaneous algebraic, nonlinear coupled equations.

SOFT COMPUTING TECHNIQUES

Palanki et al. provided an explanation of a software module for a regulation problem in a continuous stirred tank reactor in reference [5], using an Internet-mediated virtual laboratory. The fuzzy optimal control approach was utilized by Soukkou et al. to design the feedback loops of an exothermic continuous stirred tank reactor system [6]. A novel substitute for creating a fuzzy optimal controller with a smaller rule base was offered by the author. A robust fuzzy controller is suggested to be built using the genetic learning algorithm. Simulations show that the resulting optimal controller performs well. For controller design and parameter settings, it is crucial to investigate and compute steady state values. The use

of Globally Linearizing Control (GLC) formulations can significantly reduce the average computation time without compromising the closed loop performance [7].

fsolve function in MATLAB

Two equations can also be solved using the fsolve function in MATLAB. Initial guess is substituted for f(x)=0. In bisection, another guess is invoked. But if the actual solution is between f(x1) and f(x2) and the solutions of x1 and x2 are +ve and -ve, the bracketing of the solution can be done by taking a new guess by taking the arithmetic average of these two.

When the same thing is to be implemented for the two variables, then one variable may be close and other may be farther to the solution. Therefore, there is a need to do some optimization. Fsolve is doing the same. Fsolve is invoking the optimization. It is trying to minimize the sum of squares of errors of all of these variables by using an algorithm. In one variable or one dimension, only one variable is solved for f(x)=0.

To solve this nonlinear problem using fsolve, an initial guess needs to be provided. Three sets of guesses as shown in table 1 are given. Coupled nonlinear problem in higher dimensions., so it is possible that there is not a unique solution. Fsolve is a local optimizer. If there are multiple solutions, then the initial guess needs to be close to the one specific solution that is interesting. When this adiabatic operation is done, there are multiple steady states. Importance of those steady states-

What is the importance of those multiple steady states?

Are those always accessible?

What about their stability?

If a system is going to evolve with time, that means the system is dynamic. What is the fate of the system?

Table 1: The parameter sets for simulation [2][3][4]

Parameter, Unit	Case 1	Case 2	Case 3	Case 4
F/V, h^{-1}	1	1	1	1
k, s^{-1}	14825	9703	18194	3122
-ΔH, kcal/kmol	5215	5960	8195	30000
E, kcal/kmol	11843	11843	11843	30000
ρC$_p$, kcal/(m^3 °C)	500	500	500	500
T$_f$, $^{-1}$C	25	25	25	21

C_{Af}, kmol/m³	10	10	10	10
UA/V, kcal/(m3 ºCh)	250	150	750	150
Tj, ºC	25	25	25	25
CA Solved Guess1	8	8.8	6.8	10
T Solved Guess1	310	310	320	290
CA Solved Guess2	5.3	4.5	6.8	10
T Solved Guess2	340	350	320	290
CA Solved Guess3	5.3	2.9	6.8	10
T Solved Guess3	340	360	320	290

Four sets of reactor data are provided as tabulated in table 1. Following reasonable initial guesses as tabulated in table 2 are used for fsolve. The guesses are in the fairly large range, concentration from 1 to 9 kilomol per meter cube and temperature from 27 to 177 degree centigrade.

Table 2: The parameters settings of optimization algorithms. [2][3][4]

Initial Guess	Guess 1	Guess 2	Guess 3
CA Kmol/m³	9	5	1
T ºC	27	77	177

Pseudo code/Algorithm for the program

Algorithm for the program has been explained in algorithm 1 and MATLAB code has been presented in figure 2.

Algorithm 1: Procedure for solving simultaneous algebraic, nonlinear coupled equations for CSTR steady state
Input: Guesses and Parameter values
Output: Steady state Concentration and Temperature
1. Define global variables for system parameters so that a single copy of the same variable can be shared by all functions
2. Define guess for steady state concentration and steady state temperature.
3. Invoke fsolve function to solve the algebraic nonlinear coupled equations
4. Print the steady state concentration and steady state temperature

```
clc
clear
close all
global k0 H_rxn rhocp UA_by_V E R F_by_V Caf Tf Tj

Guess1=[9;300];Guess2=[5;350];Guess3=[1;450];

%parameter set
% F_by_V=1; k0=14825*3600; H_rxn=5215; E=11843; rhocp=500;
% Tf=25+273; Caf=10; UA_by_V=250; Tj=25+273; R =1.98;


% parameter set 2
% F_by_V=1; k0=9703*3600; H_rxn=5960; E=11843; rhocp=500;
%Tf=25+273; Caf=10; UA_by_V=150; Tj=25+273; R =1.98;

% parameter set 3
% F_by_V=1; k0=18194*3600; H_rxn=8195; E=11843; rhocp=500;
%Tf=25+273; Caf=10; UA_by_V=750; Tj=25+273; R =1.98;

% parameter set 3
F_by_V=1; k0=3122*3600; H_rxn=30000; E=30000; rhocp=500;
Tf=21+273; Caf=10; UA_by_V=150; Tj=25+273; R =1.98;

%solution set for each guess set
xsol11 = fsolve(@cstr_func,Guess1);
xs0121 = fsolve(@cstr_func,Guess2);
xs0131 = fsolve(@cstr_func,Guess3);

% arranging the obtained results in the form of a table

Ca_solved1=round([xsol11(1); xs0121(1); xs0131(1)],2,'significant');
T_solved1=round([xsol11(2); xs0121(2); xs0131(2)],2,'significant');
Guess = ['Guess1';'Guess2';'Guess3'];
fprintf('For Parameter Set 1:')
table(Guess, Ca_solved1, T_solved1)

%................................................................%
```

Fig. 2: MATLAB program to find steady state concentration and temperature

Global variables are defined for system parameters so that a single copy of the same variable can be shared by all functions. Three different guesses in the wide range of concentration and temperature are defined. The values for CA solved and T solved are shown in table 2. For case 2, the final steady state values are different for each individual guess values. For case 1, the CA solved and T solved values are same for guess 2 and 3. Whereas for case 3 and case 4 parameter sets, the CA solved and T solved steady state values are same for all guesses.

DISCUSSION AND SIMULATION RESULTS

The continuous stirred tank reactor (CSTR) tends to reveal unstable severe nonlinear behavior when the operating level changes [8]. As investigated in an earlier work, the hard non-linearity nature of the CSTR originates from multiple probable sets of states for the same reaction in the same CSTR under identical ongoing

inlet conditions [9]. An exothermic reaction conducted in an adiabatic continuous stirred tank reactor (CSTR) system has multiple steady states in part of its operating window. Author demonstrated that the three-state model representing the mass and energy balances of the system can be well approximated with a two-state as well as a one-state model [10]. As a consequence of high-performance requirements and strict environmental regulations, control system designers are increasingly being required to employ controller design methods that account for the system nonlinearity in an adequate/satisfactory manner [11]. When a first order irreversible exothermic reaction takes place in CSTR, the plant model relating the reactor and jacket temperatures alongwith a measurement delay is of second order unstable type. Such plants are very challenging to control [12]. A method for continuous preparation of Atrz by CSTR is reported in paper [13], and the difference of Atrz production by batch equipment and CSTR was studied. The synthesis of Atrz by CSTR is advantageous over batch reactor.

The values for CA solved and T solved are shown in table 1. For case 2, the final steady state values are different for each individual guess values. For case 1, the CA solved and T solved values are same for guess 2 and 3. Whereas for case 3 and case 4 parameter sets, the CA solved and T solved steady state values are same for all guesses.

CONCLUSION

In this paper, a steady state concentration and temperature values are calculated for different sets of CSTR conditions. The importance of setting the values of guess for fsolve is studied. The steady state concentration and temperature values for three different guess values with four different parameter cases has been demonstrated.

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A Review on Hybrid Nano Fluids as a New Generation Coolant

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ABSTRACT

Thermal systems use a variety of methods, like insert usage and tube geometry adjustments, to accelerate the rate of heat transmission. However, these approaches usually result in increased running costs. Conventional coolants like ethylene glycol and water are typically used to cool the system. Although mono-nanofluids systems have superior cooling capabilities, the tendency of these nanofluids to aggregate can make blockage more likely when more nanoparticles are added. The use of hybrid nanofluids is an innovative cooling solution because of the limitations of mono nano fluids. The outstanding performance of hybrid nanofluids has been well documented in the literature to date. This paper provides a comprehensive understanding of the effects of hybrid nanofluids on thermal systems. Factors such as viscosity, stability have a significant impact on the performance of these hybrid nanofluids. In addition, this paper investigates how hybrid nanofluids affects specific heat capacity, thermal conductivity and dynamic viscosity. It is found that reducing the nanoparticles volume fraction improves stability of hybrid nano fluids. It's clear that various factors including volume fraction, temperature, base fluid selection, and nano particle properties are most important in determination of the thermophysical performance. It's noteworthy that with the increasing nano particle volume fractions, thermal conductivity and dynamic viscosity of hybrid nanofluids tends to increase. while specific heat capacity tends to decrease with increasing nano particle volume fraction.

KEYWORDS : *Dynamic viscosity , Hybrid nanoparticles, Specific heat, Thermal conductivity.*

INTRODUCTION

The phrase "nano fluid" refers to the dispersion of nanoparticles on nanoscale in traditional coolants like EG or water. The nano particles could be made from non-metallic or metallic elements. To make nano particles , copper and gold like metals are used. metal oxides, including those included in metal nitrides and carbides, oxide ceramics, carbon nanotubes, graphite diamond, sulphur dioxide, copper oxide, and aluminium oxide. The foundation fluid can be made of ethylene glycol, water, oils, bio fluids, refrigerants, among other substances. To prevent chemical reactions with base fluid, which changes thermophysical properties of nanofluids. Ultimately decrease its efficacy, the materials utilized to make the nano particles should be stable chemically. Many variables, including temperature, base fluid selection, size of nano particles, nano particle volume concentrations and geometry of the nano particles affects performance of nano fluids. Nanofluids have uses in nearly every industry, including electronics, solar energy, the automotive and medical industries, and building heating and cooling. Studies using multiple elemental nanoparticles are appealing to researchers since the usefulness of nanofluids made from single elemental nanoparticles has been found to

be restricted. The efficiency of nanofluids is increased by the addition of several kinds of elemental nanoparticles in addition to single elemental nanoparticles. Following up on the discovery of mono nanoparticles fluid researchers introduced hybrid nano fluids, a new kind of nano fluids composed of multi-element nanoparticles with base fluid. Nano fluids efficiency influenced by nano particles thermo physical properties. Thermal conductivity can be improved by Increasing volume of nano particles in base fluid.. Adding nanoparticles by volume results in a pressure drop and the development of clusters that decrease the surface area and increase the diameter of the fluids. The pumping force is also strengthened . Clogging in pipes are a result of increment in viscosity. Right nano particles combination improves hybrid nano fluid thermo physical properties. The hybrid nano fluids found to be more stable and effective in comparison with traditional fluids.

LITERATURE SURVEY

Preparation of Hybrid Nano Fluids

The mixture of multi-elemental particles and base fluid is called a hybrid nano fluid. Several factors are playing a vital role, and they should be taken into account. Addition of nano particles to base fluid results in agglomeration, pipes get blocked due to agglomeration and this causes the corrosion on solid surfaces. Ultra sonication methods are used to solve this agglomeration problem.

The hybrid nano fluids could be produced by two methods:

Single Step approach

Two Step approach

Single step approach- This technique made it possible to produce two distinct types of nanoparticles at the same time. The single step strategy is not cost-effective for the large scale production because of its drawn out procedure, for large scale production single step method is unsuitable because of its prolonged processing time. [1]

Two Step approach- First, base fluids and nanoparticles made by a variety of physical or chemical techniques were combined at one time. To prevent clogging, surfactant is added next, and ultra sonication is done

last. It improves the nanofluids stability. The hybrid nanofluids can be made using the aforementioned techniques.
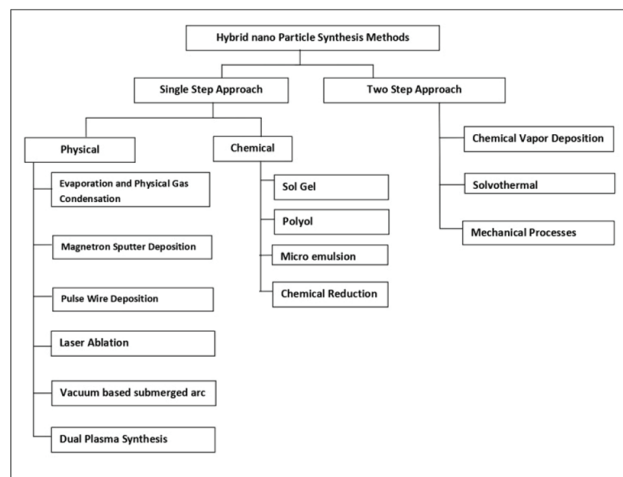
Fig 1 Hybrid Nano Fluid Synthesis Methods

The figure 1 shows methods for synthesis of hybrid nano particles. The physical and chemical listed methods are time consuming and costly Since due to their ease of use, mechanical methods like ball milling and mechanical milling are the methods of choice for most researchers for synthesizing nanoparticles.[2]

Hybrid Nano Fluids Stability

The Cohesive and van der Waals forces are mainly responsible for aggregation of hybrid nano fluids . Hybrid nanofluids propensity for coagulation reduces its potential because of its heat transmission properties. The frictional resistance and pressure drop increases due to increment in nano particles concentration with base fluids . The hybrid nano fluids stability is determining factor in its thermophysical properties. Numerous techniques like visual inspection, light scattering, and zero potential analysis can be used to analyze stability of hybrid nano fluids. The Common techniques, such as i) adding surfactant, were created to simplify analysis and lessen agglomeration. ii) Using electrostatic stabilization to regulate pH iii) Vibration using Ultrasonic are utilized to increase the stability of hybrid nano fluid. The best way to make hybrid nanofluids more stable is to add surfactant, however this approach has restrictions on the base fluid choices that can be made. The hybrid nanoparticles were stable for ten to fifteen days when mixed with the base fluid

as a water [14]. The stability of hybrid nano fluid can be improved by sonication and reducing the likelihood of blockages in pipes. The type of base fluid used also affects the stability of hybrid nanofluids. Base fluids other than water are shown to be more viscous and thus not stable over time.[15].

The structure and characteristics of hybrid nanoparticles are significantly changed by the intensity of ultrasonic waves. As the ultrasonic intensity increases ,its creates huge impact on hybrid nano fluids efficacy. This is because using compositions of smaller hybrid nanoparticles improves the hybrid nanofluids performance. [28]
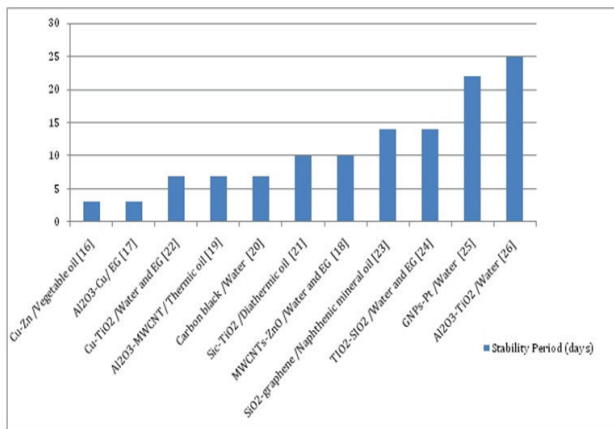
Graph 1 Stability Period of Hybrid Nano Fluids

The graph 1 illustrates numerous hybrid nanofluids stability identified by the researchers. The stability is dependent on the base fluid. The water as a fundamental base fluid is more stable. Addition of nanoparticles reduces stability, with higher density nanoparticles having the lowest stability at low volumes.

Hybrid Nano Fluids Thermo Physical Properties

The commonly preferred nano particles thermo physical properties illustrated in table 1. The Nanoparticles properties like density, thermal conductivity , specific heat affects hybrid nano fluids thermo physical properties. The higher denser nanoparticles leads to increasing dynamic viscosity which ultimately increases the agglomerations. The Silver (Ag) particles have highest thermal conductivity and density and the Silicon dioxide (SiO_2) nano particles have lowest thermal conductivity.

Table 1 Commonly Preferred Nano Particles Thermo Physical Properties

Property	Cu	Al_2O_3	CuO	TiO_2	ZnO	Ag	SiO_2
C(J/Kg k)	385	765	535.5	686.2	502	235	745
ρ (Kg/m³)	8933	3970	6500	4250	5600	10500	2200
K(w/mk)	400	40	20	8.9538	110.95	429	1.4

Esfe [22] investigated hybrid fluid made of Cu-TiO_2 hybrid nano particles with base fluid Water & EG. The study found that a 2% nano particles volume concentrations enhanced thermal conductivity ratios by a factor of 1.4 when measured at a 60 °C of temperature.

Ma [26] studied Al_2O_3-CuO/ Water and Al_2O_3-TiO_2/ Water hybrid nano fluids with 0.05% and 0.01% volume concentrations to determine hybrid nano fluids thermal conductivities. The results shown increments in thermal conductivity. He also noticed increment in dynamic viscosity of hybrid nano fluids due to use of surfactants.

The TiO_2-Al_2O_3 / Water-EG based hybrid fluid's thermal Conductivity was determined by Urmi. The study showed a 40.86% improvement in thermal conductivity for a small amount of particles for 80 0C. [29]

Mousavi [30] studied MGO-TiO_2/water based hybrid fluid. The study reported 21.8% increment in thermal conductivity at 60 0C also noticed 1% decrement in specific heat of hybrid nano fluids .

Mousavi [31] experimentally studied the CuO-MgO-TiO_2 /Water hybrid nano fluid thermal conductivity. The experiment carried with 0.10% volume concentrations of hybrid nano fluid at temperature of 50 0C and observed increment in thermal conductivity up to 78.6%. The study determined specific heat for volume concentrations up to 0.10% and reported 2.13% decrement in it. Also the study shown 161.8% increment in dynamic viscosity for 0.1% volume concentrations of nano particles.

Toghraie [32] studied hybrid fluid made up of ZNO-TiO_2 hybrid nano particles with EG as a base fluid. He reported 32% improvement in thermal conductivity for 3.5% of volume concentrations at temperature of 50 0C.

Akhgar [33] studied hybrid fluid made up of TiO_2-MWCNT hybrid nano particles and Water EG as base fluid and reported 38.7% increment in

thermal conductivity for 1% nano particles volume concentrations at temperature of 50 ^{0}C.

Esfe [35] studied hybrid nano fluid consisting SWCNT-Al$_2$O$_3$ hybrid nano particles with EG as a base fluid. He reported improvement in thermal conductivity up to 41.2% for a 2.5 % nano particles volume concentrations at temperature of 50 ^{0}C.

Bakhtiari [36] experimentally investigated hybrid nano fluid made of TiO$_2$-Gr nano particles with water as base fluid . The study observed 27.84% increment in thermal conductivity for 0.5 % volume concentrations of nano particles at 75 ^{0}C.

Esfe [37] studied thermal conductivity of hybrid nano fluid consisting of SWCNT-MgO hybrid nano particles with EG as a base fluid. The 35 % improvement in thermal conductivity reported for nano particles volume concentrations of 0.55 % at temperature of 50 ^{0}C.

Zadkhast [38] studied hybrid nano fluid made of MWCNT-CuO nano particles with base fluid as Water. The 30.38 % improvement in thermal conductivity observed for 0.6 % nano particles volume concentrations at 50 ^{0}C of temperature.

Kakavandi [40] investigated hybrid nano fluid made up of MWCNT-SiC nano particles with water-EG as base fluid. The observations reported 33% thermal conductivity increment for 0.75% volume fractions of hybrid nanoparticles at a temperature of 50 ^{0}C.

Moradi [42] studied hybrid nano fluids thermal conductivity made up of TiO2-MWCNT hybrid nano particles and EG-Water as a base fluid. The 34 % improvement observed for nano particles volume concentrations of 1% at temperature of 60 ^{0}C.

Cakmak [43] studied hybrid nano fluid consist rGO-Fe$_3$O$_4$-TiO$_2$ hybrid nano particles with EG as a base fluid. The study reported thermal conductivity enhancement by 13 % for a 0.25% volume concentrations of nano particles for a temperature of 60 ^{0}C.

Rostamian [45] studied hybrid nano fluid made up of CuO-SWCNT hybrid nano particles and base fluid as EG- Water. The 35 % improvement observed in thermal conductivity for hybrid nano particles volume concentrations of 0.75% at temperature of 50 ^{0}C.

Aparna [46] experimentally studied Al2O3-Ag/ water hybrid nanofluids for thermal conductivity determination. The 23.82% increment in thermal conductivity observed for hybrid nano particles volume concentrations of 0.1% at temperature of 52°C.

Esfe [47] studied hybrid nano fluid prepared by MWCNT-SiO$_2$ hybrid nano particles with base fluid as EG. The study reported thermal conductivity improvement by 20.1 % for volume concentrations of nano particles up to 0.86% at temperature 50 0C. He also observed 30.2% increment in dynamic viscosity for 1% of volume concentrations of nano particles.

Nabil [49] experimentally determined TiO$_2$–SiO$_2$/ water hybrid nanofluids thermal conductivity. The findings noted that 3% volume concentration of nano particles improved thermal conductivity by 22.8% for temperature of 80 °C. Additionally, he observed a 62.5% rise in dynamic viscosity at the same concentration of nano particles.

Colak [50] experimentally studied Cu-Al$_2$O$_3$/Water hybrid nano fluid. He reported 1.08% reduction in specific heat for 0.05% volume concentrations of nano particles.

Gao [51] Studied GO-Al$_2$O$_3$/Water hybrid nano fluid . He reported 7% reduction in specific heat for 0.05% volume concentrations of nano particles.

Tiwari [52] experimentally identified the specific heat of SnO$_2$-MWCNT /Water hybrid nano fluid . He reported 15.09% reduction in specific heat for 1.50% volume concentrations of nano particles.

Moldoveanu [53] experimentally identified specific heat of hybrid nano fluids made of Al$_2$O$_3$-TiO$_2$ hybrid nano particles with base fluid water. The study reported 11% reduction in specific heat for 0.12 % volume concentrations of nano particles.

Asadi [54] experimentally studied MWCNT-MgO/ SAE50 oil hybrid nano fluid and reported 65% increment in dynamic viscosity for 2% of volume fractions of nano particles.

Alarifi [55] conducted an experiment on TiO$_2$-MWCNT/ 5W50 oil hybrid nano fluid and reported 42% increment in dynamic viscosity for 2% of volume fractions of nano particles.

Senniangiri [58] studied hybrid fluid consist of Gr-NiO nano particles with base fluid coconut oil and observed dynamic viscosity increment by 28.49% for 0.5% volume concentrations of hybrid nano particles.

Dalkılıc [60] experimentally studied hybrid nano fluid made of SiO_2-graphite nano particles and base fluid water . The study reported dynamic viscosity increment by 36.12% for 2% of volume fractions of nano particles of hybrid nano fluid.

Motahari [61] experimentally studied MWCNT-SiO_2/ 20W50 oil hybrid nano fluid for 1% of volume fractions of nano particles and reported 171% increment in dynamic viscosity of hybrid nano fluid.

Ruhani [62] experimentally studied ZnO-Ag / Water hybrid nano fluid. He noted relative dynamic viscosity increment about 1.75 times for 2% nano particle volume fractions .

Kumar [65] conducted experiments to find dynamic viscosity of Al_2O_3-CuO nano particles with EG-water, PG-water base fluids. He observed 16.2% increase in dynamic viscosity for 2% volume fractions.

Ghaffarkhah [66] experimentally studied Different materials / Transformer oil hybrid nano fluid for 0.01% of volume fractions of nano particles and reported 13.618 % increment in dynamic viscosity of hybrid nano fluid.

Bahrami [68] experimentally studied Fe-CuO / Water-EG hybrid nano fluid for 1.5 % of volume fractions of nano particles and reported 70% increment in dynamic viscosity of hybrid nano fluid.

Afrand [69] experimentally studied the SiO_2-MWCNT / SAE40 hybrid nano fluid for 1 % of volume fractions of nano particles and reported 37.4% increment in dynamic viscosity.

Asadi [70] studied hybrid nano fluid made up of MWCNT-ZnO hybrid nano particles with engine oil as base fluid. The study observed 45% increment in dynamic viscosity for 1% volume fractions of nano particles.

Solatani [71] experimentally studied the MgO-MWCNT hybrid nano particles with engine oil as a base fluid . He observed 168% enhancement in hybrid nano fluids dynamic viscosity for 1% volume fractions of nano particles.

Aghaei [72] experimentally studied CuO-MWCNT nano particles with SAE5W50 oil base fluid and reported 35.52% increment in dynamic viscosity for 1 % nano particles volume fractions.

CONCLUSIONS

The hybrid nano fluids performance shows significant improvement compared with mono nano fluids. The following conclusions were noted in this exhaustive review study:

1) The stability of hybrid nano fluids is crucial as they are frequently re-circulated in thermal systems. The hybrid nano fluids with the lowest hybrid nano particles volume concentrations are the most stable, and stability declines by increasing hybrid nano particles volume concentrations in the base fluid. The base fluid like EG , coconut oil, Engine oil have the least stability, whereas base fluids such as water have the most stability. The TiO2-Al_2O_3/ Water hybrid nano fluid shown the highest stability of 25 days.

2) EG-based hybrid nanofluids show minimal thermal conductivity increase, while water-based nanofluids show significant enhancement. CuO-MgO-TiO_2/ water hybrid nanofluids shows the highest increase at 78.6%, while TiO_2-Al_2O_3/water variant shows a moderate improvement of up to 40.86%.

3) The hybrid nano fluid like SnO2-MWCNT/Water shown the highest specific heat reduction up to 15% for nano particle volume concentration of 1.50%, while TiO2-Al2O3/Water hybrid nano fluid shows moderate decrement up to 11% for nano particle volume concentration of 0.12%.

4) The base fluids like EG, Oils shown increment in dynamic viscosity of hybrid nano fluids. The highest dynamic viscosity increment up to 171% observed for MWCNT-SiO_2/20W50 oil hybrid nano fluid while the Graphene-SiO_2/Water demonstrates the least increase up to 10%. Additionally, the TiO_2-Al_2O_3/Water-EG formulation shows a viscosity increase of 161.8%.

5) TiO$_2$-Al$_2$O$_3$/Water hybrid nano fluid is found advantageous due to stability and higher thermal conductivity with lower volume fractions.

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Accelerating SHA-256 Hash Function Using FPGA for High Performance

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ABSTRACT

Many encryption algorithms have been developed to protect users' original data at this time. Cryptographic hash functions are used in many different applications to ensure the authenticity and consistency of data. The hash function (HF) is a crucial security primitive for ensuring data integrity and authentication. As a cornerstone of blockchain technology, it relies heavily on cryptographic principles, with the cryptographic hash function serving as its foundation. The integration of blockchain technology with the Internet of Things (IoT) across various sectors has significantly contributed to its growing popularity. As a result, using current blockchain technology is still challenging. Up till now, Application-specific integrated circuits (ASICs) have been the primary platform for lightweight cryptography due to their exceptional performance and energy efficiency..

Their lengthy design cycle and very high nonrecurring engineering expenses limit their deployment to high-volume applications. This article presents the design and details of a new SHA family to satisfy the requirements of the cryptographic algorithm. These schematics were first created in VHDL, and ModelSim was used to simulate and verify them. We analyse and synthesise the SHA256 FPGA implementation using Altera Quartus-II. The outcomes demonstrated that the throughput and efficiency of the Stratix-III architecture were enhanced by the proposed SHA-256 design. The high throughput of the SHA-256 architecture was attained by using a data transport speed of 1090.512 Mbps.

KEYWORDS : *Blockchain, Field Programmable Gate Arrays FPGA, Hash function, High performance, High throughput. Internet of Things.*

INTRODUCTION

Today's wireless communication smart application domains, such as smart cities, smart healthcare, smart transportation, and many more, are built on the Internet-of-things (IoT). The Internet of Things (IoT) is a part of the idea known as the Internet of Everything (IoE). The volume of data being collected in the IoE environment increases daily. For these applications, low-performance, low-power devices are used, which limit the computational power available to the design. In these situations, the addition of a "Edge Layer" will reduce the computing burden on the whole network of devices. Blockchain technology can relieve IoT systems of the need for a central organisation. Data is organized, and transactions are executed through a decentralized public ledger called the blockchain. Each

node connected to the network maintains its own copy of the ledger. As a result, security and consistency are preserved [1-2].
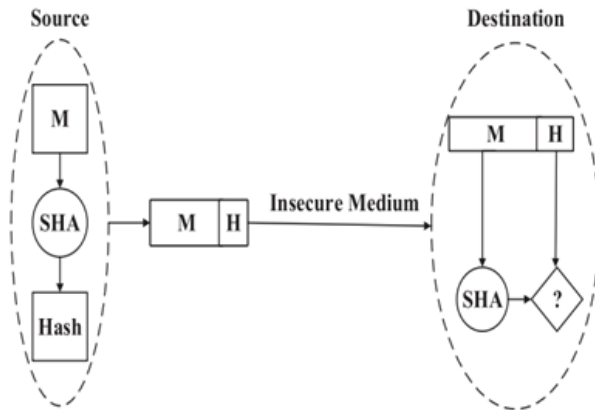
Fig. 1 Hash Algorithm Working Scenario

Typical uses for hash functions include random number generators, password tables, universal unique identifiers (UUID/GUID), and many more. However, its greatest application is in digital signatures. As seen in Figure 1, message (M) is being validated while being sent across an unreliable channel. The hash is computed and inserted on the source side using a hash function. At the destination, the message hash is calculated and compared with the attached hash value. If both hashes match, it confirms that the message received has not been altered.. Hash functions also play a key role in digital signatures, contributing to the processes of authorization and validation. [3–4]. This paper's methodology assesses each individual SHA-256 algorithm operation and the data dependencies among them to design a customised data path that maximises throughput per clock cycle, minimises memory access, and gives priority to data reuse. We were able to reduce the number of basic operations and build the required data pipeline, arithmetic, and logic units based on this evaluation. An iterative design technique was employed to reduce hardware requirements and shorten the critical path. The main contributions of the work are:

i.   A small parallel SHA256 processor architecture based on FPGA was developed, using less logic hardware resources.

ii. SHA256 processor design that is both small and effective compared to state-of-the-art methods.

RELATED WORK

Researchers described here are responsible for designing the numerous hash-based functions. The 4-2 adder compressor design ensures that SHA-256s have a quicker calculation time during the partial product accumulation stage by reducing the total number of adders employed [5]. Field programmed gate arrays are used to put a number of cryptographic techniques into practice [6]. Built on a heterogeneous computing platform, the hash-based mapping system uses a novel technique to replace the relevant BWA-MEM methods [7]. The SHA-1 Algorithm and the Advanced Encryption Standard (AES) were created with the use of an FPGA hardware board [8]. Using a 4-input ALU acting as the central component of the architecture, the new SHA-256 design is built using an optimised data path that utilises previously used modules [9]. By adjusting the SHA-256 structure, the unfolding approach is employed to produce the hash value in the hash function [10]. For SHA 3, a unique method is created [11] that uses pipelining to increase throughput. An innovative method for the implementation of variational irreducible polynomials in FPGA is presented [12], which is based on a hash algorithm. Using a hardware module of SHA-256 FPGA, the IEEE 1609.2 vehicle communications (VC) security protocol was developed [13]. The Bob Jenkins lookup3 hash function's open-source implementation is designed to work best with OpenCL [14]. Description of an optimal implementation of the cryptographic hash function [15], which tries to minimise circuit complexity while enhancing performance, might be helpful for hardware implementations of this function.

A platform [16] is demonstrated to have the ability to automatically generate hash algorithms appropriate for the hashing of network flow hashing.

A system for quickly developing hardware implementations of algorithms to accelerate cryptographic hash functions on the Xilinx ZYNQ SoC was provided [17]. An efficient FPGA implementation of the Bloom filter is presented in [18], where a large set P of l-byte patterns is pre-registered. The Troika hash function's hardware designs allowed for reconfigurable devices that are both suitably fast and nearly entirely circuitry-free [19]. The Secure Hash Algorithms and their FPGA implementations were compared and

shown using the three distinct hashing standards [20]. erratic code paths and input data depend on the new hash algorithms based on irregular programmes are presented [21].

MATERIALS AND METHODS

The parallel implementation of the hash computation and preprocessing blocks in the suggested SHA-256 architecture enables us to quickly and efficiently create the SHA-256 design shown in figure 2. These layouts were developed to offer improved throughput performance. The SHA-256 algorithm was developed using VHDL.
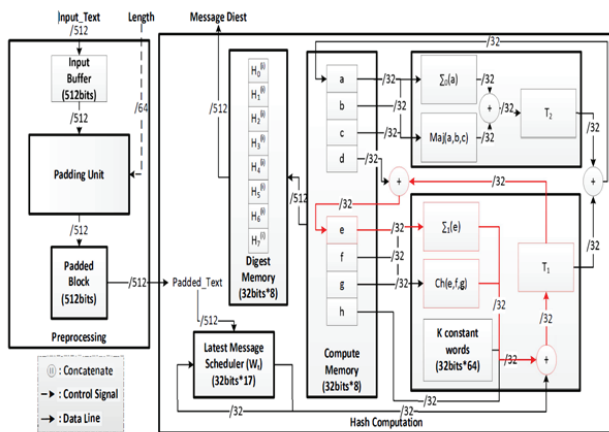
Fig. 2. Architecture pf Sha256 Processor

By pipelining the hash computation block and the new message preparation block, the suggested architecture achieves higher throughput. The input data's 512-bit padded blocks are opened and examined during the first processing phase. The last 64-bit block denotes the end of the message and includes the message length, a string of '0' bits, and a single '1' bit.

Wt calculates two temporary variables (T1 and T2) and eight working variables in the Compute Memory block. Wt values from 16 to 63 need further computations that use the Wt values that came before them in a single 32-bit register. To compute Wt between 16 and 63, we can significantly reduce the number of registers required by our present message scheduling module.

Keep track of the most recent padded message throughout the hash computation and is ready to send the appropriate one at the appropriate moment. The message digest of the input message is created at the

final stage of the 63rd round by combining the working variables of this round with the hash values from previous rounds. The hash computation block has to follow the crucial route shown by the red line in Figure 2. As can be observed, in order to do the computation of the variable, reliance on the data on the route itself is necessary. In addition, a lot of 32-bit addition operations might slow down the route's speed. We use the adder and subtractor IP logics to cut down on the lag on this important channel and boost overall performance.
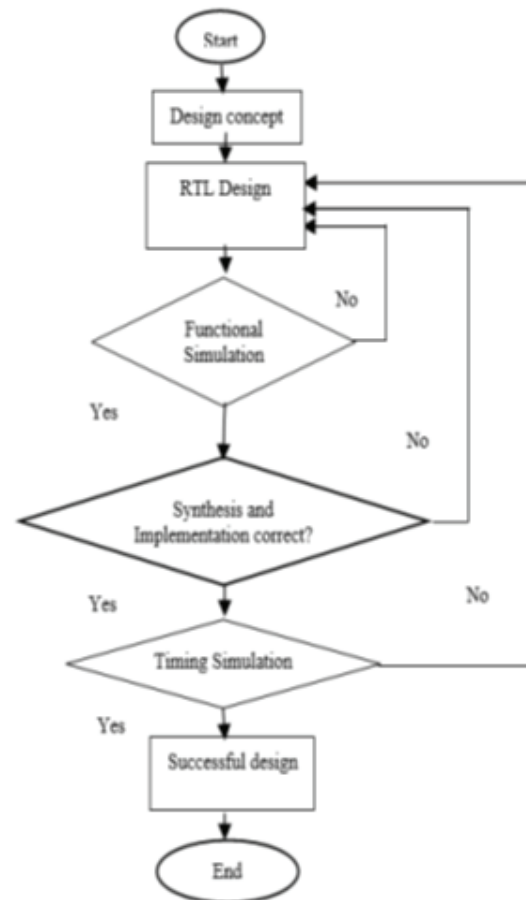
Fig. 3 Sha256 Flow Chart Design

The SHA-256 Message, Wt Each component of the throughput SHA-256 architecture needs to be tweaked for optimal performance. For the factor two architecture, for instance, you'd need two simultaneous 32-bit inputs containing constants. Similarly, this system required four sets of parallel constants and four sets of parallel 32-bit inputs. Consequently, a full data reset is needed for the subsequent cycle in the series. To implement

this strategy, modifications are necessary to each input module. Figure 3 shows the flowchart for the design. First, a variety of RTL layouts are displayed. Before the SHA-256 hash function approach was eventually downloaded to the FPGA hardware design, it was assessed using both functional and temporal simulation.

The SHA-256 algorithm's basic operations are listed in Algorithm 1, and their mathematical details are explained below.

Algorithms 1:

Input:
Padded message M = {M0, M1 . . . , Mn } Blocks
Output:
Output Hash (256 bits)
Procedure:
Step1: Initialise the hash values: h0, h1, ……., h6, h7
Step2: Create an array of round constants and initialize it.: k0…. k63
Step3: Pre-processing: Data Padding
Step4: Perform operations on the message in discrete chunks of 512 bits each:
The message is broken up into 512-bit chunks
for each chunk
Build a 64-entry message schedule array with word values ranging from 0 to 63 using 32-bit words;
copy chunk into the message schedule array's first 16 words, which are labelled w[0..15];
Extend the first 16 words into the remaining 48 words w[16..63] of the message schedule array:
Set the values of working variables to the currently relevant hash: a,b,c,d,e,f,g,h;
Compression function main loop:
For i from 0 to 63
Compute S1
Compute Ch(e,f,g)
Compute Temp1
Compute S0
Compute Maj(a,b,c)
Compute Temp2
Compute the new hash value after adding the compressed piece:
Step5: Produce the final hash value (big-endian): hash_digest := Append all hashes (h0, h1, h2, ……., h6, h7)

All the equations mentioned below are used to calculate all the functions in the SHA-256 algorithms.

$$S0 = (a \text{ rotateright } 2) \text{ xor } (a \text{ rotateright } 13) \text{ xor } (a \text{ rotateright } 22);$$
$$S1 = (e \text{ rotate right } 6) \text{ xor } (e \text{ rotate right } 11) \text{ xor } (e \text{ rotateright } 25);$$
$$Ch (e,f,g) = (e \text{ and } f) \text{ xor } ((\text{not } e) \text{ and } g);$$
$$Maj (a,b,c) = (a \text{ and } b) \text{ xor } (a \text{ and } c) \text{ xor } (b \text{ and } c);$$
$$temp1 = h + S1 + ch + k [i] + w[i];$$
$$temp2 = S0 + maj;$$
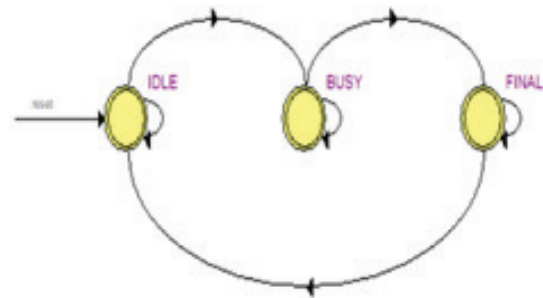
Fig. 4 Implementation of SHA256 Using FSM

As seen in Figure 4, finite-state machine logic is used to code the SHA256 implementation. The finite state machine is a mathematical representation of computing that can exist only in one of a finite number of states concurrently. Three primary states are used for the implementation: idle, busy, and final. All variables that have a hash value and the input data are initialised when the system is idle. All primary variable computations are completed while the system is busy. Additionally, a final 256-bit hash value is obtained by appending the intermediate computed hash to the final state.

EXPERIMENTAL RESULT AND DISCUSSION

Altera Quartus II was used to build the suggested SHA-256 design in VHDL. This software was utilised for all design analysis, synthesis, placement, and routing. The recommended VHDL design is ported to an Altera FPGA board using Quartus II. The data flow of the proposed architecture is examined using an ISE-based VHDL design simulation. Every time a loop ends, we compare every variable against a VHDL simulation of the conventional SHA-256 hash technique. Following the synthesis, tables show an overview of the device usage of the suggested architecture and a performance comparison between the recommended approach and

other designs. Memory and speed are required for the FPGA implementation of SHA standards because of the high number of calculations maintained during hash creation. Optimising the design for performance and memory is crucial to getting the most out of an FPGA. Metrics for the FPGA evaluation are:

1. Logic Resource Utilization: Indicative of the overall amount of lookup tables or configurable logic blocks employed in a given design. However, because to variations in placements methods between FPGA manufacturers, there may be situations in which a direct comparison of area is misleading. Therefore, using an FPGA from the same vendor is advised for this purpose.

2. Minimum Propagation Delay: A signal's latency is the time it takes to go from its source to its intended destination signal.

3. Maximum Frequency: The maximum possible operating clock rate for a certain FPGA.

4. Power Consumption: It is indicative of the overall hardware power consumption when a certain design is implemented. This characteristic is typically characterized by its frequency.

5. Throughput:The speed of hardware implementation is measured in terms of the number of bits processed in a particular time. The formula for throughput:

Throughput = (Block_Size) / (T * Nclk)

6. Efficiency: Ration of throughput to number of slices. It is defined by below equation.

Efficiency = Throughput / Number of Slices
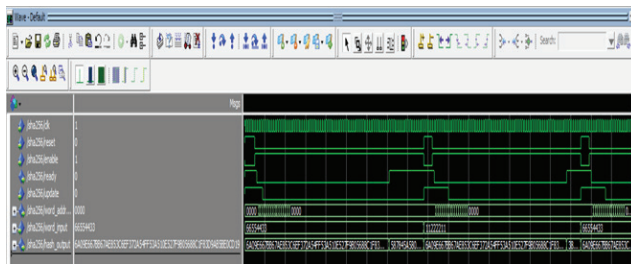
Fig. 5 Simulation Result of SHA256

Modelsim is used to compile and verify the functionality of SHA 256. Figure 5 presents the hashed output message and the input data as a consequence of the time

simulation. First, when enable is high on every positive clock edge with an active low reset, input data is applied, and after a series of cycles, an output hash value is produced. The output hash values are generated by testing the different test data. The hash values obtained using the standard SHA 256 in MATLAB program are used to confirm the output hash values once again.

Table 1 include the full SHA256 implementation on a variety of ALTERA FPGA devices. For every FPGA family examined, throughput increases approximately linearly with the number of high-performance FPGAs. This makes sense because the throughput is mostly determined by the number of clock cycles. With an efficiency of 0.327 Mbps/lr, the architecture achieves a maximum throughput of 1090.512 Mbps on Stratix III.

Table 1. Performance Evaluation of SHA 256 on Various FPGA Device Platforms

Evaluation Parameters	FPGA Devices			
	Cyclon eII- EP2C3 5F672 C6	CycloneI V- EP4CE75 F29C7	StratixI I- EP2S15 F672I4	StratixII I- EP3SE5 0F780I4 L
Logic Resources (LR)	4899	4893	3321	3334
Min Propagation Delay (ns)	7.573	3.714	6.761	3.668
Max Frequency (MHz)	132.048	269.251	147.907	272.628
Power Consumption (mW)	65.13	42.10	31.64	44.92
Throughput (Mbps)	528.192	1077.004	591.628	1090.512
Efficiency (Mbps/LR)	0.107	0.220	0.178	0.327

Figure 6, illustrates the performance of several FPGA devices in terms of logic resources, throughput, efficiency, minimal propagation delay, maximum frequency, power consumption, and so on. The Cyclone and Stratix FPGA families, which are typically low power and high-performance FPGA, are the primary subjects of evaluation performance. The Stratix II FPGA device with 3321 has the lowest use of logic resources, resulting in the lowest power consumption of 31.64 mW. I/O thermal power consumption is the power

use. With a clock-to-output delay of 3.668 ns on the Stratix III chip, the lowest propagation delay is a high-performance FPGA. Because the StratixIII device has higher throughput, its efficiency performance, measured as the ratio of throughput to the logic resources used, is efficient at 0.327.
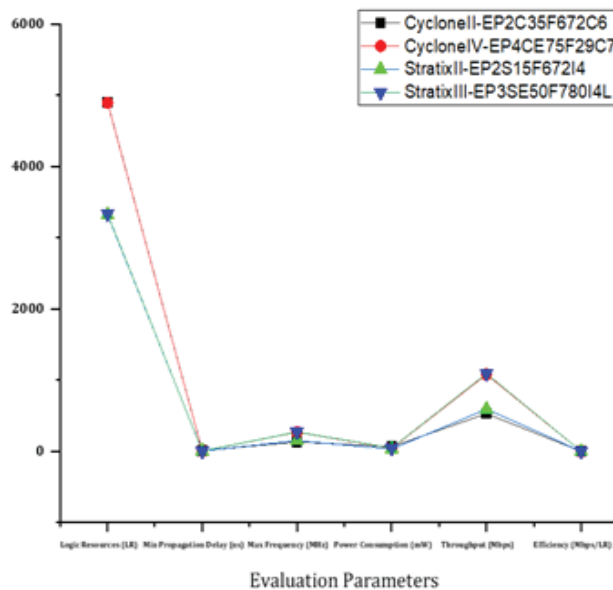
Fig. 6 Performance Evaluation

CONCLUSION

The blockchain is one of the most important technologies because it can be used in many application settings, such as the Internet of Things, and solve a variety of problems. This work offered a parallel architecture for preprocessing the SHA-256 algorithm together with hash computation. The suggested SHA-256 designs have been put into practice and thoroughly evaluated in terms of throughput, maximum frequency, and logic resources. Compared to earlier SHA-256 designs, the recommended design has the highest performance, at 1090.512 Mbps. Compared to previous state-of-the-art designs, the suggested design performs better in terms of maximum frequency, throughput, and efficiency. Furthermore, due to their functional similarities, the suggested approach can be simply expanded to other hash algorithms, such as the SHA-2 family.

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Survey on Enhancing Student Connectivity and Academic Support

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ABSTRACT

The rapid advancement of social media platforms has significantly influenced how students interact, communicate, and collaborate within academic environments. However, these platforms often lack the specificity and functionality tailored for college students, alumni, and faculty. In this paper, we propose a web- based social networking platform designed exclusively for college communities, integrating features such as user profiles, news feeds, friend requests, private messaging, notifications, and alumni connections. By aligning the platform with the college's ERP system, we ensure that all enrolled students are automatically part of the network. This platform aims to enhance connectivity, mentorship, and resource sharing among students and faculty, fostering a supportive academic environment. The paper details the design, implementation strategies, and potential impact of the platform, along with a comprehensive review of related works and existing solutions.

KEYWORDS : *Social networking platform, Student connectivity, Academic support, College ERP integration, Web-based application, College community, Mentorship.*

INTRODUCTION

In the contemporary educational landscape, social media platforms have become pivotal in shaping how students, faculty, and alumni communicate and collaborate. The growing reliance on digital communication has created a demand for platforms that cater specifically to the academic needs of students while fostering connectivity within the college community. Traditional social media platforms, while effective for general communication, often fail to meet the unique needs of academic environments. These platforms typically lack features tailored to educational support, such as the integration of academic resources, mentorship opportunities, and structured academic support systems [1],[2].

The proposed project addresses these shortcomings by offering a tailored solution designed specifically for the academic context: a college-specific social networking platform [3],[4]. By integrating the platform with the college's Enterprise Resource Planning (ERP) system, we ensure a seamless experience for students and faculty, enabling automatic enrollment of all students into the network [5]. This integration eliminates manual enrollment processes, reduces administrative overhead, and ensures that every member of the college community is included from the start [6].

Our platform aims to enhance student engagement by facilitating meaningful connections between students, faculty, and alumni [6]. It provides a centralized space for academic resources, including books, notes, and research materials, supporting students' educational needs [7],[8]. The platform also features tools for networking and mentorship, allowing students to connect with peers and alumni based on academic and professional interests [9].

The platform's design includes features to celebrate genuine student achievements and foster authentic interactions, addressing issues of inauthentic content prevalent in traditional social media [10]. Centralized announcements and event management features streamline communication from college authorities, ensuring that students are informed about important updates and events efficiently [11].

This paper presents a comprehensive overview of the design and implementation of the proposed platform, examining its potential impact on student connectivity and academic support [12]. The paper includes a detailed literature survey highlighting existing solutions and their limitations, such as inadequate integration with academic systems, insufficient networking capabilities, and fragmented communication [13],[14]. The proposed solution is discussed in detail, outlining the technical aspects, implementation strategies, and how it overcomes the identified limitations [15],[16].

LITERATURE SURVEY

This literature survey explores various studies on the development and implementation of social media platforms within educational institutions, focusing on their impact on student engagement, communication, and academic support.

Shubham Manur et al. [1] introduced a student-centric social media platform to improve communication between students, faculty, and staff. It centralizes essential information like announcements and events, while offering interactive features like forums, project spaces, and messaging to foster collaboration. The platform is designed to promote mentorship and resource sharing within the academic community, encouraging engagement and connectivity.

However, its effectiveness depends heavily on active participation, which may vary, potentially reducing its impact. Additionally, the lack of integration with university ERP systems and absence of alumni interaction limits the platform's scope for long-term engagement and broader academic utility.

Yaun Sun et al. [2] analyzed the use of enterprise social media (ESM) in Chinese workplaces, particularly through platforms like DingTalk. The study highlights how ESM enhances collaboration, productivity,

and project management by offering real-time communication tools. It provides valuable insights into the use of ESM for improving workplace efficiency, with a focus on its application in Chinese enterprises.

The study's regional focus limits its broader applicability, as it may not translate to other cultural or organizational contexts. Additionally, it overlooks privacy and security issues, which are critical when adopting ESM, particularly in countries with stricter data protection regulations.

Joseph T. Chao et al. [3] developed a social media-inspired learning platform to enhance student engagement. The system allows students to participate in lectures via mobile devices, offering features like live chat, quizzes, and peer collaboration. This interactive environment helps students engage more with the content and their peers during lectures.

However, the platform lacks features for alumni and faculty engagement and does not integrate with academic management systems like ERP, limiting its potential for broader academic use. These omissions prevent the system from becoming a more comprehensive academic tool.

Aamrapali Wandhre et al. [4] created a social media platform tailored to college campuses, addressing the limitations of general platforms like WhatsApp. The platform, built with modern web technologies, offers features specifically designed for academic environments, such as event management and resource sharing, enhancing communication and collaboration among students and staff.

Yet, the absence of ERP integration for automatic user enrollment and the lack of alumni connectivity hinder the platform's potential for higher engagement. These missing features reduce its value as a long-term solution for college networks.

Kristen Tarantino and Jessica S. McDonough [5] reviewed the role of social media in enhancing student learning, noting that its use in academic settings fosters collaboration, critical thinking, and deeper engagement with course content. Social media platforms can help create virtual learning environments that support student interaction and development.

However, the review lacks specific models or strategies for integrating social media into academic settings, which limits its practical application. Additionally, it could have addressed potential challenges like distractions or privacy concerns, which are important for understanding the balanced use of social media in education.

Sarah Mae Rubejes-Silva et al. [6] focus on enhancing alumni relations through the development of the Alumni Tracer and Engagement Hub, a secure and user-friendly digital platform. Evaluated using McCall's Software Quality Model and the ISO/IEC 25010 model, the platform excels in functionality, security, and user-friendliness. It shows strong performance in areas such as functional completeness and learnability, which are essential for fostering connections between universities and their alumni.

However, challenges remain in UI aesthetics and user perceptions of data security. User feedback indicates that the interface could be more visually appealing and that certain elements lack clarity. Additionally, concerns regarding the security of personal data were raised, suggesting the need for enhancements in these areas to improve overall user experience and platform reliability.

Hengki Hendra Pradana et al. [7] explore the factors driving alumni to engage in Organizational Citizenship Behavior (OCB) within their associated organizations, particularly focusing on a university in Surabaya. This qualitative study identifies key motivators for alumni participation in OCB, such as altruism, conscientiousness, and civic virtue. The research reveals that alumni are motivated to help current students and maintain their alumni association's reputation, contributing to a strong network that benefits both the institution and its students.

However, the study's focus on a single university in Surabaya limits its generalizability to other contexts. The findings may not apply to alumni from different institutions or regions, as the motivations and dynamics of OCB can vary significantly. This limitation suggests that further research is needed to explore alumni engagement across diverse educational settings.

Pranjul Singh et al. [8] present a web-based platform designed to enhance the educational experience for students and faculty. This application integrates various academic functions, including note sharing, attendance tracking, and performance evaluations, addressing challenges students face in managing educational resources. The platform aims to facilitate easy access to materials and provides tools for faculty to monitor student performance, thereby fostering collaborative learning.

Despite its innovative features, the application does not explore integration with other institutional systems, which limits its potential for seamless operation within a broader educational ecosystem. This lack of integration may restrict the application's ability to fully leverage existing resources and data, potentially impacting its overall effectiveness in streamlining academic processes.

H. A. Yong et al. [9] investigate the potential of social media as a tool for Personal Learning Environments (PLE), focusing on integrating both formal and informal learning to support self-regulated learning, particularly in statistics. The study highlights how PLEs enable students to tailor their learning experiences to their individual needs, which is especially beneficial for subjects perceived as challenging. Through a survey, the research investigates the effectiveness of social media platforms in facilitating learning and finds a correlation between increased social media use and higher intrinsic motivation among learners.

However, the study acknowledges that the current use of social media for educational purposes remains limited and requires enhancement. While it provides valuable insights, it also indicates the need for greater adoption of social media in educational contexts, emphasizing that further improvements are necessary to fully leverage its potential for enhancing student learning experiences.

Qusay Al-Maatouk et al. [10] apply the Task-Technology Fit (TTF) and Technology Acceptance Model (TAM) frameworks to enhance the adoption of social media for academic purposes. The study aims to address inconsistencies in literature regarding social media's impact on academic performance by using these models to assess and improve its use in higher education. Data collected from a survey of 162 students reveals significant relationships among TTF, behavioral

intentions, and student satisfaction, suggesting that a proper fit between technology and task enhances academic outcomes.

Despite its contributions, the study's focus on specific social media tools may limit its generalizability. The findings might not apply universally to all social media platforms or educational contexts, which raises questions about the broader applicability of the research. This limitation highlights the need for further studies that explore various social media tools and their impact on learning across different educational settings.

Manisha N. Amnerkar et al. [11] present a social networking website specifically designed for college environments, aimed at enhancing communication and interaction among students. The platform offers features similar to popular social media sites, such as online status visibility, friend search options, and profile viewing capabilities. Developed using HTML, JavaScript, CSS, AJAX, PHP, and MySQL, this project focuses on helping students forge new friendships while maintaining existing ones, fostering a more connected campus community.

Despite its effectiveness in facilitating social interaction, the platform closely resembles established social media sites like Facebook, which may limit its uniqueness and customization. The similarities could lead to reduced engagement, as users may find it lacks distinct features tailored to the specific needs of the college community. This resemblance highlights the importance of incorporating unique elements that address the unique dynamics of college life.

Kaustubh Jagasia et al. [12] explore the development of a social networking website aimed at providing a personalized and interactive experience for students, faculty, and industry professionals. The platform is designed to enhance communication within the college community and facilitate connections between students and industry experts, allowing users to engage with practical applications of technologies taught in college. Its focus on educational and professional networking sets it apart from general social media platforms, offering a dedicated space for collaboration and knowledge sharing.

However, while the platform showcases several beneficial features, it may not comprehensively address all academic needs. Its primary emphasis on social interaction and industry engagement could overlook essential academic support functions, such as study resources or academic advising. This limitation suggests that further enhancements are needed to create a well-rounded platform that meets diverse student requirements.

M. Mirani et al. [13] investigate the motivations driving college students' use of social networking sites (SNSs), particularly in their search for travel information. Employing hierarchical regression analysis, the study identifies key motivations, including self-expression and community participation, which influence students' engagement with SNSs for travel-related purposes. The findings underscore the significance of user interaction in shaping students' information-seeking behavior, indicating that social networking serves as an essential resource for travel insights.

However, the study's context-specific focus on students from Sukkur, Pakistan, limits the generalizability of its findings. While the identified motivations provide valuable insights, they may not apply universally to students from different cultural or educational backgrounds. This limitation suggests a need for further research to explore the motivations of diverse student demographics regarding SNS usage.

Vo Ngoc Hoi et al. [14] examine how social media, particularly Facebook, can enhance student engagement in higher education by focusing on knowledge-sharing behaviors and self-efficacy. The study investigates the impact of Facebook's perceived pedagogical affordances on cognitive engagement among students, emphasizing the importance of fostering interactive learning environments. The findings reveal that knowledge-sharing behavior significantly enhances cognitive engagement, especially among students with moderate to strong self-efficacy in sharing knowledge.

Despite these positive results, the study also indicates that the effectiveness of social media in promoting student engagement is contingent upon individual self-efficacy levels. Students with low confidence in sharing knowledge did not exhibit the same positive engagement outcomes, highlighting a critical area for intervention. To maximize the benefits of social media

for learning, educators must implement strategies that boost students' self-efficacy and cultivate a culture of knowledge sharing.

Srujana Inturi et al. [15] discuss the creation of a student- centric social networking platform designed to foster engagement and interaction among college students. This platform provides resources such as information about the college, available clubs, peer and faculty support, and campus event updates. Developed with ReactJS for the front end and incorporating a Chatbot API for interactive support, the platform aims to enhance both academic and social experiences while ensuring user privacy.

However, while the platform offers a variety of features, its effectiveness may be limited by its focus on specific functionalities. This narrow scope might not address the diverse needs of the college community, potentially leaving gaps in areas such as comprehensive academic support or external engagement. Future iterations should consider a broader range of functionalities to ensure that

all aspects of student life are adequately addressed.

Bhupali Rane et al. [16] explore the development of a social and business networking website tailored for college environments, aimed at improving both social and professional interactions among students and faculty. This platform serves as a central hub for sharing knowledge, ideas, and updates about college activities, fostering collaboration and communication. Features include sections for placement activities and ongoing initiatives, enhancing students' networking opportunities within the academic community.

Despite its valuable contributions to internal networking, the platform's focus on the college environment might limit its effectiveness in addressing broader needs. It may not adequately cater to students' requirements for connections beyond their immediate academic setting, such as industry networking or community engagement. This limitation underscores the necessity for further research to explore ways to enhance connectivity and academic support both within and outside the college framework.

Table 1 Comparison of previously done studies

Author(s) (Year)	Title	Key Features	Future work
Manur et al. (2020)	Student-Centric Social Media Platform	Centralizes communication (announcements, events) Interactive features (forums, project spaces, messaging) Promotes mentorship & resource sharing	Incorporate ERP integration and alumni features for long-term engagement.
Yaun Sun et al. (2023)	Use of Enterprise Social Media in Chinese Workplaces	Enhances collaboration & productivity Focus on Chinese enterprises (e.g., DingTalk) Real-time communication tools	Broaden focus to include privacy & security issues and expand research beyond China.
Joseph T. Chao et al. (2011)	Social Media- Inspired Learning Platform	Mobile participation in lectures Features live chat, quizzes, peer collaboration Promotes interactive learning	Add ERP integration and alumni engagement features to enhance usability.
Aamrapali Wandhre et al. (2024)	Social Media Platform for College Campuses	Academic-focused platform Event management & resource sharing Enhanced collaboration among students & staff	Incorporate ERP integration for automatic enrollment and alumni features.

Kristen Tarantino et al. (2013)	Social Media in Enhancing Student Learning	Fosters collaboration & critical thinking Supports deeper engagement in academic settings	Provide practical models/ strategies for integrating social media into academic settings.
Sarah Mae Rubejes- Silva et al. (2022)	Alumni Tracer and Engagement Hub	Focuses on alumni engagement Strong security & functionality Evaluated using McCall's Software Quality Model	Improve UI aesthetics and address data security concerns raised by users.
Hengki Hendra Pradana et al. (2023)	Alumni Engagement in Organizational Citizenship Behavior (OCB)	Focuses on alumni's OCB in Surabaya University Key motivators: altruism, conscientiousness, civic virtue	Extend research to different institutions for broader generalizability.
Pranjul Singh et al. (2021)	Web-Based Platform for Academic Functions	Integrates note sharing, attendance tracking, performance evaluations Facilitates access to materials and collaborative learning	Explore integration with institutional systems to maximize effectiveness.
H. A. Yong et al. (2015)	Social Media as Personal Learning Environments (PLE)	Combines formal & informal learning for self-regulated learning Effective for challenging subjects like statistics	Enhance social media adoption for educational purposes and refine existing features.
Qusay Al-Maatouk et al. (2020)	Task-Technology Fit and TAM Frameworks for Social Media Adoption	Applies TTF and TAM to social media adoption Positive correlation with academic outcomes Behavioral intentions & student satisfaction	Conduct studies using different social media tools to increase generalizability.
Manisha N. Amnerkar et al. (2020)	Social Networking Website for College Environments	Offers communication features similar to popular social media sites Developed using JavaScript, AJAX, PHP, MySQL	Differentiate platform by adding features specific to college needs.
Kaustubh Jagasia et al. (2016)	Social Networking for Educational & Professional Networking	Focus on education & industry collaboration Provides interactive communication among students, faculty, and professionals	Add more academic support features such as study resources and advising.
M. Mirani et al. (2011)	Motivations for SNS Use by College Students (Travel Info)	Key motivations: self-expression, community participation Travel-related social networking behavior	Expand study to include students from diverse cultural backgrounds.

Vo Ngoc Hoi et al. (2021)	Social Media in Enhancing Student Engagement (Knowledge Sharing)	Focus on Facebook's pedagogical affordances Enhances cognitive engagement through knowledge sharing	Address low self-efficacy in students for more inclusive engagement outcomes.
Srujana Inturi et al. (2023)	Student-Centric Social Networking Platform	Provides peer & faculty support, event updates Developed using ReactJS & Chatbot API for interaction	Broaden scope to address comprehensive academic and external engagement needs.
Bhupali Rane et al. (2021)	Social & Business Networking Website for College Environments	Focus on internal networking, placement activities, and initiatives Developed for collaboration and knowledge sharing	Expand platform to include industry networking and external engagement features.

PROPOSED SOLUTION

Existing social networking platforms for educational institutions often exhibit several shortcomings. Many of these platforms, such as those discussed by Shubham Manur et al.

[1] and Aamrapali Wandhre et al. [4], struggle with inconsistent user engagement and limited scope, lacking seamless integration with institutional systems. This shortfall affects the platform's ability to provide comprehensive academic support and manage student interactions effectively. Additionally, platforms like Joseph T. Chao et al.

[3] may offer interactive features but often fail to integrate fully with academic management systems, missing out on crucial functionalities such as automated user enrollment and academic management. Other studies, such as those by M. Mirani et al. [13], focus on specific contexts, which may not address the diverse needs of students across different institutions. Furthermore, issues related to user experience and data security, highlighted in research by Sarah Mae Rubejes-Silva et al. [6], often lead to dissatisfaction and concerns about privacy. Finally, some platforms, including those discussed by Kaustubh Jagasia et al. [12], emphasize social interaction but neglect academic and professional integration, which is essential for effective mentorship and career development.

The proposed college-specific social networking platform aims to overcome the limitations of previous systems by offering a comprehensive solution that integrates seamlessly with the college's ERP system. This integration ensures that all enrolled students are automatically included in the network, providing immediate access to a range of features designed to enhance connectivity and academic support.

Platform Features

1. User Profiles: Each student, faculty member, and alumnus will have a profile containing academic information, interests, and achievements. Profiles will be automatically generated and updated through ERP integration, ensuring accuracy and consistency.

2. News Feed: A dynamic news feed will keep users informed about college events, academic announcements, and other relevant updates. The news feed will be personalized based on the user's role (student, faculty, or alumni) and interests.

3. Networking: Users can build a network within the college community. The platform will encourage connections between students, faculty, and alumni, fostering mentorship and collaborative opportunities.

4. Private Messaging: Secure private messaging will allow users to communicate directly with one another, facilitating academic discussions, mentorship, and peer support.

5. Notifications: Real-time notifications will keep users informed about messages, friend requests, and important updates. Notifications will be

customizable, allowing users to choose which events trigger alerts.

6. Alumni Connections: The platform will enable students to connect with alumni, providing access to valuable mentorship and career guidance. Alumni will be able to offer advice, share job opportunities, and participate in college events.

Our proposed solution is a comprehensive web application designed to address these gaps and provide a robust platform for student engagement and academic support. This application integrates several key features to enhance connectivity, streamline communication, and support academic and professional development.

1. Automated Enrollment and Integration: The application will automatically enroll students upon admission using their ERP enrollment numbers. This feature ensures that all students are included in the platform from the outset, eliminating the issues of inconsistent participation and manual enrollment processes observed in previous platforms.

By automating student enrollment and integrating with the ERP system, our platform ensures that all students are automatically included and that their information is up-to-date. This eliminates manual enrollment issues and provides a seamless user experience, which addresses the lack of automation and integration seen in previous solutions [4],[3].

2. Enhanced Connectivity and Networking: The platform will facilitate connections between students, seniors, and alumni across various domains such as Web Development and Machine Learning. This functionality will enable students to seek academic guidance, professional referrals, and mentorship, addressing the gaps in alumni connectivity and domain-specific networking.

The networking features will enable students to connect with peers, seniors, and alumni based on specific interests and academic domains. This feature counters the limitations related to alumni connectivity and domain-specific networking by providing targeted and meaningful connections [4],[12].

3. Genuine Achievements and Engagement: To counteract the issue of exaggerated or non-authentic content, our platform will focus on celebrating genuine student achievements and fostering real engagement. This will be achieved through features that highlight authentic accomplishments and encourage meaningful interactions.

By focusing on authentic achievements and real engagement, the platform differentiates itself from traditional social media platforms that often feature exaggerated content. This approach ensures that the content and interactions on the platform are genuine and valuable, addressing concerns about authenticity [5].

4. Centralized Announcements and Resources: A dedicated section for college authorities to make announcements, share resources, and manage event details will be included. This centralized approach will enhance communication efficiency and resource accessibility, addressing the limitations related to comprehensive integration and institutional management.

The centralized section for announcements and resources will improve communication efficiency and accessibility of important information. This feature addresses the lack of comprehensive institutional management and resource sharing observed in previous platforms [3],[4].

5. Interest-Based and Event-Driven Features: Students will have the ability to connect with others based on shared interests, such as cultural events, sports, or academic projects. This functionality supports the development of diverse connections and collaborative opportunities, filling the gaps related to social interaction and academic integration.

The ability to connect based on interests and participate in events will foster diverse connections and collaborative opportunities, addressing the limited focus on social interaction and academic integration found in earlier platforms [8],[15].

6. Repository for Academic Resources: The application will feature a repository for storing and accessing books and notes, providing a valuable academic resource pool. This will support

students' academic needs by offering easy access to educational materials, addressing the absence of comprehensive academic support in existing platforms.

The repository will provide easy access to books and notes, supporting academic needs and enhancing resource availability. This feature addresses the absence of comprehensive academic support in previous solutions [8].

7. User-Centric Design and Security: The platform will incorporate user-centered design principles and robust data security measures to ensure a positive user experience and protect personal information as shown in Figure 1.

The emphasis on user-centric design and data security will ensure a positive user experience and protect personal information, addressing the UI/ UX and privacy concerns identified in existing research [6],[7].

DISCUSSION

Time Efficiency

The platform will streamline communication, mentorship, and resource sharing, reducing the time students spend navigating multiple systems and seeking help.

Enhanced Engagement
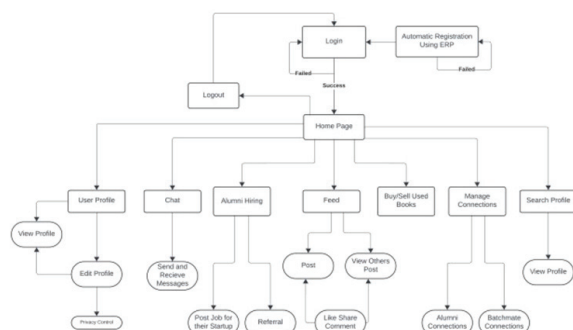
Fig. 1

Technical Implementation

- Backend: The platform will be developed using a robust backend framework that supports high scalability and security. The backend will handle user authentication, profile management, messaging, and notifications. Integration with the ERP system will be achieved through secure API calls, ensuring data integrity and consistency.

- Frontend: A responsive web interface will be designed to provide a user-friendly experience across devices. The frontend will be developed using modern web technologies such as HTML5, CSS3, and JavaScript frameworks (e.g., React.js or Angular.js) to ensure a seamless and intuitive user experience.

- Database: A relational database will be used to store user profiles, messages, notifications, and other data. The database will be designed to support efficient queries and data retrieval, ensuring quick access to information.

- Security: Security will be a top priority, with measures such as Blockchain for data security, encryption, secure authentication, and regular security audits implemented to protect user data and maintain privacy.

By addressing the limitations of previous systems and incorporating advanced features and technical capabilities, the proposed platform aims to create a comprehensive and effective solution for enhancing student connectivity and academic support within the college community.

A centralized platform will boost student interaction and participation, fostering a more connected and active campus community.

Simplified Management

Integrated features for user profiles, posts, messaging, notifications, and alumni connections will simplify administrative tasks and enhance the overall user experience.

Technical Challenges

While the platform offers significant benefits, it also faces challenges related to integration, security, scalability, and user adoption. Ensuring robust data privacy and managing ongoing maintenance are critical to its long-term success.

CONCLUSION

In conclusion, the proposed college-specific social networking platform represents a significant advancement in enhancing connectivity and academic support within the college environment. By integrating with the college's ERP system, the platform ensures a seamless and efficient user experience, while features such as alumni connections, private messaging, and personalized news feeds contribute to a supportive and collaborative academic community.

The platform addresses the limitations of existing social media solutions by providing a focused and tailored approach to student engagement, resource sharing, and mentorship. With its comprehensive design and robust technical implementation, the platform has the potential to significantly improve the educational experience for students, faculty, and alumni alike.

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A Survey on Inline power Meter and Cable Tracer

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ABSTRACT

In the fast-changing field of electronics, energy efficient power management and solid cable connections are the most important. This project describes a multi-functional device which is a DC power meter with a cable tracer that is advanced providing a comprehensive solution for monitoring electrical data and testing cable integrity. The DC power meter section is devised to measure and display the parameters such as voltage, current and instantaneous power, between a power supply and a load when energy is consumed. This facilitates the users to control the use of energy more prudently and conserve the power. It is also the case that the integrated cable tracer involves a range of ports for linking up diverse cables from different manufacturers, such as USBA, USB B, USB C, USB micro B 3.0, USB micro, USB mini, and RJ45. When the device gets connected it casts on the screen information about each pin that is either working connection or not. This function is important for troubleshooting failures in cables and ensuring as a proper metaphor for communicate across a range of devices and networks. The article shows in detail both the design and the implementation of the equipment with the focus on components, problems encountered, and the solutions developed. The project demonstrates the device's possibilities in both power control and cable diagnosis; thus, the professionals can make great efficiency with this tool.

KEYWORDS : *Inline power meter, Cable tracer, Microcontroller, Battery management system, Display, Sensors.*

EQUATION-CENTRIC APPROACHES

Nowadays, the incredibly fast development of electronic systems led to the emergence of the concept of instruments that can maintain high efficiency of the power as well as ensuring smooth navigational links. In the latest technology world of electronic devices and networks, instruments/or tools that are precise up-to-date are most important to the sector of power consumption. In the new technology world electronic. instruments/tools are more critical to the sector of managing energy and thus the importance of having them becomes great. For instance one really important application is power measurement via power meter which are needed for ascertaining consumption data for energy efficiency in a very effective way. This paper introduces the development of a multifunctional device which is a combination of a DC power meter and an advanced cable tracer to solve these issues. The DC power meter part of the device is able to measure and show the essential electrical parameters including voltage, current, instant power, with the great resolution of (mWh). Which will be shown on the OLED display. These foundational measurements are important in the case of smart buildings for the energy (green) strategies, such as energy- efficient measures, that are widely adopted by the networks. The energy disaggregation concept involves a portable operation, and an SD card module for logging power parameters over time. On the other hand, in addition to the power meter, the device is equipped with an advanced cable tracer, which has several ports typical for the connections of the cables working with the USB A, USB B, USB C, USB micro, USB mini, and RJ45 type. The cable tracer is meant to test the cables pins (loop back pins) which is used

to detect the diagnostic in the cables. The TFT Display with touch screen the pins can be seen on the display giving you the proper diagnostics of the cables. The user interface is clear-cut and thus provides a simple method of checking if the pins are working properly or not. An essential functionality of the device is the diagnostic of and the solution to wired volume problem in electronic systems. As a result of the combination of these facilities, the device provides a complete solution in both electricity measurement and cable testing. This makes it especially useful in places where the power consumption is critical and where more reliable connections are required like data centres, electronics manufacturing and field support operations. This paper will evaluate the previous research work on power meters and cable tracers, explain the designing and the development of the device, give testing results and the potential applications of the device and the effect in the field of electronics.

LITERATURE SURVEY

State-of-the-art diagnostic gadgets for electrical and electronic systems seems to be quite the fashionable thing nowadays. The inline power meters and cable tracers theme was a bit hit in recent times to which most of the technological development was directed. By the way of introduction, this project deals with a technological breakthroughs instruments and their association with the growth of current devices to electric energy measurement and then their practical applications and limitations.

Inline Power Meters

Inline power meters are crucial measuring devices normally placed inside circuits. Within industrial automation, customers are looking for this type of measurement tool to accumulate the exact energy usage of their machines $P = V \times I$ The traditional power detectors like voltage and current transformer, though being undoubted, can lead to measurement inaccuracy due to shift and non-linearity besides which Shunt resistors that measures the voltage drop across a known resistor to determine the current may cause a power loss which causes the whole system to become less efficient [2]. Hall effect sensors represent a non-intrusive and highly accurate method for AC and DC current measurement

and avoid measurement errors which make them the sensors of choice and hall devices perfectly fit into the purpose of supplying a power source with real-time information [3]. Much more capabilities have been added to the inline power meter designs with the change in technology. Digital technology has made it possible to have cutting-edge signal processing which in turn means higher accuracy and real-time data processing [4]. Wireless technology too has come a long way, with the development of power meters to transmit Wi-Fi or Bluetooth signals and thus promote cloud system integration and monitor data [8]. This is particularly crucial when analyzing all actions within a smart grid system where an ability to assess the current status of energy- outflows, and costs highly influences grid performance and reliability [9].

Just as with the refrigerators they monitor, inline power meters are Sectioned instruments running in various sectors. Industry is a sector that best utilizes inline power meters, as they play a significant part in energy management by helping to figure out the inadequate parts as well as optimize the operations. Based on the findings, the use of these meters integrated into industrial control systems will result in up to 40 percent less cost and also up to 60 percent lower energy consumption levels [5]. With commercial and residential structures, advanced inline power meters belong to the category of sustainable devices economies rely on for the purpose of energy management and consumer response to consumption patterns. With the help of smart Inline Power Meters, the users can be provided with real-time feedback, thereby enhancing the consumption management, and environment protection [6]. For sports such as cycling, these sensors help the athletes generate power meters on the way of their role, thus they are able to monitor and train much better. The growth trends of these sensors are by and large geared at their performance under various climate and weather conditions [7].

However, some constructiveness remains. Meter calibration becomes a serious problem for the devices on their ranges. This requires better calibration techniques and less error in measurement [11]. Furthermore, these devices can be quite costly. It is still a challenge to design an advanced meter for such areas like wind turbines that

is robust enough to withstand temperature variations, shock, and stress testing. Any designs proposed by the scientific community should have these situations in mind, and the methods used in the designs should address them

Cable Tracers

The Cable tracers are indispensable devices for the testing and diagnostic of a wide range of cables, such as USB and RJ45 (Ethernet) cables. They are necessary for the cable systems to function properly and have the integrity needed for data and communication systems. The most common cable tracer consists of a primary unit and a secondary remote unit. The first unit connects to one end of the cable, while the remote unit connects to the other end. The tracer transmits signals to the cable to check continuity, pin arrangement, and signal quality [1].

The RJ45, the most widespread type of cable for local data networks, ensure that the wire circuitry has been properly configured. The Ethernet system is thus guaranteed to be the right setup for communication [2]. For USB cables, tracers evaluate the connectivity of each individual pin, which is necessary for proper data transfer and communication with devices [3].

In cable tracers, the last technologies have brought in the sophistication of a number of features. Modern tracers show digital readings of more detailed data, have automatic fault detection which returns the system back to normal, and support various cable wire types due to increased versatility [4]. Furthermore, some higher-level devices have the ability to perform signal quality tests and remote troubleshooting, which enhances the diagnostic and repair of the connection problems [5]. These upgrades, along with the improvement of efficiency in these devices, are the advantages.

METHODOLOGY

Proposed Block Diagram (Inline Power Meter

An inline power meter is a complex device created to calculate very accurately the power consumption of an electronic circuit. The block diagram shows many interconnected components, which have all very important functions needed for the accurate power measurement and the good data management.
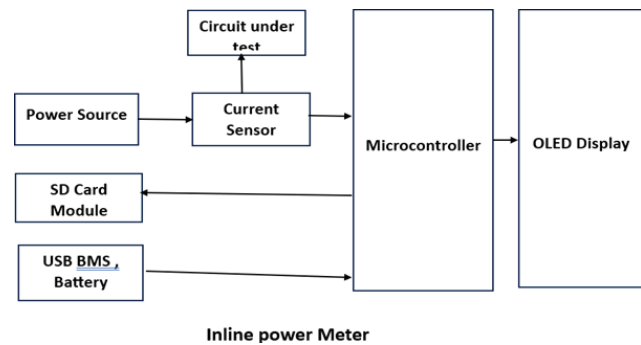
Fig 1. Block Diagram Inline Power Meter

The system is primarily powered by the power source, which is the main supply of energy for the Microcontroller and the other parts of the power system. The main supply is the initiating setting of the primary input, which is further translated into the operation of the current sensor and the energy essentials that are needed for the circuit under diagnostics.

At the crux of the system is the current sensor. This unit determines the electric current on one path. By catching the data, the current sensor provides the data, which is further analysed by the microcontroller about the performance of the circuit. The precision and consistency of the current sensor are the two most important factors that directly influence the exact measurements of the power.

Technically, the circuit under test is the specific electronic circuit, which is being analysed concerning its power consumption. It is then powered by the power source and the current sense is attached to the whole process that records the current consumption. The details obtained from the examination of the entity's traits assist in getting familiarity with its efficiency and power usage, which render them fundamental in both the development and operational contexts.

The microcontroller which is the data hub in the system is tasked as the main computer of the power meter. It is the one that receives the current data from the sensor and makes calculations to figure out the energy usage of the test circuit. Besides computation, the microcontroller also takes charge of storage and demonstrations of this information. There are also connections between a microcontroller and SD card for data logging purpose so that whenever we want that data we can get it.

OLED display is used as interface through user can monitor the processed data. By displaying the power consumption calculation by the microcontroller, It allows you for continuous observation of the circuit's power usage. The OLED Display ensures that information is presented clearly with minimal power draw.

Finally, the system is equipped with a USB Battery Management System (BMS) and battery, which provide a supplementary or backup power source. This component ensures that the power meter can continue operating even in the absence of primary power source. The BMS carefully manages the battery's charge and discharge cycles, protecting the system from potential power issues and ensuring constant performance

Proposed Block Diagram (Cable Tracer)
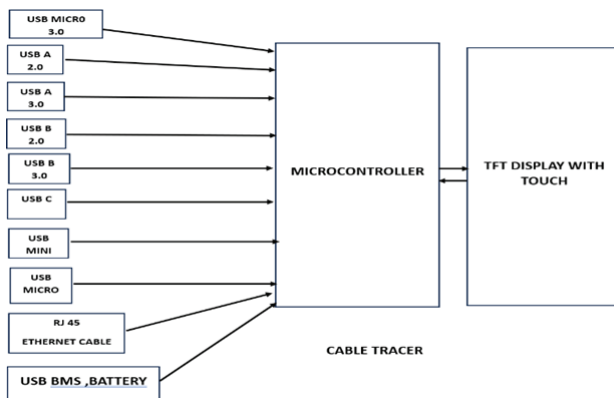
Fig. 2. Block Diagram Cable Tracer

The block diagram details a high-tech tracer for cables. It is strong enough to find out and diagnose all cable and connection types. The system is built to work with a microcontroller that links to the required IO devices to provide the devices from the users with the possibility to do the cable trace very preciously and reliable.

At the core of the system is the microcontroller, which functions as the constant processing unit. This part is in charge of managing all coming signals from different kinds of cables and connectors, processing the data, and communicating the user's results through the TFT display. The microcontroller's feature to handle multiple input types in parallel is very important for the system's flexibility and reliability. The device is constructed in such a way that it connects with the myriad cable types through the different ports it owns. For example, it can

be used to connect with USB Micro 3.0, USB A 2.0, USB A 3.0, USB B 2.0, USB Micro

3.0, USB C, USB Mini, USB Micro and other specific ports related to the computer's USB standards and hence can cover all network device types and cables.

RJ45 Ethernet Cable This input is necessary for the examination of the Ethernet cables, which are the basic elements of networking setups.

The cable tracer also comes with a USB C BMS and battery, which are both responsible for the power delivery and the continuous operation of the cable tracer which functions even when there is no external power source. This battery management system ensures that the microcontroller is always on and that the display and other equipment are functioning properly.

An endowed characteristic of the system is the TFT screen equipped with the touch feature, which allows for a natural and user-friendly interface. It flashes the processing data and diagnostics report from the microcontroller, so people can connect with it through the touch. This component is mandatory for the generation of a clear and visual feedback loop when the system is picking the right path.

ADVANTAGES AND DISADVANTAGES

Advantages

Data Logging Feature for Power Meter

The data logging function provides users with the storing of the records of power usage data for a period of time. This makes it possible to analyse and monitor the energy consumption trend of different devices in detail.

Improved Voltage Range

An improved voltage range ensures the power meter can measure a wider spectrum of voltages accurately. This makes it suitable for a broader range of electrical applications and devices.

Improved Resolution for Power Usage Calculation

A better voltage range means that the power meter can measure a wider spectrum of voltages accurately. Thus, it can be used for a much greater number of electrical applications and devices.

Long Battery Life

Prolonged battery life is the main advantage of the power meter and cable tracer which is a very useful tool in situations requiring a long time period without the need of constantly recharging. This is of utmost importance for fieldwork and continued monitoring sessions.

Low Cost

A cost-effective power meter and cable tracer is perfect for people looking for a cheap option that still provides the necessary features. It is worth the money and can be used in both personal and at professional.

Compact Size

Being light in weight the power meter is very easy to carry with you thus very convenient, and it also is very simple to handle such because of its design. The small size of the power meter enables users to carry on the go. Moreover, people can use it one- to-one in cramped conditions and also make spare applications interesting.

Many Types of Connectors Included in Cable Tracer

Adding different types of connectors in cable tracers makes it more practical. It gives users the ability to test and diagnose different types of cables and connections and thus increasing the efficiency of a troubleshooting process.

Disadvantages

Power Meter is Rated for DC Voltage Only

The power meter is only made for measuring direct current (DC) voltage. It is not fit for measuring alternating current (AC) as such, and only serves the purpose of the direct current powered devices and circuit.

Lighting Connector is Not Included in Cable Tracer

The cable tracer does not include lightning connector, meaning it can't be used to test or trace cables of this kind. Some people may need additional equipment or adapters for checking these specific connections.

APPLICATION

1. Can be used by any Electronics Engineer for calculation of power parameters.

2. Can be used by any USB/Ethernet Cord Manufacture Seller to examine the working or to detect faults of cables.

3. Can be used at any household to check power consumption of small circuits used in household. (e.g. Mobile Charger, LEDs, etc.).

4. Can be used to keep record of particular device's power consumption.

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Comparative Analysis of DVR Injection Methods for Power Quality Improvement

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ABSTRACT

Among various power quality issues, voltage sag results into heavy economical loss to industries. Dynamic voltage restorer is primarily designed for protection of sensitive load from these short duration PQ disturbances. This work explains the construction, working principle and injection strategies for DVR. Two DVR topologies and their corresponding time-domain control strategies are tested for mitigation of power quality issues such as sag and swell. Each DVR topology and its control strategy are then modeled and then tested under balanced, unbalanced sag conditions using MATLAB-Simulink environment. Their operational differences and performances are comparatively studied from the results of simulation to determine the functional advantages and limitations of each DVR topology.

KEYWORDS : *Point of common coupling, In-phase, Quadrature, Unit vector, Synchronous reference.*

INTRODUCTION

Increased use of controller based electrical equipment made the electrical loads more susceptible to variations in voltage and current waveforms i.e. Power Quality (PQ) disturbances.

Voltage sag is defined as voltage variation for short duration of 0.5 cycles to 1 minute. [1] Dynamic Voltage Restorer (DVR) is primarily designed for protection of sensitive load from these short duration PQ disturbance events. DVR is connected in series with load to be protected which act as a voltage source and mitigates voltage sag at the point of connection.[3] Thus, DVR allow power system consumers to overcome these PQ issue. It contributes in depreciation of industrial production. Hence it incurs economic losses for manufacturers and industries. [4, 5]

This paper attempts to analyze control strategies for 3-phase DVR topologies that differ in voltage injection techniques and implement their control algorithms.

3-phase 4-wire distribution network for implementation of DVR is considered using MATLAB-Simulink.

DYNAMIC VOLTAGE RESTORER

The block diagram and equivalent circuit scheme representing an inter-connection of various DVR elements is as shown in figure I. Here VG' is residual RMS phase voltage at point of common coupling (PCC) which is to be compensated by injecting compensation voltage (VDVR) per phase and VL is the load voltage which is to be regulated at 1 p.u. .

In this study for 3-phase distribution system, three 1-phase IGBT based voltage source converters (VSC) connected in open-star configuration are considered. The injection transformer of unity ratio (N2:N1) is simulated for simplification. The modified first-order line-side RLC filter is designed and implemented for higher order harmonic elimination of compensation voltage. [6, 7] Thus, considering an ideal system and using KVL we get,

$$V_G{}' + V_{DVR} = V_L \qquad (1)$$
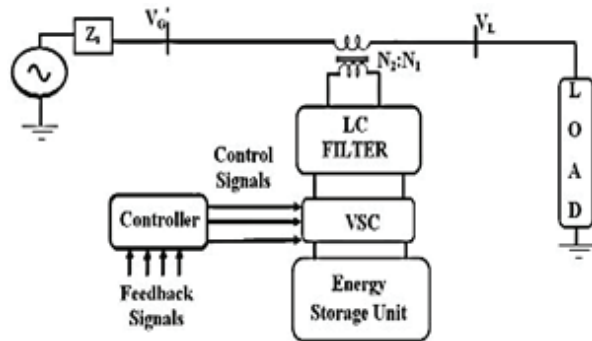
Fig. 1 Block Diagram of DVR

Topologies

Depending on energy storing elements following are two DVR topologies i.e. Battery- supported (BS-DVR) and Capacitor-supported (CS-DVR) are simulated in this study. These topologies are represented as shown in figure II. D.C. energy storage element in DVR determines the power involved (i.e. active power (PDVR) and reactive power (QDVR) during compensation to regulate VL to its rated value [8].

(a) BS-DVR

(b) CS-DVR
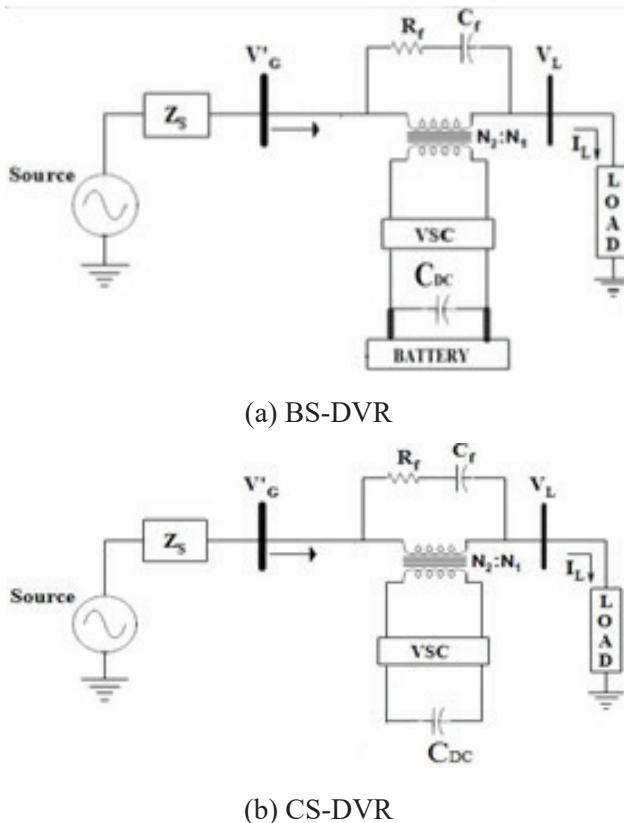
Fig. 2 DVR Topologies

Injection Techniques

In-phase and Quadrature-injection methods are implemented in this study as shown in in figure 3.

a)   IN-PHASE   b)   QUADRATURE
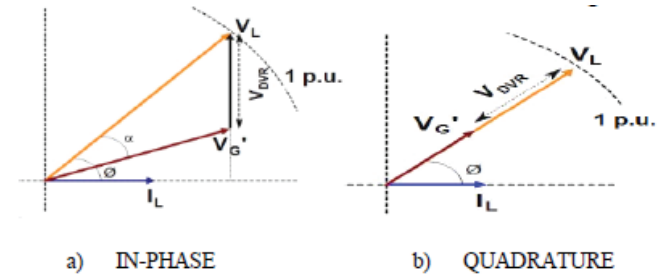
Fig. 3 Compensation Techniques

From above, comparatively it can be seen that for same |VG'|, |VDVR| required for quadrature injection is greater than for in-phase injection but with no involvement of PDVR.

The injection strategy utilized in DVR operation affects design parameters of DVR such as RMS sag voltage per phase (Vsag), VSC power rating (SVSC), RMS load phase current (IL), D.C. link voltage (VDC), RMS injected voltage by DVR per phase (VDVR), duration of compensation . [9, 10]

CONTROL ALGORITHMS

Software phase lock loop (SPLL) tracks phase angle of 3-phase grid voltages at PCC source voltage as θ_V and load current (I_L) as θ_I. Following time-domain feedback control schemes are implemented for injection of VDVR.

Unit Vector Technique (UVT) algorithm:

UVT is a simplified algorithm for in-phase injection strategy.

i)   The unit vectors (u_a, u_b, u_c) are formed in-phase with VG'.

ii)   In-phase references are then synthesized using these unit vector templates and amplitude of reference load voltage (|VL|ref).

iii) The in-phase load voltage reference signals for each phase are compared with the corresponding actual PCC voltages to produce error signals.

iv) These error signals of each phase then represents reference for tracking by VSC.
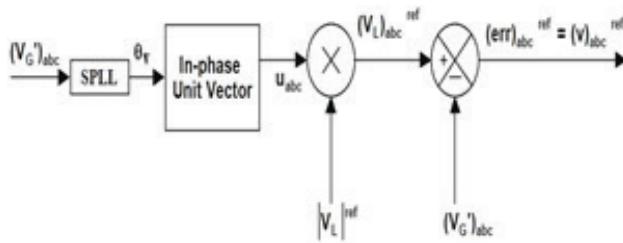
Fig. 4 UVT Control Scheme

Synchronous Reference Frame Technique (SRFT) algorithm:

SRFT algorithm is designed for quadrature injection method. [13, 14, 15]

i)   3-phase voltages are transformed using Clarke's transformation into α and β components.

Using orthogonal components, space vector

magnitude is then calculated. To remove frequency components this signal is then passed through low pass filter (LPF).

ii) Depletion in D.C. link voltage (e_{DC}) is obtained by comparing of reference (V_{DC}) and actual D.C. link voltage signal ((v_{DC})^f).

iii) In phase (V_G')$_d$ and quadrature (V_G')$_q$ reference component of VG' are calculated with reference to I_L.

iv) Inverse Park's transformation then synthesizes the reference signals.

v) Further for generating switching pulses for VSC and to track its corresponding reference signal, step (ii) and (iii) are adopted from UVT algorithm..

The switching algorithm implemented is then discussed further.

Fig. 5 SRFT Control Scheme

Switching algorithm

i)   The critical switching band width (h) is selected.

ii) The switching pulses for each VSC are then generated to track corresponding instantaneous reference (v)^{ref}.

Switch conditions for VSC can be mathematically stated as;

If,

$$v_{DVR} > v^{ref} + h$$
$$V_{DC} = -V_{DC}$$

(2)

If,

$$v_{DVR} < v^{ref} - h$$
$$V_{DC} = V_{DC}$$

(3)

RESULTS AND DISCUSSION

To evaluate the effectiveness of the implemented DVR, an analysis of the system and a comparative study of its operational parameters are required. Under various testing conditions DVR performance is evaluated by monitoring VL, total harmonic distortion (THD). The voltage unbalance factor (VUF) is calculated using negative-sequence (V2) and positive-sequence (V1) components of voltage as in [1];

$$VUF = \frac{V_2}{V_1} X\ 100\ \%$$

(4)

Design of Simulated Power System

A radial distribution system is selected for the network simulation, with the load parameters presented in Table 2.

Table 2 Load Parameters

Parameter	Specification
Power	3-phase, 5 kVA
Line voltage	440 V
Frequency	50 Hz
Power factor	0.6(lagging)
Connection-type	Star connection with Neutral grounded

For design simplicity isolation transformer ratio is considered is considered. Allowing depletion of 5% with transient state time of 200 μs, D.C. link and energy storage element specifications are as shown in Table 3. The passive filter elements components are designed to adopt switching band strategy.

Table 3 D.C. link and energy storage specificatiuons

Parameter	BS-DVR Specification	CS-DVR Specification
VDC	120 V	300 V
CDC	660 μF	175 μF

The PI controller specifications for CS-DVR are tuned. For testing simulated DVR models, sag is transferred from the 3-phase source to PCC under various power-system conditions. The parameters namely V_{DC}, V_L, V_{RMS} and THD profile are monitored for DVR performance.

The constraint for satisfactory DVR performance is then monitored as V_L to be regulated at ±10% of rated voltage, THD to be regulated at 8% .[16] VUF evaluated is to be under 3% as recommended by [15]. VDC is to be maintained at its rated level during sag. The various testing conditions are to be studied in the form of Test Cases (TC).

TC1: Balanced Sag with Fundamental Component:

The PCC voltage waveforms with 30% sag profile is as shown in same figure 6.
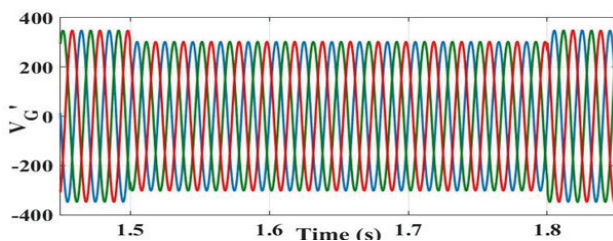
(a) PCC VOLTAGE WITH 30% SAG
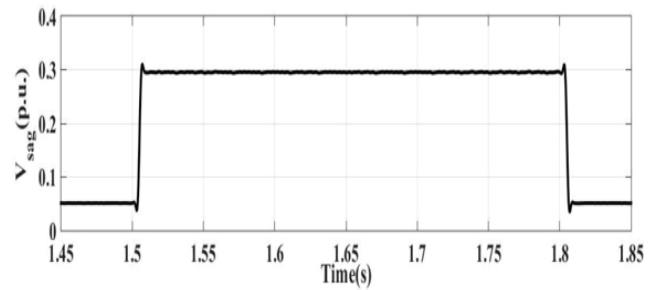
(b) PER UNIT PROFILE

Fig. 6 balanced sag with fundamental component at PCC

The monitored signals for BS-DVR in sag duration are as shown in figure 7.
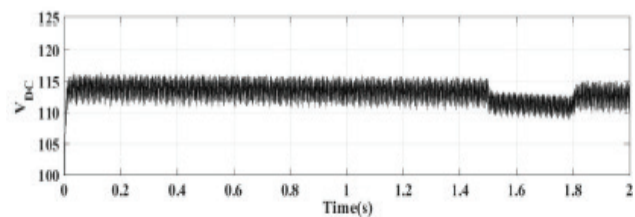
A) BS-DVR
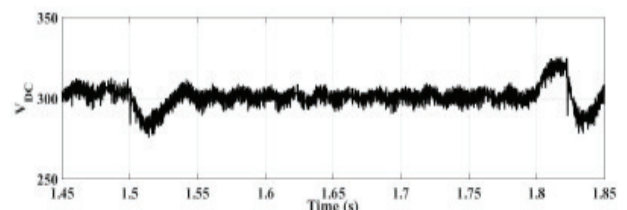
B) CS-DVR
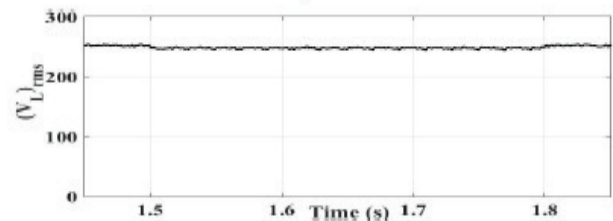
C) BS-DVR
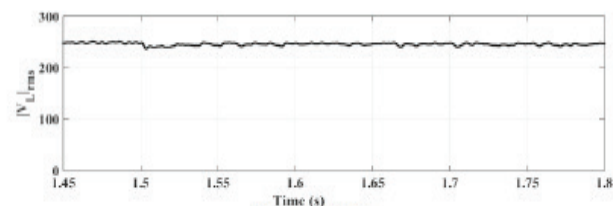
D) CS-DVR

Fig. 7 D.C. LINK VOLTAGE and load voltage RMS profile for TC1
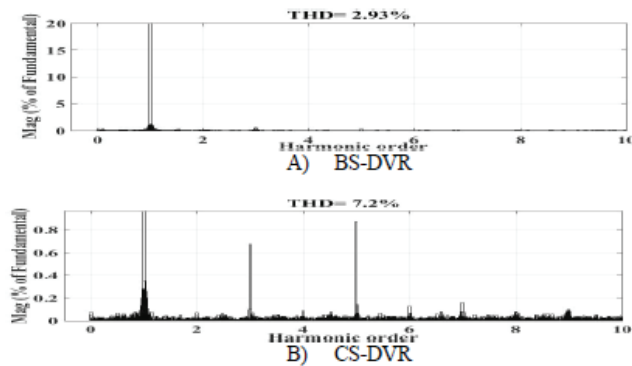
Fig. 8 Load voltage RMS profile for TC1

These result shows that BS-DVR and CS-DVR injects the required compensation voltage and hence VRMS and THD is maintained within allowable limits.

Also for detailed comparison the DVR models are tested for various load power factors with steady 30% sag depth. The result of compensation shows that at load power factor of 0.9 and unity, for the same sag level, CS-DVR is not capable of maintaining the rated load voltage as for CS-DVR, the required apparent power increases with load power factor beyond its compensation limit.

TC2: Balanced Sag with Harmonic Component:

The PCC voltage waveforms with 30% sag profile is as shown in same figure IX with 3rd and 5th order harmonics. These are superimposed with fundamental PCC voltage of equal magnitude in all 3-phases as zero, negative and positive sequence components respectively.
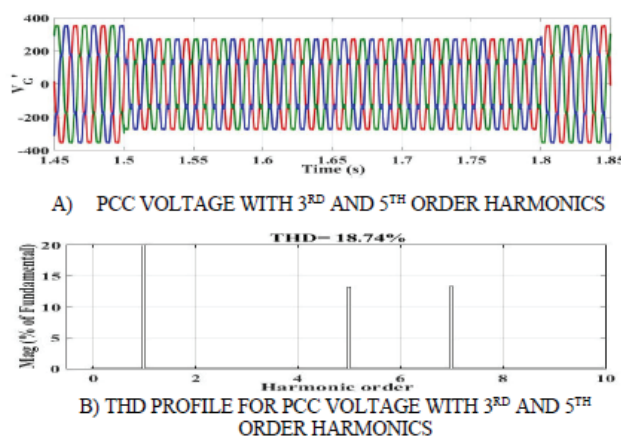
Fig. 9 Balanced Sag with Harmonics
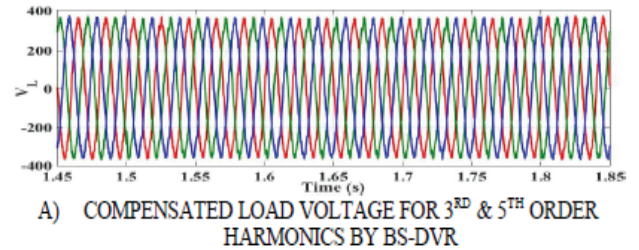
Fig. 10. Compensated Balanced Sag with Harmonics

The compensated load voltage waveforms for BS-DVR along with THD profile of the same is as shown in figure 10.
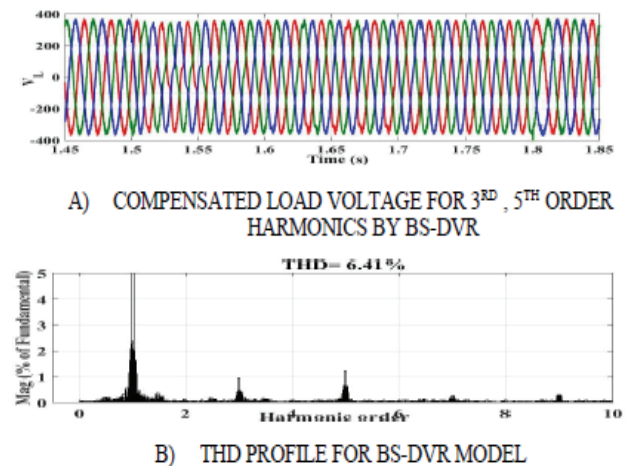
Fig. 11 Compensated Balanced Sag with Harmonics FOR CS-DVR

For TC2 performance, it can be observed that both DVR design parameters are operating to limit harmonics with BS-DVR performance is marginally better in harmonic reduction than CS-DVR.

TC3: Unbalanced Sag with Harmonic Component:

A PCC voltage waveform distorted with 3rd and 5th harmonics of 0.15 p.u. with a sag of 30% on phase-A along with THD profile and VUF is shown in figure 12.

A) COMPENSATED LOAD VOLTAGE BY BS-DVR

B) THD PROFILE

C) VOLTAGE UNBALANCE FACTOR
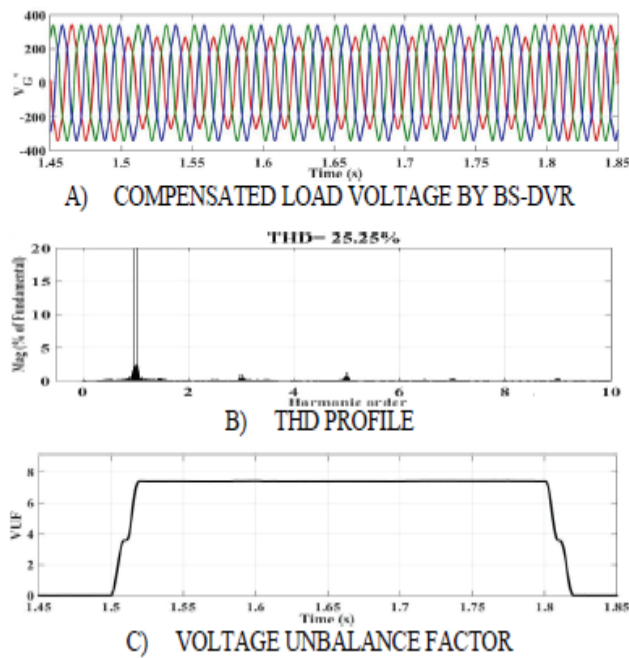
Fig. 12 Unbalanced Sag with Harmonics at PCC

The compensated load voltage waveforms along with its THD profile and evaluated VUF is shown in figure 13.

A) COMPENSATED LOAD VOLTAGE BY CS-DVR

B) THD PROFILE

C) VOLTAGE UNBALANCE FACTOR
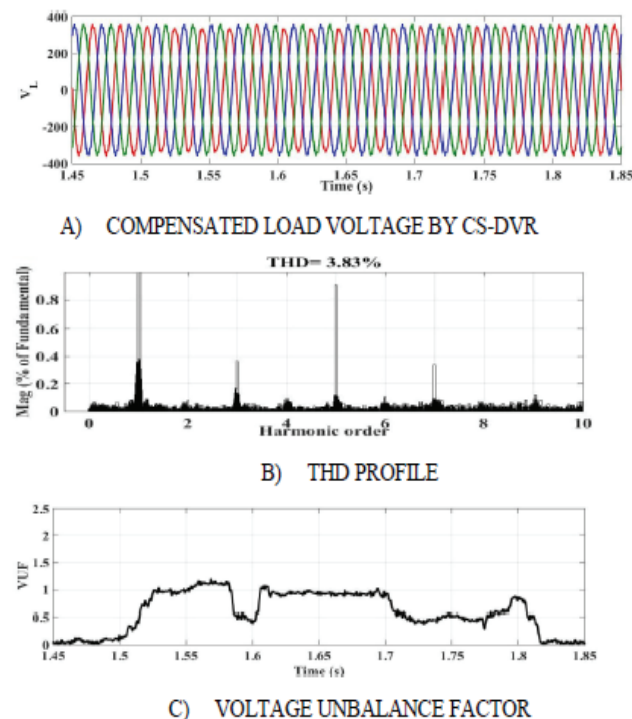
Fig. 13 Sag compensated by BS-DVR for TC3

A) COMPENSATED LOAD VOLTAGE BY CS-DVR

B) THD PROFILE BY BS-DVR

C) VOLTAGE UNBALANCE FACTOR
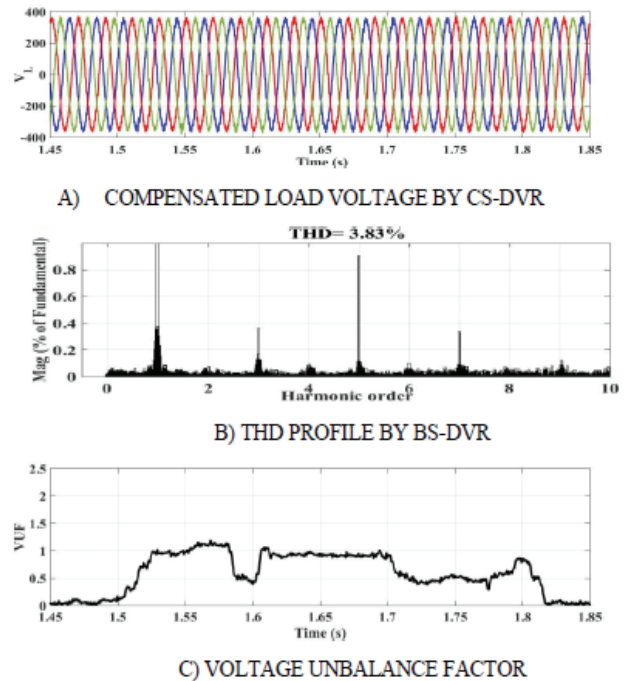
Fig. 14 Unbalanced Sag compensated by CS-DVR

TC4: Balanced Swell with Fundamental Component

A sample case of 15% swell at which BS-DVR, CS-DVR performance is monitored is discussed here. The PCC voltage waveforms along with its RMS profile is as shown in figure 15.

A) PCC VOLTAGE

B) RMS PROFILE
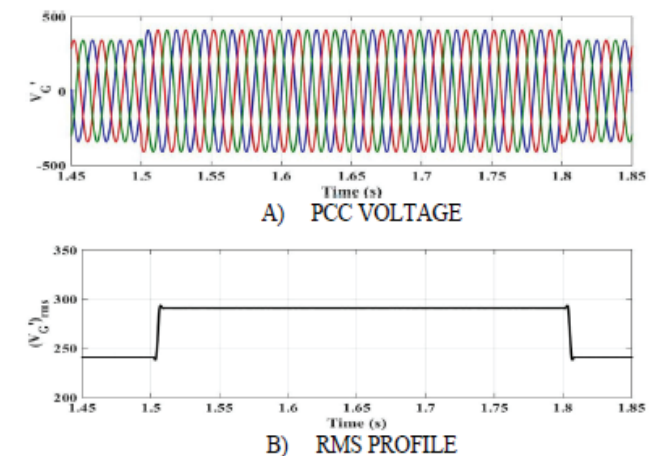
Fig. 15 Balanced Swell of 15% at PCC

To mitigate this voltage swell, BS-DVR and CS-DVR models are tested. The D.C. link voltage and the compensation results obtained for BS-DVR and CS-DVR is as shown in figure 16 and figure 17 respectively.

A)   D.C. LINK VOLTAGE

B)   LOAD VOLTAGE RMS PROFILE
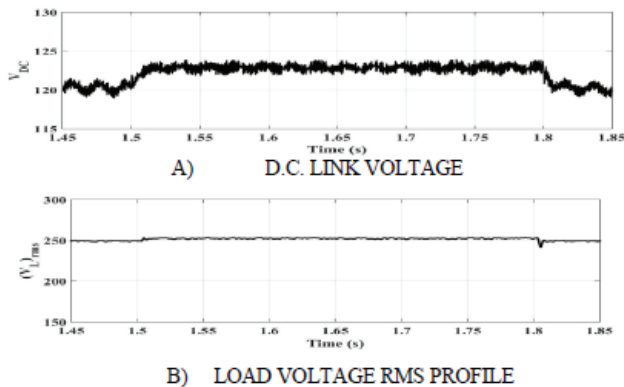
Fig. 16 Load Voltage COMPENSATION by BS-DVR FOR TC4

A)   D.C. LINK VOLTAGE

B)   LOAD VOLTAGE RMS PROFILE
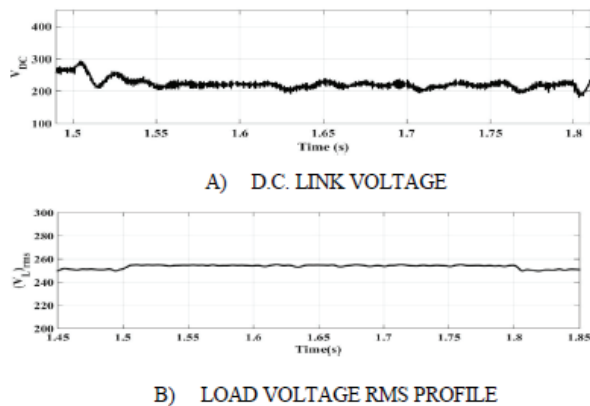
Fig. 17. Result of CS-DVR For Swell Compensation

These methods inject required VDVR and hence VRMS THD is maintained within allowable limits. BS-DVR is capable to regulate VRMS up to 25% swell but for CS-DVR, VRMS is maintained along with VDC up to 20% swell. Thus, the summarized performance results of two DVR for the simulated test cases is as shown in table 4.

Table 4 DVR Test Summary

Test Case No.	Test condition	Remark
1	Balanced sag with only Fundamental Component	-VDC is maintained for BS- DVR and CS-DVR -Both DVR regulate up to 30% sag depth -CS-DVR is not capable at 0.9 and unity p.f.
2	Balanced sag with 3rd , 5th Harmonic Component	- Both DVR regulate sag depth up to 30% - BS , CS - D V R regulates up to THD at PCC terminal -THD regulation is marginally better by BS-DVR
3	Unbalanced sag with 3rd , 5th Harmonic Component	- Both DVR regulate sag depth up to 30% - BS , CS - D V R regulates THD, VUF at PCC terminal -THD regulation is marginally better by BS-DVR
4	Balanced Swell with Fundamental Component	-VDC of BS-DVR and CS-DVR is regulated along with load voltage

CONCLUSIONS

DVR is implemented as a voltage source that mitigates voltage sag and swell. In-phase and Quadrature injection methods are implemented for BS-DVR and CS-DVR respectively. VSC is controlled using hysteresis technique which is robust, easy for realization and fast response method. The DVR implementing quadrature- injection method does not require any D.C. storage element which minimize its cost as compared to DVR implementing in-phase injection. This restricts compensation duration and compensation limit by the battery capacity. For same sag level, for quadrature injection method DVR compensation capability is restricted with respect to load power-factor as compared to in-phase injection method. From above comparing performance of BS-DVR and CS-DVR it can be found that although CS-DVR implementing quadrature injection method, its design performance is restricted by higher ratings and load power factor but shows an advantage for realization cost as no energy storage unit is required as well as no limit on duration of compensation for mitigation parameters within design limits. So DVR with quadrature injection method can be preferred over DVR with in-phase injection method.

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Study of Electronics System Design and Manufacturing Processes

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ABSTRACT

PM in his brief speech stated, "Electronics is not just an industry but it opens a door filled with boundless potential." Digital electronic circuits engines the industries from Consumer Electronics, Robotics, Digital Currencies, Automotives, Aerospace and Defense, Medical and most recently developed Automation products that process and use information in a digital format. Over the past few decades, the electronics industry has shown an inconceivable revolution. It continues to evolve, driving innovation and advancements in various industries and aspects of modern life. Observing the magnitude, India is poised to enter this ever-flourishing industry. Intending to reach US $540 Billion which is anticipated 27% of ESDM industry, GoI has allocated Rs. 6903 Cr to encourage the ESDM industry. This paper includes concise information about electronics along with the need of VLSI in system design and gives us glimpse of the core concepts of designing processes of electronics system using VLSI design flow are elaborated upon, providing a comprehensive understanding of their role in integrated circuit design. Further it delves into required manufacturing processes and the global scenarios of rankings, scopes, leveraging advancements in Electronics and future changes in numbers showcasing development made by our Nation. This paper studies India's position in the global market and what it can bring to the world.

KEYWORDS : *Electronics, Manufacturing, System design, VLSI.*

INTRODUCTION

J. A. Fleming invented vacuum diode in 1897 leading the evolution of electronic followed by invention of component like ICs, JFETS, MOSFETs, digital circuits, microprocessors, and analog integrated circuits. The significant advancements were seen from 21st century in electronic system design and its manufacturing with increased efficiency[1].
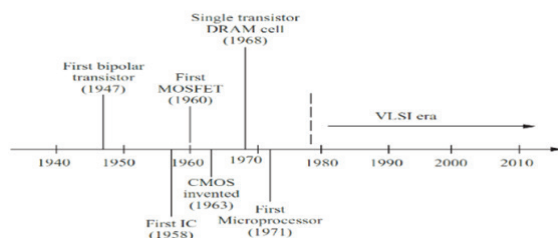
Fig 1 Evolution of Electronics
(Courtesy: VLSI Design by Debaprasad Das)

The global ESDM market size recorded in 2020 was US $ 804 Billion dollars[2]. It is expected to cross US $2 Trillion mark by FY25[3]. Our country with its improving policies in the last decade has also stepped up in the electronics industry with US $400 Billion market in FY24E in the country itself[4]. With the goal of occupying the 27% of the global industry. Focusing to increase the production, GoI has allotted Rs 21936.9 Cr in FY24 to The Ministry of Electronics and Information Technology (MEITy)[5]. Indian ESDM industry consists of US $220 Billion in FY24-25. Out of which Electronics System contains $160 Billion market and $60 Billion market gets occupied by Electronics Design. India has committed to reach US $ 300 billion worth of electronics manufacturing by 2025-26. Our country's total import of electronics components in $89.80 Billion whereas exports recorded

at all-time high which is $29.11 Billion in FY23, 23.6% greater than FY22. The Asian market plays a pivotal role in the global electronics industry global electronics industry accounting for approximately 68.4% of global production exports of electronic parts[2]-[4].
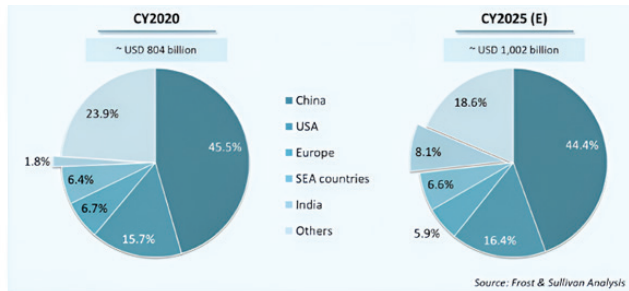
Fig. 2 ESDM Market Analysis (Courtesy to Frost and Sullivan)

As seen from the statistics, Asian countries has been ruling in electronics and its manufacturing industry with China dominating the graph. To promote Electronics Manufacturing (ESDM) industry India has launched many initiatives like 'Make in India' and 'Digital India '. But factors like increasing component cost, limited FDI, trade limitation along with limited infrastructure decelerates growth also rising fuel costs, inflation, and inflexible labour laws limit youth participation[2],[4].

DESIGN PROCESS

Analog electronics uses continuous signals, while digital electronics uses discrete signals to represent binary numbers, providing precision, accuracy, storage, and processing in devices. Number systems like binary, decimal, octal, and hexadecimal represents the data and logical operation is performed to simplify the logic expression by using logic gate in digital electronic. Digital electronics plays a central role in many devices. However, modern electronic devices cannot be achieved using simple gates alone. Very Large-Scale Integration (VLSI) technology is used to design and manufacture intricate systems like microprocessors, memory chips, and system-on-chips (SoCs). The thousands to billions of transistors can be integrated on a single chip using VLSI, which produces sophisticated digital circuits with improved power efficiency and performance in compact size. This technology leads to the innovation in fields of communication, consumer electronics, aerospace, computing and many such similar fields.

Field programmable gate array (FPGA) design, Gate array design, Standard cell-based design, Full-custom design, Semi-custom design, Programmable logic device (PLD) are popular VLSI design styles for chip implementation. Each style has its advantages and disadvantages, and is chosen based on the target application, cost, performance, and volume of production. The Y-chart introduced by Gajski–Kuhn shown in Fig illustrates a design flow for most logic chips, using design activities on three different axes (domains) which resemble the letter Y[6].
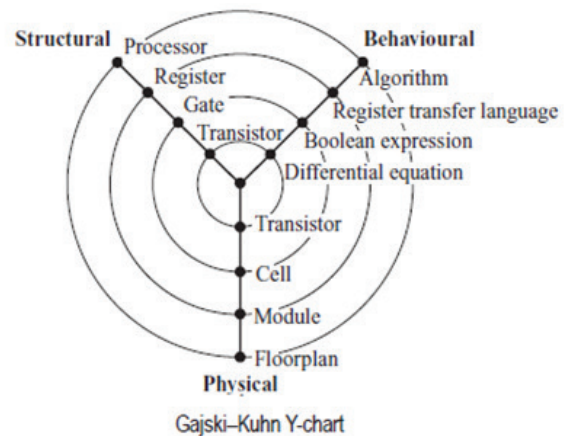
Fig. 3. The Y-Chart (Courtesy: VLSI Design by Debaprasad Das)

Hierarchical decomposition is a method used to partition a system into functional blocks, breaking it down into components and modules. This approach helps handle the complexity of VLSI design by breaking down the system into functional blocks. The locality of the blocks should also be considered to reduce interconnect length. Abstraction through a division process compartmentalizes design in different layers, allows designers to work efficiently at one layer without worrying about layers above or below. The above model divides the whole design cycle into various domains[6].

The adage "Necessity is the mother of invention" states the importance of defining the purpose or the need of an electronic device which has to be developed. The design flow in VLSI design is the sequence of steps involved in creating an integrated circuit.

Considering factors like cost, performance, architecture, and communication the objective of desired product is defined in system specification step. Power consumption,

performance, functionality, and chip area are the key specification in VLSI based system design. Then the system architecture is crafted which satisfies specified requirements, including basic architecture, layout, memory management, power requirements, internal and external communication protocols, and appropriate process technology and layer stack configuration in architectural design stage balancing successful design realization[7].
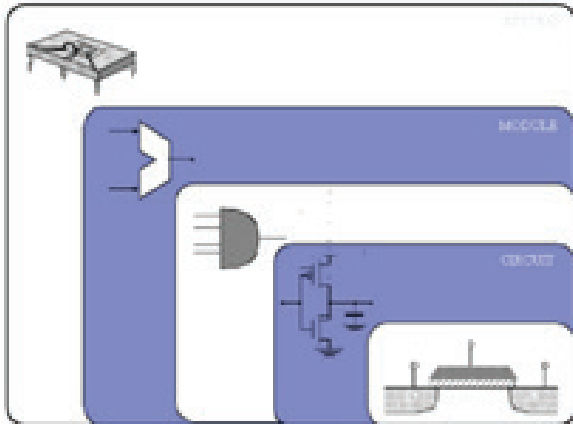
Fig. 4 Vein Diagram Representation

In RTL Design stage VHDL or Verilog hardware description languages describe the circuit in behavioral domain synthesizing them into a gate-level netlist. This impacts efficiency and performance significantly. Combinatorial and sequential designs are used for optimal operation.

Functional verification uses real-world test scenarios to identify and debug errors. It uses testbenches, programs, simulation, emulation, and formal verification techniques. It is necessary for safety-critical applications such as automotives, aerospace and medical equipment ensuring that design meets specifications which results in a successful and reliable product[8].

The design from behavioural to structural representations are converted using logic synthesis process, like logic gate networks or functional blocks. It converts a high-level textual representation into Boolean equations and equivalent registers and a netlist is produced for programming FPGA or ASIC. The design's integrity is verified by comparing the original Register-Transfer Level description with the gate-level netlist in logic verification stage which prevents error.

Partitioning, floorplanning, placement, routing, and verification to transform schematics into circuit layouts are the processes involved in physical design stage. To reduce complexity and enhance design efficiency the functional unit are grouped into distinct blocks. This process is named as partitioning and it is crucial as it sets the stage for later processes in VLSI design. Floorplanning is done to place and connect design component in minimum area, producing a two-dimensional layout with a plan for each block. In slicing floorplanning technique partitioning the die area into equal or unequal slices is done using horizontal or vertical line until all the blocks are separated individually and in non-slicing floorplan technique at least five blocks are obtained by partitioning blocks, also known as the wheel or spiral floorplan[6],[9].
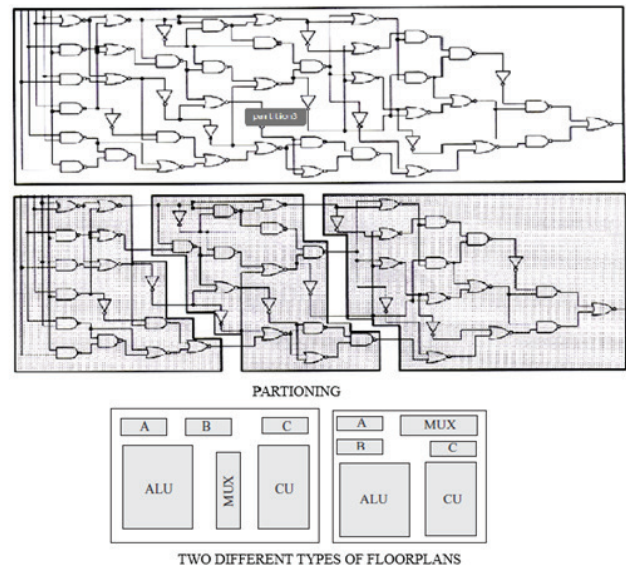
Fig. 5 Partioning and Floor Planing (Courtesy: Debaprasad Das)

To determine layout of a chip and optimizing performance, power consumption, and area placement is vital step. Clock Tree Synthesis distributes the clock equally among sequential parts of a VLSI design to reduce skew and delay. Then routing is done in the design of integrated circuits (ICs) using metal layers to create electrical paths for signal transmission between different parts of the chip. Detail routing assigns dimensions to nets on the other hand global routing generates a tentative route for each net. Channel routing and full-chip routing are the two most popular types

of detailed routing. A clocked synchronous circuit that meets all timing requirements are design by timing closure process which is easier with the right High-Level Language (HLL) and constraints for synthesis[9].

PLACEMENT

Clock Distribution Before CTS   Clock Distribution After CTS
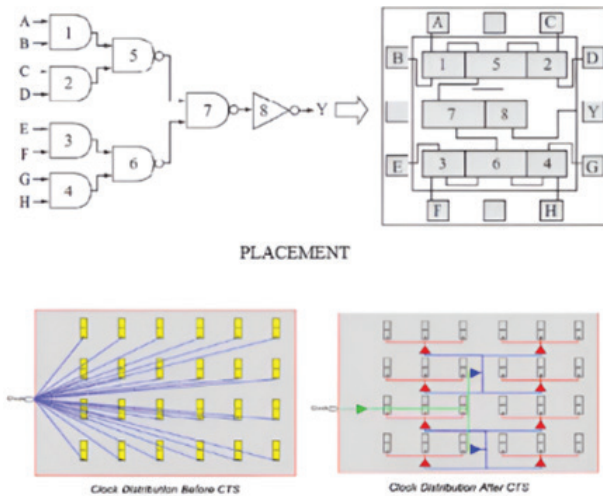
Fig. 6 Placement and Clock Tree Synthesis (Courtesy : Chipedge. com)

Fig. VLSI Design Flow
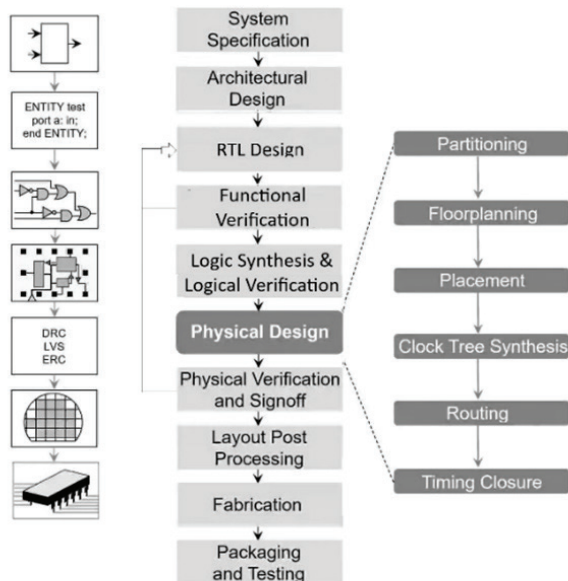
Fig. 7 VLSI Design Flow (Courtesy: Wikipedia.org)

The physical verification stage ensure that the physical layout is accurate in intended electrical behavior which can be successfully manufactured. Key checks include Layout vs. Schematic (LVS), Antenna Check,

Power Integrity Analysis (PI), Electrical Rule Check (ERC), Design Rule Check (DRC) and Signal Integrity Analysis (SI). Sign-off is done before a design is sent for fabrication only after ensuring completion of verification checks and meeting required specifications. The fabrication includes crystal growth, wafer preparation, epitaxy, dielectric and polysilicon film deposition, lithography, oxidation, and dry etching. The final product undergoes testing to ensure it meets specifications, including prototype, post-silicon validation, and production testing. Built-In Self-Test (BIST), Automatic Test Pattern Generation (ATPG) and Design for Testability (DFT) are included methods for the same[10].

The design process of VLSI is evolutionary and sequential. But there are feedback loops at each stage, with the process repeated in an iterative manner until specifications are satisfied. The above flow diagram shows the crucial stages required to create complex VLSI circuit.

Manufacturing Process- Silicon wafer production — from sand (left) to semiconductor-grade silicon wafers through the process of extracting and purifying silicon. The next step is its purification, in which it melts and turns into a cylinder by the Czochralski method with cuts to extract thin wafers using progressive diamond saws. Polishing also imparts a mirror-finish on this wafer to produce a very flat, almost frictionless surface[11]-[12].

Typically, wafer cleaning is thorough to eliminate surface contaminations like dust or other organics and metallic particles. This thermal oxidation is used to grow a thin layer of silicon dioxide (SiO_2) on the wafer surface and acting as an insulating barrier. The dry and the wet oxidation together produce a thinner oxide layer of good quality, while in many applications where thicker and more promissory is needed this part should be subjected to another kind of environment[11]-[12].

In Photolithography, a light-sensitive material called photoresist is placed on top of the wafer in which its coating thickness and uniformity are paramount for pattern formation. The wafer is then photoresist-coated, and a photomask that contains the desired circuit pattern is aligned over it; this assembly with the resist exposing on top of photomask at bottom (wafer-photo mask) may place in ultraviolet light to expose their upper surface.

Then, the wafer is exposed in to UV light and developed with a developer solution which removes areas of photoresist either where it was not (a positive resist) or where it had been deposited when using negative type resists[11]-[12].
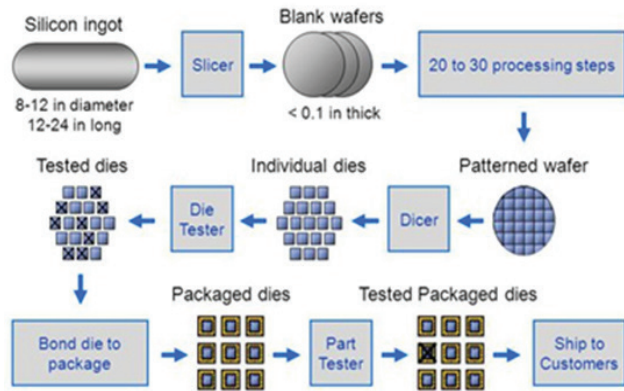
Fig. 8 Chip Manufacturing (Courtesy: Slideshare)

Anisotropic etching is an important use of plasma chemistry in microfabrication. It is related to processes that relies on uniformly anisotropic selectivity for different materials and it has gained remarkable technological importance. The plasma state, in which gases turn into reactive molecules and ions which can completely remove any material, is the key to dry etching. Here, all processes are based on free radical attacks. An electrical field is used to direct ions created in the plasma where they etch away the unwanted material. Wet etching, as you can see is due to the use of a chemical solution or mixture. Ion implantation and doping involve accelerating and implanting ions of dopants into specific regions of the silicon wafer, altering the electrical properties of the silicon to form the p-n junctions necessary for transistor operation. After implantation, the wafer is heated to repair damage and activate the dopants, rendering them electrically active.

We have all seen enough silicon wafers to know that making ICs involves the steps of deposition, planarization, metallization - testing in packaging. Deposition involves materials such as silicon dioxide, silicon nitride or polysilicon and planarization requires the wafer to be polished so that it is perfectly flat. Metallization is a process of forming thin layers of metallic aluminium or copper to create the electrical

interconnects between transistors and other components. Subsequently, the metal layer is patterned and etched by WLP photolithography to define circuit paths[11]-[12].

Basically, what wafer testing is that contact of probes on specific point on the chip, it is also called as wafer sort. Then the next step is, die cutting meaning cutting wafer into individual dies and then they are processed through steps like die bonding, wire bonding and flip-chip bonding which is also part of packaging. The dies are encapsulated to protect from environment factors [11]-[12].

The last test and quality control is for the functionality of devices, burn-in testing i.e. (all connectors are placed in position overnight), output power cable remains connectable & loose isolation meters support as well as special ordered resolution or options simultaneously at once Test on final product. So, for example functional testing tests that the chips are outputting what they are supposed to be given as an input (to a very high level of confidence) whereas burn-in only screens out certain early-life failures. The chips that pass all tests are placed in shipping containers, inspected by quality control and marked while those that have failed are removed as scrap to be recycled.

The VLSI chip manufacturing market is rapidly increasing that can be evident from a market size of approximately $500 billion announced globally for the year 2021. The key growth drivers of the market are growing adoption of IoT devices, consumer electronics such as smartphones and other smart connected electronic appliances including automotive industry. Key Market Players include TSMC, Intel, Samsung, GlobalFoundries, UMC and SMIC. The industry innovates on technology non-stop bottlenecking and advancing towards nodes shrinkage, transistor density increase. We are seeing increased demand for application-specific or domain-specific integrated circuits, in fields like AI/ML and automotive chips as well IoT devices. Historically, companies have been forming alliances and partnerships to combine their offerings for a shared market or reduce resource costs. Geopolitical factors like trade tensions might impact the IC manufacturing and semiconductor market. Market is expected to grow $800 Billion in the year 2026. This may cause a change in our country's market size too

which is supposed to grow to $55 Billion in the FY 2026.

Fig. 9 ESDM Market Analysis Global Growth (Expected) (Courtesy: Niveshaay.com)

Our country started manufacturing in 1980 and the first manufacturing hub was built in Mohali known as Semiconductor Laboratory. Our government began to promote this industry in 2000s, where Production-Linked Incentive scheme was launched in 2021 and a $10 Billion package was announced in 2022 under the "India Semiconductor Mission". Because of this only reason, Our country is still its early stages of developing Manufacturing facilities of Semiconductor, with no large-scale fabrication plants approved[13].

Consumer electronics, telecommunications, and automotive are the main sectors which are driving the semiconductor market in Our country. In 2023, our country's total semiconductor market was $34.3 Billion. IC manufacturing occupied over 40% of the total value. The total semiconductor market of our Country is projected to grow at 20.1% CAGR approximately valued at $100.2 Billion in FY2032[14].
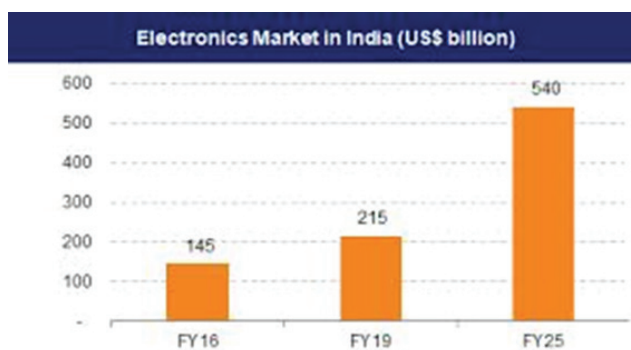
Fig. 10 Indian Electronics Market (Courtesy: ibef.org)

Even after starting late in the investments and advancements of this sector, our government is continuously focusing on development of this industry. In FY 2021, Rs 1503 Cr was allocated for the development and Rs 3000 Cr each for FY2022 and FY 2023. With outstanding demand for this sector, Rs 6903 Cr has been allocated in FY 2024[5]. Our country's semiconductor industry is still in its initial stages compared to established countries in Asia. From these figures, it can be clearly seen that government is really giving incentives through various initiatives for the development of this sector. Low-end applications for VLSI chips are locally mass built, and ATP has grown in our country but advanced VLSI chip manufacturing capacity is yet to be mass developed. Although the domestic foundries do not have as much technological capability as market leaders, they still exist. Our country's VLSI chip manufacturing market is expected to grow at higher CAGR as compared with global average; backed by government support and increasing domestic demand. Our government has already rolled out a series of policy initiatives in the direction that include Production-Linked Incentive (PLI) scheme, Modified Program for Semiconductors and Display Fab Ecosystem (M-SDE), Design Linked Incentive (DLI) Scheme. These schemes and incentives can clearly state the Governments vision behind this industry and we can clearly observe that Government is constantly focused on the growth of the Electronics manufacturing and semiconductor industry in our country[13].

Making semiconductors manufacturing in Our country is not easy because it needs high capital investment, very good ROI. An industry would need an integrated ecosystem of providers for raw materials, expert machinery and humans equipped to manage these critical parts — all in which the homegrown talent pool is deficient at present. As a corollary, our country's workforce is only just beginning to acquire deep skills in microelectronics, materials science and precision engineering. Inadequate infrastructure, such as sporadic electricity and water provision along with subpar logistics and transportation network also qualifies. Our country's infrastructure is far from world-class which a high-tech industry like semiconductors requires. IP & R&D Challenges: There is restricted investment in Research and Development that is comparatively less than the other countries like USA, China. While IP protection is important in order to encourage foreign investment and innovation at home, we struggle to lure

international semiconductor firms. Countries have to compete globally against countries that are much larger like Taiwan and South Korea as well the US which also has significant natural advantages, there is also always trade restrictions such geopolitical dynamics make this very difficult. Now, our country's companies are seeing an opportunity to make re-seeding self-reliance and their stocks for the semi-conductor plant but how they would find investors in this coveted field if a country like US is already engaged reshoring back its capital!
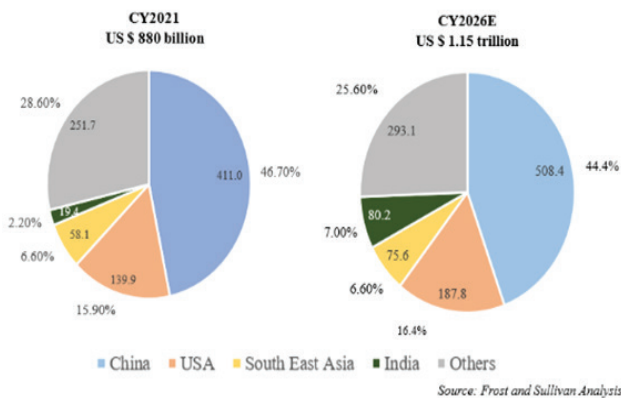
Fig. 11 ESDM Market Country Wise (Courtesy: Niveshaay. com)

As to think of the challenges faced by this industry, Our Government introduced PLI schemes can really pull some attraction from the investors. These initiatives could really help the industry if provided with more favourable tax regimes. Further what really is required is investments in sectors like infrastructure, education and skill department and most important is global collaborations and partnerships. Specialized training centres and R&D labs can build a skilled workforce and generate more talent in the country. To make our country one of the top manufacturing country, government should focus on supply chains and less capital-intensive parts of the industry.

Conclusion- VLSI designing and manufacturing is complex and requires specific skills so as create workable and manufacturable chips with performance, Power and Area (PPA) specifications. As discussed, some of stages are Specification, Synthesis, Floorplanning, Placement, Routing Physical Verification and then the manufacturing of the chip is complex. These processes can be used to effectively produce VLSI chips. But handling this

effectively and in smart ways with Advanced-Design tools enables designers create an innovative, high-performance chip. Finally, revisioning of VLSI chip design in future advancements and the explosive demand on specialized chips drives the growth. Our country's VLSI chip manufacturing industry, which is in its infancy has shown encouraging growth over the years with sustained government efforts along-with expanding domestic market for electronic products. The Production-Linked Incentive (PLI) scheme has brought in investments from some big semiconductor players, along with the Modified Program for Semiconductors and Display Fab Ecosystem(M-SDE), which gives financial assistance to set up manufacturing units. The government emphasis on the research and development activity has ensured innovative measures in that sector. Even in building and educator base for semiconductor learning, the Indian universities & research institutions have played quite an active role filled with talent. The growth of the domestic market is an important opportunity for domestic chip manufacturers. The country's fab story is still just that, a story with the investigation committee recommendations gathering dust and local companies courting global semiconductor players to enter into partnerships established both technology transfer access as well as market entry points. However, the VLSI Chip manufacturing in our country has immense potential to greatly benefit in the global outlook for semiconductors. With this relentless government support, skill development, technology adaption and global partnership will lead to a sustainable dominance in the world - with VLSI chips manufacturing our country supporting rapid economic growth and moving towards technologically advanced country.

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Multiple Gigabit Network Deployment using XPON DWDM

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ABSTRACT

The concept of DWDM on XPON architecture creates a platform for wavelength-based logical point-to-point connectivity upon a physical point-to-multipoint fiber topology. It deploys a simple concept that has the capability to combine unified access and backhaul connectivity ready for futuristic deployments, carrying large-scale data from residential, business, and carrier services on a single platform. Its wide-scale capability and bandwidth scalability enable ISPs and corporate users to serve more end points from fewer active sites without compromising security and availability.

KEYWORDS : DWDM, XPON, EPON, GPON, Fiber optic communications, OLT, SFP modules, AES encryption, scalability.

INTRODUCTION

PON technology uses a single mode 9/12.5µm optical fiber from the OLT connected to PON SFP, which acts on both TX and RX in the same module to connect to the end CPE. Optical Splitter then splits optical power into N separate paths to the users. The optical paths can vary between 2 and 128 depending upon the split division mechanism, like 1:64 in EPON and 1:128 in the GPON network.

From the optical splitter, a single optical strand runs to each user's ONT. PON adopts two signal multiplexing mechanisms for downstream and upstream separate technology. Generally, PON systems can operate up to 20 km from the PON module to the last-mile CPE ONU. As per recent updates, growing PON technologies can theoretically connect up to 40 odd kilometers, which enhances future-proof expansion. This steady, fast growth in operational limits has benefited many long-distance connectivity requirements in rural areas.

PON technologies scale in EPON and GPON concepts, which deploy scalability and performance at low cost and maintenance requirements. G/EPON uses 1490 nm wavelengths as uplink wavelengths for connecting CPE at end points, while it uses 1310 nm wavelength as downlink connectivity. In earlier days, long-distance connectivity over fiber was based on media converters, which were active devices that were used to connect fiber networks scaling up to 20 kilometers max. Though it had long spans to connect, it was still unmanageable and difficult to troubleshoot in case any maintenance occurred. It also limited transmission capability up to one gigabit only. Next, it used physical fiber cores for every connectivity path, which was more cost-consuming at large-scale deployments. Other issues also included media packet drop factors when media converters worked without any reboot. As a result, many critical installations replaced these media converters with SFP modules, but still some drawbacks were later discovered: maintenance on long haul distances impacted data transmission at periodic stages. However, only PON technologies relaxed the use of physical multiple fiber core requirements at layer 1 of deployment. It gradually lowered the physical core requirement as was utilized in other media connectivity options previously.

It uses the same light reflection mechanism based on light rays passing through a glass prism in which multiple light color spectrums can be seen. Splitting

in OFC DWDM works on the relatively same scenario in which multiple wavelengths are used in the same fiber media without any disturbances to the other light spectrum in case of wavelengths.
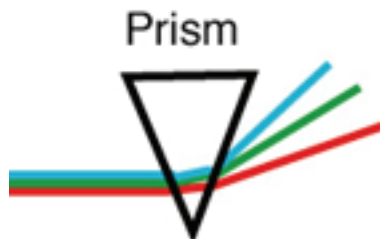
It also enables low-down latency at extreme levels and enhances low-jitter traffic communications, which can be easily felt while using high bandwidth or real-time requirement applications by users. Theoretically, EPON deploys 1.25 gigabit in both uplink and downlink connectivity for end-to-end connectivity. Similarly, in GPON, it uses 2.5 gigabits in downlink and 1.25 gigabits in uplink connectivity [1].
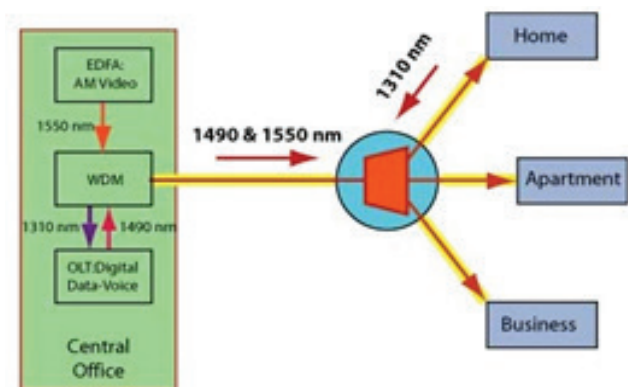
However, in many instances in GPON networks, ratio couplers may impact performance minutely. Ratio couplers have very low optical power loss and split ratios and provide very low insertion losses to forward media. OLT has many management features inbuilt, like maintaining bandwidth limitations and loopback detection, which enhances network flow performance. It also enhances administrator's ability to monitor any rogue activity if triggered from the CPE end. OLT can also act as a RADIUS server if profiles are defined at admin levels, which enhance centralized control over the entire network topology. As a result, many ISPs and core networks use this as a very good alternative for optical power management at large scales.
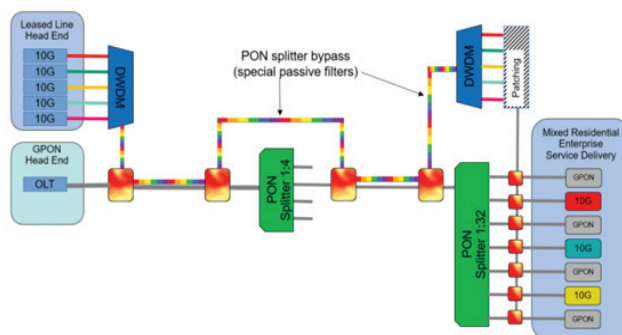
OLT is Layer 2/2+/3 switch/router-based equipment that manages every bit of system in PON technology. It also uses many routing and switching protocols to deal with bandwidth shaping and routing to enhance performance factors. This may vary depending upon distance from OLT to CPE and various criteria like insertion losses, cable losses, splicing losses, media losses, and other environmental factors. In many cases, ratio couplers are used to split bandwidth at uneven ratios. Ratio coupler enables to utilize precious fiber core and reduces cost and maintenance at very large scale.

OLT also maintains security and other protocols for CPE ONU authentication and rogue device discovery to prevent any cyber-attack about to happen. OLT also acts as a management console to monitor bandwidth and advance features for customer management, such as RADIUS, AAA, and triple play connectivity, enhancing multiple profiles to be connected on the same CPE and lowering the cost of end-point connectivity at large scales.

CONCEPT OF DWDM

Dense wavelength-division multiplexing (DWDM) is optical fiber multiplexing data transmission technology that is used to increase the bandwidth of existing fiber networks without changes in the existing OFC environment. It combines data signals from different sources over a single core of optical fiber cable while maintaining complete separation of the data streams from each other. Every separate light wavelength carries a different signal emerging from different sources directing towards the same endpoint on which other wavelengths are being dumped finally.

Economically, DWDM acts as a price negotiator with other high-priced technologies till now. This approach

helps maintain data integrity between different sources and their destinations, if any. As of now, DWDM was finally designed to multiply the capacity of a single fiber rather than adding a bus of OFC to the same media without any modifications in existing network infrastructure. [2]
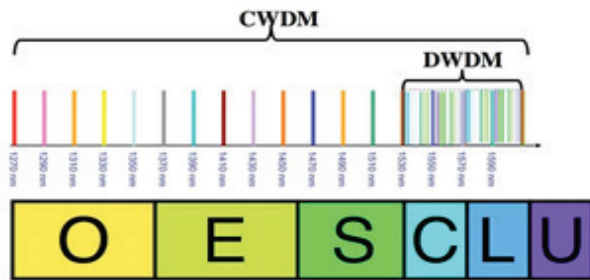
DWDM-PON networks initially used 1310-1510 nm and 1310 nm transmissions for downstream and upstream. Wavelength division multiplexing is a technology where multiple optical signals are multiplexed into a single fiber core instead of using multiple physical optical fiber cores. For this, several different wavelengths are used through lasers (colors of light) to transport different signals, just as a ray of light passes through a glass prism and emits a rainbow of lights in sequence of their visibility to human eyes. WDM systems allow many high-speed TDM (time division multiplexing) channels to be multiplexed onto a single fiber, increasing the transmission capacity of the system and providing multigigabit data communication solutions to users at affordable costs.

In DWDM-PON technology, each client has a wavelength (colors of light) reserved to communicate with the OLT. One of the channel division methods for users is the use of AWG (Array Waveguide Grating). It works as a passive wavelength router, determining that the input optical signal is routed to a certain output port depending on the length. Wavelength, working as follows: the OLT sends all wavelengths with the desired information in a single fiber, and the AWG, once its routing is defined, is responsible for sending each wavelength to the ONU that must receive the information.

DATA SECURITY

XPON (X Passive Optical Network) is a prominent technology for delivering broadband services, especially in fiber-to-the-home (FTTH) deployments. Like all network infrastructures, ensuring security in XPON is essential to protect user data and maintain network integrity. Here's an overview of XPON security.

Physical Security: One inherent advantage of fiber-optic networks like GPON over copper-based networks is that fiber is inherently more secure due to its nature. It's challenging to tap into a fiber line without causing noticeable disruption or attenuation (decrease in signal strength).

Encryption: The PON system uses Advanced Encryption Standard (AES) encryption to secure the data transmitted between the Optical Line Terminal (OLT) and the Optical Network Unit (ONU). The encryption ensures that even if someone were to tap into the fiber, interpreting the data would be a challenge, as intruders can face a more tedious job to encrypt and decrypt such text rather than plain text data bits. [5]

Authentication: During the initial setup or when a new CPE is added to the network, a process called authentication takes place. The OLT identifies the distance and timing of the ONU/ONT. Additionally, the ONU/ONT must provide a valid serial number and password to be authenticated by the OLT. This process helps in ensuring only legitimate devices are connected to the network.

Downstream & Upstream Privacy: In XPON, the downstream direction (from OLT to ONU/ONTs) is broadcast, meaning that the data is sent to all ONU. However, due to the encryption mentioned earlier, only the intended ONU can decrypt and process the data meant for it.

The upstream direction (from ONU/ONT to OLT) uses the Time Division Multiple Access (TDMA) frame system for periodic communication. Each ONU is assigned specific timeslots during which they can transmit data, ensuring that ONUs don't access the medium simultaneously.

This time frame concept routes the user to connect in a proper time slot, reducing jitter and maintaining low latency in the PON network.

Rogue ONU Protection: To prevent malicious ONUs from joining the network, XPON has mechanisms to

identify and block rogue devices. Proper management and monitoring of the OLT can help in identifying suspicious activities or devices.

Vulnerabilities and Concerns: Like all technologies, XPON is not without its vulnerabilities. Over the years, researchers have discovered flaws or weaknesses, particularly in certain vendor implementations. These vulnerabilities could potentially allow unauthorized access, denial of service attacks, or information disclosure. It's crucial for service providers to stay updated with patches and firmware upgrades from vendors and follow best practices for XPON deployment.

Best Practices: Service providers should regularly monitor and audit their XPON infrastructure.

- Keeping the OLT firmware up-to-date is essential to patch any known vulnerabilities.

- Limiting access to network management interfaces and using strong, unique passwords can prevent unauthorized access.

- Regular penetration testing and vulnerability assessments can help in identifying potential weak points in the GPON deployment.

In XPON's OLT's downstream broadcasting, packets are being sent from the OLT to all connected ONTs on specified route paths, like the same PON module or configured as per the network requirements of ISPs. At times, some intruders may even reprogram their intruders own ONT to capture incoming information that was meant for another ONT user.

In this scenario, the rogue ONT can not only intercept data, but there can also be a fake OLT transmitting and receiving data from multiple subscribers, which may divert the data traffic of an authorized user to be diverted towards rogue users, compromising other users data privacy at breach. The intruder, once accessible to the entire PON network, may now intercept important data being sent up and downstream, such as passwords, OTPs, banking credentials, and key logs of users, by using advanced techniques like phishing and other cyber tools for data mining.

Due to this capability of interception, XPON's recommendation is that an encryption-based stringent

algorithm, Advanced Encryption Standard, can be used, so it will be difficult for information to be encrypted by using multiple byte keys (128, 192, and 256-bit AES [5]) at maximum bit level. Encryption offers high-class security to user data while connected to a PON network by encrypting key points like passwords in encrypted text format to be accessible only to authorized users.

While chasing the future requirements in fiber networks, PON systems are being advancing day by day. Currently at lab testing levels, PON systems are being tested up to 10 gigabit downlink speeds and 2.5 gigabit on PON ports to provide more data-carrying capacity at OLT ends. It gradually defines the need for the future, where these bandwidths may also fall short at times. Ease of management is also being moderated so as to provide more easy management at admin levels. Earlier EPON systems supported up to 64 CPE per port at max for field deployments. Progressively, GPON extended this limit to 128 CPE per GPON port.

CONCLUSION

Looking about the future is looking at DWDM-PON as a very promising alternative. This technology has the ability to improve the efficiency of optical networks by transmitting multiple signals at different wavelengths simultaneously along a single optical fiber. PON technology gradually decreases the cost of communication equipment and their maintenance costs on a large scale. This means we have greater data transmission capacity, which allows us to have greater bandwidth (multigigabit) and better network performance. This technology still has room to evolve and is expected to be improved to allow a significant increase in transmission speed, greater energy efficiency, and lower implementation and maintenance costs.

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Blockchain Technology in Healthcare Application

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ABSTRACT

Digital healthcare being a promising area many researchers are focused towards it. Electronics Health Records must be secured along with privacy maintained as disclosure of data may lead to unwanted access of sensitive health data. Data security and privacy remains important for all the stake holders involved in the healthcare system. Along with Electronics Health Records, Remote Patient Monitoring is also going to bring great boom and value to health industry. Remote Patient Monitoring will increase the quality of diagnosis by decreasing the time requirement. Also these sectors will make easy availability of health data. Electronics Health Records as well as Remote Patient Monitoring requires data storage and access in a secured way. Blockchain being a decentralized technology proves to be a boon in this sector. This paper provides a detailed review of Blockchain technology in Electronics Health Records and Remote Patient Monitoring. The review is made taking into consideration various parameters including consensus protocols used, storage type, implementation framework, type of blockchain network, validation tools, ledger type and limitations. Features including privacy, security, confidentiality, transparency, access control, speed etc are also compared and suitable conclusions are drawn which can be very helpful to the researchers desirous to work in this area.

KEYWORDS : Blockchain, Electronic Health Records.

INTRODUCTION

In the digital age, healthcare is experiencing a transformative revolution. Numerous challenges are encountered ranging from interoperability issues, patient data security, drug availability and security, Medical device connectivity,loss of ownership and fraudulent access to stored medical (personal) data, fraud in medical claims and bills, etc. thereby increasing the need for streamlined administrative processes. So there is a huge requirement of a platform, which is highly secured and provides collaboration of a team of healthcare professionals to deal with critical cases. If to manage the huge amount of data available in healthcare system, a traditional method is used then challenges faced are numerous. These challenges can be dealt with the efficient use of Blockchain technology in healthcare applications. Blockchain is a decentralized system that functions as a public, unchangeable, append-only ledger. It offers additional benefits such as autonomy, integrity, verification, fault tolerance, anonymity,

and the ability to audit. [1]. Due to these features Blockchain acts as best promising solution to solve the healthcare industry problems. This paper embarks on a comprehensive survey of the diverse applications of blockchain technology within the healthcare sector. It aims to provide understanding of how blockchain is being used to bring about transformative changes in healthcare, including electronic health record (EHR) management, clinical trials, drug supply chain management, telemedicine, and health insurance. Through an in-depth exploration of the current state of blockchain adoption in healthcare, we will explain the potential benefits and challenges associated with its implementation. By synthesizing existing knowledge, identifying gaps in the literature, and presenting insights into the future prospects of blockchain in healthcare, this survey paper seeks to serve as a valuable resource for researchers, healthcare professionals, policymakers, and technologists interested in the intersection of blockchain technology and healthcare. Additionally we will discuss the challenges and limitations

associated with blockchain adoption in healthcare and highlight the ethical and regulatory considerations that must be addressed to unlock its full potential. Finally, we will conclude with a forward-looking perspective on the future of blockchain technology in healthcare emphasizing its capacity to reshape the industry and enhance patient- centric care delivery. Figure 1 shows different use cases of Blockchain in medical applications.

BLOCKCHAIN

Blockchain stores data in a public ledger, where transactions can be added, accessed, and verified by participating nodes. This ensures both integrity and availability of the data. The ledger operates in an append-only manner, meaning once data is recorded, it cannot be altered or deleted. Since blockchain is a decentralized system, consensus protocols are used to ensure all participants reach a unified agreement. The system inherently maintains key features such as autonomy, immutability, verification, integrity, fault tolerance, and transparency.[1].Various Consensus protocols like byzantine fault tolerance, practical byzantine fault tolerance, proof of work, proof of stake, delegated proof of work etc. are used. To ensure security, blockchain uses various cryptographic techniques like digital signatures and hash functions. Since blockchain operates as a decentralized system, there is no central authority controlling it. As Satoshi Nakamoto, the creator of Bitcoin, once said, "The root problem with conventional currency is all the trust that's required to make it work." Blockchain eliminates that need for trust by distributing control across participants. Various frameworks like etherium, hyperledger, hyperledger fabric, distributed ledger etc. can be used for developing blockchain.

BLOCKCHAIN IN ELECTRONIC HEALTH RECORDS

Hospitals maintain the medical records of the patients including lab reports, current and previous medical examination reports, MRI's, etc. in digital form which are saved electronically which are referred as Electronic Health Records. Authorized users can access these records and can share them with organizations in health care fields for multiple reasons like study, research and examination. This leads to workflow optimization for healthcare professionals. Using this method the drawbacks of physical storage can be easily eliminated and thus data is protected against manipulations, natural calamities, theft etc.[4] Electronic Health Records minimize errors, thereby increasing accuracy of information and making information clearer, which potentially supports patient's health monitoring, examination and related activities. Doctors and Patients relations are shored up, as Electronic Health Records provide opportunity for fast interactions as and when needed and also eliminate the treatment delays and test repetitions. This also helps doctors in taking decisions in better way, which ultimately improves the care quality provided to patients. The rapid growth in Information Technology makes software and tools easily available that can be inappropriately used by unauthorized users to attack these Electronic Health Records. Attackers can use this information for their personal interest. Providing proper security to the data is the need of time so that they can be kept safe. Blockchain based approach can be a optimum solution to store this records as it is decentralized technology and can easily overcome the drawbacks faced in cloud based storage. Table 1 shows classification of work done in the field of Electronic health record based on various parameters including framework ,consensus algorithms, Hash functions, Validation tools, storage used, ledger type and threats present. Comparison on the basis of features of blockchainlike robustness, transparency, security, privacy, confidentiality, scalability, immutability, access control, delay, integrity and tracebility is provided in table 2.

BLOCKCHAIN IN REMOTE PATIENT MONITORING

Remotely monitoring the patient can be helpful in terms of cost and time saving as patient need not to visit hospital for primary checkup, diagnosis and follow ups. Also for critically ill patient, who find it difficult to visit hospitals Remote[6] Patient Monitoring can be considered as boon. Using wearable devices real time information of patient including temperature, blood pressure, heart rate and ECG can be collected which can be used for the purpose of diagnosing the patient

thereby providing suggestions. This process improves patient's health. However patients real time monitoring involves remotely managing patient's real time-data. Current system involves design where multiple nodes which are connected to a central server. However in case of failure of central server, there can be an information loss. Also such type of system can increase the threat to confidentiality and integrity of data. There are also chances numerous types of malicious attacks. Real time data updation and maintaining transparency of data stands out to be a tough task in centralized system. To all these problems Remote Patient Monitoring using Blockchain which is distributed immutable ledger is a solution. Blockchain Technology when used can efficiently solves the problems stated above as it efficiently exhibit properties of confidentiality, integrity, transparency, authenticity and related properties which solve the problem of conventional system.[8] Table III shows classification of work done in the field of Remote Patient Monitoring based on various parameters

including framework ,consensus algorithms, Hash functions, Validation tools, storage used, ledger type and limitations. Comparison on the basis of features of blockchain like robustness, transparency, security, privacy, confidentiality, scalability, immutability, access control, delay, integrity and traceability is provided in table 4.
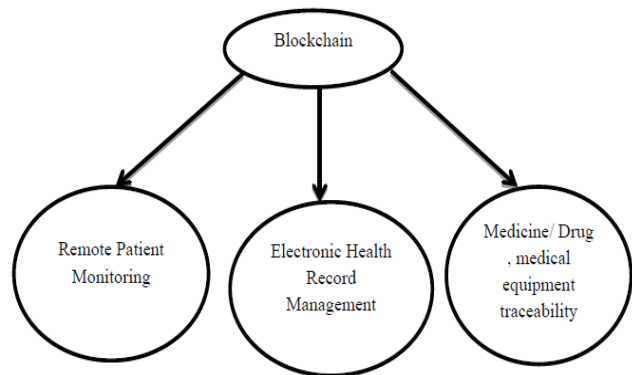
Fig 1. Blockchain use cases in medical applications

Table 1. Electronic Health Records: Summary of work done and comparison

Reference	Type of Blockchain	Framework	Consensus Algorithm	Hash Function	Validation tools	Storage	Ledger	Threats
[5]	Permissioned	Hyperledger fabric and Hyperledger Composer	PBFT : Practical Byzantine Fault Tolerance Algorithm	IPFS generates t hash of data	HyperledgerCaliper Smart Contratcs(Access Control)	OrbitDB with IPFS: Interplanetary File System Blockchain Database	Distributed Ledger	spoofing attack tampering threat repudiation threat
[9]	Private/ Consortium	Ethereum	Practical Byzantine Fault Tolerance (PBFT)	Not Available	Solidity + Smart contracts	Designed EHR storage database	Distributed Ledger	Not Available
[12]	public	Bitcoin	Delegated Proof of Stake	IPFS generates the hash of the data	Data masking, hash and improved consensus algorithm	Interplanetary File System Blockchain Database	Not Available	tampering threat
[13]	Private	Ethereum Framework	In Amazon servers two Ethereum nodes are deployed which are responsible for mining	Not Available	Testnet of Ethereum and Solidity language	Cloud database	Distributed Ledger	
[10]	Consortium	Java	BFT-SMaRt	Not Available	Implementing using Java	Local Database	Distributed Ledger	tampering threat repudiation threat attack resistant

[8]	Public	Not available (N/A)	More than fifty percent of nodes select a endorser who validates the transaction..	SHA256	Latency of service provider requests/Security analysis.	Local Database	Distributed Ledger	tampering threat anonymous Identity disguise Replay attack Binding attack
[11]	Consortium	IBM's HyperLedger / Ethereum, Chain Core /Openchain	Proof of Work (PoW) Proof of Stake (PoS)	SHA256	HDFS: BigData Storage & RDBMS: Relational Database Management System	Signature forgery attack	Distributed Ledger	forgery attack security threats
[14]	Permissioned	Ethereum	Proof of Work	SHA256	smart contracts,	Local Database	Distributed Ledger	tampering threat
[15]	Permissioned	Not available (N/A)	Consensus Node fetch the unprocessed blocks, and publish them only after authenticity verification	SHA256	improved consensus algorithm	cloud-based	Distributed Ledger	tampering threat security threats
[16]	Consortium / Permissioned	Hyperledger Fabric Framework	DPoS: Delegated Proof of Stake alogorithm and PBFT: Practical Byzantine Fault Tolerance algorithm	Not available (N/A)	Smart Contratcs(Attribute based Access Control)	Cloud database	Distributed Ledger	tampering threat security threats
[17]	Permissioned	Ethereum	Proof of Work	SHA256	smart contracts,	Local Database	Distributed Ledger	tampering threat

Table 2. Electronic Health Records: Comparison on basis of features

Reference	Robustness	Security	Privacy	Confidentiality	Scalability	Integrity	Availability	Traceability	Immutability	Access control	delay	Transparency
[5]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	negligible	No
[9]	NA	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	negligible	Yes
[12]	NA	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No	NA	NA
[13]	NA	Yes	Yes	Yes	Yes	Yes	No	No	Yes	No	NA	NA
[10]	NA	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	small	NA
[8]	NA	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	small	NA
[11]	NA	Yes	No	No	No	Yes	No	Yes	Yes	No	NA	NA
[14]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	small	Yes
[15]	NA	Yes	Yes	NA	Yes	NA	NA	Yes	Yes	Yes	negligible	Yes
[16]	NA	Yes	Yes	NA	Yes	Yes	Yes	NA	NA	Yes	small	No
[17]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	small	Yes

Table 3. Remote Patient Monitoring: Summary of work done and comparison

Reference	Type of Blockchain	Framework	Consensus Algorithm	Hash Function	Validation tools	Storage	Ledger	limitation
[18]	Permissioned , Private/Consortium	Not Specified	POW/POS/BFT/ PBFT either can be used	SHA256	Smart Contratcs	Distributed ledger technology (DLT)	Distributed	NA

[19]	Private	Hyperledger Fabric	PBFT	SHA256	Hyperledger composer + Caliper	Distributed ledger technology (DLT)	Distributed	Heavy storage is required, Lack of communication and Authenitcation
[22]	Consortium / permissioned	Ethereum and Hyperledger Fabric	POW	SHA256	Through Experimental Simulation approach	Etherscan: Cloud database	Distributed	NA
[24]	Public	Hyperledger Fabric	Cloud server allocates ID to servers and blocks are added by server with lowest ID first moving in ascending order	NA	HyperledgerCaliper + Smart Contratcs	Cloud Based staorage	NA	Scalability need to be studied and improved
[25]	Consortium / permissioned Private	Ethereum	PBFT	SHA256	smart contracts	NA	Distributed	Key management issue if implemented on large scale
[27]	NA	Testnet of Ethereum TESTRPC	NA	NA	smart contracts	GitHub	NA	Decentralized storage not available
[28]	permissioned	Hyperledger Fabric	NA	NA	smart contracts	External Data Storage	NA	NA
[29]	Public	EthereumRinkeby platform	Proof of Authority /Voting Based PBFT	SHA256	smart contracts	decentralized file storage	Decentralized	Time and key management issues

Table. 4: Remote Patient Monitoring: Comparison on basis of features

Refer-ence	Robust-ness	Security	Privacy	Confiden-tiality	Scalab-ility	Integ-rity	Availab-ility	Traceb-ility	Immuta-bility	Access control	Delay	Transpe-rancy
[18]	NA	Yes	Yes	Yes	Yes	Yes	Yes	NA	Yes	NA	small	Yes
[19]	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	small	Yes
[22]	NA	Yes	Yes	NA	No	Yes	Yes	NA	Yes	Yes	Medi-um	Yes
[24]	Yes	Yes	Yes	NA	No	Yes	NA	NA	Yes	Yes	small	Yes
[25]	NA	Yes	Yes	Yes	NA	No	Yes	Yes	Yes	Yes	small	NA
[27]	NA	Yes	Yes	Yes	NA	Yes	Yes	NA	Yes	NA	NA	Yes
[28]	NA	Yes	Yes	NA	Yes	Yes	NA	NA	NA	Yes	NA	NA
[29]	Yes	Yes	Yes	NA	Yes	NA	NA	NA	Yes	NA	small	Yes

CONCLUSION

Using blockchain technology in electronic health records and remote patient monitoring helps improve security, making it a crucial tool for protecting data. Blockchain offers features like decentralization, interoperability, immutability etc. which improves privacy, security, speed, integrity, confidentiality, availability, transparency, scalability and traceability of Healthcare system. Health care data sharing, storage and access thus becomes easy and secured and patient diagnosis is also improved. After doing a comprehensive review we arrived to a conclusion that Permissioned and Private blockchain stands out to be a major choice for most of the healthcare applications. This paper provided a detailed study of Electronics Health Records and Remote Patient Monitoring , two major healthcare application where use Blockchain technology significantly improves the performance. Major contribution of this paper is it explores the possibilities of using blockchain in two vital areas of healthcare sector that includes Elecronics health record and Remote patient monitoring. This papers highlights technical details of the work done in this area and also provides a detailed information about algorithms and working model and security threats included.

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Paging Implementation in Rust for Memory Management on ToyOS

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ABSTRACT

Operating systems are designed to manage a computer's hardware and software resources. As technology is getting developed day by day, the management of resources and the memory optimization are very important for computing to solve real-world problems has become essential. Over time, advanced researchers continue to study big problems to find solutions within minimal time. To overcome these problems of memory management there are various concepts available in operating systems like memory isolation, segmentation, paging, virtual memory, fragmentation etc. In This paper proposes a custom toy operating system in Rust programming language which aims to solve the problems occurred in memory management and found an effective way of memory optimization using the concept of paging. Because Rust offers a higher level of memory safety without relying on a garbage collector than C and C++, it ischosen over other programming languages which will help in memory optimization.

KEYWORDS : *Operating system, Paging, Segmentation, Memory management, Memory optimization, Rust, ToyOS.*

INTRODUCTION

In a computer that can execute many programs, the operating system takes up a minimal amount of memory, with the remainder being divided across multiple processes. The process of assigning different tasks to different memory locations is known as memory management. Operating systems regulate disk and main memory accesses throughout process execution through memory management. Memory management's primary objective is to maximize memory's usefulness. There are two primary divisions of the Memory management Techniques. Loaded at different memory regions that are not necessarily next to one another, the program is divided into discrete blocks. This type of memory management is called non-contiguous. There are many categories for this scheme based on the blocks' sizes and whether or not they are in main memory. A Few Key Terminologies–

- Virtual Memory: By using secondary memory as though it were a component of main memory, virtual memory is a memory management strategy. A computer operating system that is commonly utilized in the virtual memory technique (OS). With virtual memory, a computer can temporarily shift data from random access memory (RAM) to disk storage by combining hardware and software. overcoming physical memory limits. Memory chunks are mapped to disk files so that computers can use using secondary memory in place of primary memory.

- Fragmentation: When processes are loaded and fragmentation happens in the operating system when data is released from memory, making free memory space become disorganized. Small size prevents assigning processes to memory blocks; hence the memory blocks remain unused. When processes

enter RAM, contiguous memory allocation allots them space. Both fixed and dynamic partitioning techniques are used to separate these RAM areas. These regions of memory are broken up into little bits when the process is loaded and unloaded in and out of memory, making it impossible to assign them to subsequent processes.
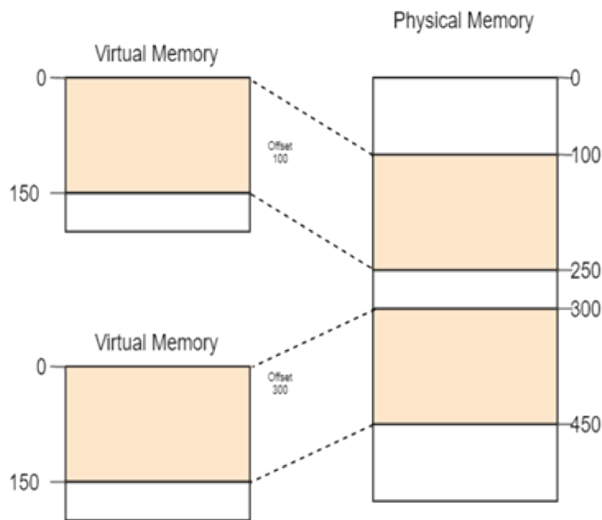
Fig. 1.   Virtual Memory
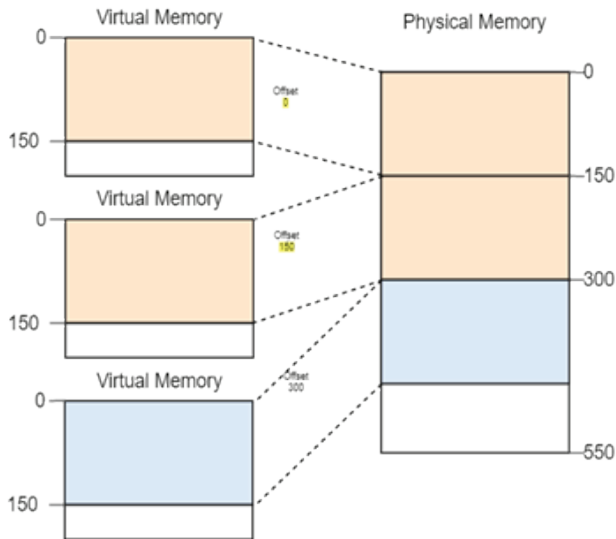
Fig. 2.   Fragmentation

- Paging: Through the use of paging, an operating system may retrieve pages representing processes from secondary storage and transfer them to the primary memory. The paging mechanism divides the primary memory into discrete frames,

or small fixed-size physical memory blocks. To optimize main memory usage and prevent external fragmentation, a frame's and a page's sizes must remain constant. It makes sense to use paging to give users faster access to data.
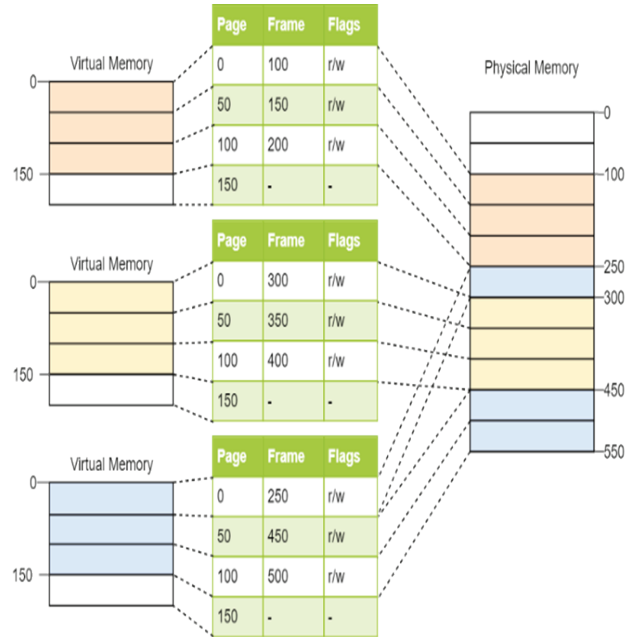
Fig. 3. Paging

- Rust: The ownership notion, extensive type system, speed, and memory efficiency of Rust make it a dynamically compiled language. Memory and thread safety are guaranteed, and developers may debug at build time, which enables it to power performance-critical services. High-end features also include integrated package managers and multiple editors with auto-completion and type checking, as well as an intuitive compiler, are all included in Rust. Rust is exciting because, like JavaScript, Ruby, and Python, it comes preconfigured to be secure and it prevents all crashes. This is far more powerful than C/C++ as it cannot develop bad parallel code and cannot identify faults in Rust. It properly and swiftly reflects a wide variety of programming paradigms.

LITERATURE SURVEY

In [1], authors have suggested a two-level memory variant of online paging. Technologies that allow for the modification of fast cache pages and hence have

upon evictions, specifically rewritten into the sluggish memory. In a single joint eviction, up to random pages can be shifted from the cache to the slow RAM for faster performance. Even if requests for pages are still made one at a time.

In the paper [6], Self-paging was proposed by the author as a technique for providing applications. In this study, quality of service was covered. The ability to precisely isolate the impacts of application paging has been demonstrated through experiments, enabling the coexistence of paging with time-sensitive applications.

In [2],this paper proposed that, the suggested data reorganisation does not alter the database engine's concurrency mechanism or the physical data structures' pointer structures, it is broadly applicable. Their proposal can be less than ideal because some data structures keep invariants that may require reading cold data while looking up hot tuples.

In [3], the research paper authors came up with a conclusion that the technique of dynamic paging is superior to the static paging algorithm since a process has a privilege to change its locality while it is in the running state. After the examination of both the algorithms, authors demonstrate how the working set algorithm effectively implements in the case of dynamic paging algorithm, and suggests a strategy for exploiting the approach to further enhance memory and system economy.

In [4], this paper proposes the demand paging systems that have already been put into place have generally revealed that these benefits come at the expense of working storage and/or backing storage that is quicker than what was previously thought to be required for the throughput and reaction times that have been achieved.

In [8], this paper describes the primary hardware components of the system, which include a 64-page main memory, a 512-page linear address space with each page sized at 4096 bytes, a single-level page-per-track backup store, and a 512-entry translation memory to manage the system's virtual memory.

In [7], the author builds on previous work in this study by framing page replacement as an optimal control problem, which can be solved using methods such as dynamic programming. This new formulation does not require familiarity with reference string lengths or conditional probabilities, making it more accessible. Additionally, a variety of computational strategies beyond dynamic programming can be applied to solve the control problem; for further details, refer to any standard text on optimal control theory. These features make the formulation valuable on its own.

PROPOSED APPROACH

This study offered suggestions for how we canmake kernel support paging? It initially examines several methods of giving the kernel access to the actual page table frames and compares their benefits and drawbacks. After that, a function for translating addresses and one for creating new mappings are implemented.

Fig. 4. Translation
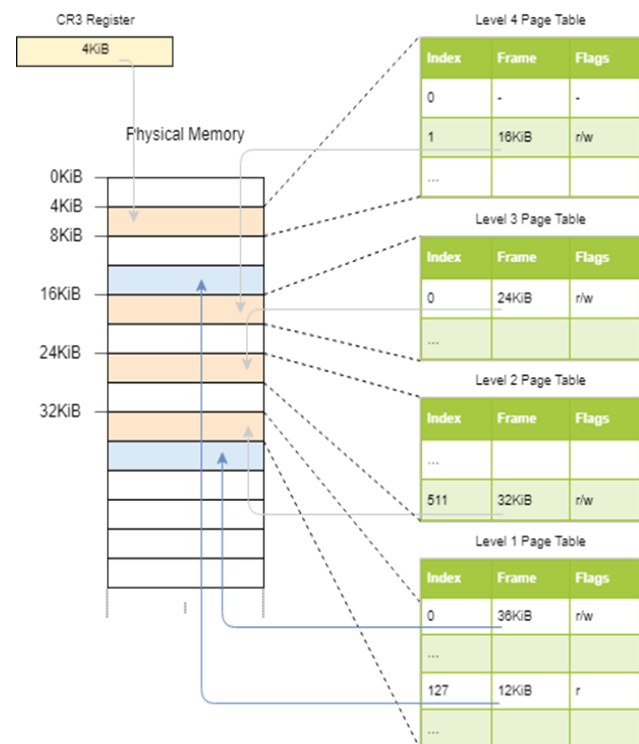
- Many non-empty entries exist, each corresponding to a distinct level 3 table, with different areas allocated for kernel code, kernel stack, physical memory mapping, and boot information. Manually navigating through the page tables offers insight into how the CPU performs address translation. To handle cases where only the physical address corresponding to a given virtual address is needed,

a function can be written. Translating a virtual address to a physical address requires traversing the four-level page table until the mapped frame is reached.

- Boot loader:This study discovered that kernel already operates on virtual addresses. As a page table structure had been established for it by the bootloader. This enhances security as unauthorized memory accesses now result in page fault exceptions rather than changing any physical memory. This studyinvestigates various methods for providing kernel with access to the page table frames. After weighing the benefits and downsides of each strategy, system will select one for kernel. These strategies need page table adjustments for setup. For instance, it may be necessary to establish mappings for the physical memory or to recursively map a level 4 table item. The issue is that needs a mechanism to access the page tables in order to build these necessary mappings. As a result, the bootloader is required since it generates the page tables that our kernel relies on.

Fig. 5.   Temporary Mapping

The proposed work must therefore map some virtual pages to page table frames in order to access them.

These mappings can be made in a variety of methods, and they all let us access any page table frame, this could only temporarily map the page table frames for devices with extremely little physical memory when needed to access them.

- Heap Allocation: It explains dynamic memory and demonstrates how frequent allocation problems are avoided by the borrow checker. The next step is to set up an allocator crate, create a heap memory region, and implement Rust's fundamental allocation interface. By the end of this post, our kernel will have access to all of the built-in alloc crate's allocation and collection types.

RESULTS AND DISCUSSION

The proposed system will configure the boot-loader first because it needs its support in order to put the strategy into practise. Next, in order to transform virtual addresses. to physical addresses, system will construct a function that iterates across the page table hierarchy. This workdiscovers how to locate memory frames that aren't being utilized for fresh tables and how to add new mappings to the page tables. This kernel already uses paging to operate. A 4-level paging structure that associates each page of kernel with a physical frame has already been established by the boot-loader that included in the post titled "A basic Rust Kernel." Because paging is required in x86 64 64-bit mode, the boot-loader performs this action.

As a result, kernel each memory address utilized was a virtual address. Accessing the VGA buffer at location 0xb8000 was successful because of the concept where the memory page is being mapped by the boot-loader identity, which tells us the change from virtual page to the physical frames (0xb8000 to 0xb8000). Paging makes this concept of paging makes kernel safe as each memory process want to access and which, instead of writing to random physical memory, is absent from our main memory causes a page fault error. Even better, the boot-loader sets up each page's access rights, ensuring that only data pages may be modified and only pages containing code can be executed.

When the page fault occurred, it is necessary to trigger some space for it and so system focused on to allocate additional memory outside the kernel for this purpose.
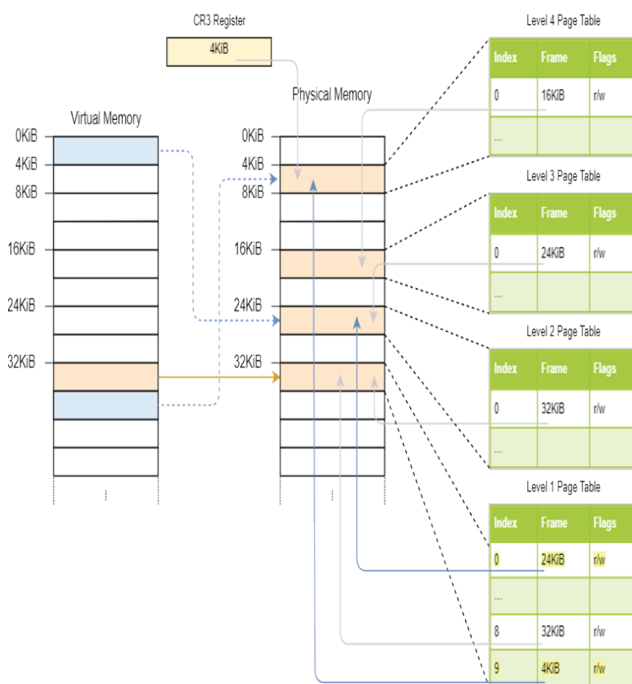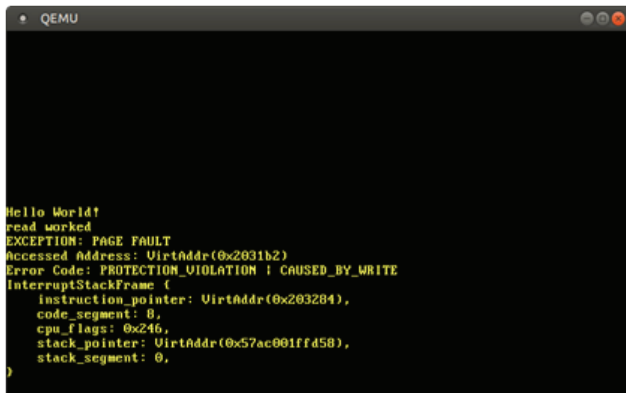
In order to notice a page fault exception rather than a general double fault, system first develop a page fault handler and register it in our IDT.
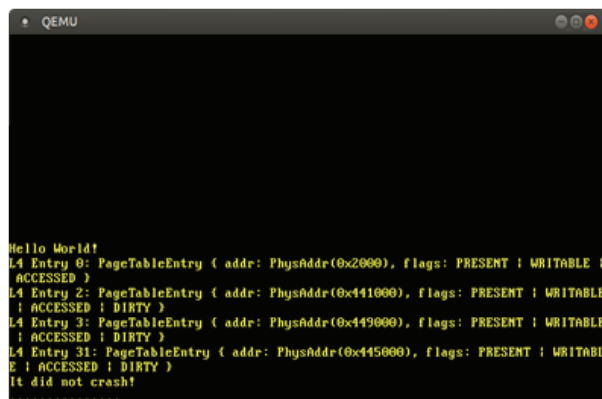
Fig. 6. Page fault handler

The message "read worked" is printed, which shows that there were no errors during the read process. But a page fault happens instead of the "write worked" message. This time, in addition to the CAUSED_BY_WRITE flag, the PROTECTION_VIOLATION flag is set, indicating that although the page was present, the operation was not permitted on it [9]. Since code pages are mapped as read-only in this instance, writing to the page is not permitted [9].

This study can start using page table code now that is actual RAM accessible. Let's first go through the page tables that our kernel has is currently using. Creating a translation mechanism that provides a physical address that correlates to a certain virtual address is the second stage. Lastly, by changing the page tables, system will attempt to create a new mapping.
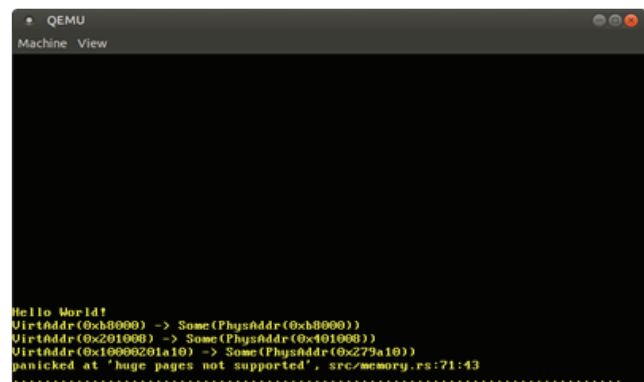
Fig. 7. Accessing the Page Tables

It is clear that multiple non-empty entries exist, each of which corresponds to a distinct level 3 table. Since the kernel code, kernel stack, boot information, and physical memory mapping all use different memory addresses., there are numerous distinct regions. It's interesting to manually navigate through the page tables since it shows how the CPU performs the translation. First, let's write a function to deal with the case where mostly only need to know the physical address that corresponds to a certain virtual address. This System must navigate through the page table's four levels up until the mapped frame in order to convert a virtual address to a physical address.
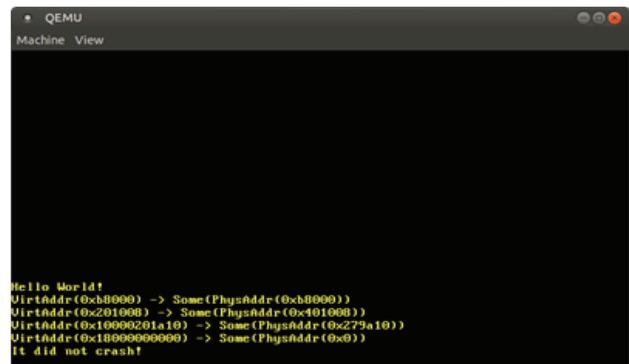
Fig. 8. Translating Addresses

It is to be expected that the address 0xb8000 that is identity mapped corresponds to the same physical-address. Based on the original mapping of our kernel to physical locations by the bootloader, separate random physical addresses. are translated to by the code on the page and stack page. Since the final 12 bits are the page offset and are not translated, it makes logical that they are always the same after translation.

Fig. 9. Using Offset Page Table

An abstraction for the ubiquitous OS kernel operation of converting virtual to physical addresses. is provided by the x86 64 crate. This study will use the following implementation rather than adding giant page support to own version, since it supports enormous pages and has many more page table functions than translate_addr. Now that everything is configured, let's modify the kernel_main function to assign the page at virtual location 0 usingcreate_example_mapping technique. Now that the page has been mapped to the frame of the screen, system should be able to write to it using the VGA text buffer in the future.
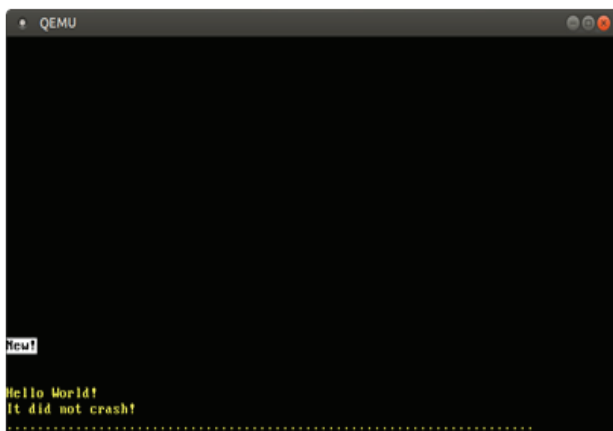
Fig. 10. Creating the Mapping

As discovered while talking about the GlobalAlloc trait, the alloc method may return a null pointer indicating an allocation problem. The # [allocation error handler] property comes in handy in this situation. In the case of an allocation issue, it offers a method that is called in a comparable manner as our panic handler.Itrequires a feature gate to make the current alloc error handler code reliable because it is insecure. The sole input that the function takes is the Layout instance that was supplied to alloc after the allocation attempt failed. The systemsends out a panicked message with the Layout instance's structure since system don't know what to do. the structure of it.

Because the global allocator's alloc function is implicitly called by the Box: new function, the error handler is triggered. Every allocation fails because the dummy allocator consistently returns a null pointer. To correct this, an allocator that really returns useable memory must be developed.
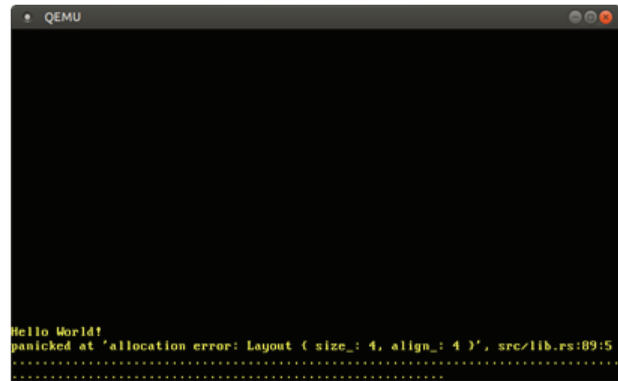
Fig. 11. The #[alloc_error_handler] Attribut

The researchbegins by using an external allocator crate because building an allocator is a bit complicated.
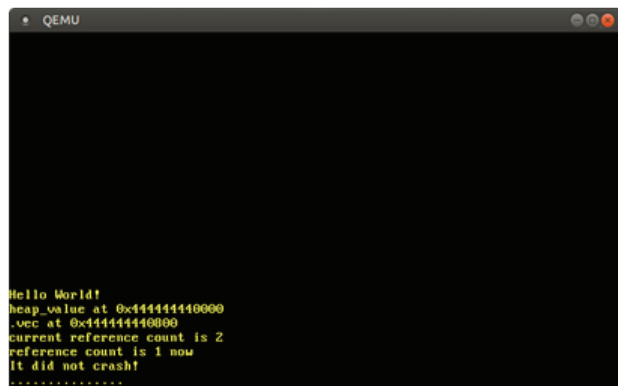
Fig. 12. Using an Allocator Crate

As expected, the address beginning with the prefix 0x_4444_4444_* indicates ensure the heap has the values for the Box and Vec. The reference counted value functions as anticipated as well; it returns 1 following the removal of one instance and 2 following the clone call.

Reallocations take place when the vector has to expand to accommodate more data; as a result, the vector begins at offset 0x800 bytes rather than the boxed value of 0x800 bytes. In case system wish to add another member and the vector has 32 pieces, it will automatically create a new backing array with 64 pieces and duplicate each component.

FUTURE SCOPE

In this paper proposed a custom toy operating system in Rust programming language which aims to solve the problems occurred in memory management and

found an effective way of memory optimization using the concept of paging. Some enhancement can be done in this for future work like investigating multitasking, starting with async/await cooperative multitasking options, try to implement concepts like processes, multiprocessing and threads in Rust programming language on proposed custom ToyOs.

CONCLUSION

Segmentation and paging were two memory management strategies in Rust programming Language that were covered in this paper. The latter employs fixed-sized pages and offers considerably finer-grained control over access permissions, whereas the former uses variable-sized memory areas and experiences external fragmentation. Page tables with one or more levels are where paging saves the mapping data for pages. The page size for the x86 64 architecture is 4 KB, and 4-level page tables are used. Overlook through the pages tables is being done automatically by the hardware, and the translation look-aside buffer stores the resulting translations (TLB).

When the page table is changed, this buffer must be manually flushed because it is not updated transparently. This research discovered that page fault exceptions are brought on by unauthorized memory accesses and that kernel already operates on top of paging. The CR3 register maintains a physical address that cannot directly access from kernel, therefore when it is attempted to retrieve the active page tables, thus this have successfully optimized the memory.

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Structural Health Monitoring Using Piezoelectric Sensors: Core Principles, Present Status, and Future Directions

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ABSTRACT

Structural Health Monitoring takes a decisive part in assessing the status and integrity of structures in present, evaluating their remaining lifespan, and guiding maintenance decisions. Piezoelectric material is the key for this technology, which derives electrical signals in backflash to mechanical stress or strain. This overview provides a comprehensive review of recent advancements in piezoelectric materials and sensors used for structural health monitoring. It commences with an introduction to the basic principles of the piezoelectric effect and focuses on various engineering strategies applied to enhance these materials and their sensor applications. The discussion draws the inference with an examination of current challenges and potential research opportunities aimed at developing high-performance piezoelectric materials and sensors for more effective structural health monitoring.

KEYWORDS *: Electrical signals, Piezoelectric materials, Real-time assessment, Sensors; Structural health monitoring.*

INTRODUCTION

Asymmetric crystals display a phenomenon known as 'Piezoelectricity', in which the application of stress causes the material to become charged or electrified. On the other hand, an applied electric field immediately correlates with the development of an induced strain. Actuation makes use of the latter phenomena, which is referred to as the reverse effect. Changes in acceleration and dynamic pressure are sensed by the former, which is known as the direct effect [1]. To ascertain whether a material belonging to a piezoelectric point group actually exhibits observable piezoelectricity, experimental measurement is necessary [2].

The frequency range in which piezoelectric materials are able to record modifications in force or motion is from less than one Hz to few MHz, provided that the right design and material selection are adopted. It is possible to be exactly measure force shifts from mN to kN as well as displacements in the μm range. Because of their adaptable design, industrial piezoelectric ceramic sensors function well over a broad scale of temperatures, may resist being damaged by intense vibration or shock, and can function under the most severe ecological circumstances [3]. Certain crystals, like quartz and rochelle salt, contain piezoelectricity. It can also be created in polymers, like nylon, by copolymerizing vinylidene fluoride (VDF) with either tetrafluoroethylene (TeFE) or trifluoro ethylene (TrFE) [4]. Structural health monitoring (SHM) relies heavily on inexpensive, highly reliable, and sensitive sensors. To perform the SHM, an assortment of sensors has been created, including strain gauges [5], accelerometers [6], fibre optic [7-8], displacement [9], piezoelectric [10], and laser Doppler vibrometers [11]. Piezoelectric sensors, including flexible smart sensors, piezoelectric sensors deposited directly into structures, smart aggregates, and piezoelectric transducers, have been heavily researched and investigated in the past few years [12-16].

PIEZOELECTRIC EFFECT

The "piezoelectric effect" of piezoelectric materials was discovered by the Curie brothers in 1880, and this is the

principle upon which a piezoelectric sensor operates. [17]. They discovered that both ends surfaces of some dielectric crystals will result in bound charges that are both positive and negative in electrical magnitude, when pressure or strain from the outside is applied in a specific direction. This phenomenon, known as the "positive piezoelectric effect," is correlated with the amount of applied stress. The existence of the inverse piezoelectric effect was later predicted and demonstrated by G. Lippman and Curie brothers, respectively, in theory and experiment. In other words, a material having a comparable deformation will result from a piezoelectric effect when exposed to a particular electric field, and this deformation will be reinstated when the electric field that was applied is withdrawn. Reciprocal inverse effects, the positive and inverse piezoelectric effects together describe the capacity of piezoelectric materials to achieve the transformation of electrical and mechanical energy [18]. A crystal's ability to produce piezoelectric effect is dependent upon how symmetrical its crystal structure is. According to the Neumann principle, all macroscopic physical characteristics of a crystal must take into account the degree of symmetry of the crystalline group to which it belongs. Consequently, piezoelectric effects can occur in crystals that lack symmetry centers. A rigorous mathematical derivation reveals that there are 32 different types of point groups without translation operations, or macroscopic symmetries, in crystals. There are two categories for these 32-point groups, based on symmetry: noncentral symmetry and central symmetry. Only 21 of these are probably going to have piezoelectric effects because 11 of them are centrally symmetric. On the other hand, point group 432 (O) lacks a symmetry centre but has very high symmetry and no piezoelectric effect. Furthermore, an applied electric field has the ability to reverse the impulsive polarization of a portion of the pyroelectric material. Ferroelectrics are the name for these crystals. It should be noted that dielectric material is a prerequisite for piezoelectric material. Second, pyroelectric and ferroelectric materials can also be found in piezoelectric materials.

STRUCTURAL HEALTH MONITORING USING PIEZOELECTRIC SENSORS

An updated review of published research on piezoelectric sensors for structural health monitoring in the recent time is presented in the following sections. Various technologies are briefly described and current pertinent advancements in piezoelectric sensors are exhaustively explored with the goal to provide comprehensive insight. In order to accomplish the SHM, the piezoelectric SHM can function in active mode as well as in passive modes. Active monitoring sensors are frequently employed by guided wave propagation, ultrasonic propagation, or electro-mechanical impedance, whereas passive monitoring sensors are dependent on stress wave or acoustic emission technique.

Electro-Mechanical Impedance based Sensors

An outperforming, potent and inventive techniques for structural health monitoring is electromechanical impedance-based (EMI) monitoring. The electromechanical impedance-based SMH utilizes the electromechanical characteristics of piezoelectric materials, as well as the combination of piezoelectric sensors and object structure. The EMI sensors can be embedded into structures like smart aggregates or affixed to its exterior. When used as actuators, EMI sensors can convert an electric voltage signal into a mechanical stress response. The structure's mechanical response can be translated into an electric signal by means of piezoelectric sensors, which can function as sensors in the course of time. It is possible to deal with the feedback electric signals advance by employing algorithms to identify, locate, and describe structural deterioration. Ongoing monitoring and first stage identification of structural problems, such as joint issues, the debonding process and crack detection, is made possible by the application of EMI techniques. So as to characterize the interaction among the PZT and the host structure, Liang et al. emerge the idea of the electromechanical impedance and proposed a 1-DOF free-body diagram of a PZT–structure system. [19-20]. Over the past years, EMI sensors are utilized to identify the presence, region, and kind of damage in structures [21]. Owing to the restricted region for detecting damage, EMI sensors are consistently affixed to critical and damage-prone locations. Variable high frequencies (usually above 30 kHz) tend to offer susceptibility to environmental noise and vibrations that are frequently encountered in real-world applications. This enhances

the EMI sensors' sensitivity to minimal damage, further creates the problem of low signal strength from a distance, which restricts the EMI sensor to monitoring merely local damage. A few studies on EMI sensor design have been carried out to increase the monitoring system's sensitivity. [22-24]. The specified frequency band and wavelength of the excitation signal that the EMI sensor generates has an immediate effect on how sensitively damage can be detected using EMI. ZS/ZT, or the sensitivity, is determined by the dimensions of the PZT piezoelectric sensor. ZS/ZT is the ratio of the mechanical impedance of the host structure to the mechanical impedance of the PZT transducer. The dimensions of the sensors should be between 0.1 x 0.3 mm and thickness about 5 to 20 mm, respectively, for the use of frequencies below 125 kHz.[22]. Hire et al. assessed the effect of patch sizes of sensor and the range of sensitivity employing Giurgiutiu et al.'s model.[24]. Additionally, they used sensor patches in concrete and air to test the impedance in actual steel. It is also found that, the theoretical and experimental outputs are in-line to each other. Also, it shows that, the piezoelectric patch's sensitivity for damage detection can be strengthened with its correct layout.

Research in self-diagnostic sensors for electromechanical health monitoring has evolved as a critical concern in the past few years. [25-28]. Identifying malfunctions in sensors and functional deteriorations from structural damage will have an immediate impact on the efficiency and precision of SHM. For electromechanical impedance monitoring, Jiang et al. developed an artificial neural network using K-means clustering analysis to enable piezoelectric active sensors to self-diagnose [25]. The average change of conductance peak, the RMSD of susceptance, and the RMSD of conductance are the three outputs which are delivered by the impedance signals. Subsequently, the principal components were utilized to cluster various instances of sensor damage using the K-means technique. Furthermore, to determine the extent of the sensor damage, analysis and artificial neural networks were employed. Analysing admittance characteristics, the K-means clustering analysis will differentiate between four types of sensor damages: debonding, pseudo-soldering, wear and breakage, from structural damage. Nguyen et al. investigated the EMI response characteristics corresponded to an

experimental model based on a bolted steel girder connection [26]. A comprehensive study of the implications of four prominent degradation types—transducer breaking, transducer debonding, interface detaching, and shear lag effect on the EMI response is conducted by simulation.

Guided Wave or Ultrasonic Propagation Based Sensors

This section introduces a usual technique for assessing the structural health using specific wave, such as ultrasonic or guided waves. Guided waves, notably Lamb and Rayleigh waves, are characterized by their extensive propagation range, loss of energy. It concludes that guided wave propagation-based sensors represent a particularly significant technological advancement in SHM.

Guided wave-propagation-based SHM is extensively employed for fault/damage identification in case of Pipelines, Steel and composite structures [29]. The guided wave-propagation-based SHM can make use of piezoelectric components as sensors or actuators. Pitch–catch mode, pulse–echo mode, thickness mode, and impact detection mode are the four key guided wave propagation modes identified by the functioning of piezoelectric sensors [30].

In contrast to the local EMI-based SHM, guided wave monitoring technology enables both global and local damage observation. Guided waves could be employed to monitor hybrid bonded joints in the context of local damage monitoring. The ultrasonic interface guided waves were used by Jahanbin to inspect the disbond and delamination [31]. The high degree of purity of shear horizontal (SH0) wave generated by piezoelectric transducers is the favored method of attaining global monitoring with minimal transducers. Boivin [32] used models and experiments to modify the transducer's form in order to produce a 23.0 dB SH0 wave. In order to remove the out-of-plane wave well in the fundamental SH0 mode's propagation direction, Zennaro [33] made revisions to the transducer design. Ostachowicz [34] and Mustapha [35] focused on sensor network to obtain efficient SHM system. Several researchers have concentrated on creating algorithms that can achieve entire or substantial coverage of damage monitoring while minimizing the number of piezoelectric

transducers. Algorithms such as, Genetic Algorithms (GA), combinatorial optimization, iterative optimization, and artificial neural network (ANN) techniques, have been created to increase distribution of sensors [35]. For effective arrangement of piezoelectric sensors Ismail et. al. [36] conveys a method of converting any complex or closed structure surface. There exist intriguing studies about vast area monitoring, apart from the optimization of sensor networks for worldwide surveillance. For contact -type damages Nonlinear lamb waves have been extensively used due to its high sensitivity. Using multi-mode guided waves, Ju et al. [37] presented a nonlinear ultrasonic testing technique for broad-area monitoring of realistic structures of any complexity. By utilizing flexible circuit technologies and piezoelectric materials, numerous researchers created smart sensor networks. [38-40].

Sensors Based on Acoustic Emission and Stress Wave

When external forces apply on a structure, they produce transitory elastic waves that allow to leave strain energy and can be detected using acoustic emission-based SHM. This passive monitoring-focused approach is perfect for spotting damage progression and initiation, such as cracks or delaminations. These sound waves are picked up by piezoelectric sensors that are positioned close to important locations to keep an eye on the structural integrity. Acoustic-emission-based SHM has advanced significantly since its early use for merely detecting damage occurrence. Initial research has evolved to enable deeper damage monitoring and analysis [41-42]. The method was later enhanced to accurately localize damage in plates and structures. [43-45]. Capineri et al. have examined acoustic emission sensors an innovative technique for detecting and locating impacts [46]. Garrett et al. introduced an artificial intelligence method for estimating length of crack induced due to fatigue in thin metallic plates. This approach utilizes acoustic-emission-based structural health monitoring [47].

Low-frequency dynamic loading, generates the elastic waves and transmitted to piezoelectric materials. By analysing the output voltage of piezoelectric sensors, which is influenced by piezoelectric effect, the stress deviations in the structures can be assessed. The use of piezoelectric stress/strain sensing techniques for structural health monitoring (SHM) noticed globally

with the initial study by Krueger et al. [48]. Sha et al. designed an implant smart piezoelectric sensor specifically for structural health monitoring of concrete [49]. The external membrane /coating ratio was optimized to achieve suitable mechanical performance. Additionally, the mechanical sensing capabilities of the implant sensors under dynamic compressive loads were examined in concrete, highlighting the significant potential of concrete SHM using piezoelectric sensors.

Combined Passive and Active Sensor Systems

In broad scenarios, passive monitoring alone is inadequate. For instance, wallop events on aircraft or aerospace structures can lead to destruction that may deteriorate or spread with time due to continuous usage. In such situations, active monitoring is essential track till end the variation in the damage. In this situation, continuous monitoring is necessary to track the progression of damage. Similarly, solely relying on active monitoring comes with its own limitations. Piezoelectric transducers must constantly emit inspection waves, leading to unnecessary effort when they are not required. Consequently, combining passive and active sensors is preferred to mitigate their individual shortcomings.

Two flexible layouts of Polyvinylidene fluoride (PVDF) interdigital transducers were designed with the dual purpose of passive impact identification and active damage evaluation via guided Lamb waves. In a similar vein, Guo et al. introduced an integrated Structural Health Monitoring (SHM) system that leverages piezoelectric transducers for both monitoring of impacts and assessing the impedance [50]. A "scheduling module" approach is employed to coordinate the timing of commands sent to the PZT sensors and to route their signals to various pre-processing units., depending on whether the system is detecting impacts or measuring Electro-Mechanical Impedance (EMI). This system is installed in the framing structure of a sailplane. Gayakwad et al. engineered smart sensing units (SSUs) to enhance the monitoring system's competence. These units include Lead Zirconate Titanate (PZT) patches that detect both nearby and distant damage in concrete structures using Electro-Mechanical Impedance (EMI) and wave propagation methods [51].

LIMITATIONS AND OPPORTUNITIES FOR ADVANCEMENT

Piezoelectric sensors are crucial for monitoring the health of structures. In the past period of time, substantial progress has been made in the field of piezoelectric materials and sensors, greatly enhancing their application in structural health monitoring. However, in spite of these progressions, there persists considerable potential for enhancement, as highlighted by the ongoing issues. Piezoelectric materials are crucial for piezoelectric sensors used in structural health monitoring. To achieve high-performance sensors with outstanding sensitivity and to advance their operational use, it is essential to develop advanced piezoelectric materials. It is anticipated that high-throughput computations, machine learning, thorough characterisation, experimental synthesis, and the notion of materials genome would significantly speed up the search for novel piezoelectric materials with hitherto unheard-of piezoelectrical qualities.[52].

As various documented examples show, piezoelectric materials consistently operate as layered wafers in piezoelectric sensors and structural health monitoring systems. On the other hand, it makes placement harder and reduces dependability, as seen in debonding errors. Because piezoelectric films are highly flexible and versatile for use in complicated configurations, they can be integrated in composite structures or adhered to the surface of other structures [40].

Currently, the majority of research efforts are concentrated on addressing deployment issues with SHM that fall within the experimental category. Several issues need to be addressed before the experiment's results can be applied in the real world. These include sensors' ability to detect themselves, how environmental changes affect monitoring signals, the mechanism of failure of the fundamental structure, and more. One of the major concerns for a dependable Structural Health Monitoring system is accurate sensor self-diagnostics, particularly in engineering systems. If the sensor fails without identifying itself, damage detection will result in a wrong diagnosis. The engineering SHM's long-term monitoring is susceptible to sensor failure or debonding failure. It is necessary for one to examine at various sensor malfunctions in order to improve SHM

system reliability [53]. Research on self-diagnostics for piezoelectric transducers focuses on detecting changes in wave propagation signatures and electromagnetic interference (EMI) signatures. These changes help identify potential issues and assess the transducer's health [54-56]. Sensor self-diagnostics could enhance reliability in engineering structural health monitoring (SHM) applications by detecting and addressing issues early. Changes in environmental conditions might introduce errors into SHM systems, but self-diagnostics can help mitigate these effects. Piezoelectric materials experience significant changes in properties with varying operating temperatures. These temperature-induced variations can affect the performance and reliability of piezoelectric devices. In guided-wave-based structural health monitoring (SHM) systems, temperature variations have a substantial impact on the baseline comparison of guided waves. As the temperature fluctuates, the wave propagation characteristics may alter, impacting the precision of damage assessment. To tackle this challenge, it is crucial to implement an effective baseline selection technique that considers the range of environmental temperatures. This approach helps ensure reliable and accurate monitoring despite temperature variations [57-58]. In EMI-based structural health monitoring (SHM) techniques, the dielectric constant has a significant influence on the electrical impedance of PZT sensors. Changes in the dielectric constant lead to shifts in the frequency and amplitude of impedance signatures. These variations can affect the accuracy of damage detection and monitoring [59].

The material, sensor, and structural designs are crucial to the effectiveness of structural health monitoring (SHM) systems. This influence is clearly noticeable in EMI-based monitoring techniques, where design choices significantly impact performance. The operational frequency range of the system is determined not merely by the design of the piezoelectric sensor besides the properties of the structure being monitored. Thus, careful consideration of all these factors is essential for accurate and reliable SHM. Aabid et al. put forward several open research areas to advance the field, including the development of packaging techniques for piezoelectric materials to achieve Wide operational frequency ranges. They also suggested exploring the integration of sensor networks with localized artificial

intelligence (AI) and machine learning (ML) data-processing platforms. These advancements could enhance the performance and capabilities of structural health monitoring systems. Further research in these areas could significantly improve the efficiency and accuracy of monitoring technologies [60]. Based on the review, sensors utilizing guided wave propagation or acoustic emission are uniquely positioned to achieve comprehensive global damage monitoring. In practical engineering domain, such as for bridges, aircraft, and airplanes, structural health monitoring (SHM) systems are often designed to cover large areas. This requirement necessitates the use of numerous piezoelectric transducers and a complex network of wiring to effectively monitor the entire structure. To optimize structural health monitoring (SHM) systems, deploying a wireless sensor network for data collection and processing is a top priority. Typically, these networks require large batteries to supply power, which need frequent replacement due to their limited capacity. Accordingly, there is a strong demand for self-powered wireless sensor networks, especially in the context of structural health monitoring. The direct piezoelectric effect allows piezoelectric devices to convert surrounding mechanical and vibrational energies, like structural vibrations and airflow, into electrical power. This capability enables the harvesting of energy from the environment to power electronic systems. Consequently, piezoelectric devices can function as self-sustaining power sources in various applications [61].

CONCLUSION

This paper offers a thorough examination of recent progress in piezoelectric materials and sensors employed in structural health monitoring. It begins with an overview of the basic principles behind the piezoelectric effect and then explores different engineering approaches to improve piezoelectric materials and their use in monitoring structures. The paper also discusses the challenges and future research opportunities in developing advanced piezoelectric materials and sensors. The goal is to advance the field and accelerate the creation of cutting-edge technologies for structural health monitoring.

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Implementation of Nano-Refrigerants/Nano-Lubricants in Air Conditioning System: A Review

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ABSTRACT

Nanotechnology, an emerging field, is creating new opportunities for researchers across various disciplines worldwide. Its applications span a wide range, including the growth of nano-refrigerants and nano-lubricants. These nanofluids demonstrate superior heat transfer capabilities compared to traditional refrigerants, although they are still in the research and development phase. In a last few years, significant research is conducted to promote refrigeration and air conditioning systems which are efficient enough to save energy, using nano-refrigerants and nano-lubricants as promising alternatives to conventional methods. This manuscript contributes to this effort by providing an overview of experiments, investigations, applications, current trends, and future prospects of nano-based refrigerants and lubricants, particularly for air conditioning. A critical review reveals that incorporating nano-refrigerants and nano-lubricants in air conditioning systems leads to notable improvements in overall system performance, including enhanced COP and reduced compressor workload.

KEYWORDS : *Air condition system, Energy efficient, Nanolubricant, Nano-refrigerant.*

INTRODUCTION

Air conditioning systems are essential to modern life, serving various applications such as human comfort, industrial processes, vehicle climate control, residential and commercial cooling, ice production, gas liquefaction, and the preservation of historical documents, where controlling and maintaining air properties is critical. These systems account for about 17% of global energy consumption [1]. The rising demand for energy has driven researchers to seek innovative, energy-efficient alternatives to conventional systems.

In recent years, the concept of nanofluids, which involves suspending metallic or nonmetallic nanoparticles (less than 100nm) in base fluids to enhance heat transfer, has gained significant attention. First proposed by Choi et al. [2], nanofluids unveil greater thermal conductivity when compared with traditional heat transfer fluids due to the increased surface area of nanoparticles. Nanofluids also achieve greater heat flux under pool boiling conditions. Common nanoparticles include metal oxides (zirconia, alumina, titania), metal carbides (SiC), various forms of carbon (fullerene, graphite, carbon nanotubes, diamond), stable metals (copper, gold), nitrides of metals (SiN, AlN), and oxide ceramics (CuO, Al2O3, TiO2). Base fluids range from water and bio-fluids to organic liquids, oils, lubricants, and polymer solutions. When conventional refrigerants are used as the base fluid, the resulting nanofluid is termed nano-refrigerant.

Nano-refrigerants, which integrate nanoparticles into traditional refrigerants, aim to improve thermal conductivity and heat transfer, potentially leading to more energy-efficient cooling systems. Key benefits include advanced heat transfer, greater energy efficiency, enhanced thermal conductivity, and environmental advantages. However, challenges such as nanoparticle stability, potential corrosion or clogging, and production costs must be addressed. Nano-refrigerants remain a developing technology, with ongoing research focusing on overcoming these issues for practical applications.

Similarly, nano-lubricants incorporate nanoparticles into lubricants to enhance their performance in reducing friction and wear. The goal is to improve properties such as viscosity, thermal conductivity, and stability, resulting in more efficient, durable machinery. Nano-lubricants offer promising advantages, including reduced friction, better heat conductivity, improved stability, energy savings, and environmental and cost benefits.

Since last two decades, researchers have extensively explored on enhancing the performance of thermal systems using nanofluids. A number of reviews regarding selection of nanomaterials, thermal and rheological properties has been attempted [3-11]. In this article, a comprehensive review has been carried out on their work and the application of nanofluids especially in the area of air conditioning is consolidated. This paper covers a detailed overview of the studies and investigations carried out by different researchers on the effect of applying nanofluids on the performance of air conditioning systems so that it will be useful to fill the identified research gaps and overcome the limitations of using nanofluids in practical air conditioning systems.

DETAILED OVERVIEW OF WORK DONE BY DIFFERENT RESEARCHERS:

1) Ruixiang Wanga et.al [12] experimentally examined and validated the practicality of a novel nano-refrigeration oil which is mineral-based(MNRO) made by mixing some nanoparticles (NiFe2O4) into mineral oil B32 which is naphthene based, for use in retrofitted residential air conditioners (RAC) using HFC refrigerant to reduce the energy consumption. A method in which NiFe2O4 nanoparticles were dispersed in mineral oil

refrigeration lubricants was discussed. Also, their stability was examined spectrophotometrically using Tianjin Optical Instrument Factory Production, UV–vis spectrophotometerWFZ-26A, having a wavelength range of 190–900 nm. Whether the novel MNRO dissolves in HFC refrigerants like R407C, R134a, R425a and R410a was checked and the results were as shown in Figure 1.
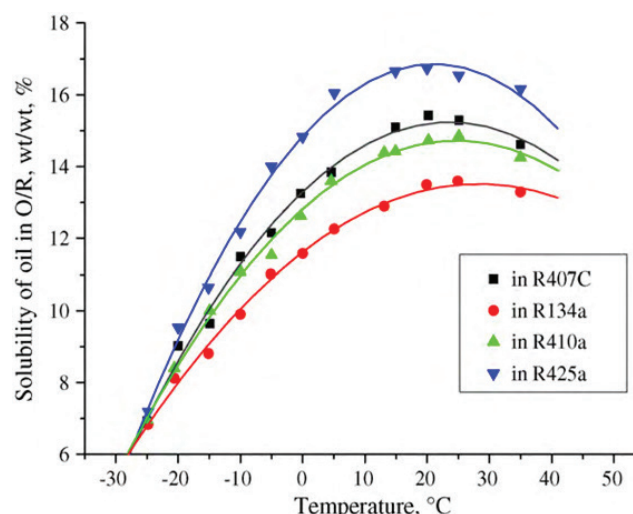
Fig 1 Dissolution of the New Mineral Based Nano Refrigeration Oil in Different Refrigerants [3]

An experimental investigation was done using the three existing RAC units each with different refrigerant and lubricant combinations such as MO/R22, POE/R410a and MNRO/R410a to evaluate its performance. Key performance indicators like cooling/heating capacity, power input and energy efficiency ratio (EER) were evaluated. It has been observed that replacing Polyol-Easter oil VG 32 with MNRO in the R410a refrigerant system led to nearly 6% improvement in the cooling/heating EER. This suggests that MNRO is a viable alternative to POE for retrofitting R22 systems with R410a.

2) Faizan Ahmed et.al [13] suggested an idea of making use of cooling jackets containing nanofluid to externally cover the condenser of an air conditioning system as indicated schematically in Figure II representing the diagram of the set up used for experimentation. So as to adapt the variations in the system, thermostatic control is employed in the expansion valve and compressor is provided with spiral tubing at its inlet and outlet to

prevent the transmission of compressor vibrations to the complete set up. The experimental investigation was focused to evaluate the performance of the air conditioner incorporating two types of nanofluids i.e. copper and aluminum oxide owing to their enhanced thermal conductivity, availability and cost effectiveness. The nanofluid was prepared by dispersing Copper and Al_2O_3 nanoparticles of 70nm size in water which acted as the base fluid.
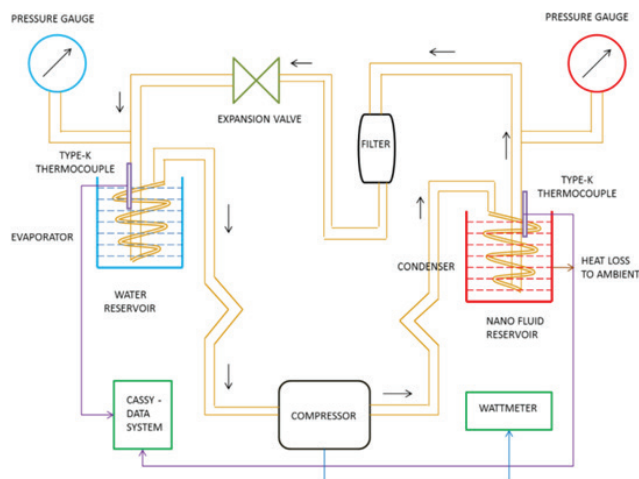
Fig. 2 Schematic Diagram of Experimental Set Up [4]

The ambient temperature was retained at 22°C. The condenser section was surrounded by an external medium of nanofluid to boost the rate of heat transfer. Using the base fluid water, the nanofluids using Cu as well as Al_2O_3 were prepared in three fractions by volume viz. 1%, 2% and 5%. By operating the system with and without nanofluid, an evaluation of the air conditioner performance was carried out. According to the experimental results, a remarkable improvement of COP was noticed by employing Cu and Al_2O_3 nanofluids. The more the volume fraction, the more the improvement in COP. When the volume fraction was maximum i.e.5%, the COP was increased by 22.1% for Al_2O_3 nanofluid against 29.4% for copper nanofluid. It was seen that copper nanofluid exhibited better results than alumina nanofluid because of the higher value of thermal conductivity of copper nanofluid.

3) N.N.M. Zawawi et al. [14] made investigations regarding the performance of an automotive air conditioning (ACC) system with respect to its tribological behavior, like coefficient of friction (COF)

and wear rate simulating cylinder liner contact or a piston ring making use of composite nano-lubricants using Al_2O_3 and SiO_2 nanoparticles in the lubricant PAG under reciprocating test conditions. Two step method was used for preparing the nanofluids of various volume concentrations ranging from 0.01% to 0.10% by dispersing Al_2O_3 (13nm diameter in size and purity 99.8%) and SiO_2 (30nm diameter in size and purity 99.5%) nanoparticles the lubricant Polyalkylene Glycol (PAG 46). Any surfactant was not used for preparing the composite nanolubricant. Stability of the composite nano-lubricants was checked by zeta potential analysis and visual observation. As shown in Figure 3 no sedimentation is found in any of the samples even when a period of 30 days was elapsed. COF and wear performance of the system was measured by using a tribology test rig as shown in Figure IV by changing the control factors like load (2-10 Kg) and piston speed (200-300 rpm).

Fig. 3 Composite Nanolubricant (Al_2O_3–Sio_2/Pag) Samples [5]

Field emission scanning electron microscopy (FESEM) was used for examining the morphologies of the worn surfaces whereas energy dispersive spectroscopy (EDX) was used to check the settlement of the nanoparticles on worn surfaces (tribo-film). The worn surfaces of the piston ring were analyzed for its chemical characterization of the tribo-film at the boundary using a surface sensitive technique, X-Ray Photo Electron Spectrometry (XPS). Table 1 shows how the wear rates of composite nano-lubricants Al_2O_3–SiO_2/PAG decrease at all volume concentrations and table II shows decrement in COF with the use of composite nanolubricant Al_2O_3–SiO_2/PAG. From the above observations the maximum COF reduction was obtained upto 4.49% at 0.02% volume concentration while the minimum was 0.01% at 0.01% volume concentration. Similarly, the maximum wear rate reduction was

12.99% with a volume concentration of 0.02% and the minimum was 0.26% with a volume concentration of 0.06%. For volume concentrations above 0.06%, there was hardly any reduction in COF and wear rates.

(a) Tribological test rig bench

(b) Schematic diagram of tribological test rig bench
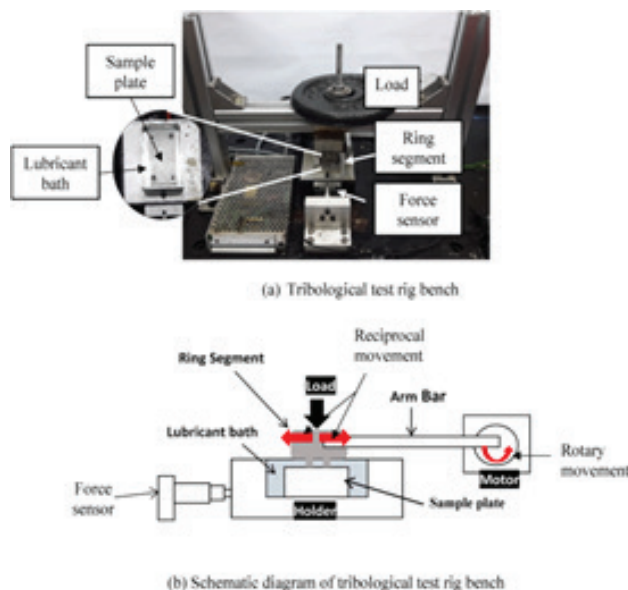
Fig. 4 Test Rig Bench for Tribology and Line Diagram [5]

So, the authors recommended going for a volume concentration of 0.02% for Al_2O_3–SiO_2/PAG composite nano-lubricants.

Table 1 Reduction in Wear Rate for Composite Nano-Lubricants Al_2O_3–Sio_2/Pag [5]

Speed (rpm)	200	250	300
Volume concentration (%)	Wear rate Reduction (%)		
0.01	3.75	1.12	2.84
0.02	12.99	6.86	11.48
0.03	9.24	5.74	10.06
0.04	1.87	6.11	3.61
0.05	1.61	2.24	1.42
0.06	0.27	0.26	0.65

Table 2 Reduction in COF for Composite Nano-Lubricants Al_2O_3–Sio_2/Pag [5]

Speed (rpm)	200	250	300
Volume concentration(%)	COF Reduction (%)		
0.01	0.26	0.01	0.12
0.02	4.49	2.13	3.71
0.03	3.15	1.81	2.59
0.04	1.58	1.11	1.53
0.05	1.13	0.76	0.91
0.06	0.3	0.35	0.63

4) M.Z.Sharif et al. [15] developed a test rig using the original components of an automotive air conditioning system to replicate the air conditioning system in an actual vehicle for evaluating the proficiency of ACC i.e. automotive air conditioning. Spherical SiO2 nanoparticles (99.9% purity and 30nm size) are procured and used for experimentation. According to earlier research, when PAG i.e. Polyalkylene glycol lubricant was employed with hydroflorocarcon (HFC) refrigerants it demonstrated superior tribological properties as compared to other mineral oils. So it was used in the test rig and the refrigerant used was 134a. The nanolubricant SiO2/PAG was developed using two step method and any surfactant was not added during the preparation. Its dispersion stability was checked in colloidal form over a period of one month. Very minimum sedimentations were observed.

The performance of ACC working with the nanolubricant SiO2/PAG was evaluated with various concentrations and speeds of the compressor speeds varying in the range of 900 RPM to 2100 RPM. The mass flow rate and cooling capacity of the refrigerant were evaluated using calorimeter method. Temperature indicators, pressure gauges and digital power analyzer were located at proper locations in the ACC system. Vapour compression refrigeration cycle was employed with the following assumptions: (a) The condenser, evaporator and pipelines have no pressure drop. (b) The evaporating and condensing pressures are equal to the suction and delivery pressures indicated by the pressure gauges. (c) Steady state operating condition is achieved by running the system for 20 minutes. (d) Kinetic and potential energy changes are negligible.

The parameters such as compressor work, heat absorbed and COP were noted for different volume concentrations of SiO2/PAG nanolubricant. It was noted that, when the volume concentration is more, the heat absorbed is also more, but the heat absorbed decreases with the rising compressor speeds. For all compressor speeds, at

volume concentration of 0.05%, the compressor work is seen as minimum as compared to pure refrigerant. On an average the COP is found to be enhanced by 10.5% whereas the maximum enhancement was reported to be 24% for volume concentration of 0.05%. Also, the effect of nanorefrigerant on various components of ACC was observed. The evaporator micro channel which is more likely to be affected was observed visually and there was no clogging found. So, it was concluded that the nanorefrigerant has no harmful effect on any component of the ACC.

5) M.Z. Sharif et al. [16] investigated the viscosity as well as thermal conductivity of the Al2O3/polyalkylene glycol (PAG) 46 nano-lubricants at temperatures of 303.15 to 353.15 K for volume concentrations of 0.05 to 1.0% for its use in automotive air conditioning. PAG is selected as the lubricant as it exhibits better tribology performance and excellent lubricity over other mineral oils when used with hydroflorocarbon refrigerants. Moreover, it is less soluble in the gaseous refrigerant. PAG lubricant was used to dissolve Al2O3 nanoparticles with 99.8% purity and 13nm size and two step method was employed to prepare the nanolubricant. FESEM image in ×300,000 magnification is as shown in Figure V(a). The shape of the nanoparticle is found to be spherical and its size is approximately 13nm. Image of Al2O3 nanoparticle(TEM) dispersed in PAG lubricant in × 88,000 magnification is shown in Figure V (b). TEM images depict that the nanoparticle dissolves good enough in the lubricant with a little clustering/ agglomeration of nanoparticles. Thermal conductivity was determined by KD2 Pro Thermal Properties Analyzer while LVDV-III Rheometer was used for viscosity measurement.

From the experimental investigations as depicted in Figure VI, it is seen that with an increase in the volume concentration, the thermal conductivity as well as viscosity of the nano-lubricants increases. On the other hand with the increase in temperature, the thermal conductivity and the viscosity of the nanolubricant decreases as shown in Figure VII. Now, when the volume concentration is alike, the rate of increase for viscosity was noted to be greater in comparison with that for thermal conductivity. From the observations, for concentrations more than 0.3%, there was a sharp

increase in the viscosity. As compared to PAG lubricant, the values of maximum thermal conductivity and velocity ratio were noted as 1.04 and 7.58 times more for 1.0% and 0.4% concentrations of nanolubricant, respectively. Thus, for automotive air conditioning system, the authors recommend to employ the Al2O3/ PAG nano-lubricants with less than 0.3% concentration.
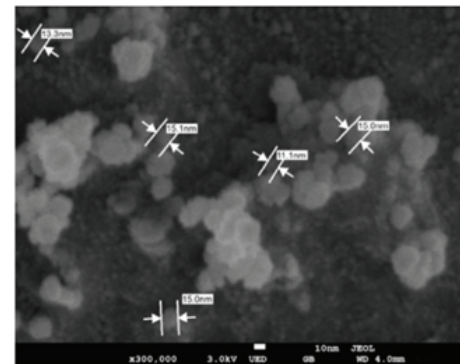
(a) FESEM image of dry nanoparticle at X 300,000 magnification
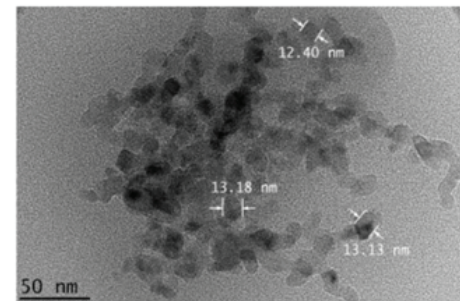
(b) TEM image of nanoparticle suspended in PAG lubricant at X 88,000 magnification

Fig. 5 Images Of Al$_2$O$_3$ Nanoparticle (Fesem and Tem) [7]
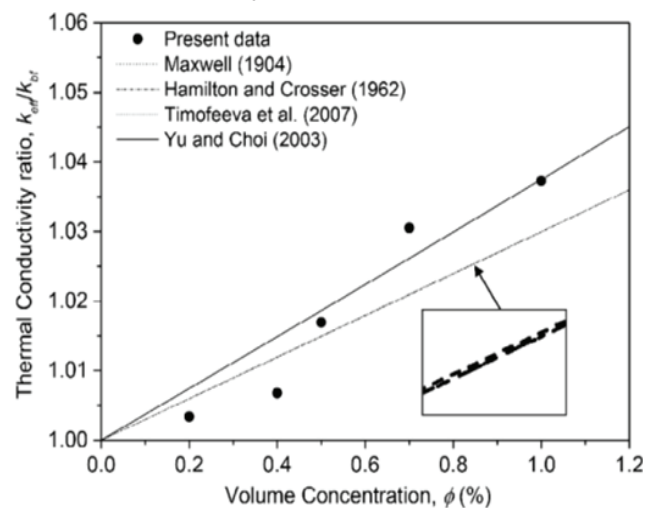
Fig. 6 Thermal Conductivity vs Volume Concentration [7]
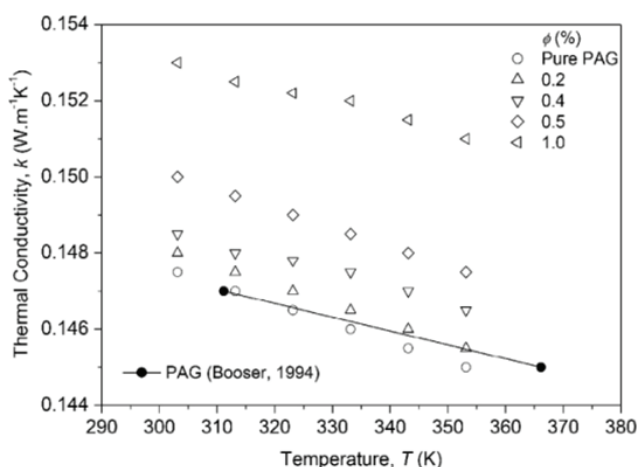
Fig. 7 Thermal Conductivity vs Temperature [7]

6) Prof. Avesahemad S. N. Husainy et al. [17] carried out experiments to determine the improvement in COP of a ducted air conditioning system with R-134a as a refrigerant using CuO/POE oil nanolubricant in different mass fractions. Nanolubricant was synthesized by adding CuO particles of 50nm size in POE compressor oil and vibrated on an ultrasonic agitator for 3 hours to prepare a homogeneous mixture. Such nanolubricant was prepared for various concentrations of 0.25%, 0.50%, 0.75%, 1% mass fraction. The DBT and WBT readings for inlet and outlet sections were taken for all the concentrations of nanolubricant separately. Also the energy consumption was noted from the energy meter readings. The COP and power consumed were calculated using standard expressions.

From the values in the table III and from the graphs shown in Figure VIII and IX, it is concluded that for 1.0% mass fraction of nanolubricant the COP of the system was highest while the compressor work was the lowest.

Table 3 Results for CUO Nanoparticles with Different Mass Fraction, Ref [8]

Percentage of Nanoparticles	COP Carnot	COP Theoretical	COP Actual	Compressor Work (kW)
0	5.6	4.08	1.105	1.306
0.0025	5.489	4.1	1.348	1.203
0.005	5.489	4.108	1.286	1.168
0.0075	5.6	4.162	1.373	1.072
0.01	6.06	4.27	1.512	1.027
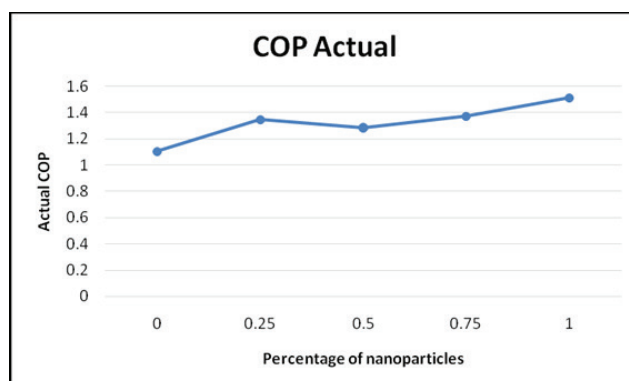
Fig. 8 Actual Cop vs Percentage of Nanoparticles [8]
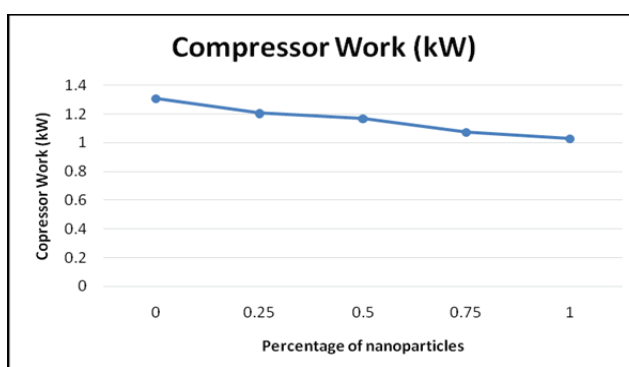
Fig. 9 Compressor Work vs Percentage of Nanoparticles [8]

So, the overall system performance was enhanced as compared to pure compressor oil. As compared to conventional system, there is a fall of 21.37% in the compressor work and a hike 26.92%, 4.45% and 7.6% in actual COP, theoretical COP and Carnot COP respectively. Solubility of the solution was enhanced by using surfactants.

7) A.A.M. Redhwan et al. [18] conducted a comparative study of thermo-physical properties like thermal conductivity and dynamic viscosity of SiO_2 and Al_2O_3 nanoparticles dissolved in Polyalkylene glycol (PAG) lubricant at an operating temperature of 303–353 K with volume concentrations of 0.2–1.5%. The SiO2 (average sizes of 30nm) and Al2O3 (average sizes of 130nm) nanoparticles in powder form were dispersed in PAG oil. Two step method was used to prepare the nanolubricant with volume concentrations ranging from 0.2 to 1.5% for both the nanolubricants namely, SiO_2/PAG and Al_2O_3 /PAG. Characterization of SiO_2 and Al_2O_3 nanoparticles was attained by applying field

emission scanning electron microscopy (FESEM) and Transmission Electron Microscopy (TEM) imaging methods. The FESEM method affirmed the nanoparticle size and the spherical shape in dry form while the TEM method reaffirmed the shape and size in suspended form and the dispersity of the nanoparticles in the base fluid. The viscosity of the nano-lubricants was observed by programmable viscometer LVDV-III with temperature-controlled bath and KD2 Pro thermal property analyzer depicted the thermal conductivity. After experimentation and calculations, it was concluded that both the properties of the SiO_2 nano-lubricants enhances with volume concentration but reduces with the increase in temperature. The application of SiO_2 nano-lubricants with less than 1% volume concentrations is recommended by the authors for applications in the automotive air conditioning system since SiO_2 nano-lubricants demonstrate far good rise in thermal conductivity compared to Al_2O_3 nano-lubricants due to limitation of viscosity.

8) I.M. Mahbubul et al. [19] analyzed the thermophysical properties like thermal conductivity, viscosity, density and specific heat of Al_2O_3 /R-134a nanorefrigerant for 5% concentration at temperatures ranging from 283 to 308 K. The study was performed through a horizontal smooth tube for a homogeneous mass flux using already established correlations and equations. The observations depicted that the thermal conductivity rises linearly with temperature showing hike of 28.58% in the thermal conductivity in case of nanorefrigerant as compared to traditional refrigerant due to which the COP was increased by 15%. Viscosity and density augmented about 13.86% and 11% respectively due to use of nanorefrigerant compared to pure refrigerant. The values of density and viscosity were affected adversely with the increase in temperature. As a function of viscosity and density also, the COP is found to be increased. The value of specific heat of nanorefrigerant was slightly lower than the traditional refrigerant but the COP was 2.6% higher when nanorefrigerant was used.

CONCLUSIONS

After critical study and review of the work done by various researchers/ scholars the following conclusions are drawn:

- Nano-lubricants/ nano-refrigerants obviously seem to be the most promising materials to substitute the conventional lubricants/refrigerants owing to their enhanced tribological and thermophysical properties which ultimately leads to better performance of the system in terms of increase in COP and reduction in power consumption as compared to conventional system.

- Two step method of synthesizing the nano-lubricants and nano-refrigerants results in stable nanofluids and is found to be more reliable approach than one step method and hence it is used by most of the researchers.

- Different concentrations of the nanoparticles result in varied results. So, research is to be extended to decide an optimum concentration ratio depending on the type of nanofluid and base fluid.

- Characterization of nanoparticles can be best attained by applying field emission scanning electron microscopy (FESEM) method for dry form and Transmission Electron Microscopy (TEM) imaging method for suspended form due to its specific advantages such as high resolution, surface topography, non destructiveness, fast imaging, 3-D imaging and high contrast.

- The use of nanoparticles in the air conditioning system does not have any harmful effect on any of the components of the system according to M.Z.Sharif et.al [15] . However, the tendency of corrosion of parts of refrigeration system in long term is needed to be investigated.

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Integrating Hilbert Transform and KNN for Accurate Voltage Sag Cause Identification

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ABSTRACT

This research paper presents a novel methodology for classifying the underlying causes of voltage sag using the Hilbert Transform in conjunction with soft computing techniques. Voltage sags, characterized by short-duration drops in voltage levels, can significantly impact the reliability and performance of electrical power systems. Accurate identification of their causes is essential for implementing effective mitigation strategies. In this study, the Hilbert Transform(HT) is employed to extract distinctive features from voltage and current waveform during sag events. These features are then analyzed using soft computing techniques such as K-Nearest Neighbor (KNN), to classify the causative factors. The proposed approach is validated through extensive simulations data, demonstrating its efficacy and robustness in accurately diagnosing voltage sag causes due to induction motor starting(IMS), transformet energization(TE)and LLLG fault. The findings suggest that this integrated method can significantly enhance the reliability of power systems by enabling more precise and timely interventions.

KEYWORDS : *Root Causes of Voltage Sags, Hilbert Transform (HT), K-Nearest Neighbour (KNN)*

INTRODUCTION

Voltage sags are transient reductions in voltage levels that can last from a few milliseconds to several seconds, often causing significant disruptions in power quality and reliability in electrical power systems. These disturbances can result from various factors such as faults, abrupt load changes, and transformer energizing. Understanding the underlying causes of voltage sags is crucial for developing effective mitigation strategies and ensuring the stability of power systems.

Recent advancements in power quality disturbance detection have focused on hybrid methodologies that combine signal processing techniques like the Stockwell Transform and Hilbert Transform for enhanced accuracy in time-frequency localization, particularly in complex scenarios[1]-[3].The integration of machine learning algorithms, such as SVMs and decision trees, has further improved the robustness of disturbance classification, even in noisy environments [6]-[11]. Additionally, studies have adapted these techniques for use in renewable energy systems, addressing the challenges posed by the variability of these sources[7]-[18]. Comprehensive reviews underscore the trend toward AI-based and hybrid methods, which are increasingly seen as essential for reliable power quality monitoring in modern, renewable-rich grids [19]-[28].

In recent years, substantial research has been conducted to identify and classify the sources of voltage sags. Traditional methods, primarily based on waveform analysis and statistical approaches, have provided valuable insights but often fall short in terms of accuracy and adaptability to diverse conditions. The Hilbert Transform has emerged as a powerful tool for signal processing in power systems, offering a means

to analyze and extract features from voltage waveforms that can reveal underlying sag causes. Its ability to provide instantaneous amplitude and phase information makes it particularly suitable for characterizing voltage disturbances.

Soft computing techniques, including neural networks, support vector machines, KNN etc. have shown promise in handling the complexity and variability inherent in power system disturbances. Neural networks, with their capacity for learning and pattern recognition, can adapt to various types of voltage sags by training on historical data. Support vector machines, which excel in classification tasks, can effectively distinguish between different sag causes based on extracted features.KNN is particularly useful in power quality disturbance classification due to its ability to handle complex, non-linear relationships without making any assumptions about the data distribution. Its simplicity, ease of implementation, and robustness to noise make it a valuable tool for distinguishing between various types of disturbances such as sags.

Several studies have explored the application of these techniques individually and in combination. For instance, neural networks have been used to predict voltage sag events by learning from past occurrences. Support vector machines have demonstrated high accuracy in distinguishing between sag causes, particularly when used with feature extraction methods like the Wavelet Transform. KNN's simplicity, non-parametric nature, and effectiveness in handling multi-dimensional data make it a suitable choice for voltage sag cause analysis. It can leverage historical data to identify patterns and provide reliable classification, aiding in the efficient management and mitigation of voltage sag events.

Despite these advancements, there remains a need for an integrated approach that leverages the strengths of both the Hilbert Transform and soft computing techniques to improve classification accuracy. This paper aims to address this gap by proposing a comprehensive methodology that combines the feature extraction capabilities of the Hilbert Transform with the adaptive and robust classification power of neural networks, support vector machines and KNN.

The proposed methodology is validated through extensive simulations and analysis of real-world data, highlighting its potential to enhance the precision and reliability of voltage sag classification. By accurately identifying the underlying causes of voltage sags, this approach can contribute to more effective mitigation strategies, ultimately improving the resilience and stability of electrical power systems.

HILBERT TRANSFORM

The Hilbert Transform is a mathematical tool used to derive the analytic representation of a real-valued signal. By providing a way to shift the phase of each frequency component by 90 degrees, it transforms a real-valued signal into a complex-valued signal, facilitating various signal processing tasks. Mathematically, for a given real-valued time-domain signal x(t), the Hilbert Transform $\hat{x}(t)$ is defined as:

$$\hat{x}(t) = \frac{1}{\pi} P.V. \int_{-\infty}^{\infty} \frac{x(\tau)}{t-\tau} d\tau \qquad (1)$$

where P.V. denotes the Cauchy principal value of the integral. The Hilbert Transform shifts each frequency component of the signal by 90 degrees, effectively generating a quadrature signal. The analytic signal z(t) is then formed as:

$$z(t) = x(t) + j\hat{x}(t) \qquad (2)$$

where j is the imaginary unit. This analytic signal has the original signal as its real part and the Hilbert Transform as its imaginary part.

The Hilbert Transform is particularly useful in applications such as envelope detection, modulation, and demodulation in communications, and instantaneous frequency analysis. By providing both amplitude and phase information, it allows for a comprehensive analysis of signals, making it an invaluable tool in various fields of signal processing.

K-NEAREST NEIGHBOR (KNN)

K-Nearest Neighbors (KNN) is a non-parametric algorithm used for classification and regression. It classifies a data point based on the majority class of its K-nearest neighbors, determined by a distance metric like Euclidean distance.

Euclidean Distance: For points $x=(x_1, x_2,\ldots\ldots x_n)$ and $y=(y_1, y_2,\ldots\ldots y_n)$:

$$d(x,y) = \sqrt{\sum_{i=1}^{n}(x_i - y_i)^2} \qquad (3)$$

Steps of Algorithm:

Training Phase: Store all training data points and their labels.

Prediction Phase:

For a test point x:

Calculate distances to all training points.

Identify the K nearest neighbors.

Classification: Assign the classĉ based on the majority class:

$$\hat{c} = mode\left(c_{(1)}, c_{(2)}, \ldots, c_{(K)}\right)$$ (4)

Regression: Predict the value y^ hat{y}y^ by averaging the values of the K nearest neighbors:

$$\hat{y} = \frac{1}{K}\sum_{j=1}^{K} y(j)$$ (5)

KNN is simple and versatile but computationally intensive and sensitive to the choice of KNN and the distance metric.

METHODOLOGY FOR VOLTAGE SAG UNDERLYING CAUSE IDENTIFICATION

The proposed methodology involves multiple stages, beginning with signal generation and ending with the identification of the underlying cause of voltage sag. Below is a detailed step-by-step explanation:

Signal Generation Stage
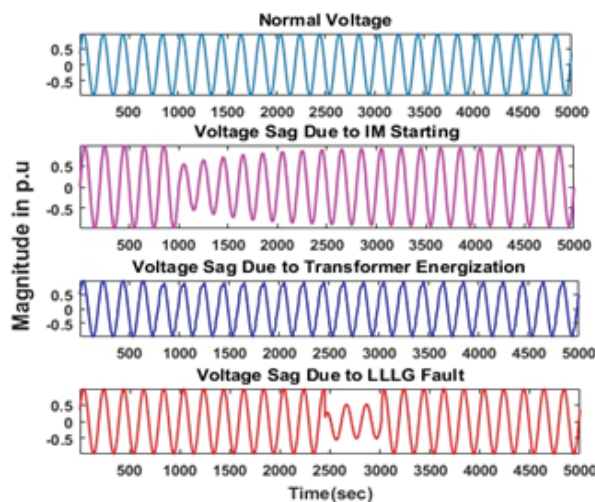
Fig 1. Healthy Voltage and Voltage Sag Waveforms of Different Root Cause

In the first stage, voltage sags are generated under various scenarios representing different underlying causes. These scenarios may include normal operations, induction motor (IM) starting, transformer energization, and LLLG fault. The voltage sags due to different underlying cause simulation are carried out in the matlab [14]. The voltage and current data are sampled at a sampling frequency of 10 kHz as shown in fig.1 & 2. The key objective here is to capture the voltage and current signals that exhibit characteristics related to the specific causes of voltage sags.

Signal Processing I Stage

The voltage and current signals obtained from the previous stage are processed using the Hilbert Transform (HT). The HT is a powerful tool in signal processing that helps in extracting the instantaneous amplitude, frequency, and phase of a signal. By applying the HT to the voltage and current signals, it becomes possible to highlight certain features that are indicative of different underlying causes of voltage sags. The processed signals are then used to create a Hilbert plot.
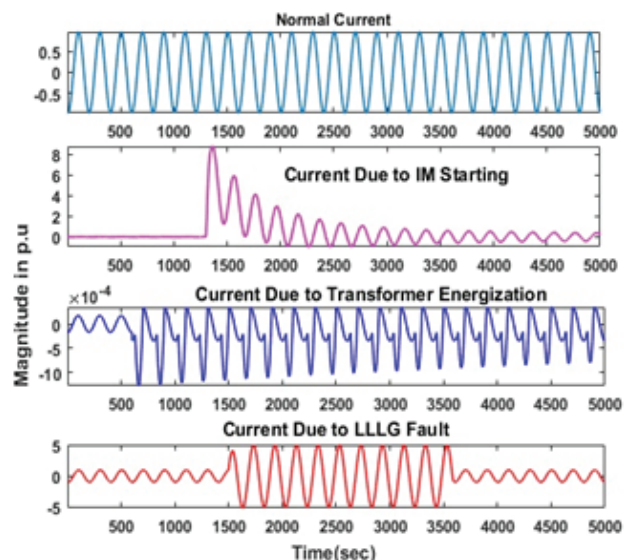
Fig 2 Healthy Current and Current Waveforms Due to Different Root Cause

Signal Processing II Stage

In this stage, the Hilbert plot generated from the processed signals is converted into a visual format and saved as an RGB image. This visual representation allows for better analysis of the signal characteristics

by transforming the time-domain information into a spatial format. The RGB image preserves the details of the signal in a format that can be further processed for feature extraction.

Image Processing Stage

The RGB image obtained in the previous stage is converted into a grayscale image. This conversion simplifies the image by reducing it to a single intensity channel, thereby removing color information that may not be essential for feature extraction. The grayscale image retains the structural details necessary for the subsequent stages of analysis.

Feature Extraction Stage

In this stage, statistical parameters are calculated from the grayscale image. These parameters may include features such as mean intensity, standard deviation, skewness, kurtosis, and other texture-related metrics. The goal is to extract meaningful features that capture the underlying patterns in the voltage sag signals, which can be used to differentiate between the different causes of voltage sag. The statistical features extracted from the gray scaled image of HT of both voltage and current signals like Mean, Standard Deviation, Entropy, Skewness, Kurtosis, Energy and Homogeneity

Classification Stage

Once the features are extracted, they are compiled into a feature vector that serves as input for a classification algorithm. The classifier is trained using labeled data, where each label corresponds to a known cause of voltage sag. During the testing phase, the classifier is used to predict the underlying cause of voltage sag based on the extracted features from new, unlabeled data. In this paper KNN is used as a classifier.

Decision Stage

Finally, the decision stage involves interpreting the output of the classifier to identify the specific cause of the voltage sag. The classification result is compared against predefined categories, such as normal operation, IM starting sag, transformer energization sag, and LLLG fault . The identified root cause is then used for further analysis or for taking corrective actions in the power system. The flow chart of the proposed methodology as shown in fig. 3.
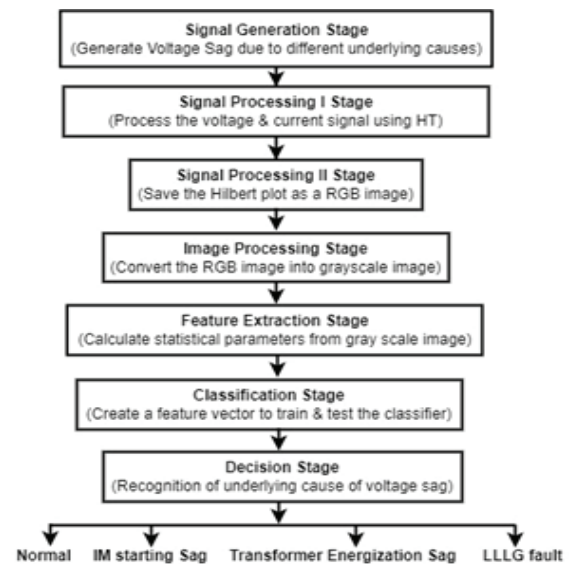
Fig. 3. Flowchart of Proposed Methodology

RESULT AND DISCUSSION

The figure 4 shows Hilbert plots of voltage sag waveforms due to different underlying causes. Each plot is a result of applying the Hilbert Transform (HT), which provides a way to analyze the signal's instantaneous amplitude and phase by mapping the real axis (representing the original signal) against the imaginary axis (representing the Hilbert-transformed signal).
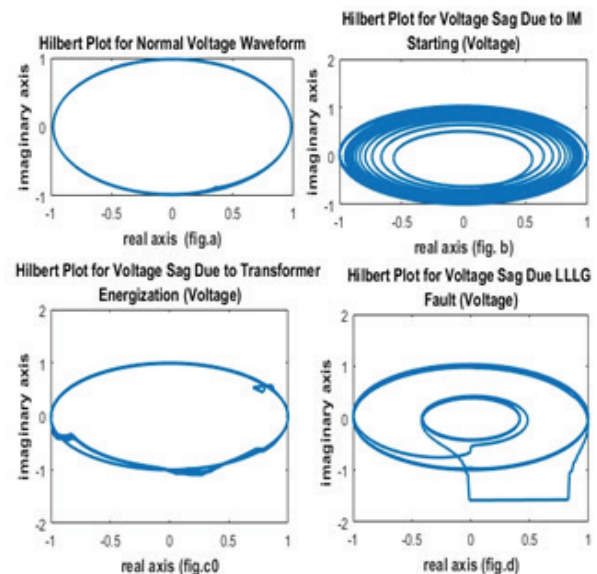
Fig. 4. Hilbert Plot A. Normal Voltage B. Voltage Sag Due to IMS C. Voltage Sag Due to Te D. Voltage Sag Due to LLLG Fault

Hilbert Plot for Normal Voltage Waveform (Fig. 4A)

This plot showcases the Hilbert representation of a normal, undisturbed voltage waveform. The plot appears as a near-perfect ellipse, indicating a steady and consistent sinusoidal waveform without any significant perturbations or distortions. The uniformity of the ellipse reflects the stability of the voltage signal under normal operating conditions.

Hilbert Plot for Voltage Sag Due to IMS (Fig.4B)

In this plot, the effects of an induction motor starting are evident. The Hilbert plot shows a more complex pattern with multiple concentric ellipses, signifying the presence of a voltage sag. This disturbance occurs as the induction motor demands a high inrush current during startup, leading to a temporary reduction in voltage magnitude, which is captured by the Hilbert transform as changes in the signal's amplitude and phase.

Hilbert Plot for Voltage Sag Due to TE (Fig.4c)

This plot depicts the voltage sag caused by the energization of a transformer. The pattern is slightly distorted compared to the normal voltage waveform, reflecting the transient nature of the sag. The irregularities and deviations from the elliptical shape indicate the disturbances in the voltage signal as the transformer are energized, causing a momentary drop in voltage.

Hilbert Plot for Voltage Sag Due to LLLG (Fig.4d)

This plot represents a severe voltage disturbance caused by a Line-Line-Line-Ground (LLLG) fault. The Hilbert plot exhibits significant deviations from the elliptical shape, with multiple loops and irregular patterns. This complexity indicates a major disruption in the voltage waveform, characterized by a deep and prolonged sag, which is typical of a severe fault involving multiple phases and ground.

These Hilbert plots effectively illustrate how different disturbances affect the voltage waveform, providing a visual means to differentiate between normal conditions and various types of sags. The variations in the plots' shapes and complexity underscore the utility of the Hilbert Transform in identifying and analyzing power quality disturbances in electrical systems. Similarly, the hilbert plots of current waveforms due to different underlying causes are shown in figure V.
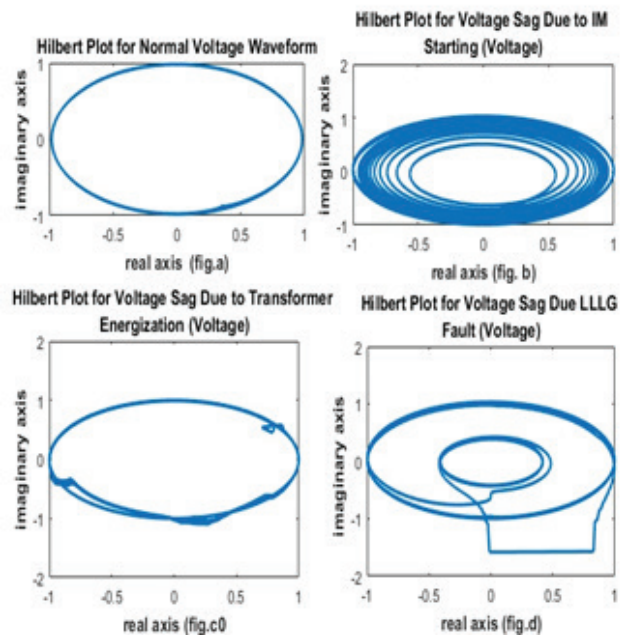
Fig. 5. Hilbert Plot of A. Normal Current B. Current Due to IMS C. Current due to Te D. Current Due to LLLG Fault

Comparison Between Hilbert Plots of Voltage and Current

The Hilbert Transform plot (fig4.A) for voltage and current waveforms (fig5.A)   provide distinct visual patterns that can help in recognizing the underlying causes of voltage sags. Both normal voltage and current HT plots are nearly identical under normal conditions, as no significant disturbances are present.

The Hilbert plot (fig4.B) for voltage during IM starting shows multiple concentric loops, reflecting the impact of the inrush current on the voltage waveform. The current plot (fig5.B) also displays a series of concentric loops, but with a more pronounced and complex structure, indicating the high magnitude of inrush current. The current plot exhibits more complexity and a larger spread compared to the voltage plot, which signifies that the current waveform is more heavily disturbed during motor starting.

The voltage Hilbert plot (fig4.C) shows a distorted shape, indicating a transient event with significant deviations from the normal sinusoidal waveform. The current plot (fig5.C) is highly irregular and significantly deviates from the normal elliptical shape, showcasing

the substantial inrush current during transformer energization. The current plot is more irregular and complex than the voltage plot, making it easier to identify transformer energization by observing the sharp deviations in the current waveform.

The Hilbert plot (fig4.C) for voltage during an LLLG fault is highly irregular, with multiple loops and deviations indicating a severe disruption. The current plot (fig5.D) also displays an irregular and complex pattern, with even more pronounced deviations compared to the voltage plot. Both plots show significant irregularities, but the current plot often exhibits sharper and more chaotic patterns, which helps in distinguishing the severity and nature of the fault.

Key Differentiations for Recognizing Underlying Causes

Current plots generally exhibit greater deviations in magnitude and complexity in their patterns compared to voltage plots, especially during events like motor starting and transformer energization. The pattern complexity of the Hilbert plot (e.g., number of loops, spread, and irregularity) is typically higher in current waveforms, which can be a key indicator in identifying the type of disturbance. Severe disturbances like LLLG faults cause significant irregularities in both voltage and current plots, but the current plot tends to show more pronounced deviations, making it more effective in diagnosing severe faults. By analyzing these differences, one can more accurately recognize the underlying causes of voltage sags, with current waveforms often providing clearer indications of the disturbance's nature and severity.

K-Nearest Neighbor (KNN) Result

In this study, the K-Nearest Neighbor (KNN) classifier was employed to classify the underlying causes of voltage sags using statistical features extracted from the Hilbert Transform of voltage and current waveforms. The classification was conducted using MATLAB's Classification Learner app, which provides a user-friendly interface for training and testing machine learning models.

Training and Testing Data

The dataset was split into two parts: 75% was used for training the KNN model, and the remaining 25%

was reserved for testing. The training set was utilized to train the model by exposing it to various instances of voltage sag events along with their corresponding causes. The model learned to recognize patterns within the statistical features, which included parameters like mean, standard deviation, entropy, skewness, and kurtosis, among others.

Classifications Performance

After training, the KNN model was tested on the unseen 25% of the data. The performance was evaluated using a confusion matrix, which provides a visual representation of the model's accuracy in predicting the causes of voltage sags. The diagonal elements of the confusion matrix represent the correctly classified instances, while off-diagonal elements indicate misclassifications.
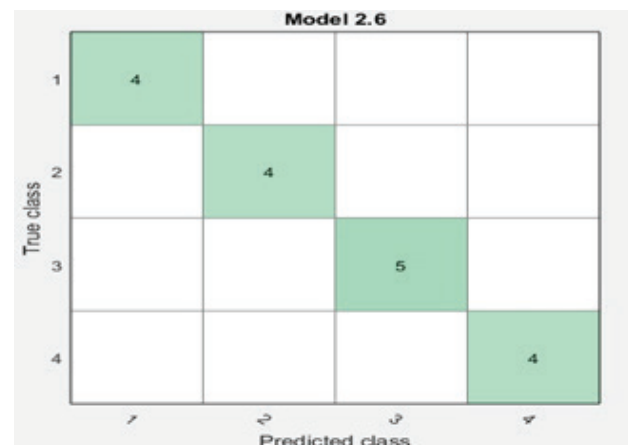
Fig. 6 Confusion Matrix

The results showed a high level of accuracy in classifying the causes of voltage sags. The majority of the test cases were correctly classified, indicating that the KNN model effectively learned the relationship between the statistical features and the underlying causes of the sags. The advantages of this methodology are that, recognition of underlying causes are independent of threshold value [1]. The future scope is that, the root causes of voltage sag are recognized using pattern recognition method in the real time system. In this paper HT of complete signal is taken. For real time monitoring hybrid approach can give superior performance. The signal processing method is used for the events detection. After an event is detected the proposed approach will recognize the original root cause of the events using image processing based pattern recognition method.

CONCLUSION

The analysis of voltage sags using Hilbert transform plots for both voltage and current waveforms has proven to be an effective method for distinguishing between various underlying causes. The visual differentiation in the Hilbert plots for different events, such as IM starting, transformer energization, and LLLG faults, provides clear signatures that can be used to classify these disturbances accurately. The successful classification of the normal current waveform, IMS, TE and LLLG fault using the KNN algorithm further validates the reliability of this approach. By accurately identifying the class associated with a normal current waveform, IMS, TE and LLLG fault, the methodology confirms its potential in practical applications for real-time monitoring and diagnosis of power quality issues, thereby enhancing the stability and reliability of electrical systems.

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Exploring Blends of Diesel, Biodiesel, Waste Plastic Pyrolysis Oil and Ethanol as Alternatives Fuel to Reduce Emissions: A Review

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ABSTRACT

This study explores the potential of waste plastic pyrolysis oil (WPPO) as a sustainable substitute fuel for diesel based engines, addressing the global challenge of increasing plastic consumption. The research focuses on the circular economy, emphasizing recycling and energy recovery, with WPPO showing promise when blended with diesel and biodiesel. Key findings indicate that WPPO, with properties comparable to diesel, can reduce pollutants such as CO ,NOx and PM . Additionally, the inclusion of ethanol in WPPO-biodiesel blends improves fuel flow and atomization by mitigating the higher viscosity of biodiesel. However, challenges such as engine compatibility and the economic feasibility of large-scale WPPO production remain. The study's objectives are to assess the effect of WPPO blended with biodiesel and ethanol on the engine performance, emissions, sustainability, and building on existing research to optimize fuel efficiency and reduce harmful emissions. The research gap identified highlights the need for further exploration of collective influence of WPPO,ethanol, and biodiesel influencing engine output, emissions, and long-term engine wear, particularly in the context of emission control and sustainable waste management.

KEYWORDS : *Biodiesel blends, Emission reduction strategies, Sustainable fuel alternatives, Waste plastic pyrolysis oil (WPPO).*

INTRODUCTION

The consumption of plastic is projected to double within the next two decades, following a similar trend over the past fifty years. Addressing environmental challenges requires emphasize recycling rather than single-use plastics. The circular economy, emphasizing recycling and energy recovery, has become a key strategy. Mechanical recycling plays a crucial role but faces challenges like incompatible mixing and reduced mechanical properties. Meanwhile, thermal recycling, particularly pyrolysis, presents an effective way to convert waste plastic into fuel, offering both economic and environmental benefits (Geyer et al., 2017).

Diesel fuels is well known for its fuel efficiency and economy, are extensively used in various industries. Exploring alternative fuels, such as plastic pyrolysis oil, has gained interest. Research has shown that plastic oil blends can affect engine performance and emissions differently depending on the blend ratio and production method. For instance, Singh et al. (2020) found that using 50% plastic oil blends resulted in reduced efficiency and slightly increased emissions, while Das et al. (2022) observed higher brake thermal efficiency with 20% blends but noted higher emissions at greater blend ratios. Other studies have explored the use of various polymers and catalysts in pyrolysis, highlighting the potential and limitations of this approach (Mangesh et al., 2020; Bukkarapu et al., 2018; Chandran et al., 2020).

The rapid accumulation of plastic waste, driven by population growth, urbanization, and lifestyle changes, underscores the need for effective waste management. Global plastic production continues to rise, with significant environmental impacts due to inadequate

disposal methods, especially in developing countries. Transforming waste plastics into high-value oils through processes like depolymerization and thermal degradation holds promise for reducing environmental impact and providing economic benefits. These methods offer a viable solution for managing plastic waste while contributing to the production of alternative fuels (Patni et al., 2013; Miandad et al., 2019; Ilyas et al., 2018)..

OBJECTIVES

The review aims to evaluate the incorporation of waste plastic pyrolysis oil (WPPO) in conjunction with biodiesel and ethanol as a viable fuel alternative for diesel engines. It explores how these blends impact engine performance, emissions, and sustainability, with a particular focus on reducing environmental impact. The study builds on existing research on biodiesel and ethanol blends, seeking to optimize fuel efficiency and minimize harmful emissions.

PLASTIC WASTE & ITS INFLUENCE

Plastic waste consists of discarded used plastics, including single-use containers and packaging, ranging from microplastics to larger items (Sahajwalla and Gaikwad, 2018). This waste significantly impacts soil, water, wildlife, and human health. About 50% of plastics are non-recyclable, leading to long-term environmental persistence (Panda et al., 2010).

Influence on Terrestrial Land: Chlorine-containing plastics can harm ecosystems and contaminate water sources.

Influence on Waters: Approximately 165 million tons of plastic waste pollute oceans, harming marine ecosystems and posing a health risk to humans through contaminated seafood. (Panda et al., 2010).

Plastics are synthetic organic macromolecules formed through polymerization, typically characterized by high molecular weight and often mixed with fillers for enhanced stability. Plastics are categorized into thermosetting and thermoplastic types. The Organization of Plastic Manufacturers created a seven-category coding system to assist recycling efforts based on plastic composition and usage. (Singh et al., 2020). The seven primary types of plastics, each with unique properties and recycling potential, include (Griffey,

2014; Jaafar et al., 2022; Al-Sherrawi et al., 2018; Demaid et al., 1996):

- Polyethylene Terephthalate (PET): Recyclable thermoplastic polymer.

- High density Polyethylene (HDPE): Recyclable thermoplastic derived from ethylene.

- Polyvinyl Chloride (PVC): Solid, recyclable plastic made from vinyl chloride.

- Low density Polyethylene (LDPE): Recyclable thermoplastic made from ethylene.

- Polypropylene (PP): Generally not recyclable thermoplastic.

- Polystyrene (Styrofoam): Not recyclable polymer.

- Other Plastics: Includes non-recyclable materials like polycarbonate and nylon.

BLENDING TO IMPROVE ENGINE PERFORMANCE AND EMISSION

A study compared the power output of pure diesel to different blends of pyrolysis plastic oil and diesel. Pyrolysis, a thermal treatment method, converts waste plastics, specifically, high-density polyethylene (HDPE) was converted to pyrolysis oil. The increasing global plastic production has led to significant plastic waste accumulation in landfills, impacting non-renewable petroleum resources, as plastics are derived from fossil fuels.

Dayana et al. (2018) discuss the specific properties and optimization of the pyrolysis oil, while Montejo et al. (2011) analyze the higher heat value of refuse derived fuel (RDF) from solid waste collected as municipal corporatio, making it suitable for energy recovery. Pyrolysis offers a sustainable alternative for waste management, using only about 4% of world's gas and oil production. The hydrocarbon-rich gas produced can be utilized for power generation and transportation, addressing plastic waste disposal and fossil fuel depletion. Kabeyi & Olanrewaju (2023) emphasize the economic feasibility of pyrolysis gas for energy recovery, highlighting its potential to reduce dependence on external energy sources. Shrivastava et al. examined the impact of Karanja biodiesel, ethanol, diesel blends on diesel engine output performance and

emissions. A Taguchi method and ANOVA analysis was used by researcher to optimized input parameters (injection angle, compression ratio, blend %, and load) to achieve optimal engine responses (BTE, BSFC, EGT, CO2, CO, NOx, HC).

WASTE PLASTIC OIL BLENDED BIODIESEL

Researchers are actively exploring alternative fuels to address the fossil fuel crisis, with a focus on renewable sources like biodiesel. Biodiesel, which shares properties with diesel, is gaining popularity as a solution to fuel shortages and environmental concerns. Blending biodiesel with diesel significantly reduces harmful emissions and enhances sustainability. This review evaluates Studies have shown that biodiesel blends can reduce ignition delay and emissions in diesel engines and reduce the emissions of CO,HCPM compared to conventional diesel (Kaewbuddee et al., 2020). The table 1 illustrate the review.

Overall, it is observed that waste management, positioning WPPO as a viable option for another fuel source for compression ignition engines.

Table 1 Review of WPPO and Biodiesel blend

Year	Study	Findings
2016	Khan et al.	Characterized waste plastic pyrolysis oil (WPPO) from HDPE, confirming compliance with diesel fuel standards and its potential as a superior alternative to conventional diesel.
2016	Kaimal and Vijayabalan	Evaluated Waste Plastic Oil (WPO) synthesized from waste plastic via pyrolysis, showing reduced emissions with WPO blends, making it a promising alternative fuel.
2018	Dillikannan et al.	Examined the impact of injection timing and EGR on combustion and emissions in a DI diesel engine using WPPO; found significant reductions in smoke and NOx emissions.
2019	Ellappan et al.	Used WPO in a low heat rejection diesel engine, finding improved performance and reduced specific fuel consumption and emissions, except NOx, in coated configurations.
2020	Das et al.	Blending waste plastic oil (WPO) with diesel improved brake thermal efficiency but increased NOx emissions at higher loads.
2020	Kaewbuddee et al.	Review of biodiesel blends showed reduction in ignition delay and harmful emissions (CO, HC, particulate matter) compared to conventional diesel.
2020	Khatha et al.	Analyzed fuel properties of waste plastic crude oil (WPCO) and WPO, revealing similar fuel properties to diesel and emissions improvements, though increased NOx emissions were noted.
2022	Maithomklang et al.	WPO derived from PET bottles showed similar properties to diesel; recommended blending up to 20% to maintain combustion and emissions characteristics.
2022	Padmanabhan et al.	Tested waste plastic fuel (WPF) from HDPE with additives, leading to a 4.7% increase in brake thermal efficiency and reductions in CO and HC emissions.
2024	Pumpuang et al.	Compared WPOs from different plastics; HDPE blends performed similarly to diesel, while polypropylene (PP) had lower brake thermal efficiency but reduced NOx emissions.

DIESEL-ETHANOL BLENDS AND ADDITIVES FOR REDUCED EMISSIONS

Compression ignition engines are significant contributors to pollutants like hydrocarbons (HC) and carbon monoxide (CO). Using biofuel fuels as ethanol, which has a less carbon content, may significantly mitigate these emissions. An experimental study analyzed various diesel-ethanol blends diesel with % ethanol as E2,E4,E6,E8,E10,E12 at engine speeds from 1600 - 2000 rpm. The results indicated a reduction in CO by 3.2–30.6% and HC by 7.01–16.25% due to ethanol's higher oxygen content, although NOx emissions increased by 7.5–19.6% due to higher combustion temperatures. The optimization identified optimal performance conditions: an engine speed of 1977

rpm with a 10% ethanol blend, yielding CO2-6.81%, CO-0.27%, HC-3 ppm, NOx- 1573 ppm, specific fuel consumption -239 g/kW•h, power -56 kW, and torque =269.9 N•m (Shadidi, Alizade, & Najafi, 2021). In addition to ethanol blends, the use of additives in diesel has been explored to further enhance performance and reduce emissions. Fayyazbakhsh and Pirouzfar (2017) reviewed diesel additives, noting that higher alcohol content can improve premixed combustion and reduce emissions. Bridjesh et al. (2018) examined substituting diesel with Waste Plastic Oil (WPO) mixed with additives like methoxyethyl acetate (MEA) and diethyl ether (DEE) to enhance engine performance. Further research by Sachuthananthan et al. (2021) study found that adding alcohol to plastic pyrolysis oil with magnesium oxide nanoparticles can reduce emissions, especially at higher loads. Adding castor oil significantly reduced emissions across load conditions, with diethyl ether showing a stronger effect than butanol (Sushma, 2018).

Tests with various WPF-diesel blends indicated smooth engine operation, but higher emissions and a 2-4% reduction in brake thermal efficiency were observed. It is recommended to use a higher proportion (30-40%) of diesel in blends utilizing WPF in standard diesel engines (Sukjit et al., 2017). In another study, WPF produced from household waste plastics was evaluated in a direct-injection diesel fuel engine, showing that a 20% WPF blend achieved good brake thermal efficiency and lower emissions, meeting U.S. EPA standards. However, the 40% blend should be limited to rated engine speeds below 2500 RPM (Lee et al., 2015).

BLENDS OF DIESEL-BIODIESEL-WPPO

This study examines the benefits of blending diesel with waste cooking oil (WCO) biodiesel and waste plastic pyrolysis oil (WPPO).Testng fuels were formulated with 10 and 20 percent by volume of WPPO, 20% WCO biodiesel, and varying diesel volumes, labelled as D80%B20%, D70%B20%P10%, and D60%B20%P20%. A direct injection mono cylinder (DI) diesel fuel engine was used to analyze ignition characteristics, performance, and emissions at different load conditions, comparing outcomes with base fuel diesel. The blend D60B20P20, having 20% WPPO, shown a 12.2% rise of brake thermal efficiency and a

9.60% reduction in brake specific fuel usage compared to biodiesel blends base diesel. Additionally, exhaust emissions decreased significantly, with D60B20P20 achieving an overall reduction of about 30% in NOx, CO, and unburned hydrocarbon (UBHC) emissions at full load (Mukul et al., 2020). A similr study found that using diesel-WCO biodiesel blends with WPPO can reduce emissions, especially NOx and smoke. While EGR and timing adjustments can improve emissions, it may also decrease BTE. This research highlights the potential of these blends for cleaner diesel engines. (Naik & Kota, 2020).

SUITABILITY OF DIESEL, BIODIESEL, WASTE PLASTIC PYROLYSIS OIL, AND ETHANOL BLENDS AS ALTERNATIVE FUELS

A comparative analysis of diesel, biodiesel, WPPO, PPO, and ethanol provides valuable insights into their potential as alternative fuels. Ethanol, a bio-alcohol, is recognized for its high octane rating and oxygen content, which improve combustion efficiency and reduce CO and hydrocarbon emissions when blended with diesel. While ethanol has lower energy density than diesel and biodiesel, it contributes to reduced overall carbon emissions due to its renewable nature.

Blending these fuels with diesel can optimize combustion efficiency, lower emissions, and enhance fuel sustainability. The performance output of each blend depending on factors such as blend ratios, engine compatibility, and operating conditions. Table 2 shows the basic properties of diesel, biodiesel, ethanol and waste plastic pyrolysis oil (WPPO).

Table 2 The properties of diesel, biodiesel, waste plastic pyrolysis oil (WPPO),) and ethanol

Property	Diesel	Biodiesel	WPPO	Ethanol
Density (g/cm³)	0.83 - 0.87	0.88 - 0.90	0.80 - 0.85	0.789
Viscosity (cSt)	2.5 - 4.5	4.0 - 5.0	3.5 - 5.0	1.2
Flash Point (°C)	55 - 75	100 - 170	40 - 60	13

Cetane Number	40 - 55	50 - 60	30 - 40	N/A
Calorific Value (MJ/kg)	42 - 46	37 - 39	36 - 40	26.8
Octane Rating	-	-	-	129
Khan et al.,2016; Pacheco et al., 2021; Hunicz et al.,2023				

The table 3 presents the blending characteristics of diesel, biodiesel, ethanol and waste plastic pyrolysis oil (WPO). The estimated calorific value of each blend was calculated using the following equation:

Estimated Blend Calorific Value = (Diesel % × Diesel Calorific Value) + (Biodiesel % × Biodiesel Calorific Value) + (WPO % × WPO Calorific Value) + (Ethanol % × Ethanol Calorific Value)

Assume average calorific values of 36.5 MJ/L for diesel, 36 MJ/L for WPO, 32 MJ/L for biodiesel, and 26 MJ/L for ethanol. The table 3 shows that the calorific value of the blend reduces slightly as the of WPO percentage increases. However, the addition of WPO can still contribute to reducing emissions and improving engine performance when used in appropriate proportions.

Table 3 Estimated calorific value of diesel, biodiesel, waste plastic pyrolysis oil (WPPO),) and ethanol

Diesel (%)	Biodiesel (%)	WPO (%)	Ethanol (%)	Estimated Blend Calorific Value (MJ/L)	References
55	20	25	10	42.6	Khan et al.,2016; Pacheco et al., 2021; Hunicz et al.,2023
50	20	30	10	42.4	
45	20	35	10	42.2	
40	20	40	10	42	

RESEARCH GAP

While significant progress has been made in exploring the usage of biodiesel- ethanol blends in diesel engines, there remains a gap in understanding the full potential of waste plastic pyrolysis oil to be used in fuel blend. Specifically, the combined effects of WPPO with biodiesel-ethanol on engine output performance, emissions, and long-term engine wear are not fully understood. This gap highlights the need for comprehensive studies to establish WPPO blend with biodiesel and ethanol, particularly in the context of emission control, circular global economy and sustainable waste management strategies.

CONCLUSION

This research comprehensively explores the potential of waste plastic pyrolysis oil (WPPO) as an alternative fuel for diesel engines. By analyzing the properties of WPPO in comparison to traditional diesel and biodiesel, the study demonstrates its viability as a sustainable fuel source. Key findings indicate that WPPO exhibits favorable properties, including a calorific value similar to diesel, ranging from 36 to 40 MJ/kg, and a viscosity between 1.98 and 7.24 cSt at 40°C. Additionally, WPPO can be effectively blended with diesel and biodiesel, offering potential benefits in terms of emissions reduction and energy efficiency. Notably, the addition of ethanol to WPPO-biodiesel blends can help offset the increased viscosity associated with biodiesel, thereby improving fuel flow and atomization properties. Furthermore, blending WPPO with diesel and biodiesel, along with the incorporation of ethanol, has shown promise in reducing emissions of harmful pollutants such as NOx, CO, and particulate matter. However, challenges remain, including ensuring compatibility between WPPO blends and various diesel engine types for successful implementation. Moreover, further research is needed to evaluate the economic viability of WPPO production and utilization on a larger scale, which will be crucial for its widespread adoption as an alternative fuel.

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Categorisation and Localisation of Transmission Line Fault by using Machine Learning

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ABSTRACT

In the modern era, the demand for electricity is rising swiftly, but the available transmission capacity cannot keep up. An electrical power system will inevitably experience fault current, which is any abnormal electric current. Such a fault may destabilize the whole system, which might result in its eventual collapse. Given that transmission lines are responsible for more than half of all power system faults, transmission line protection is a crucial topic in power system engineering. Real-time monitoring and prompt control are required to protect the modern power system against transmission line faults. The categorization and location of faulty situations is a crucial task for the trustworthy operation of power systems. Automatically categorizing the faults into one of the 10 fault classes is the aim of this work. The collection of ten artificially created faults in overhead transmission lines has a 100 km length, a 400 kV rating, and operates at 50 Hz. The simulation is carried out using the MATLAB/Simulink program. Additionally, the user interface is created to provide access to the model and to display the type and location of faults using multiple linear regression, a supervised machine learning technique in Python that is implemented in the Spyder IDE. Additionally, it has a QR code that, when scanned, shows the nearest station to the fault's position on a Google Map. The results show that fault localization and categorization have very high precision.

KEYWORDS : *Transmission lie, Fault, Python, Spyder IDE, QR code.*

INTRODUCTION

A power system network is separated into various elements, each of which is a system: distribution systems, sub transmission systems, power generating systems, and power transmission systems. One of the key elements of the power system is the transmission lines, which transmit massive amounts of electricity from generating stations to substations at high voltages and act as a vital link in the nation's energy infrastructure. The modern power grid is a convoluted network as a result of industrialisation and urbanization. Power systems need a protection system that is fast, responsive, accurate, and reliable. The most serious threat to power supply continuity is a system fault.

Fault is merely an electrical system flaw. For clarification, let us relate transmission system malfunctions to human ailments. For instance, if a healthy person has any aberrant condition—which includes illnesses like the common cold, cough, fever, heart attack, cancer, and so forth—their everyday routine becomes disrupted. Comparably, in power transmission systems, a defect arises when abnormal circumstances cause the system quantities (phase angle, current, voltages, etc.) to exceed their threshold values [1]. An MVA is used to express the defect value. Because it is primarily exposed to outside circumstances, the overhead transmission line has a higher fault incidence rate than the other essential parts of the electrical power system. Electrical power system malfunctions [2]. Faults have a significant influence on end users in addition to the dependability of the system. Furthermore, the difficulty of maintaining transmission line networks grows as configurations get more complicated. Increased operating dependability, stability, and catastrophic power outages can all be prevented by accurately predicting faults (type and location) [3]. The primary objective of all studies, publications, and ideas for faults in the high voltage

transmission line is to design a quick, accurate, and dependable protective model to identify, categorize, and locate the fault. Digital technology was added with the establishment of the smart grid, making it possible to install sensors along transmission lines that can gather real-time defect data. Because they provide valuable data that can be utilized to detect issues in transmission lines [4-5].

Over the last two decades, many intelligent approaches such as wavelet approach [6-7], fuzzy & Neuro-fuzzy based methods [8-9], Neural network [10-11], artificial neural network [12-13], SVM-based approach[14-15], and linear regression[16] approach have been developed and deployed in transmission systems to address these difficulties. However, as compared to other ways, resolving the issue using a regression algorithm is one of the simplest methods for such study. Automatically categorizing the faults into one of the 10 fault classes is the aim of this work. The collection of ten artificially created faults in overhead transmission lines has a 100 km length, a 400 kV rating, and operates at 50 Hz. The simulation is carried out using the MATLAB/Simulink program. Additionally, the user interface is created to provide access to the model and to display the type and location of faults using multiple linear regression, a supervised machine learning technique in Python that is implemented in the Spyder IDE. Additionally, it has a QR code that, when scanned, shows the nearest station to the fault's position on a Google Map. The results show that fault localization and categorization have very high precision.

PROPOSED METHODOLOGY

The simscape electrical library is used to model three-phase transmission lines in MATLAB/Simulink R2021a when the input parameters and algorithm are finalized. Here, the transmission line's nominal Pi model is used. Innocent Kamwa et al [17] study's work was used as the basis for the simulation of the length, base voltage, load active power, phase to phase voltage, and base power of a transmission line. Three-phase fault blocks are used to simulate various kinds of symmetrical and unsymmetrical faults once designing is successfully completed. Total 1010 fault incidences are taken into account, or 10 faults at a single place and 101 spots overall, spaced 1 kilometre apart. Then, database under

fault condition is created. A complete database is stored in the form of an excel sheet. The dataset serves as the foundation for the algorithms developed for fault diagnostics. The database is made homogonous in such a way that it is accompanied for an algorithm. The algorithms are created in the Python environment known as ANACONDA (Spyder IDE). Multiple linear regression is the method employed for fault diagnosis, gained knowledge from the model output, which improved the accuracy of the algorithm.
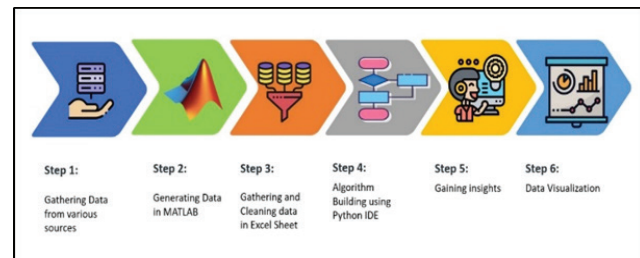
Fig. 1. Proposed Methodology

Task of Data visualisation is done by using Spyder IDE and HTML. Spyder IDE helps to send data to website. And task of Frontend i.e., webpage making carried out by HTML. Webpage gives type, location of fault and also a QR code which we scan gave the location on the Google map. Fig. 1 depicts the complete process of proposed research.

MODEL DEVELOPMENT AND DATASET GENERATION

Modeling of each section is required to create a complete model of the transmission line. A 400 kV transmission line system is used to develop and implement for the purposed architecture and algorithm. There are three sections that make up the entire model. The sending end section is the first one, and it contains a generating block. The Π - section line and fault block make up the second transmission line section. The third section is the receiving end section, which includes the three-phase load. For the aim of simulating the transmission line system, MATLAB/Simulink software is employed. The the transmission line model is shown in Fig.2.

Dataset Generation

A fault dataset is required for the training and performance testing of a classifier. The fault dataset is generated with the help of the MATLAB/Simulink

model of the transmission line, and the designing of the transmission line has been explained briefly in the above section. For this classifier, we considered both unsymmetrical and symmetrical faults. In the case of an unsymmetrical fault, we have considered single line to ground fault (LG) with all cases that are A-G, B-G, and C-G, then double line fault (LL) with all cases that are A-B, B-C and A-C and double line to ground fault (LLG) with all cases that are AB-G, BC-G, and AC-G. In the case of a symmetrical fault, we have only considered the case of a three-line fault (LLL). The Fault block is used to assist construct faults. A fault that occurred at t = 20 ms at multiple locations was simulated numerous times for 100 milliseconds in order to induce variance in the classifier dataset. The transmission line under consideration is 100 km long, with a 1 km distance between faults. As a result, the total number of instances increases to 101, including the origin (0 km). A total of 1010 fault cases are taken into consideration since we are considering a total of 10 different sorts of faults.

Fig.2. Schematic of Transmission Line Model

DEVELOPMENT OF ALGORITHM

The synthetic dataset has been created by performing a simulation on the transmission line. The building of a machine learning model that resol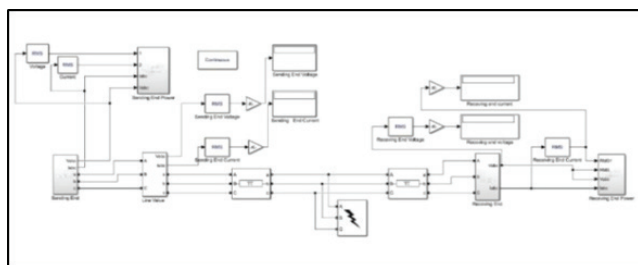ves the issue is the next stage. The machine learning algorithm that was used to resolve the issue is linear regression, or if specifically said, multiple linear regressions. In this section, we describe the process of developing an algorithm and how to get the results through it. Fig. 3 depicts the complete algorithm. The Spyder IDE's Python environment was used to create the entire algorithm. The first stage is to import the libraries that help with the whole model development process.

As discussed above, the generated dataset has been stored in an excel sheet. However, the dataset is not directly compatible with the Python environment. It

has to be converted into a CSV file. Spreadsheets and databases use the simple CSV (Comma Separated Values) file format to store tabular data. In a CSV file, tabular data—that is, text and numbers—is kept as plain text. Every line in the file contains a data record in it. Python comes with a built-in module called csv that may be used to interact with CSV files. We import the dataset after it has been converted. Then import the Flask Library, which will help to develop the webpage. Flask is a micro-web framework written in Python. It is regarded as a micro framework as it doesn't require any particular tools or libraries. It doesn't have any components, like a database abstraction layer or form validation, that already have third-party libraries that offer common functionality. After that, in next section, we first compared entries from the csv file by manual matching. If the entries match exactly, then it appears as results. Otherwise, multiple linear regression is used for the results. In brief, if exact entries are not matched, then a process of multiple linear regression will be executed. In this algorithm, the trend is developed on the basis of the database and the entries are matched with respect to the trend, which gives the output. The result is shown on a webpage which is developed using HTML. These results consist of the category of fault and the place where it occurred. On the basis of the type of fault, the model shows the type in written as well as diagrammatically of the resultant fault, and on the basis of location, it gives a QR code which gives displays the nearest station to the location of the fault on a Google Map. Here, both the diagram and the location are stored on the cloud and fetched whenever required. On the basic of this algorithm a python program is developed.
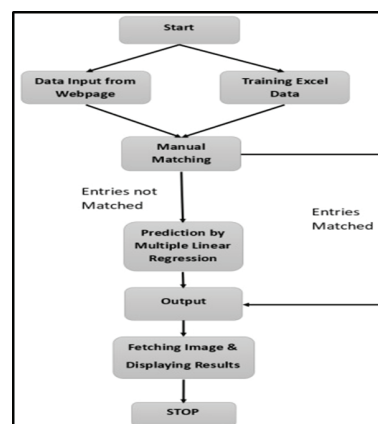
Fig. 3. Flowchart of ML Model

RESULT

The transmission line model is thoroughly discussed in [17] is simulated with specified parameters in MATLAB/Simulink software to obtain the synthetic dataset. The proposed work's goal the categorization and localization of faults using machine learning-was accomplished by employing a synthetic dataset of fault cases to identify homogeneity in the dataset of different kinds of fault.

Synopsis of L-G Fault
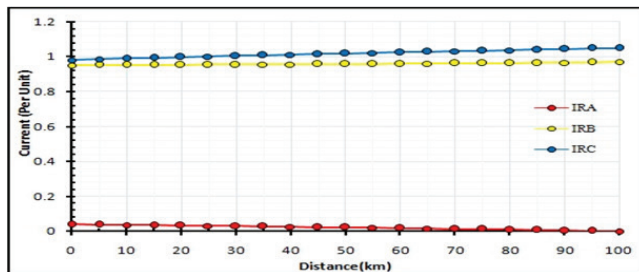
Fig.4 (a) Receiving end current under fault A-G
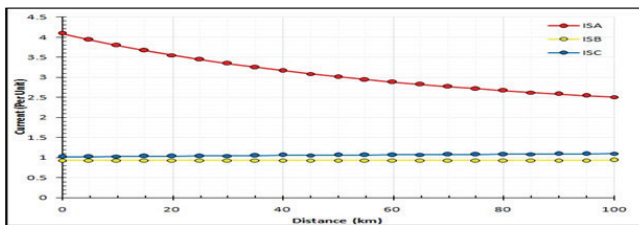
Fig.4 (b) Sending end current under fault A-G

On the basis of the synthetic dataset which has been generated, an L-G fault has been introduced. Fig. 4 (a, b), Fig.5 (a, b), and Fig.6 (a, b) depict the plot of current versus distance for all single line to ground (L-G) fault scenarios. Fig.4 (a, b) depicts the changes that occur when the L-G fault occurs on Phase A, that is, fault A-G. Fig.5 (a, b) depicts the changes that occur when fault B-G, or the L-G fault, occurs on Phase B. Similarly, Fig.6 (a, b) depicts the changes that occur when the L-G fault occurs on Phase C, that is, fault C-G. Whenever the L-G fault occur on any of the phase that one phase disconnected from receiving end. Therefore in the case of an A-G fault Phase A disconnected,for BG fault Phase B disconnected and for C-G fault Phase C is disconnected. , the receiving end will not receive current via faulty phases. However,healthy phases Phases B and C for case A-G fault,Phases A and C for

B-G fault and A and B for C-G fault will continue to operate effectively. As a result, if an A-G, B-G and C-G faults occurs anywhere along the line, current flow in Phase A,Phase B and Phase C is minimal, as seen in Fig. 4 (a), Fig.5 (a) and Fig.6 (a) respectively. However, at the sending end, the generator keeps the supply flowing via the faulty phase, causing Phase A in AG fault case, Phase B in B-G fault case and Phase C in C-G fault case to experience far more current flow than the healthy phase receives. The fault current, as seen in Fig.4 (b), Fig.5 (b), and Fig.6 (b), reduces with the distance of the fault location from the source end.

Fig. 5 (a) Receiving end current under fault B-G

Fig. 5 (b) Sending end current under fault B-G

Fig. 6 (a) Receiving end current under fault C-G

Fig. 6 (b) Sending end current under fault C-G

Synopsis of L-L Fault

On the basis of the synthetic dataset which has been generated, an L-L fault has been introduced. This section covers the analysis of Fault A-B, Fault B-C, and Fault A-C. Fig.7 (a, b), Fig.8 (a, b), and Fig.9 (a, b) depict the plot of current versus distance for all double Line (L-L) fault scenarios. Fig. 7 (a, b) depicts the changes when the L-L fault occurs on Phase A and Phase B, that is, fault A-B. Fig. 8 (a, b) depicts the changes that occur when the L-L fault occurs on Phase B and Phase C, that is, fault BC. Similarly, Fig. 9 (a, b) depicts the changes when the L-L fault occurs on Phase A and Phase C, that is, fault A-C. Whenever the L-L fault occur on any two of the phases that both phases connected to each other and still some how connected to receiving end.As a result, current flow in faulty phases is decreased if an L-L fault manifests itself anywhere along the line, as seen in Fig.7 (a),Fig.8 (a), and Fig.9 (a).However, at the sending end, as seen in Fig.7 (b),Fig. 8 (b), and Fig.9 (b), decreases as the fault location advances away from the source end.
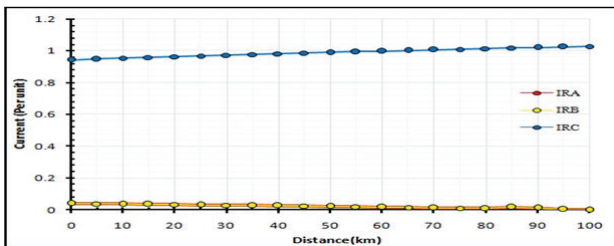
Fig. 7(a) Receiving end current under fault A-B

Fig. 7 (b) Sending end current under Fault AB

Fig. 8 (a) Receiving End Current under Fault B-C
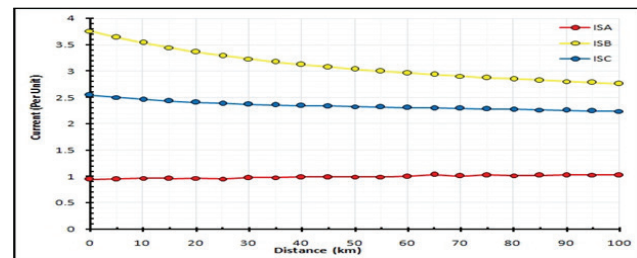
Fig. 8 (b) Sending end current under Fault BC
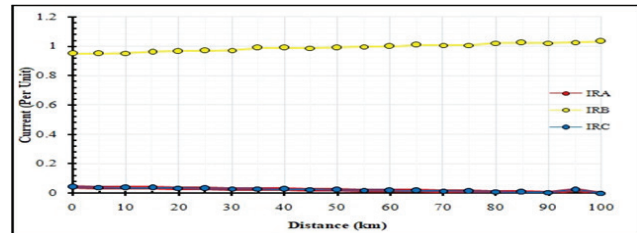
Fig. 9 (a) Receiving end current under Fault A-C
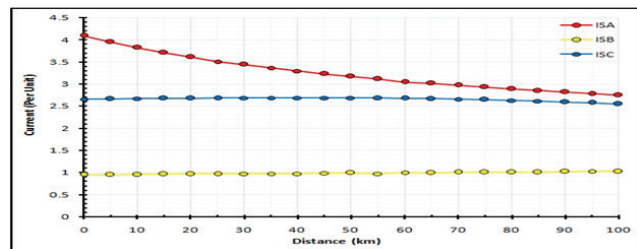
Fig. 9 (b) Sending end current under Fault AC

Synopsis of L-L-G-Fault

An insertion of an L-L-G defect has been made using the generated synthetic dataset. The investigation of faults A-B-G, B-C-G, and A-C-G is covered in this section.. This section covers the analysis Phase A and Phase C experience the L-L-G fault, which is also known as fault A-C-G. Fig. 10 (a, b), Fig. 11 (a, b), and Fig. 12 (a, b) depicts the plot of current versus distance for all double Line to ground (L-L-G) fault scenarios. Fig. 10 (a, b) depicts the changes that when the L-L-G fault occurs on Phase A and Phase B, that is, fault A-B-G. Fig. 11 (a, b) depicts the changes that occur when the L-L-G fault occurs on Phase B and Phase C, that is, fault B-C-G. Similarly, Fig. 12 (a, b) depicts the changes when the L-L-G fault occurs on Phase A and Phase C, that is, fault A-C-G.

Whenever the LLG fault occur on any two of the phases that both phases connected to each other and disconnected from receiving end. As a result, current

flow in faulty phases is decreased if an L-L-G fault manifests itself anywhere along the line, as seen in Fig.10 (a), Fig.11 (a), and Fig.12 (a). However, at the sending end, the generator keeps the supply flowing via the faulty phase, causing Phase A and Phase B in A-B-G fault case, Phase B and Phase C in B-C-G fault case and Phase C and Phase A in A-C-G fault case to experience far more current flow than the healthy phase receives. The fault current, as seen in Fig.10 (b),Fig.11 (b), and Fig.12 (b), decreases as the fault location advances away from the source end.
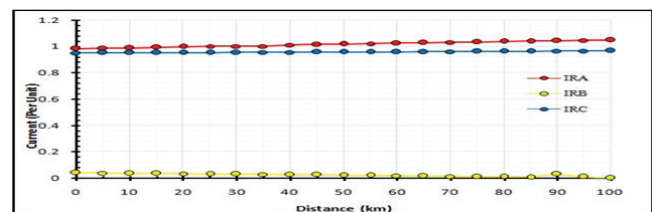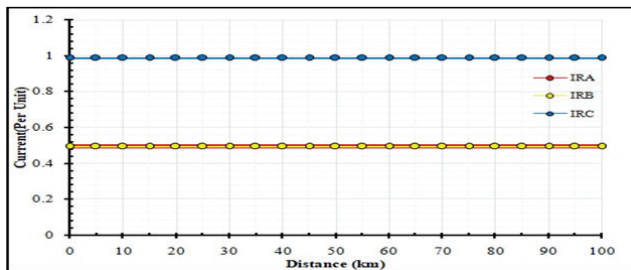

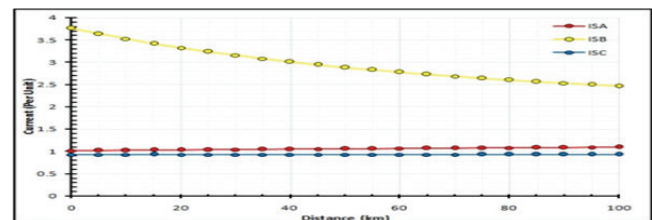**Fig. 10 (a) Receiving end current under fault A-B-G**
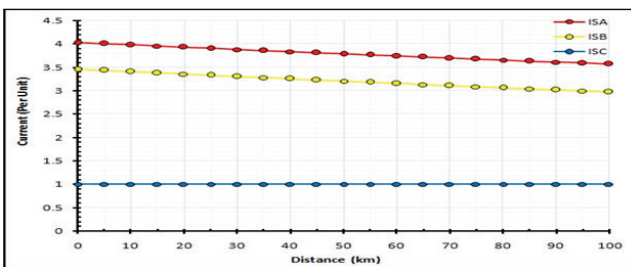
Fig. 10 (b) Sending end current under fault A-B-G
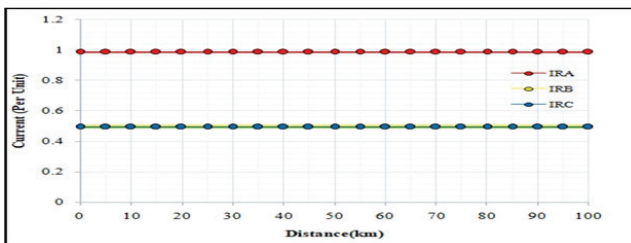
Fig. 11 (a) Receiving end current under fault B-C-G
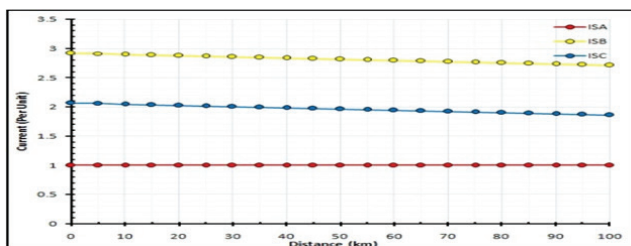
Fig. 11 (b)   Sending end current under fault   B-C-G
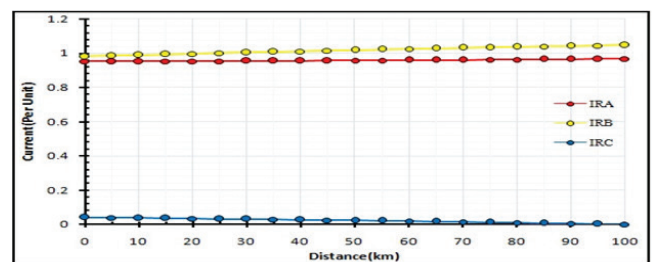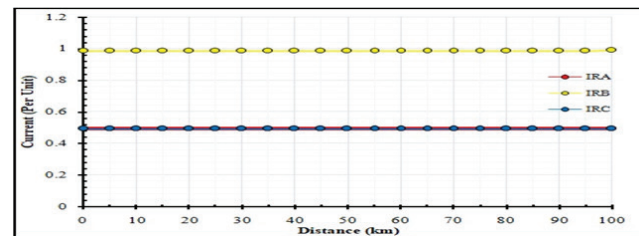

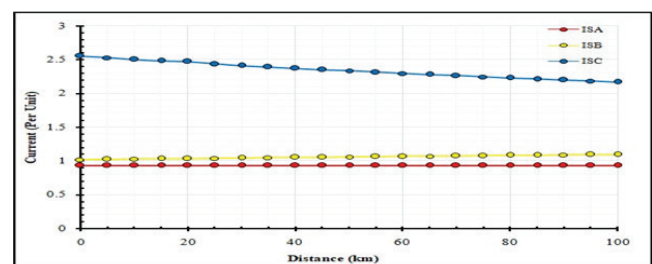**Fig. 12 (a) Receiving end current under fault A-C-G**
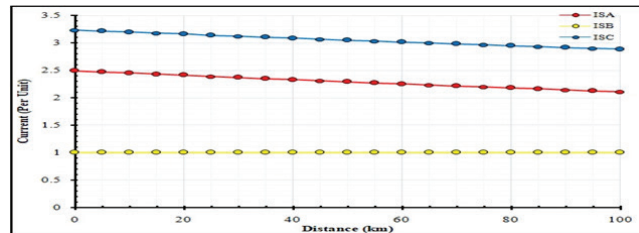
Fig. 12 (b) Sending end current under fault   A-C-G

Synopsis of L-L-L Fault

On the basis of the synthetic dataset which has been generated, an L-L-L fault has been introduced. This section covers the analysis of Fault A-B-C. fig.13 (a, b) depicts the plot of current versus distance for triple line (L-L-L) fault scenario. Whenever the L-L-L fault occur on all of the phases the phases connected to each other and disconnected from receiving end. Therefore in the case of an A-B-C fault Phase A , Phase Band Phase C will be disconnected from receiving end and current received via these faulty phases will be negligible. As a result, current flow in faulty phases is decreased if an L-L-L fault manifests itself anywhere along the line, as seen in fig.13 (a). However, at the sending end, the generator keeps the supply flowing via the faulty phase, causing Phase A , Phase B and Phase C to experience far more current flow. The fault current, as seen in fig.13 (b) decreases as the fault location advances away from the source end .
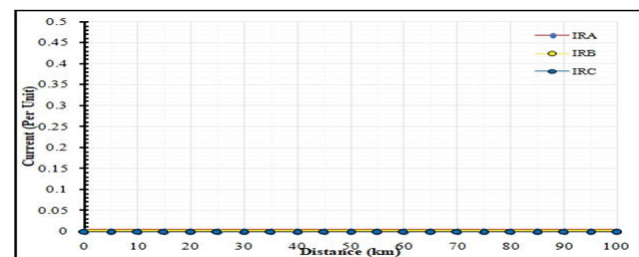
Fig. 13(a) Receiving end current under fault A-B-C
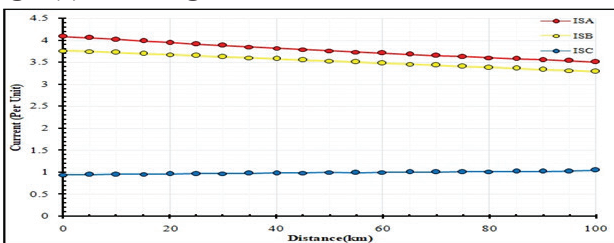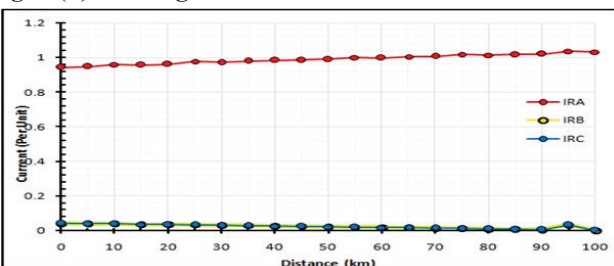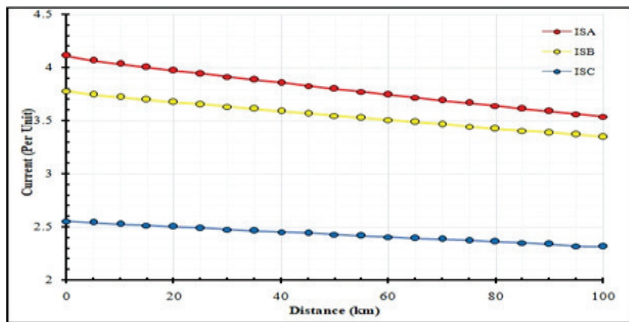
Fig. 13(b) Sending end current under fault   A-B-C

Classification and Localisation

A Synthetic dataset was created by modeling several fault scenarios on the intended transmission line. Transmission line model is designed in MATLAB/ Simulink environment. The machine learning model development has been completed by using Python on the basis of the fault dataset and the web page development by using HTML as per requirement. Here, the ratio of testing data to training data is 30:70. When different entries are given as an input, it starts to display the desired result. If the entries match exactly, and then it appears as results. Otherwise, multiple linear regression is used for the results. The entire webpage is created with HTML and made model-compatible with the Flask Function. http://127.0.0.1:5000 is the URL to access. When input is entered and the predict button is pressed, it produces an output. Output consists of the location of the fault, which is measured from the starting location. Fig. 14 depicts the outputs. It also displays an image of the type of fault as well as a QR code as shown in fig. 15. that, when scanned, displays the nearest location from the fault location. However the basic requirement is there should be availability of QR scanner such as android or IOS device. In order to scan the QR code there is a feature known as Google Lens which is now preinstalled in every android phone. In case of IOS devices (for example Apple Devices) scan by using camera with the feature of view finder. Fig.15 shows the QR code which gets as an output and shows the location that gets after scanning. The tasks of fault localization, fault classification, and fault detection were all satisfactorily completed in this study.
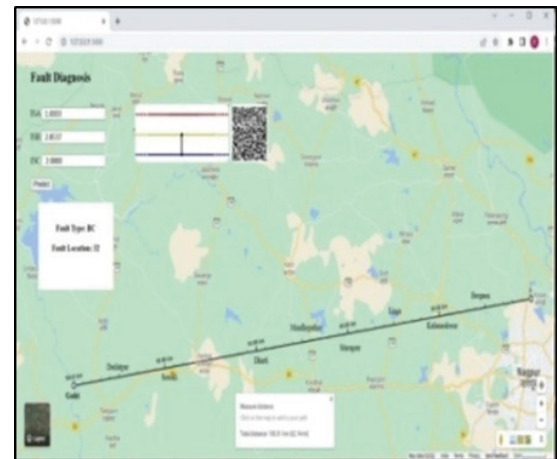
Fig. 14 Outputs

Fig. 15 QR code

CONCLUSION

This study has effectively classified and localized power system issues by using machine learning. Machine learning does not need any explicit programming but requires a database in order to develop the algorithm. So, a transmission line model is developed in the MATLAB/Simulink environment in order to create a synthetic dataset which will become the basis of the whole research. All 10 types of fault are simulated on the designed model and a dataset is created. The dataset consists of current and voltage at the sending and receiving end. However, in the algorithm, only the end-current values are utilized. Multiple Linear Regression, which is a type of supervised machine learning algorithm, is used to develop an algorithm was created in the Python environment known as ANACONDA

(Spyder IDE), that is the Environment for Scientific Python Development, user interface (webpage) was created by using HTML.

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Condition Monitoring of Power Transformer using Fuzzy Logic Approach

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ABSTRACT

Failures of power transformers are nearly invariably catastrophic and result in irreversible internal damage. Several condition monitoring strategies can be used to optimise maintenance schedules. Power transformers have been designed with the aim of minimising operating expenses, boost and increase operational dependability, Power supply as well as customer service. In order to increase the dependability of electric power systems, preventative diagnosis and maintenance of these transformers have become increasingly important in past few years. Most of distribution transformers in the field actually fail owing to overloading, unexpected temperature increases, transformer oil leaks, and improper maintenance. Dissolved Gas Analysis (DGA) is a professional and extremely sensitive method for detecting possible electrical failures. This paper presents a novel fuzzy logic method to lessen reliance on expert professionals as well as to support DGA interpretation standardization methods. In situations where no calculations are required, an expert system can be utilised as a substitute to traditional approaches. Additionally, it provides the user with information on the operating conditions of the transformer and the recommended measures that should be taken in order to prevent failures. The outcomes showed that the precision of forecasts 95% of the Fuzzy based approach was derived from IEC ratio calculations.

KEYWORDS : *Condition monitoring, Dissolved gas analysis, Power transformer, Fuzzy logic, IEC gas ratio method.*

INTRODUCTION

For electrical companies to give their consumers a consistent power supply, its infrastructure is vital. Among the most crucial and expensive components of the power system's infrastructure is the power transformer, and the safety of power operations is directly impacted by the transformer's dependability [1]. Condition monitoring and maintenance monitoring of power transformers are crucial for asset managers since their failure might result in a reduction in transfer capacity or possibly fatal consequences. However, due to its complex and interdependent subsystems, transformer health condition estimation is a challenging task [2-5].

One extremely effective method for keeping a gaze on transformers while they are in service is dissolved gas analysis, or DGA. This test can pinpoint an underlying issue, provide an early diagnosis, and raise the likelihood of locating the right treatment [6]. The working idea is based on the insulation's gradual, innocuous deterioration that occurs with developing defects. It takes the form of hot spots brought on by

unusually high current densities in conductors or sparks or arcs from the dielectric failure of strained or weak insulating parts [7].

Regardless of the source, These strains will lead to the chemical breakdown of particular amounts of the oil molecules and cellulose that comprise the dielectric insulation. Gases are the primary by-products of degradation, which are dissolved fully or partially in the oil and are readily identified by DGA at the level of parts per million (ppm) [8]. Many interpretation techniques, including as the Rogers, IEC Ratio Codes and DUVAL's Triangle approaches are based on DGA and are used to assess the type of transformer deterioration. These techniques were established after extensive research on the gases produced by particular faults [9]. Gases formed inside the transformer oil that leads to possible determination of faults are Methane - CH4, Ethylene – C2H4, Ethane – C2H6, Hydrogen – H2, Acetylene - C2H2,. Possible faults that can be detected by interpreting DGA results are [10,11],

- Arcing – It occurs when acetylene and hydrogen are created in high proportions. The two main minor amounts that decompose are ethylene and methane. Arcing happens at high temperatures and currents.

- Corona – Corona is an electrical defect with low energy. The two main by products that cause corona are methane and hydrogen.

- Thermal Heating - Aside from trace amounts of hydrogen and ethane, the principal breakdown gases are methane and ethylene. This is associated with temperature increase of transformer.

In the conventional method, human professionals' experience is required to evaluate the results and diagnose the power transformer failure. There is a pressing requirement for growth because there are instances when a great deal of ambiguity and discrepancy has been absorbed regarding the results interpretation by various human specialists. This paper explains the AI techniques utilised for DGA.

IEC RATIO METHOD

The 1978 assessment, which can be found in "Interpretation Guide for the Analysis of Gases in Transformer and Other Oil-filled Service Equipment" served as the foundation for this IEC standard. Further this is well interpreted and modified in [12]. This method gives the assessment of the condition of the transformer and the possible incipient fault developing inside the transformer and if not diagnosed properly, can lead to permanent failure of the transformer [13]. Each ratio is calculated using the individual gas, and displayed the limits that are assigned to it in table 1 and 2.

Table 1 IEC Ratio Codes

Ratio Code	Range	Code
R1 C_2H_2/C_2H_4	$x < 0.1$ $0.1 \leq x \leq 3$ $x > 3.0$	0 1 2
R2 CH_4/H_2	$x < 1.0$ $0.1 \leq x \leq 1$ $x > 1$	1 0 2
R3 C_2H_4/C_2H_6	$x < 1.0$ $1.0 \leq x \leq 3.0$ $x > 3.0$	0 1 2

Table 2 Fault Classification using IEC Ratio Codes

R1	R2	R3	Diagnosis
NS	<0.1	<0.2	KD(Partial Discharge)
>0.1	0.1-0.5	>1	D1 (Low Energy)
0.6-2.5	0.1-1	>2	D2 (Arcing of High Energy)
NS	NS	<1	T1 (300˚<Thermal Fault)
< 0.1	>1	1-4	T2 (300˚<Thermal Fault<700˚)
<0.2	>1	>4	T3 (Thermal Fault> 700˚)

IMPLEMENTATION OF FUZZY LOGIC

Three sequential processes are used in the fuzzy logic control system: fuzzification, fuzzy inference, and defuzzification. A crisp value of gas ratio is transformed into a fuzzy input membership by fuzziness. A chosen fuzzy inference system (FIS) is tasked with drawing inferences from the knowledge-based fuzzy rule set of if-then logic based statements [11]. The fuzzy output values are subsequently transformed back into clear output actions using defuzzification.
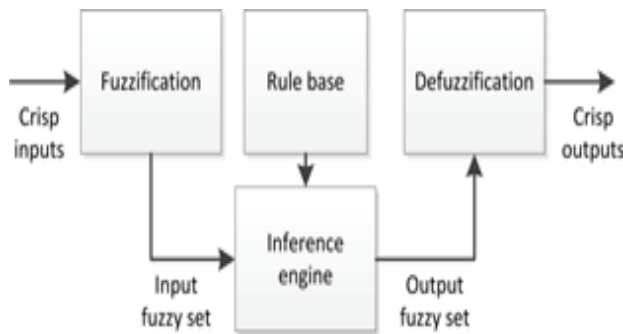
Fig. 1 Flow Diagram for Fuzzy Logic Implementation

As seen in Figure 1, the fuzzy system is developed by identifying the fuzzy input and output variables needed to build the fuzzy logic model towards the IEC gas ratio codes as interpreted and indicated in Table 1 and 2.

Choice of Membership function (mf)

For gaining specific linearity, trapezoidal mf is selected in this work as the gas ratios are specified in specific ranges. This function can be defined as below that if, p, q, r and s represents the x coordinates of the membership function, then

$$Trapezoid(x; a, b, c, d) = 0 \ if \ x \le p$$
$$= (x\text{-}p)/(b\text{-}p) \ if \ p \le x \le q$$
$$= 1 \ if \ q \le x \le r;$$
$$= (s\text{-}x)/(s\text{-}r) \ 0 \ if \ r \le x \le s;$$
$$= 0, \ if \ s \le x.$$

$$\mu_{trapezoid} = \max(\min(\frac{x-p}{q-p}, 1, \frac{s-x}{s-r}) \quad (1)$$
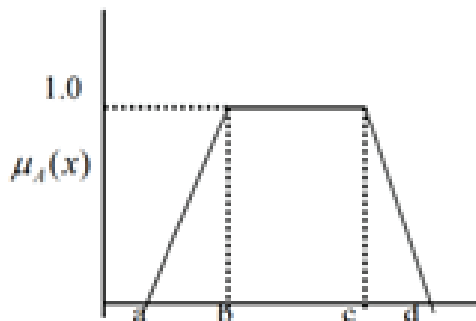
Fig 2 Trapezoidal Membership Function

Figure 2 show mathematical interpretation of trapezoidal mf as per equation 1. that can be easily implemented in FIS in MATLAB.

Implementation in MATLAB

As shown in Figure 3, rule base is designed in the FIS toolbox in MATLAB software by using trapezoidal mf and ratio codes indicated in Table 1.

Fault classification using trapezoidal mf for input and output gas ratios as per conditions given in table II is shown in Figure 4 and 5.
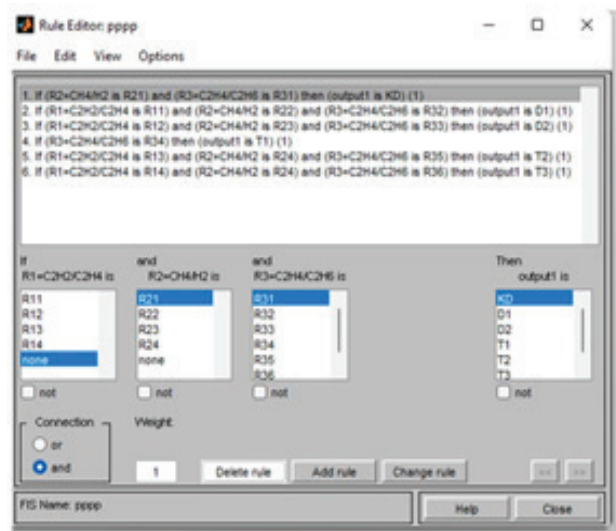
Fig. 3 Design of Rule Base
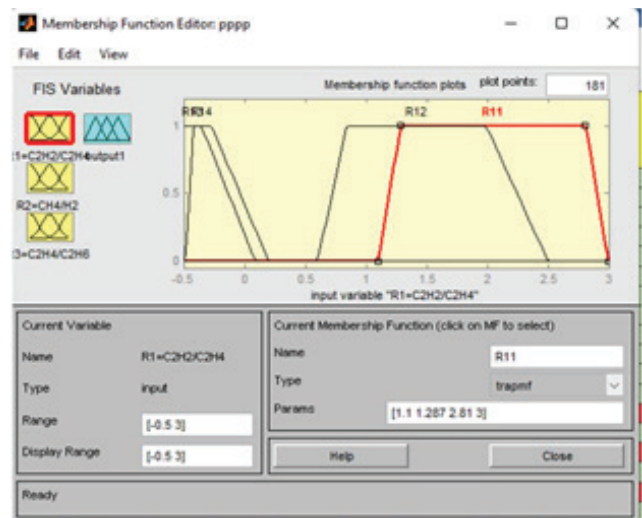
Fig. 4 Input Membership Functions
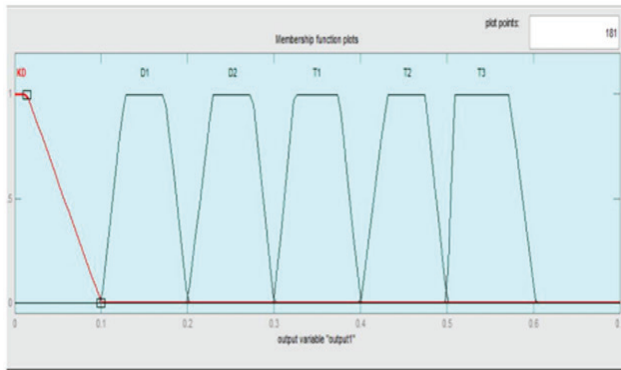
Fig. 5 Output Membership Functions

Output of FIS with the designed rule based can be visualized in FIS as shown in figure VI but needs to be interpreted as the input and output are in crisp form.

CASE STUDY

Designed system in the previous section is tested using DGA data for the utility transformer of 50 MVA,
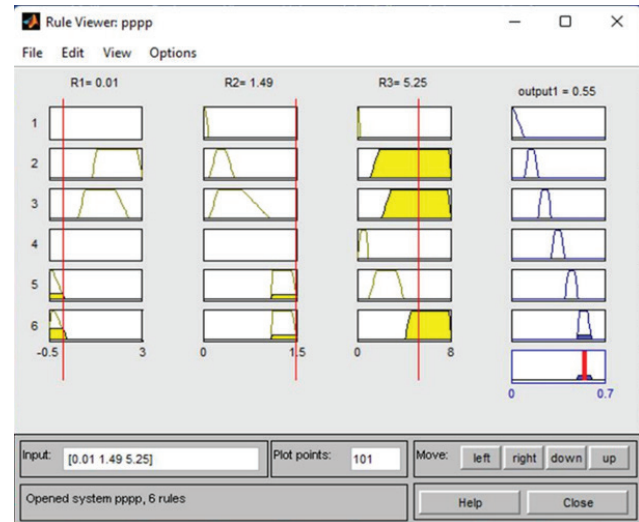
Fig. 6 Output of FIS

132/33kV located at MSETCL, Amravati. Out of the 25 power transformer test cases that are examined, 19 are found to be normal, and 6 test cases are found to be faulty as indicated in table III.

Table 3 Results of Fault Diagnosis by Fuzzy System

H2	CO	CH4	CO2	C2H4	C2H6	C2H2	R1	R2	R3	Diagnosis by Fuzzy system
0	276	8	1872	6	0	0	0	NS	NS	(Normal)
0	272	8	1804	6	0	0	0	NS	NS	(Normal)
581	141	31	899	49	2	0	0	0.08	24.5	(Normal)
0	123	21	796	42	20	0	0	NS	2.1	(Normal)
0	134	18	805	44	18	0	0	NS	2.44	(Normal)
63	205	15	862	0	0	0	NS	0.23	0	(Normal)
68	212	16	878	0	0	0	0	0.235	0	(Normal)
616	171	30	976	33	2	343	10.91	0.0487	16.5	(Normal)
0	58	8	448	23	4	0	0	NS	5.75	(Normal)
0	54	9	432	25	5	0	0	NS	5	(Normal)
0	278	5	1872	5	0	0	0	NS	NS	(Normal)
0	270	4	1861	5	0	0	0	NS	NS	(Normal)
9	831	302	3936	651	124	9	0.01	33.55	5.25	0.55 (T3)
13	420	4	3041	37	1	0	0	0.3	37	(Normal)
149	112	117	1570	211	28	190	0.9	0.78	7.53	0.25 (D2)
2	2	0	56	0	0	0	0	0	0	(Normal)
690	14	284	131	494	50	525	1.06	0.41	9.88	0.249 (D2)
0	10	1	200	4	0	0	0	NS	NS	(Normal)
127	602	780	5038	1077	137	19	0.01	6.14	7.86	0.55 (T3)
82	397	359	2739	401	196	0	0	4.37	2.04	0.35 (T2)
2	7	2	335	3	0	0	0	1	NS	(Normal)
522	672	50	2294	23	8	27	1.17	0.095	2.87	(Normal)

5	708	5	5416	46	2	1	0.02	1	23	(Normal)
153	133	175	2216	202	72	4	0.019	1.143	2.805	0.451 (T2)
135	185	13	1100	7	8	0	0	0.096	0.875	(Normal)

DISCUSSIONS

As per the results shown in table III, in the diagnosed six faulty cases, internal high energy arcing is observed and has been matching with the actual diagnosis. Some hot spots may be created into the tank. On the other hand, remaining cases are found as normal. This transformer is highly recommended for the continuous monitoring of its loading condition and development of other hot spots.

CONCLUSION

It can be concluded that implementing expert system in the conventional IEC ratio method gives better accuracy in the fault diagnosis of the transformers. The densities of the gases discharged owing to power transformer failures were used in this study's dissolved gas analysis. For failure analysis, IEC gas ratio using fuzzy logic systems is applied to 25 samples of readings of gas concentration, which is based on the threshold values of the generated gases as a result of the fault. Results have shown better accuracy in determining the transformer insulation condition and validated with the actual transformer condition. Performance of the designed system is found satisfactory and in future can be combined with other methods to gain highest accuracy level.

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Design and Analysis of Optimized Multiband Microstrip Planar Patch Antenna for Wireless Applications

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ABSTRACT

A multiband microstrip planar patch antenna (MMPPA) that functions at 2.44 GHz, 4.51 GHz and 5.29 GHz frequencies is proposed in this paper. The antenna is specifically tuned to work at these frequencies, making it well-suited for use in Wi-Fi, Bluetooth and a variety of industrial, scientific, and medical (ISM) band applications within wireless communication systems. The compact microstrip design of the antenna ensures seamless integration with modern communication devices. Keysight's Advanced Design System (ADS) is used to analyze the antenna's gain, return loss, bandwidth and radiation efficiency. The results show that the antenna has good impedance matching at the specified frequencies, with return loss values below -10 dB and satisfactory gain across all bands. Furthermore, the antenna demonstrates stable radiation characteristics and has a directional pattern which is suitable for wireless applications. This paper provides a thorough approach for creating optimized multiband microstrip antennas, which will help researchers improve the performance of wireless communication systems.

KEYWORDS : *Bandwidth, Gain, Efficiency, Return loss, etc.*

INTRODUCTION

In modern wireless communication systems, the demand for compact, efficient, and versatile antennas has significantly increased. Microstrip patch antennas are well-known for their planar structure and easy integration into various systems and hence they have become a popular choice for various applications. Among these, multiband antennas, which can operate efficiently at multiple frequencies, are particularly valuable for devices that must support different communication standards.[1]

This article is centered on the creation and examination of a multiband microstrip patch antenna operating at three distinct frequencies: 2.44 GHz, 4.51 GHz, and 5.29 GHz. These frequencies are strategically chosen to cover multiple wireless communication bands, including the widely used ISM band and higher frequency bands that are increasingly relevant for advanced wireless communication technologies.

The design process involves optimizing antenna dimensions, substrate selection, and feeding techniques to achieve resonance at specified frequencies while maintaining acceptable levels of return loss, gain, and radiation efficiency. The analysis includes simulation-based evaluations of characteristics related to how well a system performs, including factors like return loss, radiation pattern., and bandwidth. This paper aims to contribute to the development of antennas suitable for multifunctional wireless devices by achieving a

compact multiband design. Multiple resonant modes are created by adjusting the patch size and shape, enabling the antenna to transmit and receive signals over a wider frequency range. The resonant modes can be excited by changing the patch size or using different feeding mechanisms. Advantages of a multiband microstrip patch antenna include compact size and suitability for use in portable devices.[2][3]

A multiband microstrip patch antenna has high efficiency, selective resonant modes, wide bandwidth, and the ability to switch between frequency bands. However, it also faces challenges in achieving good impedance matching and requires complex design and fabrication processes. The fabrication process also requires precision machining and printing techniques to ensure accurate dimensions and alignment. Despite these limitations, multiband microstrip patch antennas are commonly utilized in contemporary communication systems because of their small dimensions, high efficiency, and wide bandwidth. Microstrip patch antennas offer good impedance matching and low cross-polarization, which leads to reduced interference and improved signal quality. Further advancement in this area will boost the significance of multiband microstrip patch antennas in the future.[4][5]

REVIEW OF RELATED LITERATURE

The development of multiband microstrip planar patch antennas is of utmost importance to significantly enhance the performance and efficiency of modern wireless communication systems.[6] To achieve this, researchers have implemented several design approaches and techniques, including slot-loading, the utilization of Defective Ground Structure (DGS), the incorporation of stacked patches, the integration of parasitic elements, and the incorporation of fractal geometries. These endeavors have resulted in remarkable advancements in achieving multiband operation, which in turn has facilitated the integration of these antennas into a wide array of applications.[7][8] Research is still underway to enhance the capabilities of multiband antennas while also tackling the challenges they present. These efforts are crucial in ensuring the continuous progress and evolution of wireless communication systems as shown in Table I. This literature review serves to emphasize the indispensability of multiband microstrip planar

patch antennas and underscores the substantial impact they have on the ever-evolving and dynamic field of wireless communication. Through their continued refinement and innovation, these antennas will continue to revolutionize and shape the future of wireless communication systems.[9][10]

Table 1 Evolution of Antenna Design: Key Factors, Techniques and Impact

Antenna Stages	Key Factor	Techniques	Impact
Initial Development [11]	Single-band operation.	Rectangular/ circular patch designs.	Compact, low-profile antennas
Multiband Techniques [12]	Multiband operation.	Slot loading, parasitic elements.	Supports multiple frequency bands.
Bandwidth Enhancement [13]	Increasing bandwidth.	Stacked patches, DGS.	Broader frequency range.
Compact Design [14]	Reducing antenna size.	Fractal geometries, miniaturization.	Fits in smaller devices like IoT systems.
Advanced Materials [15]	Performance improvement.	Metamaterials, graphene.	Higher gain, more frequency bands.
Future Advancement [16]	Overcoming fabrication challenges.	Smart materials, AI-driven optimization.	Efficient, high-performance future antennas.

Table 2 Comparative Analysis of Antenna Designs: Year-Wise Parameters, Performance and Usage

Design Year Parameter	2021 [18]	2022 [19]	2023 [20]	2024 Proposed Antenna
Resonant Frequency	2.4 GHz, 3.5 GHz, 5.0 GHz	2.4 GHz, 3.0 GHz, 5.0 GHz	2.4 GHz, 3.6 GHz, 5.8 GHz	2.44 GHz, 4.51 GHz, 5.29 GHz
Return Loss (dB)	-17 dB, -19 dB, -20 dB	-16 dB, -18 dB, -22 dB	-19 dB, -21 dB, -23 dB	-13.9dB, -22.9 dB, -25.9 dB
Gain (dBi)	6.0 dBi, 6.5 dBi, 7.0 dBi	6.2 dBi, 6.8 dBi, 7.2 dBi	6.7 dBi, 7.1 dBi, 7.3 dBi	6.2 dBi, 6.8 dBi, 7.1 dBi
Size (mm²)	55 x 55	65 x 65	70 x 70	38 x 25
Substrate Material	Taconic TLY-5	FR4	Rogers RT/Duroid	FR4
Substrate Thickness	1mm	1.2mm	1.5mm	1.6mm
Dielectric Constant	2.5	3	2.2	4.4
Usage	WLAN, Bluetooth	WLAN, Cellular	WLAN, Satellite	Wi-Fi, WLAN, Bluetooth
Complexity	low	High	High	Low

This research paper focuses on Multiband Microstrip Planar Patch Antenna, exploring different designs and their effectiveness. Multiband antennas offer versatility in wireless communication systems, and their advantages include size, weight, cost, and performance. The analysis examines various parameters as shown above in Table II.ADS simulation tool and Rohde & Schwarz Vector Network Analyzer(VNA) are used for accurate results. Various antenna configurations, materials, and substrate properties are considered. The findings aid in selecting the most suitable antenna for specific applications, contributing to the development of wireless communication systems.

DESIGN OF MMPPA

Designing an antenna involves systematic steps for optimal performance. First, choose resonant frequencies for the target application. Select substrate height and dielectric constant. Decide on patch and ground plane size. Choose feed point location for impedance matching. Simulate antenna using Keysight's ADS software. For multiband operation of antenna FR4(Flame Retardant 4) substrate with dielectric constant 4.4 and thickness 1.6 mm is chosen due to low profile.[17] The design of a MMPPA was done using essential equations as stated hereafter. The width of the patch is calculated by (1) where, c is velocity of light in vacuum, f is the operating frequency of the antenna, and ε_r is the dielectric constant of the substrate. Effective dielectric constant (ε_{reff}) is calculated by (2) where, h is the height of the dielectric substrate. The effective length (Leff) of the patch is calculated by(3), extension length (ΔL)due to fringing fields is calculate by(4), and actual length of the patch(L) is calculated by (5).

$$w = \frac{c}{2f} \times \sqrt{\frac{2}{\varepsilon_r + 1}} \tag{1}$$

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{-\frac{1}{2}} \tag{2}$$

$$L_{eff} = \frac{c}{2f\sqrt{\varepsilon_{reff}}} \tag{3}$$

$$\Delta L = 0.412h \frac{(\varepsilon_{reff} + 0.3)\left(\frac{w}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{w}{h} + 0.8\right)} \tag{4}$$

$$L = L_{eff} - 2\Delta L \tag{5}$$

The ground plane length(Lg) and width (Wg) is calculated by (6) and (7) respectively.

$$L_g = 6h + 1 \tag{6}$$

$$W_g = 6h + w \tag{7}$$
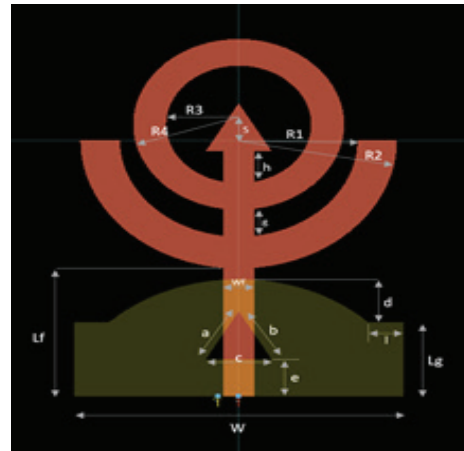
Fig. 1 Proposed Antenna Structure

The design utilizes microstrip line feeding. It is important to position the feeding point at the patch's location where the input impedance is 50 ohms for the resonant frequency. Feedline and slot dimensions are calculated by[21].The radius of the patch (r) is calculated by (8). The proposed antenna structure is shown in Figure 1, the computed parameters are shown in Table 3, and the designed prototype is shown in Figure 2.

$$r = \frac{87.9 \times 10^6}{f\sqrt{\varepsilon_r}} \tag{8}$$

Table 3 Calculated Parameters of Proposed Antenna

Parameter	Size	Parameter	Size
L	38 mm	a	5.1 mm
W	25 mm	b	5.1 mm
Lg	7 mm	c	5 mm
Wg	2.5 mm	d	4 mm
Lf	12.2 mm	e	3.4 mm
R1	9 mm	g	2.5 mm
R2	12 mm	h	1.6 mm
R3	5.6 mm	l	2.7 mm
R4	8 mm	s	1.45mm
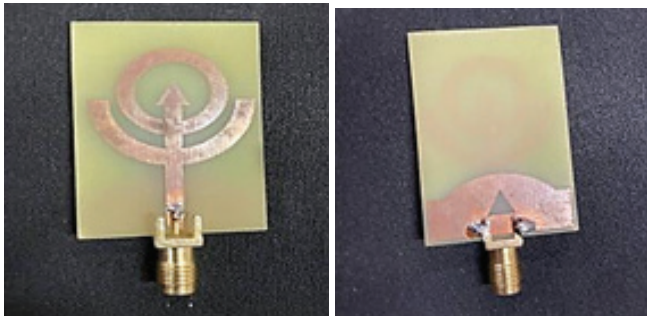
Fig. 2 Fabricated Antenna Structure on FR4 Substrate (Front View and Back View in Order)

RESULT AND ANALYSIS

As shown in Figure III, simulated return losses for three different frequencies m1, m2, and m3 are -24.005dB, -29.702dB, -17.896dB respectively on ADS whereas measured return losses on VNA are -13.987dB, -22.951dB, -25.907dB respectively. All return losses are below -10dB, so more than 90% of power is delivered to the MMPPA and less than 10% of power is radiated back.
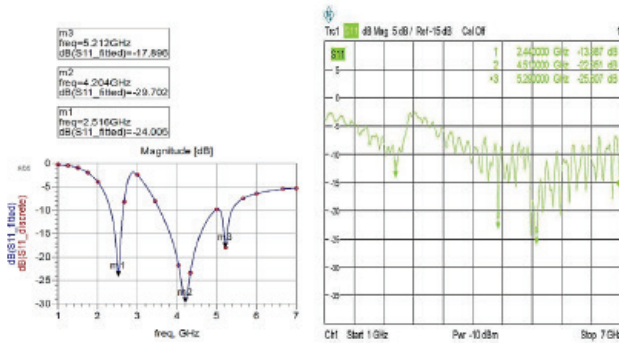
Fig 3 Simulated and Measured Return Loss

In contrast to the outcomes generated through simulation, the return loss of the higher frequency band is improved from -17.896dB to -25.907dB hence power will be delivered to the antenna practically.

A low VSWR indicates a more effective impedance match, resulting in increased power transfer from the radio or transmission line to the antenna. Conversely, a higher VSWR indicates a less effective impedance match, leading to decreased power transfer from the radio or transmission line to the antenna.[22] As shown in Figure 4, the measured VSWR of the proposed antenna for three different frequencies 2.44 GHz,

4.51 GHz, and 5.29 GHz are 1.461, 1.171, and 1.111 respectively which is below 2 and hence proved the good impedance matching of MMPPA.As shown in Figure V, various parameters like gain and return loss are measured on Rohde & Schwarz ZVL VNA available in the Communication Engineering Laboratory at the Department of Electronics and Telecommunication Engineering of Shri Sant Gajanan Maharaj College of Engineering Shegaon, Maharashtra State, India.
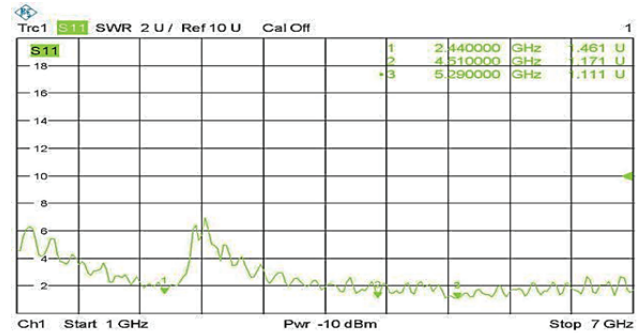
Fig. 4 Measured Voltage Standing Wave Ratio(VSWR)

Figure 5. Measurements of Various Parameters of MMPPA of VNA
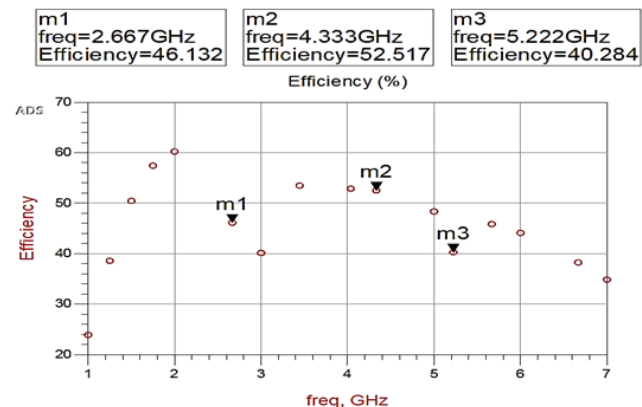
Fig. 6 Simulated Efficiency of MMPPA on ADS
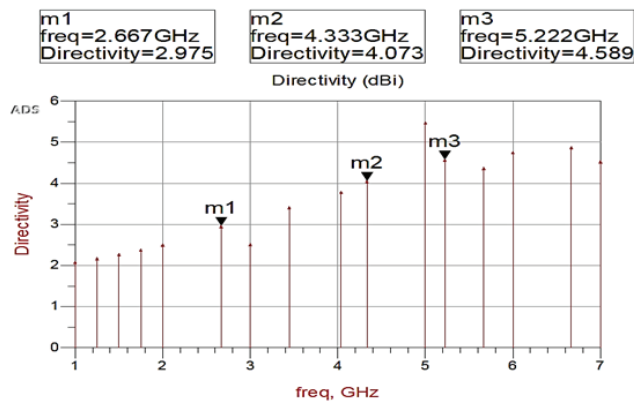
Fig. 7 Simulated Directivity of MMPPA on ADS

As shown in Figure VI, the efficiency of our proposed MMPPA for three different frequencies m1, m2, and m3 are 46.132%, 52.517%, and 40.284% respectively whereas Figure VII shows the directivity of 2.975dBi, 4.073dBi, and 4.589dBi respectively for same frequencies which are well suited for the specified applications. It's important to note that the gain may vary for different frequency bands due to the antenna's design and the characteristics of the frequency bands themselves. The gain is typically determined based on the antenna's radiation pattern, directivity, and other factors.

CONCLUSION

The design and analysis of proposed MMPPA was completed using Keysight's ADS and VNA. Through the utilization of these advanced tools, both simulated and measured results of the MMPPA have showcased exceptional agreement, validating its optimized performance in terms of patch size, return loss, directivity, and bandwidth. With such promising results, the versatility of the designed antenna allows for its effective application in various domains which encompasses a variety of technologies such as Wi-Fi, Wireless Local Area Network (WLAN), and Bluetooth. Considering its wide range of potential uses, the MMPPA stands as a testament to its efficiency and adaptability. Thus, it serves as a reliable choice for diverse wireless communication requirements.

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Thermoacoustic Investigation of Ehtanol Bended Gasoline

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ABSTRACT

The density, viscosity, surface tension and ultrasonic velocity have been measured in the binary mixture of gasoline with ethanol. The thermo-acoustic studies were carried out at different temperatures ranging from 298.15 to 318.15K having difference of 5K. Thermo-acoustical properties such as solvation number (Sn), relative association (R_A), ultrasonic relaxation time (τ_u), dielectric relaxation time (τ_{Di}) were estimated and examined in the present work. The acoustic and thermodynamic properties have been analyzed to investigate the notable interactions occurring between the molecules in the binary mixtures. Solvation is more effective at lower concentrations but becomes less efficient as more solute is added. At higher temperatures, RA values are notably higher compared to lower temperatures. This suggests that the degree of molecular association or interaction within the ethanol-blended gasoline becomes more pronounced as both temperature and concentration increases.

KEYWORDS : *Gasoline nanofluid, Ultrasonic velocity, Binary mixtures and Intermolecular interactions.*

INTRODUCTION

The development and efficiency of a country's infrastructure largely relies on its communication and transportation networks. These systems are categorized into three main modes: land, air, and marine transport. A key component that powers all these transportation methods is gasoline, a crucial petrochemical product. To address this issue, scientists have been exploring alternative fuels or additives that could mitigate both the fuel shortage and pollution [1]-[3]. One promising solution identified through research is ethanol, which has proven to be an effective gasoline additive. Ultrasonic techniques, which have been recognized as powerful tools for examining solute-solvent interactions, allow for the measurement of parameters derived from ultrasonic velocity and the corresponding excess functions in mixtures of gasoline and ethanol. These measurements offer valuable insights into molecular associations, packing, movement, and various types of intermolecular interactions [4]-[9]. Thus, this study aims to explore the potential associations and interactions between gasoline and ethanol at the molecular level.

This study explores the thermoacoustic properties of ethanol-blended gasoline, focusing on solvation number, relative association, ultrasonic relaxation time, and dielectric relaxation time. By analyzing various ethanol concentrations in gasoline, we observed how ethanol affects solvation dynamics and molecular interactions [10]. The solvation number and relative association parameters revealed significant changes in how ethanol interacts with gasoline molecules, while ultrasonic and dielectric relaxation times provided insights into how the blend alters acoustic and dielectric responses [11]-[12]. The thermo-acoustic studies of ethanol blended gasoline elaborate deeper understanding of particle–fluid, particle–particle interactions as functions of concentration, temperature [13]-[14]. In addition, the paper is intended to formulate a relationship between thermo-acoustic properties and concentration of ethanol in gasoline. Our findings indicate that ethanol blending notably impacts the thermoacoustic characteristics of gasoline, suggesting alterations in fuel properties that could influence performance and acoustic sensing applications.

EXPERIMENTAL

Ultrasonic interferometer model F-81 of fixed frequency 2 MHz having accuracy. 03% and hydrostatic plunger method having accuracy. 05% were used for measurement of ultrasonic velocity and density, similarly Ostwald viscometer having accuracy. 01% and stalagmometer method having accuracy. 02% were used for measurement of viscosity and surface tension of different percentage of volume concentration of ethanol from 5%, 10%, up to 95% in gasoline at different temperatures. The calibration of the apparatus was done with air and deionizer double-distilled water.

RESULTS AND DISCUSSION:

The values of salvation number (Sn), relative association (RA), ultrasonic relaxation time (τ_u), dielectric relaxation time (τ_{Di}), excess adiabatic compressibility (β_{ad}^E), and excess volume (V^E) have been calculated using following formulae-

$$S_n = \frac{n_1}{n_2}\left(1 - \frac{\beta_{ad}}{\beta_{ad}^0}\right) \qquad (1)$$

$$R_A = \left(\frac{\rho}{\rho_0}\right)\left(\frac{u_0}{u}\right)^{1/3} \qquad (2)$$

$$\tau_u = \frac{4\eta}{3\rho u^2} \qquad (3)$$

$$\tau_{Di} = \frac{3b\eta}{4NKT} \qquad (4)$$

Where, ultrasonic velocity = u,

density = ρ,

viscosity = η,

adiabatic compressibility = β,

Temperature= T.

The experimental values have been found in the table below-

Solvation number, dielectric relaxation time, ultrasonic relaxation time, adiabatic compressibility at different temperatures and at different volume concentrations.

Conc. x %	Sn	RA	τ_u	τ_{Di}
298.15K				
10	0.039903	1.00786	8.73E-11	2.46E-05
20	0.036205	1.01656	9.59E-11	2.38E-05
30	0.031458	1.02498	1.04E-10	2.33E-05
40	0.026815	1.03352	1.12E-10	2.28E-05
50	0.022002	1.04150	1.2E-10	2.24E-05
60	0.017581	1.05044	1.28E-10	2.21E-05
70	0.012986	1.05827	1.35E-10	2.19E-05
80	0.008628	1.06719	1.43E-10	2.17E-05
90	0.004255	1.07500	1.5E-10	2.15E-05

Conc. x %	Sn	RA	τ_u	τ_{Di}
303.15K				
10	0.058590	1.00819	8.73E-11	2.34E-05
20	0.048456	1.01640	9.53E-11	2.26E-05
30	0.041056	1.02459	1.03E-10	2.20E-05
40	0.034438	1.03277	1.11E-10	2.15E-05
50	0.028206	1.04094	1.18E-10	2.11E-05
60	0.022228	1.04910	1.25E-10	2.08E-05
70	0.016444	1.05724	1.32E-10	2.05E-05
80	0.010822	1.06537	1.39E-10	2.03E-05
90	0.005345	1.07349	1.45E-10	2.01E-05

Conc. x %	Sn	RA	τ_u	τ_{Di}
308.15K				
10	0.058590	1.00774	8.62E-11	2.39E-05
20	0.048456	1.01575	9.35E-11	2.45E-05
30	0.041056	1.02374	1.01E-10	2.47E-05
40	0.034438	1.03171	1.07E-10	2.46E-05
50	0.028206	1.03967	1.14E-10	2.42E-05
60	0.022228	1.04762	1.2E-10	2.36E-05
70	0.016444	1.05555	1.27E-10	2.26E-05
80	0.010822	1.06346	1.33E-10	2.14E-05
90	0.005345	1.07137	1.38E-10	1.99E-05

Conc. x %	Sn	RA	τ_u	τ_{Di}
313.15K				
10	0.055039	1.00796	8.54E-11	2.24E-05
20	0.049313	1.01570	9.19E-11	2.28E-05
30	0.042921	1.02343	9.82E-11	2.29E-05
40	0.036479	1.03114	1.04E-10	2.27E-05
50	0.030107	1.03883	1.1E-10	2.23E-05

60	0.023840	1.04650	1.16E-10	2.16E-05
70	0.017694	1.05416	1.21E-10	2.07E-05
80	0.011671	1.06180	1.26E-10	1.95E-05
90	0.005773	1.06943	1.31E-10	1.81E-05

318.15K				
10	0.067781	1.00729	8.415E-11	2.10E-05
20	0.056523	1.01483	8.983E-11	2.12E-05
30	0.047990	1.02235	9.529E-11	2.12E-05
40	0.040267	1.02985	1.005E-10	2.09E-05
50	0.032969	1.03734	1.056E-10	2.04E-05
60	0.025963	1.04480	1.104E-10	1.97E-05
70	0.019190	1.05225	1.151E-10	1.88E-05
80	0.012617	1.05968	1.195E-10	1.77E-05
90	0.006225	1.06709	1.238E-10	1.64E-05

Following graphs shows curves of ultrasonic relaxation time, dielectric relaxation time, adiabatic compressibility and solvation number verses volume concentration.

Fig.2 RA vs. Conc.

Fig.2 Sn vs.Conc.

Fig.1 τ_u vs. Conc.
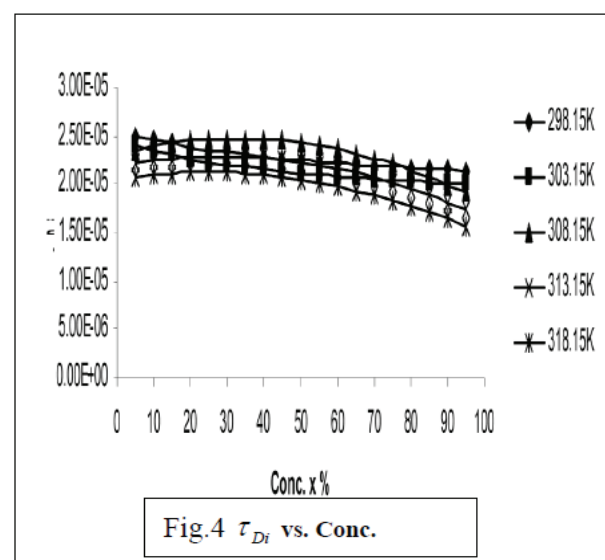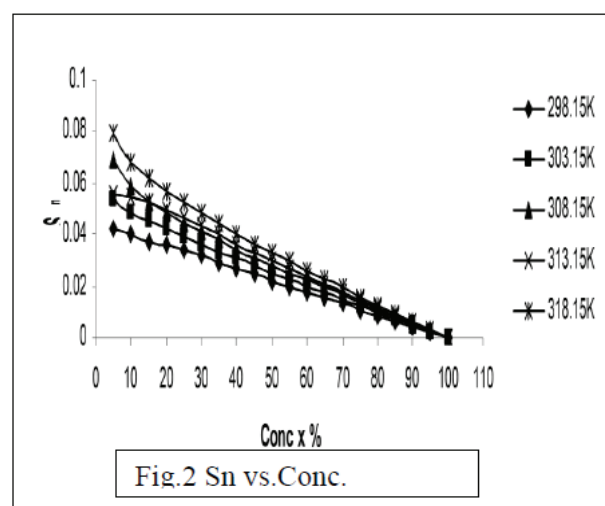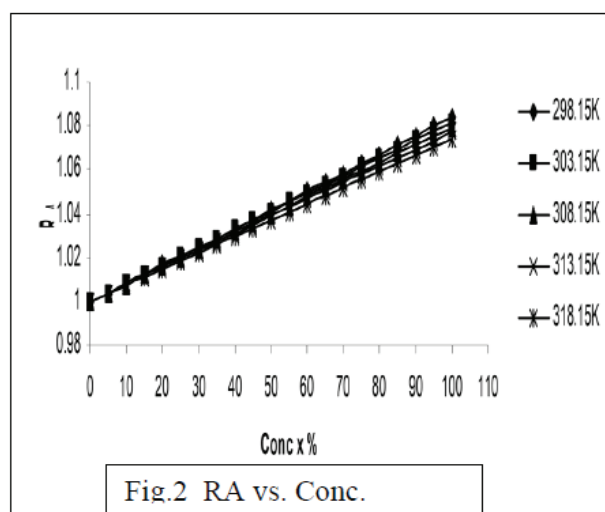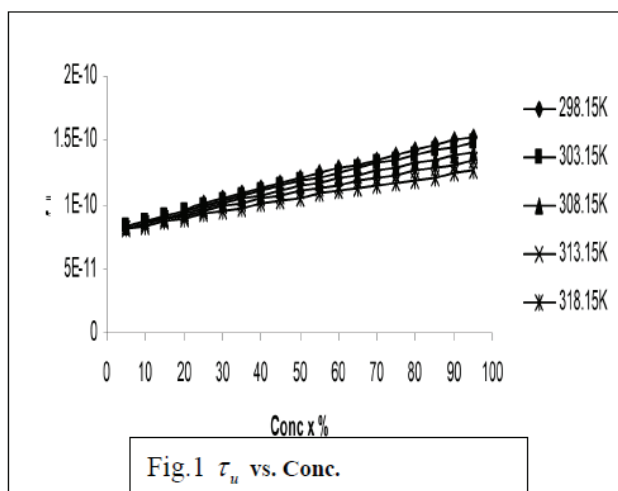

Fig.4 τ_{Di} vs. Conc.

Fig. 1, the ultrasonic relaxation time is higher at lower temperatures and increases further with higher solute concentrations indicates that as the concentration of the solute increases, the time required for the ultrasonic waves to relax is proportionally increases. This suggests that higher solute concentrations it will more resistance or complexity to the propagation of ultrasonic waves. The higher value of relaxation time at lower temperatures implies that the solution becomes more resistant to ultrasonic wave propagation, probably due to increased solute-solvent interactions or due to viscosity. Thus, the concentration and temperature on the ultrasonic relaxation process in ethanol-blended gasoline, reveals that how these factors influence the response of the solution to ultrasonic waves. Fig. 2 exhibits the variation of relative association (RA) with percentage volume of mixture at five different temperatures which increased linearly. The increase in RA with concentration suggests that salvation of ions predominates over the breaking up of the solvent aggregates on addition substance. At higher temperatures, RA values are higher as compared to lower temperatures. This suggests that the degree of molecular association or interaction within the ethanol-blended gasoline becomes more prominent as both temperature and concentration increase. The higher RA at elevated temperatures shows enhanced molecular interactions or clustering effects, caused by increased thermal energy. This pattern highlights the influence of both concentration and temperature on the molecular dynamics within the solution, suggesting that increased temperature and concentration enhance the extent of molecular association in ethanol-blended gasoline Fig. 3 shows the variation of salvation number (Sn) with percentage volume of mixture at all five temperatures. The value of Sn decreases with increase in percentage volume which suggest that ethanol is preferentially solvated by gasoline. The positive salvation number of solution suggests that the compressibility of the solution will be less than that of solvent. A high solvation number indicates efficient solvation, where many solvent molecules are interacting with each solute particle. At low concentrations, solvation might be less efficient because there are fewer solute particles for the solvent molecules to interact with. At high temperatures, the solvation number exhibits a high value at low concentrations. This indicates that at elevated temperatures, solvation is more effective at lower concentrations but becomes less efficient as more solute is added. Fig.4 shows a constant value across different concentrations, indicating that concentration does not significantly impact the dielectric response. However, the relaxation time is higher at lower temperatures. This suggests that while concentration has little effect, lower temperatures increase dielectric relaxation time, this is due to reduced molecular mobility or increased viscosity.

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Experimental Evaluation of Heat Transfer Characteristics in 10 PPI Porous Metal Foam with Al₂O₃/H₂O and Graphene/H₂O Nanofluids

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ABSTRACT

This research presents a novel experimental investigation into the thermal management capabilities of Graphene-water (Gr-H₂O) nanofluids within a 10 PPI porous copper metal foam, and compares their performance with traditional alumina-water (Al₂O₃-H₂O) nanofluids. Addressing a significant gap in experimental validation, this study aims to provide empirical evidence supporting the superior heat transfer performance and cooling efficiency of Gr-H₂O nanofluids. By evaluating both types of nanofluids across a Reynolds number range from 300 to 1800, the study extends beyond existing theoretical and computational findings to offer a practical perspective on advanced electronic cooling applications.

Experimental results reveal that Gr-H₂O nanofluids exhibit notably enhanced thermal performance compared to Al₂O₃-H₂O nanofluids when integrated into 10 PPI porous metal foams. The Graphene-based nanofluids demonstrate superior heat transfer coefficients and cooling efficiency, which can be attributed to the higher thermal conductivity and unique properties of Graphene. This comprehensive analysis not only validates the improved performance suggested by previous simulations but also provides new insights into the practical application of these nanofluids in enhancing electronic cooling systems.

The findings underscore the potential of Graphene-water nanofluids as a promising alternative to traditional nanofluids, highlighting their role in advancing thermal management solutions. This study significantly contributes to the field by bridging theoretical models with experimental data, thereby advancing our understanding and application of advanced cooling technologies.

KEYWORDS : *Heat transfer Coefficient, Nanofluids, Porous media, Temperature Drop.*

INTRODUCTION

Managing heat is one of the key challenges in the development of small, multipurpose electronic devices. While military electronics may produce heat levels above 1000 W/cm², consumer electronics are predicted to produce heat levels exceeding 100 W/cm². Device performance may suffer as a result of the increased heat generated by smaller electronics. The primary issues are (a) inefficient heat evacuation from chips and (b) unequal power dissipation among the device's many components. Chip durability is shortened by high power density, erratic heat creation, and excessive heat production[1]. The increasing need for more effective cooling solutions derives from a number of issues, including confined space for equipment, noise concerns, deploying air cooling systems in confined places, and high heat flux from individual chips [1]. Innovative cooling tackles like as liquid cooling, phase change materials (PCMs), nanofluids, and novel materials like porous metal foams have been developed to meet those challenges[2].

One of the most intriguing techniques among them is the combination of nanofluids and open-cell porous media.

Since adding nanoparticles to base fluids enhances their heat conductivity, nanofluids have attracted a lot of attention lately[3]–[5]. They have a lot of promise, particularly for uses like electrical equipment where there is a need for significant heat dissipation. For example, it has been established that CuO nanofluids surpass pure water 7.7% more thermally when cooling central processing units. Due to this benefit, there is now more interest in blending porous media and nanofluids to improve the thermal performance of high-heat-dissipating devices[6].

CuO-H_2O nanofluids and metal foam heat sinks (Al-6101) raised efficiency by 26.3% to 42.5%, according to a preliminary investigation comparing the two with finned commercial surfaces. Further study into alumina-water nanofluids in a micro heat sink with a copper porous medium under a heat flux of 62.5 W/cm² revealed that heat transfer coefficients and Nusselt numbers were improved by 1% to 22% in high porosity media and 2.3% to 26.4% in low porosity media with increasing Reynolds numbers[7].

Heat transfer was improved in $TiO2$-H_2O nanofluids by 6.3%, 22.9%, and 32.1% at 0.1%, 0.3%, and 0.5% mass percentages in comparison to water. A 35.7% boost in heat transfer efficiency was noticed at a 0.3% weight fraction, which was the best result[8]. However, much of the research in this area relies on numerical methods and CFD simulations

The article evaluated the impacts of uniform and non-uniform velocity impinging jets by doing a numerical analysis of the flow and thermal characteristics of a heat sink coated with open-cell metal foam. Three cooling fluids were examined in the study: hydrogen, air, and Cu-water nanofluid. It emerged that higher nanofluid volume fractions resulted in quicker heat transfer rates[9].

In a separate investigation, a pore-scale method and Buongiorno's model were used to assess the flow characteristics and convective heat transfer of two-phase nanofluid flow in open-cell metal foams (OCMFs). The Brownian force was shown to be responsible for the 2% to 14% improvement in heat transmission in OCMFs at a concentration of 3% nanoparticles. On the contrary hand, heat transfer and Darcy velocity dropped by 4% with a spike in nanoparticle diameter, whereas increasing the particle concentration from 3% to 5% improved heat transfer by up to 10% [10].

Based on the numerical simulation, fluid pressure and velocity decrease as metal foam's PPI (pores per inch) increases. At a fluid velocity of roughly 30 m/s, copper metal foam outscored aluminium metal foams in terms of heat transfer rate by 4–10% [11]. Owing to the simulation results, when metal foam PPI developed, so did the heat transfer coefficient and Nusselt number. The outcomes imply that metal foams have the capacity for better heat transmission in thermal technology applications. Specifically, at an intake velocity of 1 m/s, a 45 PPI metal foam channel carried heat 1.77 times faster than a 10 PPI metal foam channel[12].

Limited experimental work has been done in the subject of thermal management employing porous media and nanofluids, despite a lot of analytical and simulation investigations. By offering experimental validation of previously published theoretical and simulated findings, this study seeks to close this gap [13].

Most previous studies have examined Reynolds numbers (Re) ranging from 200 to 1200. This research extends the investigation to Reynolds numbers between 300 and 1800. The goal is to deepen our understanding of how metal foam structures and nanofluid enhancements interact by studying the thermal behavior of open-cell metal foam combined with Graphene-water & Al2O3-H2O nanofluid. This work is expected to significantly advance knowledge in this area by providing new insights into the combined effects of these cooling technologies.

METAL FOAM SPECIFICATION & PROPERTIES OF NANOFLUIDS.

Metal Foam Specification

This experimental study utilizes open-cell porous metal foam with a pore density of 10 PPI and a porosity of 95%. Notably, porous metal foams are defined by three key properties: porosity, pore density, and pore diameter. Porosity refers to the void spaces within the material that enable fluid flow through the foam. Pore density, measured in pores per inch (PPI), indicates the number of pores present in one inch of the material. Pore diameter represents the average distance between the pores.

Fig. 1: 10 PPI Copper Metal Foam

Preparation & Properties of Nanofluids

Nanofluids can be defined as a fluid in which nanoparticle size metal or metal oxide are dispersed in base fluids like water, glycol [14]–[19]. Popularly, Nanofluids are made by 2 methods, but 2 step methods are used extensively as it is easier and time saving.

Two Step Approach: The technique relies on distinct methodologies for integrating the nanoparticles before dispersing them into the base fluid, which is then followed by techniques such as ultrasonication, stirring, or sonication. [18], [20]–[23].

To calculate the mass of nanoparticles required to achieve a desired volume concentration using the densities of the base fluid and the nanoparticles [24].

$$\varphi = \frac{1}{\frac{\rho_{np}}{\rho_{bf}} \times \frac{100}{m} + 1} \times 100\%$$

(1)

The subscripts np and bf denote the nanoparticle and base fluid, respectively, while φ indicates the volume concentration, m indicates the mass of nanoparticles, and ρ indicates the density (kg/m3) in this instance.

The graphene nanoparticles were weighed using a DAB 220 digital analytical balance, manufactured by Wensar Weighing Scale Ltd., a company based in Chennai, India. The balance has a readability and repeatability of 0.1 mg.

To prepare nanofluids of varying concentrations, the nanoparticles were mixed with distilled water (DW) produced in the laboratory.

The mixture was manually shaken and stirred for 30 minutes, followed by ultrasonication to break up any possible nanoparticle agglomeration.
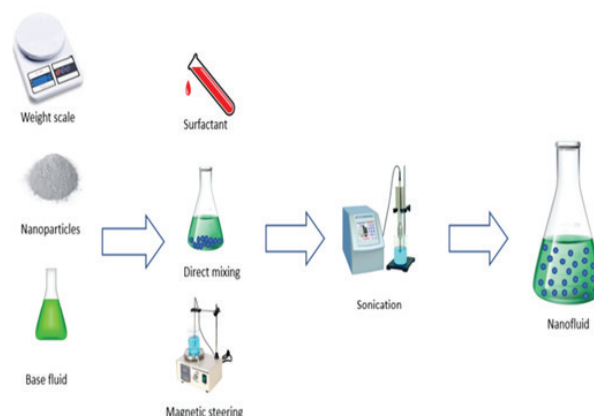
Fig. 2: Two-Step Method for Nanofluid Preparation

This ultrasonication process was conducted at using a Probe Sonicator (manufacturer – Helix Biosciences, India)

EXPERIMENTAL SETUP
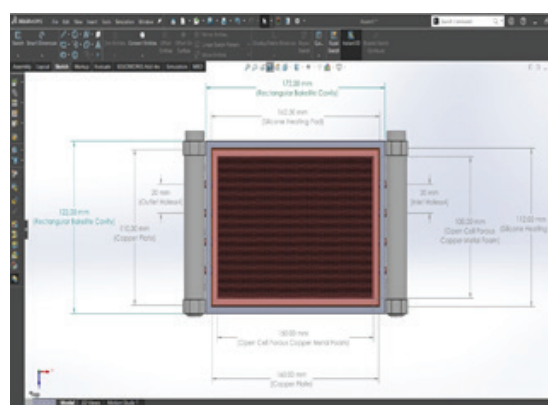
Fig. 3 Experimental Setup & CAD Diagram of Cavity

The experimental setup is meticulously designed with several key components to ensure accurate investigation. In the heating section, a rectangular cavity (170 x 120 x 24 mm) holds a 150 x 100 x 20 mm open-cell metal foam, under which a 1 mm-thick copper plate ensures uniform heating. Heat is applied from three silicone heating pads, each measuring 150 x 100 mm, with a constant heat flux of 45 W. A differential pressure transmitter monitors the pressure drop across the foam. Temperature is measured using eight K-type thermocouples placed in the 10 PPI foam, with two more at the inlet and outlet to track the flowing medium's temperature. The nanofluid is pumped into the cavity at a specific concentration using a 12-volt DC motor, regulated by a wall to ensure even flow. After heating, the nanofluid transfers heat to a water stream in the cooling section before returning to the storage tank in a closed-loop system. Data is recorded through a 16-channel data logger connected to a laptop for real-time monitoring and analysis, providing insights into heat transfer in porous media using nanofluids.

THERMAL ANALYSIS

Thermal Analysis was done using following formulae and investigation was carried out.

Average temperature across the metal foam:

$$T_{wall,avg} = \frac{T_1 + T_2 + T_3 + T_4 + T_5 + T_6 + T_7 + T_8}{8} \tag{2}$$

Average temperature of Nanofluids

$$T_{nf,avg} = \frac{T_9 + T_{10}}{2} \tag{3}$$

Reynolds No is calculated as:

$$Re = \frac{\rho_{nf} \times u \times d_p}{\mu_{nf}} \tag{4}$$

Heat absorbed by the nanofluids in heat sink:

$$Q_{nf} = c_{pnf} \times \dot{m} \times (T_{10} - T_9) \tag{5}$$

Heat transfer Coefficient & Nusselt Number:

$$h = \frac{Q_{nf}}{A \times (T_{wall,avg} - T_{nf,avg})} \tag{6}$$

RESULTS & DISCUSSIONS

For Φ= 0.1% Concentration

Effect on Heat Transfer Coefficient due Al2O3 & Graphene Nanoparticles

The plot shown in figure 4 compares the heat transfer coefficient (h) for three different fluids: distilled water, Al_2O_3-H_2O nanofluid, and Graphene-H_2O nanofluid, at varying Reynolds numbers (Re) and a constant nanoparticle concentration of 0.1%.For all three fluids, the heat transfer coefficient (h) increases with increasing Reynolds number (Re).
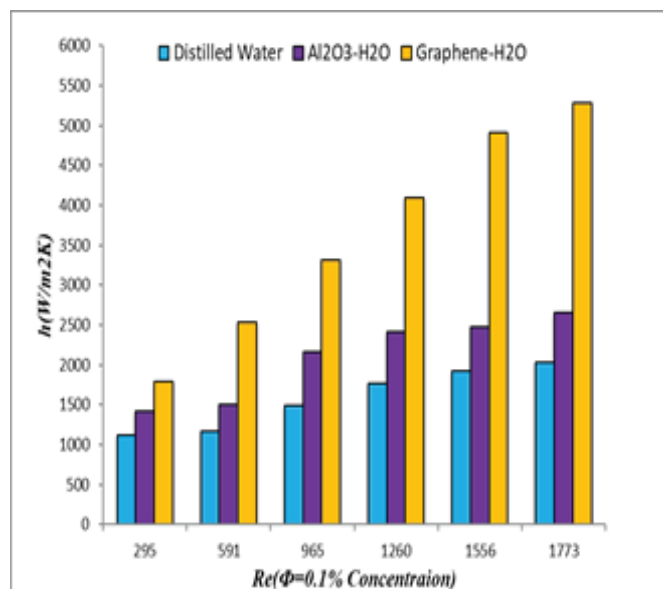
Fig. 4: Heat Transfer Coefficent (H) vs. Reynolds Number (Re)

It is discovered that at low Re the graphene nanoparticles has enhanced heat transfer coefficient by 20.84% and 37.83% compared to Al2O3 nanoparticles & Distilled water respectively. Whereas for higher Re graphene nanoparticles has enhanced heat transfer coefficient by 49.84% and 61.51% compared to Al2O3 nanoparticles & Distilled water respectively. This enhancement is due to graphene remarkable thermal conductivity stems from its distinct atomic structure, robust sp² hybridized bonds, efficient phonon transport, minimal phonon scattering, and the presence of unique phonon modes. These characteristics make graphene an exceptional material for thermal management and enable a wide array of applications in various devices

Effect on Average Wall Temperature due Al2O3 & Graphene Nanoparticles
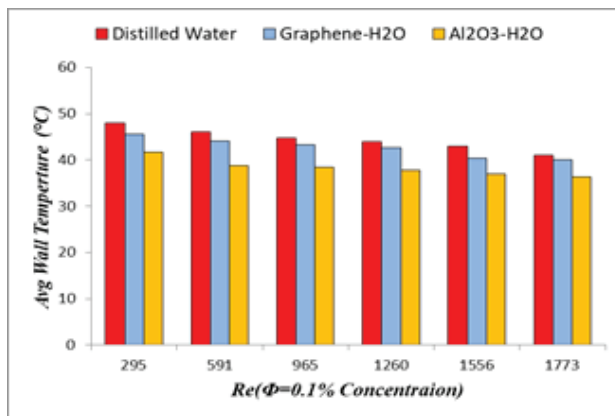
Fig. 5: Average Wall Temperature (H) vs. Reynolds Number (Re)

Figure 5 compares the average wall temperature for three different fluids distilled water, Al_2O_3-H_2O nanofluid, and Graphene-H_2O nanofluid at varying Reynolds numbers (Re) and a constant nanoparticle concentration of 0.1%. It was observed that Al_2O_3 nanoparticles has cooled the heat sink at low Re by 4.94% & 13.28% as compared to graphene nanoparticles and distilled water. Also at higher Re it is noticed that Al2O3 nanoparticles has cooled the heat sink at low Re by 2.43% & 11.52% as compared to graphene nanoparticles and distilled water. The results indicate that Al_2O_3 nanoparticles enhance heat dissipation more effectively than graphene nanoparticles and distilled water, especially at low Reynolds numbers where conduction plays a bigger role in heat transfer. At higher Reynolds numbers, while the cooling effect remains, the difference between the fluids narrows due to the increasing dominance of convective heat transfer in turbulent flow conditions. This highlights the importance of considering both the type of nanoparticles and the flow regime when selecting nanofluid for thermal management applications.

For Φ= 0.3% Concentration

Effect on Heat Transfer Coefficient due Al2O3 & Graphene Nanoparticles

Figure 6 shows compares the heat transfer coefficient (h) for three different fluids: distilled water, Al_2O_3-H_2O nanofluid, and Graphene-H_2O nanofluid, at varying Reynolds numbers (Re) and a constant nanoparticle

concentration of 0.3%. Graphene nanoparticles were found to boost the heat transfer coefficient at low Reynolds numbers (Re) by 10.78% and 59.62%, respectively, when in comparison with Al2O3 nanoparticles and pure water. Graphene nanoparticles outperformed Al2O3 nanoparticles and distilled water in regards to heat transfer coefficient at higher Reynolds numbers, by 5.63% and 75.47%, respectively.
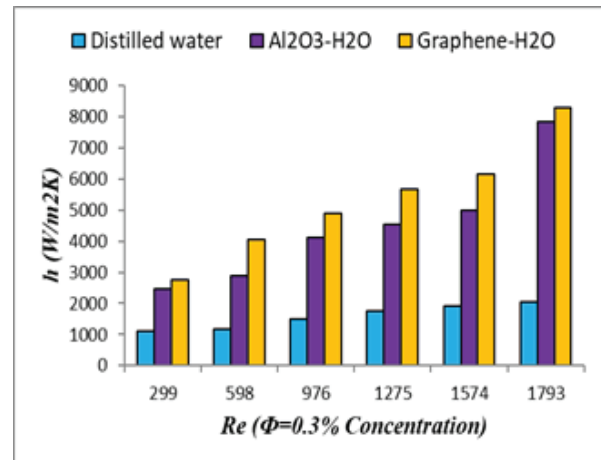
Fig 6: Heat Transfer Coeff, cent (H) Vs. Reynolds Number (Re)

Effect on Heat Transfer Coefficient due Al2O3 & Graphene Nanoparticles
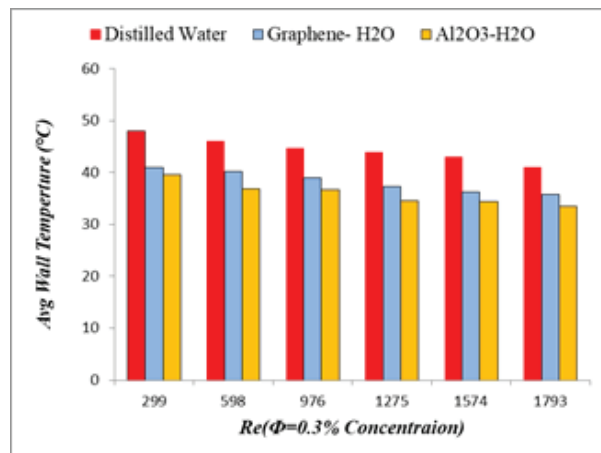
Fig. 7: Average Wall Temperture (H) vs. Reynolds Number (Re)

The average wall temperature for three distinct fluids— distilled water, Al2O3-H2O nanofluid, and graphene-H2O nanofluid—is compared in Figure 7 for varied Reynolds numbers (Re) and a fixed 0.3% concentration

of nanoparticles. In comparison to graphene nanoparticles and distilled water, it was established that Al_2O_3 nanoparticles cooled the heat sink at low Re by 14.84% & 17.70%. In addition, it appears that Al2O3 nanoparticles, as opposed to graphene nanoparticles and distilled water, have cooled the heat sink at low Re by 12.80% and 18.29% at higher Re.

For Φ= 0.5% Concentration

Effect on Heat Transfer Coefficient due Al2O3 & Graphene Nanoparticles
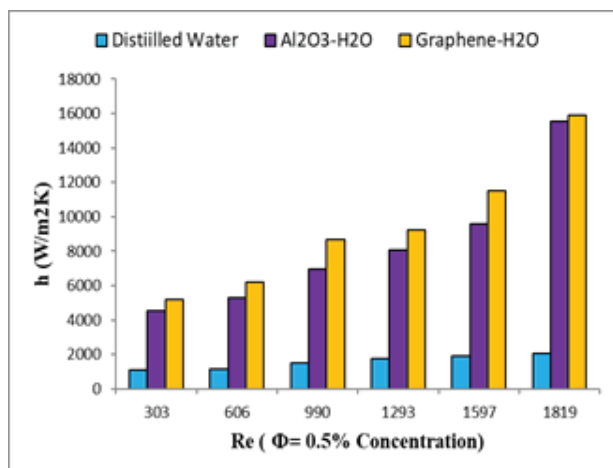
Fig. 8: Heat Transfer Coefficient (H) vs. Reynolds Number (Re)

The heat transfer coefficient (h) of three unique fluids—distilled water, Al_2O_3-H_2O nanofluid, and graphene-H2O nanofluid—at various Reynolds numbers (Re) and a fixed concentration of 0.5% of nanoparticles are compared in Figure 8. When compared with Al_2O_3 nanoparticles and pure water, graphene nanoparticles were observed to raise the heat transfer coefficient at low Reynolds numbers (Re) by 12.82% and 78.59%, respectively. At higher Reynolds numbers, graphene nanoparticles performed superior in terms of heat transfer coefficient than Al2O3 nanoparticles and distilled water, by 2% and 87.19%, respectively.

Effect on Heat Transfer Coefficient due Al_2O_3 & Graphene Nanoparticles

Figure 7 illustrates the average wall temperature comparison for three different fluids: pure water, Al_2O_3-H_2O nanofluid, and graphene-H_2O nanofluid, for a range of Reynolds numbers (Re) and a constant

0.5% concentration of nanoparticles. It was found that Al_2O_3 nanoparticles cooled the heat sink at low Re by 17.18% & 20.05% in contrast to graphene nanoparticles and pure water. Furthermore, it indicates that Al2O3 nanoparticles have cooled the heat sink by 14.93% at higher Re and 22.25% at low Re compared to graphene nanoparticles and pure water.

Fig. 9: Average Wall Temperture (H) vs. Reynolds Number (Re)

CONCLUSION

This study investigates the thermal performance of three different fluids—Al_2O_3-H_2O nanofluid, Graphene-H_2O nanofluid, and distilled water—flowing through a 10 PPI (pores per inch) metal foam.

The study reveals at low Reynolds numbers (Re), graphene nanoparticles improve the heat transfer coefficient by 20.84% and 37.83% relative to Al_2O_3 nanoparticles and distilled water, respectively. At higher Reynolds numbers, the performance of graphene nanoparticles becomes even more pronounced, boosting the heat transfer coefficient by 49.84% compared to Al_2O_3 nanoparticles and by 61.51% compared to distilled water.

By improving heat dissipation, graphene-water nanofluid enables electronic devices to withstand larger power levels without going over their thermal limits. As a result, modern cooling systems can benefit from increased performance, dependability, and possibly longer component lifespans.

In comparison to graphene nanoparticles and distilled water, it was found that Al_2O_3 nanoparticles cooled the heat sink at low Re by 4.94% & 13.28%. In addition, it is seen that Al_2O_3 nanoparticles, as opposed to graphene nanoparticles and distilled water, have cooled the heat sink at low Re by 2.43% and 11.52% at higher Re.

Graphene-water nanofluid relieve thermal stress by dispersing heat more evenly across surfaces, lowering the chance of material degradation and failures in crucial components like CPUs, power transistors, and LEDs. By keeping even, the most heat-intensive locations within safe operating limits, this tailored cooling increases the overall dependability and durability of electronic systems.

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Exploring the Impact of Internet of Things (IoT) Based Instrumentation Applications: Revolutionizing Data Acquisition and Control for Water Treatment Plan

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ABSTRACT

The advent of the Internet of Things (IoT) has marked a transformative period in various industries, with water treatment plants standing out as a significant beneficiary of its capabilities. This paper explores the impact of IoT-based instrumentation applications on data acquisition and control processes within these facilities. By integrating IoT technologies, water treatment processes can achieve enhanced automation, real-time monitoring, and efficient data management, which are critical for optimal operational performance. The deployment of sensors and intelligent devices allows for the collection of extensive data on water quality parameters, flow rates, and chemical usage, facilitating improved decision-making and responsiveness to environmental changes. Moreover, predictive analytics powered by machine learning algorithms enable proactive maintenance and resource management, reducing downtime and operational costs. Case studies illustrate how various water treatment plants have successfully implemented IoT solutions, demonstrating significant improvements in water quality, energy consumption, and compliance with regulatory standards. The paper discusses the challenges and future prospects of IoT integration in water treatment, including data security concerns, connectivity issues, and the need for skilled personnel. Ultimately, this exploration underscores the potential of IoT technologies to revolutionize the operational dynamics of water treatment plants, leading to more sustainable and resilient water management practices in response to growing global demands

KEYWORDS : Internet of Things (IoT), Water treatment plants, Data acquisition, Process control, Smart water management,

INTRODUCTION

The advent of the Internet of Things (IoT) has revolutionized various industries, particularly in the realm of data acquisition and control systems. IoT, characterized by the interconnection of physical devices through the Internet, facilitates the collection, exchange, and analysis of data in real time. This connectivity allows for enhanced monitoring and management of processes across diverse sectors, including healthcare, agriculture, and transportation. However, one area that stands to gain significantly from IoT advancements is water treatment plants, which are critical infrastructures responsible for ensuring the availability of clean and safe water.

Water scarcity and quality have emerged as pressing global issues, exacerbated by urbanization, climate change, and population growth. According to the United Nations, approximately two billion people currently live in countries experiencing high water stress, and this figure is expected to rise dramatically in the coming decades [1]. Consequently, efficient water management and treatment protocols have never been more vital. Traditional water treatment systems often rely on out-dated methodologies that lack real-time data capabilities, leading to inefficiencies, higher operational costs, and compromised water quality. The integration of IoT-based instrumentation applications presents a transformative approach that can significantly enhance the efficacy and precision of water treatment processes.

IoT enables continuous monitoring of water quality parameters such as temperature, pH, turbidity, and chemical concentration through smart sensors, which transmit data to centralized systems for analysis. This capability not only provides operators with a comprehensive understanding of the water treatment ecosystem but also facilitates predictive maintenance, allowing for timely interventions and reducing the likelihood of system failures [2]. Additionally, the implementation of automated control systems powered by IoT can optimize chemical dosing and energy usage, significantly lowering operational costs while ensuring compliance with health and safety regulations.

Moreover, IoT technology fosters improved stakeholder communication and transparency. With real-time data sharing, water treatment facilities can better engage with regulatory authorities and the communities they serve, thus building trust and accountability. It can also pave the way for participatory approaches to water resource management, where end-users are empowered to make informed decisions based on accessible data [3]. As a result, the potential of IoT-based instrumentation to revolutionize data acquisition and control in water treatment processes is immense.

In summary, as urban centres expand and water challenges become more complex, integrating IoT in water treatment infrastructure offers a promising solution. By leveraging real-time data analytics, automation, and enhanced communication, water treatment plants can operate more efficiently, safeguard public health, and contribute to sustainable water resource management. This paper aims to explore the various IoT applications which revolutionize data acquisition and control in water treatment plants, highlighting the technologies involved, the benefits of implementation, and the challenges that must be addressed to realize this potential. IoT-based water treatment systems leverage sensor networks, cloud computing, and advanced data analytics to optimize water management processes and enhance decision-making.

ARCHITECTURE OF IOT IN WATER TREATMENT

IoT revolutionizes water treatment by enabling enhanced monitoring, control, and optimization, driving efficiency, sustainability, and service improvements through essential, interconnected components.

Sensor Layer

At the foundational level, the sensor layer encompasses various physical devices and sensors that collect real-time data related to water quality and infrastructure performance. These sensors can measure parameters such as pH levels, turbidity, temperature, dissolved oxygen, and other critical factors affecting water quality. Advanced sensors, including smart meters and chemical analyzers, are deployed throughout the treatment plant to capture data locally. For instance, smart water meters can provide real-time insights into water flow and leakage, facilitating proactive maintenance and resource management [4]. The diversity of sensors ensures comprehensive surveillance of both raw and treated water quality.

Communication Layer

The communication layer is crucial in facilitating data transmission from the sensor layer to data storage and processing units. Various wireless communication protocols can be implemented, such as LoRaWAN, Zigbee, WI-Fi, and cellular networks, enabling effective connectivity in different plant environments. The choice of protocol depends on the range, energy consumption, and environmental conditions of the deployment area [5]. Ensuring robust communication is essential for real-time data transfer and operational reliability. Secure communication protocols also play a vital role in safeguarding data integrity and preventing unauthorized access to sensitive information.

Data Processing Layer

Once the data is collected and transmitted, the data processing layer undertakes the responsibility of data aggregation, analysis, and storage. Cloud computing technologies are increasingly used to handle massive datasets generated by IoT devices. This layer leverages data processing tools such as edge computing to conduct preliminary analysis closer to the source, reducing latency and bandwidth usage [6]. Machine learning and data analytics algorithms can be employed to derive actionable insights from historical and real-time data. Anomalies in water quality metrics can thus be detected early, enabling prompt intervention and reducing operational costs.

Control Layer

The control layer integrates the findings from the data processing layer into actionable controls within the water treatment system. Automated control systems can make real-time adjustments to operations, such as regulating chemical dosing, optimizing pump usage, or altering filtration processes based on quality indicators [7]. This layer solidifies the overall system's response to dynamic environmental conditions or changes in raw water quality. Additionally, predictive maintenance algorithms can inform maintenance schedules based on wear and tear metrics, thus preventing downtime and extending the lifespan of critical infrastructure.

User Interface Layer

The user interface layer provides a visual representation of the data and control interactions, thus allowing operators and decision-makers to monitor the plant's performance intuitively. Dashboards displaying real-time data, alerts, and performance trends enable quick assessments and informed decision-making [8]. Mobile applications and web-based platforms facilitate remote monitoring, ensuring that stakeholders can oversee operations regardless of their physical location. Enhanced visualization tools empower plant operators with intuitive navigation and straightforward access to operational controls, promoting efficient management.

The architecture of IoT in water treatment plants is multi-faceted, integrating components that work harmoniously to revolutionize data acquisition and control. Through a synergistic approach, the IoT framework affords utilities improved operational efficiency and responsiveness, driving sustainable practices and enhancing service delivery. As technology continues to evolve, the envisioned future of IoT in water treatment holds immense potential for further innovation and impact.

SYSTEM DESIGN AND IMPLEMENTATION

The integration of Internet of Things (IoT) and Cloud Supervisory Control and Data Acquisition (SCADA) systems has emerged as a transformative approach in managing water treatment plants. This section details the system design architecture to effectively implement monitoring, control, and optimization processes using these advanced technologies.

The design of a modern water treatment plant system requires a robust architecture to ensure real-time data acquisition, processing, and responsive control. The advent of IoT technologies has facilitated widespread connectivity of devices, while cloud-based SCADA systems offer vast data storage and processing capabilities, making them ideal candidates for managing water treatment operations efficiently.

Overview of the System

The proposed system architecture includes the following fundamental components:

- IoT Sensors and Devices
- Edge Computing Unit
- Cloud-Based SCADA System
- User Interface Dashboard

The first component consists of various IoT sensors deployed throughout the water treatment facility. These sensors measure critical parameters such as pH levels, turbidity, temperature, and flow rates. Wireless communication protocols like LoRaWAN and Zigbee can be employed to ensure reliable data transmission with low power consumption [9]. Each sensor is connected to a microcontroller, which processes the raw data and prepares it for transmission to the edge computing unit.

The edge computing layer serves as an intermediary between IoT sensors and the cloud. It is responsible for initial data filtering, processing, and aggregation, reducing the latency and bandwidth required for data transmission to the cloud. The edge device can run algorithms for anomaly detection and basic predictive maintenance, enabling faster decision-making processes on-site [10]. This unit can also be tasked with executing local controls based on predefined thresholds, ensuring immediate corrective actions.

A cloud-based SCADA system provides centralized monitoring and control capabilities. It consists of:

- Data Storage: Utilizing services like Amazon AWS or Microsoft Azure, vast amounts of data collected

from IoT devices can be securely stored and easily accessed. This data can support long-term trend analysis and reporting [11].

- Real-Time Data Visualization: The SCADA system can offer real-time dashboards displaying operational metrics and alerts for system anomalies. Advanced analytics capabilities using machine learning can transform this data into actionable insights for optimizing water treatment processes [12].

- Remote Access: Cloud SCADA allows operators to monitor and control operations remotely, facilitating efficient management of water treatment plants from any location.

A user-friendly dashboard is crucial for operators to interact with the SCADA system. The dashboard should provide intuitive access to data analytics, alerts, and control functions. Technologies such as HTML5, CSS3, and JavaScript frameworks like React or Angular can be used to develop responsive web applications that work on various devices [13]. Customizable views can be provided to allow users to focus on specific operational aspects.

Implementing IoT and cloud technologies in water treatment plants brings about critical security concerns. Incorporating encryption protocols, such as HTTPS and TLS, for data transmission is essential to protect sensitive information. Furthermore, rigorous authentication and access control mechanisms must be enforced to safeguard against unauthorized access to the system [14].

The implementation of a system design that incorporates IoT and Cloud SCADA technologies can significantly enhance the operational efficiency and reliability of water treatment plants. By leveraging advanced data analytics and remote monitoring capabilities, operators can make informed decisions that optimize processes, ensuring the provision of safe drinking water.

ADVANTAGES OF IOT IN WATER TREATMENT PLANTS

The Internet of Things (IoT) has emerged as a transformative technology with significant implications for various industries, particularly in water treatment plants. Implementing IoT solutions in these facilities has the potential to enhance operational efficiency, promote sustainability, and ensure better compliance with water quality standards. This paper discusses several key advantages of IoT in water treatment plants, illustrating the benefits of smart technologies in enhancing water management.

Enhanced Monitoring and Control

One of the primary advantages of IoT in water treatment plants is the ability to implement real-time monitoring and control systems. IoT devices such as sensors and smart meters can continuously collect and transmit data regarding water quality parameters (e.g., pH levels, turbidity, and contaminant concentrations) to a centralized system. This data allows operators to monitor conditions more effectively and make informed decisions quickly, reducing the risk of water quality violations or system failures [15].

Predictive Maintenance

IoT technologies facilitate predictive maintenance by using data analytics to assess the condition of equipment. Smart sensors can detect anomalies in pumps, valves, and other critical components of the treatment plant, allowing maintenance teams to perform repairs before failures occur. This predictive approach minimizes downtime and extends the lifespan of costly machinery, ultimately leading to substantial cost savings [16].

Improved Efficiency and Resource Management

The integration of IoT solutions can significantly enhance the operational efficiency of water treatment plants. Monitoring of water quality parameters flow rate, totalizer, pH, for immediate response Smart systems can optimize the use of chemicals and energy by adjusting treatment processes based on real-time data inputs. For instance, IoT applications can automatically modify chlorine dosages based on the detected contaminant levels, reducing chemical waste and operational costs while ensuring effective treatment [17].

Data-Driven Decision Making

IoT generates vast amounts of data that can be analyzed to improve decision-making processes. By incorporating advanced analytics and machine learning algorithms, water treatment facilities can identify

trends, predict future demand, and optimize resource allocation accordingly. This data-driven approach fosters better planning and management, ultimately leading to increased service reliability and quality [18].

Enhanced Regulatory Compliance

Water treatment plants are subject to strict regulatory standards regarding water quality and safety. IoT-enabled systems provide comprehensive documentation and reporting capabilities, making it easier for facilities to demonstrate compliance with regulations. Continuous monitoring ensures that any deviations from standards can be addressed promptly, reducing the risk of non-compliance penalties [19].

Water Quality Improvement

IoT technologies contribute to the improvement of water quality by enabling real-time detection of contaminants and pollutants. For example, smart sensing technologies can quickly identify harmful microorganisms in the water supply, allowing operators to respond swiftly and mitigate health hazards. This capability is vital for ensuring that the treated water meets safety standards before being distributed to consumers [20].

Increased Automation

IoT facilitates higher levels of automation within water treatment plants. Automated systems can perform routine tasks such as data collection, chemical dosing, and equipment inspections without human intervention. This not only reduces labor costs but also enhances the reliability and consistency of processes, ultimately leading to improved treatment outcomes [21].

Remote Accessibility

IoT systems enable remote monitoring and control of water treatment operations. Operators can access data and manage facilities from virtually any location, thanks to cloud-based platforms and mobile applications. This capability is particularly beneficial for large facilities with multiple treatment sites, allowing for centralized oversight and quicker responses to emerging issues [22].

Sustainability and Energy Efficiency

IoT applications promote sustainability by enabling water treatment plants to lower their energy consumption and reduce waste. Smart systems can optimize energy usage across various operations, such as pumping and aeration, leading to a smaller carbon footprint. Additionally, enhanced water management reduces the risk of leaks and wastage, contributing to overall water conservation [23].

The adoption of IoT technologies in water treatment plants brings numerous advantages that are critical for modern water management. From enhanced monitoring and predictive maintenance to improved regulatory compliance and sustainability, IoT reshapes how facilities operate and interact with their environment. As water scarcity becomes an increasingly pressing global issue, the implementation of IoT solutions will play a vital role in creating efficient, reliable, and sustainable water treatment systems for the future.

CHALLENGES OF IMPLEMENTING IOT IN WATER TREATMENT

The integration of Internet of Things (IoT) technology into water treatment processes holds significant promise for enhancing efficiency, monitoring quality, and optimizing resource management. However, several challenges impede the effective implementation of IoT in this domain. This paper outlines the primary challenges associated with the deployment of IoT solutions in water treatment systems.

Data Management and Integration

One of the foremost challenges is the effective management and integration of the vast amounts of data generated by IoT devices. Water treatment facilities often deploy numerous sensors to monitor various parameters such as water quality, flow rates, and chemical levels. Handling, processing, and analyzing this data in real-time requires robust data management systems and scalable cloud infrastructure. The complexity of integrating data from heterogeneous sources can lead to inefficiencies and hinder the realization of data-driven decision making [24].

Interoperability

Interoperability among devices and systems is another significant challenge in IoT deployment. Many water treatment facilities utilize equipment from different manufacturers, each with its own communication protocols and data formats. Achieving seamless

interoperability among diverse devices is crucial to ensure comprehensive monitoring and control of water treatment processes. The lack of standardized protocols complicates this integration and can lead to silos of information, which obstruct effective operations [25].

Cybersecurity Threats

In IoT-based water treatment applications, cybersecurity threats such as unauthorized access, data manipulation, and denial-of-service attacks pose significant risks. Protecting sensitive operational data is crucial to ensure the integrity and reliability of these critical infrastructures [26].

High Initial Costs

Implementing IoT technology often involves substantial upfront costs, including purchasing sensors, upgrading infrastructure, and investing in software solutions. While IoT may lead to long-term savings through improved efficiency and reduced operational costs, the high initial capital investment can deter many municipalities and water treatment facilities from adopting these innovations. Budget constraints may force decision-makers to prioritize short-term investments over long-term technological enhancements [27].

Skill Gap and Workforce Training

The successful implementation of IoT in water treatment also hinges on the availability of skilled personnel capable of managing and analyzing IoT data. There exists a notable skill gap in the workforce, particularly in the fields of data analytics, cybersecurity, and IoT technology. Training existing employees or hiring new talent can be a resource-intensive process, complicating the transition to IoT-enabled operations [28].

Regulatory and Compliance Issues

Water treatment facilities must navigate a complex landscape of regulations and compliance standards. The incorporation of IoT technology introduces new variables that must be addressed within the existing regulatory framework. Ensuring compliance while adapting to new technologies can be a cumbersome process, often requiring additional time and resources [29]. Additionally, the lack of specific regulations governing IoT devices in water treatment further complicates compliance efforts.

Reliability and Maintenance

The integration of IoT-based instrumentation in water treatment plants enhances system reliability through real-time monitoring and predictive maintenance. By utilizing sensor data, potential failures can be detected early, reducing downtime and maintenance costs. Regularly updated algorithms ensure optimal performance, contributing to the longevity and efficiency of treatment processes.

The following figures show the anywhere access IoT Based Cloud SCADA Dash-Boards for water Treatment Plant.

Fig. 1 Water Treatment Plant Main Overview

Fig. 2 Quality Parameters

Fig 3. Tank Parameters
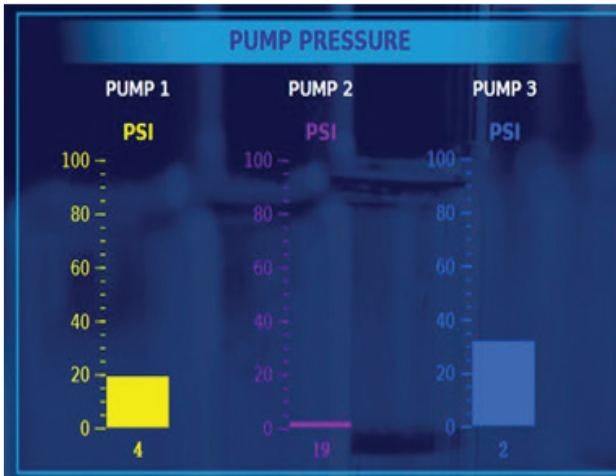
Fig. 4 Pump Pressure
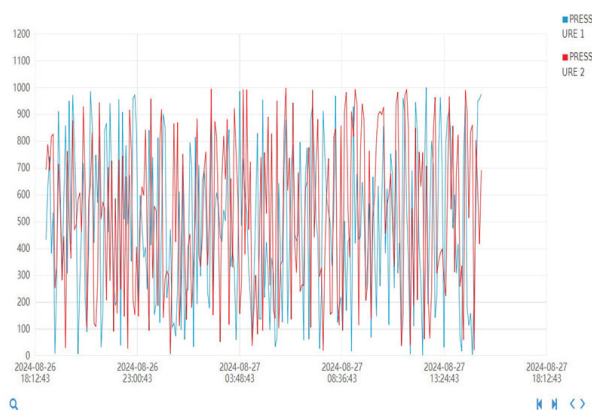
Fig 5 Pressure Alarms

CONCLUSION

IoT-based instrumentation applications have significantly transformed data acquisition and control processes in water treatment plants. Enhanced monitoring capabilities and real-time data analytics not only improve operational efficiency but also ensure better resource management and environmental compliance, ultimately fostering sustainable practices in the water treatment industry.

In conclusion, IoT-based water treatment systems hold tremendous potential for addressing critical water management challenges. By leveraging real-time data analysis and automation, these systems can ensure safer, more efficient water treatment processes that benefit both urban and rural populations.

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Design of Remote Controlled Surface Vehicle for Efficient Reservoir Cleaning

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ABSTRACT

Water pollution from suspended solids like silt, plastic, and waste is a major threat to aquatic ecosystems. Tackling contamination in reservoirs and rivers typically requires significant time, manpower, and resources. This paper presents a solution: an automated, solar-powered, remote-controlled floating surface vehicle. Designed to clean water surfaces effectively, it minimizes manual labor and addresses pollution efficiently. The vehicle is operated via remote control and uses DC pumps for directional control and a servo motor for precise steering. Solar panels charge its battery, enabling continuous operation with minimal recharging. It features a wire mesh net for collecting up to 12 kg of debris and a lightweight, pontoon-shaped hull for stability and maneuverability. This eco-friendly approach offers a cost-effective method for maintaining cleaner water bodies and improving water quality management. Incorporating advanced technologies, the vehicle provides a practical and sustainable solution to combat water pollution.

KEYWORDS : *Remote controlled vehicle, Surface vehicle, Water pollution, Suspended Solids.*

INTRODUCTION

Surface water, which covers approximately 70% of the Earth's surface, includes oceans, lakes, and rivers, and supplies over 60% of the freshwater used in homes. However, the U.S. Environmental Protection Agency states that nearly half of rivers and more than a third of lakes are polluted, making them unsuitable for swimming, fishing, or drinking. A key contributor to this pollution is suspended solids, which can cause waterborne diseases and negatively impact aquatic life. These solids reduce water clarity, obstruct fish feeding, and damage fish by clogging their gills, slowing their growth, and impairing reproduction. Once settled, they can also smother fish eggs and insect larvae, further disrupting ecosystems. The rising volume of waste, particularly plastic, in water bodies—80% of which originates from land—poses a serious threat to marine ecosystems and underscores the urgent need for effective waste collection solutions.

The Namami Gange Programme [1], launched by the Indian government, aims to treat sewage and monitor industrial effluents to conserve and restore the Ganga River. However, it does not specifically target the use of automated devices for river cleaning. Researchers have investigated various robotic solutions for cleaning water bodies.

Over time, several studies have examined robots designed for cleaning water surfaces, with many concentrating on specific, targeted solutions [2-5]. The Ro-Boat [6] is an unmanned vessel designed for autonomous detection, collection, and removal of surface debris and chemical sewage. However, it lacks features to ensure the robot's security in aquatic environments. In [7], a self-organization approach using artificial neural networks was proposed, proving useful for applications in video surveillance. Ovidiu, Stan, and Liviu Miclea [8] developed a system that uses a live camera feed from a Pi cam, hosted on port 8000, which can be accessed via a RESTful API service. Xiahong Gao and Xijin Fu [9] designed a miniature water

surface cleaning bot controlled wirelessly via WiFi with an STC12C5A60S2 controller and a mobile app. This lightweight prototype has a limited range of 20 meters and lacks waterproofing. A modified YOLO v3-based method [10] was introduced for high-precision garbage detection, enhancing real-time object detection in dynamic aquatic environments and improving the robot's performance. M. N. Mohammed et al. [11] developed a rubbish collection system featuring an Arduino microcontroller to drive DC motors powered by solar energy, with ultrasonic sensors for obstacle distance measurement. Hsing-Cheng Chang et al. [12] created a multifunction unmanned surface vehicle equipped with autonomous obstacle avoidance, navigation, water quality monitoring, sampling, water surface detection and cleaning, and remote navigation control with real-time information display. Most of above mentioned robots lack simplicity in design with enhanced stability.

In response, this study presents a waste-collecting vehicle designed for use in water bodies to help mitigate pollution-related issues, such as flooding. The research involves the analysis, design, development, and testing of a robotic system for cleaning smaller water areas. Operated via remote control, the robot's effectiveness in larger areas will also be assessed, providing a sustainable and eco-friendly solution to water pollution.

METHODOLOGY

The operation of a remotely controlled, solar-powered vehicle relies on the integration of mechanical, electronic, and software systems, enabling it to navigate on water while being remotely controlled by a user from the surface. Fabrication is essential across many industries, involving processes such as cutting, forming, and assembling materials to construct specific structures. The Fig. I demonstrate the methodology adopted for design and development of surface vehicle for c Efficient Reservoir Cleaning.

The development of an surface vehicle for reservoir cleaning involves a systematic approach, beginning with a preliminary analysis to define design and operational requirements. A basic 2D design is created, followed by electronic PCB design to manage control functions. A remote control system is integrated for

real-time operation, and solar panels are added to enable sustainable power recharging. A servo mechanism ensures precise movement of the cleaning tools, while 3D CAD modeling refines the vehicle's design for optimal performance. Careful material selection and weight calculations ensure durability and buoyancy. Finally, simulations, experimentations, and validations are conducted to test and confirm the vehicle's effectiveness and reliability in surface conditions.
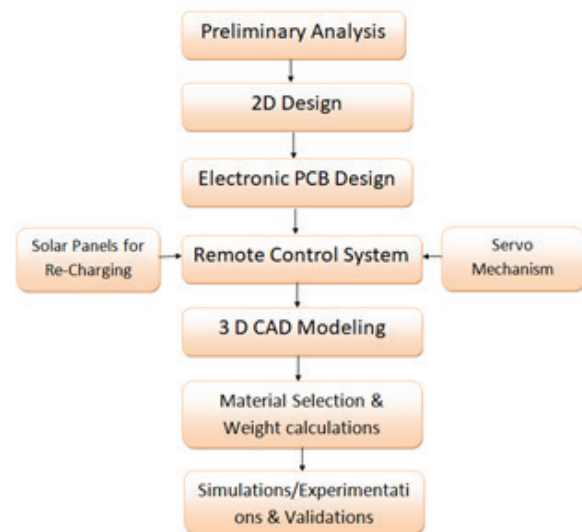
Fig 1 Adopted Methodology for Vehicle Design

MATERIAL SELECTION AND BUOYANCY CALCULATIONS

The material used for the vehicle's body frame is Aluminum 5052 due to its excellent corrosion resistance, good workability, and high fatigue strength. Aluminum 5052 consists primarily of aluminum (97.5% to 98.7%), with magnesium (2.2% to 2.8%) and chromium (0.15% to 0.35%) as its main alloying elements.

The vehicle's buoyancy force is calculated using its dimensional data and mass as follows: Length of the vehicle = 0.54 m; Width of the vehicle = 0.42 m; Height of submerged part = 0.2 m (estimate); Total mass of the vehicle = 7 kg; Density of water = 1000 kg/m³; g = 9.81 m/s²

Step 1: Calculate the Submerged Volume

$V_{submerged}$=Length×Width×Height (submerged part)

$V_{submerged}$=0.54m×0.42m×0.2m=0.04536 m3

Step 2: Calculate the Buoyant Force

$F_b = \rho_{fluid} \times V_{submerged} \times g = 1000kg/m^3 \times 0.04536m^3 \times 9.81m/s^2 = 445.28N$

Step 3: Calculate the Weight of the Vehicle, $W = m \times g = 7kg \times 9.81m/s^2 = 68.67N$

Since $F_b > W$, the vehicle will float because the buoyant force is significantly greater than the weight of the vehicle.

DESIGN CONSIDERATIONS

To ensure cost-effective and efficient manufacturing, this work incorporates several key structural design considerations. These principles are relevant to various joining methods and are crucial for both subassemblies and the complete structure. SolidWorks, a CAD and CAE software from Dassault Systems is employed for designing and developing mechanical systems throughout the entire project lifecycle. In the initial phases, the software supports key tasks such as project planning, visual ideation, 3D modeling, feasibility studies, prototyping, and overall project management, streamlining the engineering process from concept to completion. Figure II illustrates the vehicle design modeled in SolidWorks, showcasing four different views: isometric, side, front, and 3D. Table I outlines the key specifications and parameters utilized in the design and functioning of the vehicle, providing a detailed overview of its operational capabilities and design features.

(a) Isometric view   (b) Side View

(c) Front view   (d) 3D View
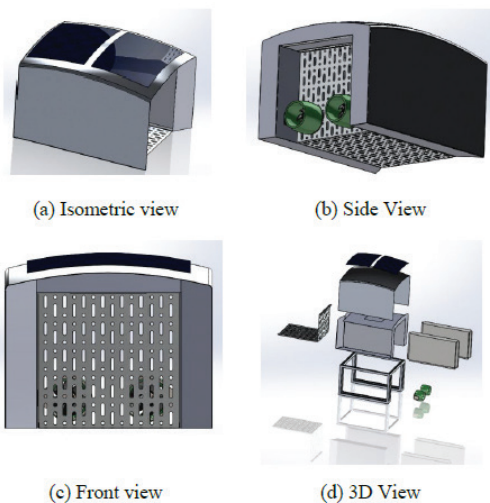
Fig. 2 Vehicle Modeling using Solidworks

Table 1 Vehicle Specifications

Design Parameters	Value
Overall dimensions of the vehicle (height × width × length)	33 × 42 × 54 cm
Material used for body frame	Aluminium 5052
Net weight of the vehicle without load	7 kg
Maximum weight of the vehicle with load	19 kg
Average battery while cleaning	1.5 hours
Propeller type	Dual propeller with 7 blades each
Control system	Remote control – manual
Wireless module	FlySky CT6B 2.4GHz 6CH Transmitter with an FS-R6B Receiver
Battery	Rechargeable 14.8V 5200mAh Lithium Polymer battery pack
Solar Panels	6 solar panels 6W 150 mA; size- 8.5 × 9cm
DC Motor	BLDC 5010 750KV High Torque Brushless Motor
Servo Motor	MG996R model, 4.8V to 6.6V
Wireless Camera	Willen 16 MP WiFi Waterproof 4K Action 170° Camera, WI-09

HARDWARE REQUIREMENTS

The following hardware components have been utilized in this work to develop a remotely controlled vehicle:

1. Atmega328: An 8-bit microcontroller commonly used in Arduino boards. It manages the logic, processes sensor inputs, and controls the motors, serving as the vehicle's central processing unit.

2. pH Sensor: Measures the pH levels of water to collect water quality data.

3. Turbidity Sensor: Measures the clarity of water by detecting suspended particles.

4. Frame: Provides structural support and stability for mounting the various components of the vehicle.

5. Floaters: Ensure that the vehicle can operate on water surfaces by keeping it buoyant.

6. Solar Panels: Supply renewable energy to the vehicle's battery or directly to its components.

7. Wire Gauge Net: Offers protective covering and reinforcement for critical parts of the vehicle.

8. RC Receiver: Receives commands from the RC remote to control the vehicle's movements.

9. RC Remote: Allows the user to remotely adjust the vehicle's direction and speed.

10. Servo Motor: Provides precise control for parts requiring exact positioning, such as steering mechanisms.

11. DC Pump: Moves fluids for purposes like propulsion or sampling.

12. Diodes: Protect components from reverse voltage and manage the direction of current flow.

13. PCB and Breadboards: Aid in connecting components and laying out the circuit.

14. Switch: Manages the power flow to different parts of the vehicle.

15. Transformer/Adapter: Converts mains voltage to the appropriate level for powering the vehicle's electronics.

16. Push Buttons: Allow manual control for tasks like resetting or powering the system on and off.

17. IC (Integrated Circuit): Performs various functions including signal processing and motor control.

18. IC Sockets: Enable easy replacement of integrated circuits without soldering.

19. LED: Indicates the status of the system, such as power, operation, or errors.

20. Resistors and Capacitors: Regulate electrical signals to ensure the proper functioning of sensors and motors.

21. Cables and Connectors: Establish electrical connections between sensors, motors, and the microcontroller.

These components collectively enable the creation of a remotely controlled vehicle capable of navigation, environmental data collection, and autonomous operation powered by renewable solar energy.

SOFTWARE REQUIREMENTS

This project utilizes the Arduino IDE (Integrated Development Environment) as shown in Fig. III, to write the logic sequence code. The code is designed to read sensor inputs, control the speed of two ESCs (Electronic Speed Controllers) connected to motors, and log data onto an SD card. It processes inputs from pH and turbidity sensors while also reading RC (Radio Control) input channels to manage motor speeds.
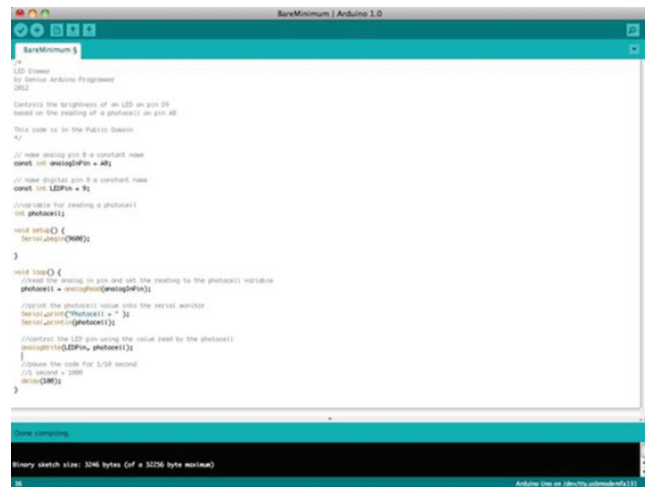
Fig. 3 Arduino IDE (Integrated Development Environment)

Logic Flow Summary is described as follows:

1. Initialize hardware components (Serial, SD card, ESCs, sensors, RC channels).

2. Continuously:

   a. Read RC input signals and adjust motor speeds based on user commands.

   b. Collect and process data from the pH and Turbidity sensors.

   c. Log sensor data to the SD card.

3. Adjust motor speeds dynamically, ensuring they stay within valid operating ranges.

4. Repeat the process in a continuous loop, collecting and logging real-time data.

This process forms the basis of controlling a vehicle or system that reads environmental data and allows user control via an RC system.

REMOTE CONTROL SYSTEM

The vehicle is operated remotely using a transmitter-receiver system. An operator on the surface utilizes a handheld controller to send commands, which are transmitted wirelessly via radio frequency signals to the vehicle's onboard receiver. The vehicle is equipped with two propulsion systems, such as thrusters or propellers that provide the necessary thrust for surface movement. These systems can be controlled independently for

precise maneuverability. Powering the vehicle is a rechargeable 14.8V 5200mAh Lithium Polymer battery pack located within its body. This battery supplies electrical energy to the propulsion systems, sensors, and communication modules.

To enhance power efficiency and extend operational time, the vehicle also incorporates six 6W solar panels. For wireless communication, the vehicle uses the FlySky CT6B 2.4GHz 6CH Transmitter with an FS-R6B Receiver. The data collected by the vehicle's sensors, including images and environmental measurements, is transmitted wirelessly to the operator's control station in real-time. This allows the operator to monitor the vehicle's performance and make informed decisions throughout its operation. Advanced control algorithms interpret the operator's commands and convert them into precise vehicle movements, ensuring stable and accurate control. This enables the vehicle to navigate effectively through complex surface environments. The Fig. III shows the bock diagram representation of vehicle's remote control system.
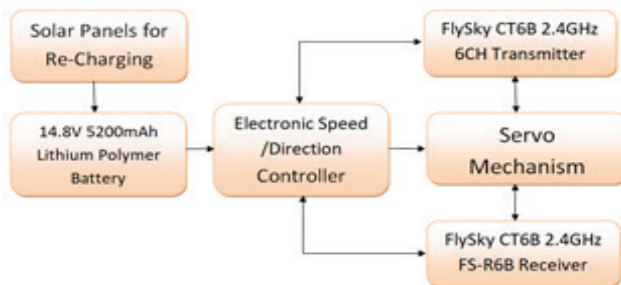
Fig. 4 Vehicle's Remote Control System

RESULTS AND DISCUSSIONS

Water body contamination from human activities has become a pressing issue, leading to the depletion of clean water sources. While developing sustainable wastewater treatment and garbage disposal methods is essential for long-term pollution control, immediate cleanup of our water bodies is critical. Fig. V ((a) to (d)) shows images of vehicle doing cleaning work in the reservoir.

The proposed remotely controlled vehicle addresses key challenges in lake and pool maintenance:

1. Eliminates the Need for Motorized Boats: Traditional cleaning often relies on expensive and

time-consuming motorized boats. The remotely controlled vehicle offers a more efficient alternative, reducing dependency on such boats.
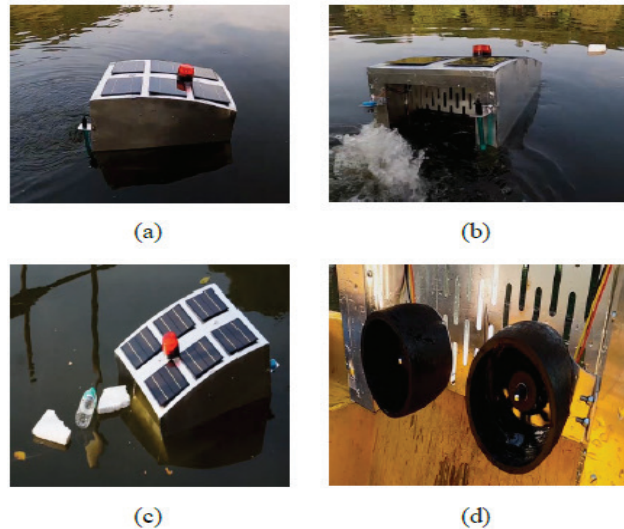
Fig. 5 Experimentation Results

2. Reduces Labor: Designed for single-person operation, this vehicle eliminates the need for a two-person team typically required for cleaning tasks, thereby lowering labor costs and simplifying the cleaning process.

3. Ensures Consistent Cleaning: Manual methods often result in irregular cleaning schedules due to their labor-intensive nature. The automation of the vehicle ensures regular and consistent cleaning.

4. Cost-Effective Operation: The vehicle uses solar panels to extend its operational hours and lower energy costs, making it a financially viable solution for water body maintenance.

5. Monitors Pollution: Equipped with pH and turbidity sensors, the vehicle not only collects debris but also monitors and maps pollution levels, aiding in data-driven pollution control.

6. Enhances Reliability: Its rudderless design minimizes moving parts, increasing reliability and ease of maintenance.

7. Improves Visibility: With remote control capabilities, a wireless live stream camera, and a strobe light, the vehicle offers enhanced visibility and control even in challenging conditions.

Powered by high-torque motors, solar panels, sensors, and an Atmega microcontroller, the remotely controlled vehicle efficiently collects garbage, monitors pollution, and safeguards aquatic life. It stands as a sustainable and cost-effective solution for maintaining clean and healthy water resources.

CONCLUSION

This paper introduces a solar-powered featured surface vehicle designed to clean plastic debris from water surfaces and combat pollution. Structural analysis using SolidWorks confirms the vehicle's durability, while buoyancy calculations demonstrate its ability to float and carry up to 12 kg of waste without failure. The vehicle features a wireless control system for precise remote operation and employs open-source technology for cost-efficiency and scalability, enabling the use of multiple units for larger water bodies. Future enhancements include optimizing the control system, improving garbage detection algorithms, and scaling the robot for practical applications. Research suggests incorporating multi-task capabilities, such as waste sorting, water quality monitoring, algae removal, and chemical application. This vehicle aims to reduce manual labor and offer a sustainable solution to pollution, with potential to address ongoing environmental challenges effectively.

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Comparative Analysis of Various Intrusion Detection Systems using Deep Learning for VANET and their Issues and Challenges with IoT Devices Integration

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ABSTRACT

Vehicular ad-hoc Networks (VANETs) have become a very crucial element of intelligent transportation systems with the advent of autonomous cars, enabling communication between vehicles (V2V) and infrastructure (V2I). However, along with pros, cons also expose them to various security risks, such as intrusion attacks. Intrusion Detection Systems (IDS) are essential for protecting VANETs by detecting and countering malicious activities. This paper provides insight intoa comparative analysis of various IDS techniques used in VANETs, concentrating on the deep learning approach, and examines the challenges and opportunities of incorporating IoT devices into IDS.

KEYWORDS : *IDS, Deep-Learning, Issues, Challenges, IoT.*

INTRODUCTION

Vehicular Ad Hoc Networks (VANETs) are poised to play a crucial role in the future of intelligent transportation systems (ITS), where vehicles communicate wirelessly with each other and infrastructure to improve road safety, optimize traffic flow, and enable autonomous driving. However, the highly dynamic and decentralized nature of VANETs also makes them vulnerable to various security threats, such as denial-of-service (DoS) attacks, message tampering, and eavesdropping. This has prompted significant research into developing Intrusion Detection Systems (IDS) that can detect and mitigate such threats.

The integration of IoT devices into VANETs adds a new layer of complexity, as the number of connected devices continues to grow exponentially, creating vast amounts of data and increasing the attack surface. In this context, deep learning-based IDS has emerged as a promising approach due to its ability to learn complex patterns in large datasets, making it ideal for detecting sophisticated and previously unknown attacks.

This paper aims to address a critical gap in the literature by exploring the intersection of VANETs, IoT integration, and deep learning-based IDS. The significance of this research lies in its potential applications in smart transportation systems, including autonomous driving and smart city implementations, where ensuring security is paramount. By performing a comparative analysis of various deep learning models, we seek to identify the most effective approaches for securing VANETs while accounting for the added complexity of IoT integration.

Research Objectives: This paper tried to have a comparative analysis of the available IDS system. Integration of IoT devices is not that easy and how deep learning can be used to mitigate the challenges and issues posed in VANET.

DL for Intrusion Detection: Provide a comprehensive overview of DL techniques used in intrusion detection, focusing on their network security applications. We will discuss the advantages and limitations of different DL architectures, such as CNNs, RNNs, LSTM, GRU and

Auto encoders, for VANET and IoT scenarios. [2,5-7,10,12,14,15]

VANET Security: Analyze the unique security challenges VANETs face, including vulnerabilities, threats, and existing countermeasures for mitigation purposes. Exploring the specific characteristics of VANETs that make them susceptible to attacks, such as the ad-hoc nature of communication, the reliance on wireless channels, and the presence of many devices.

RELATED WORK

Various intrusion detection techniques in VANETs

Signature-based IDS

Principle: Matches network traffic patterns against known attack signatures.

Advantages: Effective against known attacks, low computational overhead.

Disadvantages: Limited effectiveness against new or variant attacks.

Anomaly-based IDS

Principle: Identifies deviations from normal network behaviour.

Advantages: Can detect unknown attacks, adaptable to changing environments.

Disadvantages: Prone to false positives, requires extensive training data.

Hybrid IDS

Principle: Combines signature-based and anomaly-based techniques.

Advantages: Provides a balanced approach, and improves detection accuracy.

Disadvantages: Increased complexity and computational overhead.

Machine Learning-based IDS

Principle: Utilizes machine learning algorithms to learn and classify normal and abnormal traffic patterns.

Advantages: High accuracy, and adaptability to new threats.

Disadvantages: Requires large datasets for training, computational overhead.

Block chain-based IDS

Principle: Leverages blockchain technology for decentralized and tamper-proof intrusion detection.

Advantages: Enhanced security, trust, and transparency.

Disadvantages: Increased computational complexity, potential scalability issues.

The popular Intrusion Detection Systems (IDS) that are used in Vehicular Ad-Hoc Networks (VANETs):

Open-Source IDS

Snort: It is open-source network intrusion detection system that can be configured for VANET environments.

Suricata: Again open-source IDS that offers high performance and scalability.

Bro: A powerful network security monitor that can be utilised for intrusion detection and traffic analysis in VANETs.

NIDS: A lightweight and efficient IDS aimed specifically for VANETs.

Commercial IDS

McAfee Intrusion Prevention System (IPS): A comprehensive security solution that includes both IPS and IDS.

Fortinet FortiGate: A combined threat mitigation platform that offers IDS and IPS functionalities.

Palo Alto Networks Next-Generation Firewall: A firewall solution that includes advanced attack prevention features, including IDS.

Cisco Intrusion Prevention System (IPS): A network security appliance that provides intrusion detection and prevention both simultaneously.

Research-Based IDS

VANETIDS: A research-based IDS specifically designed for VANETs, aimingat detecting and preventing various types of attacks.

VANET-IDS: Another research-based IDS that utilizes machine learning (ML) techniques for intrusion detection in VANETs.

Vehicular Intrusion Detection System (VIDS): A structure for developing customized IDS solutions for VANETs.

As per our requirement choice of IDS system for a VANET environment depends on factors such as the network size, security requirements, type of environment and available resources. It's often suggested to evaluate multiple options and select the one that best ensembles the specific needs of the VANET deployment.

IoT devices and its integration

IoT Security: In the era of 5G and 6G where alldevices are connected to the internet the security risks associated with IoT devices, particularly in the context of VANETsincrease. IoT devices are vulnerable to insecure protocols, weak authentication, and lack of encryption. IoT attacks in VANETs lead to privacy breaches, service disruptions, and physical harm. [3,4,8,20]

Vehicle-mounted Devices

Sensors

Cameras: For capturing real-time video footage of the road and surrounding environment.

Radar: For detecting objects and obstacles in the path of the vehicle.

LiDAR: For creating a 3D map of the environment and accurately measuring distances.

Ultrasonic sensors: For detecting objects close to the vehicle, such as pedestrians or parked cars.

Temperature and humidity sensors: For monitoring environmental conditions.

Air quality sensors: For measuring air pollution levels.

Communication Modules

On-board units (OBUs): To establish communication between vehicles and infrastructure.

Cellular modems: These are used to connect to cellular networks and access the internet.

Table 1. Challenges in IoT devices integration and its descriptions

Challenge/Issue	Description's
Security and Privacy	Protecting sensitive data transmitted over the network, preventing unauthorized access, and ensuring privacy for users.
Scalability	Handling a large number of vehicles and devices in a dynamic environment, ensuring efficient communication and resource allocation.
Reliability	Ensuring reliable and uninterrupted communication, even in challenging conditions such as low signal strength or interference.
Interoperability	Ensuring compatibility between different VANET systems and devices, promoting seamless communication and data exchange.
Dynamic Topology	Dealing with the constantly changing topology of VANETs due to vehicle movement, network changes, and environmental factors.
QoS and Delay	Guaranteeing quality of service (QoS) for critical applications, minimizing latency and ensuring timely delivery of data.
Spectrum Management	Efficiently allocating and managing spectrum resources to avoid interference and maximize network capacity.
Integration with Existing Infrastructure	Integrating VANETs with existing transportation infrastructure and systems, such as traffic management systems and roadside units.
Cost-Effectiveness	Balancing the benefits of VANETs with the costs of deployment, maintenance, and operation.
Regulatory Framework	Developing and implementing appropriate regulatory frameworks to govern VANET operations and address legal and ethical issues.
Privacy Preservation	Protecting the privacy of individuals and ensuring that their data is not misused or disclosed without their consent.
Security Against Attacks	Protecting VANETs from various security threats, such as denial-of-service attacks, eavesdropping, and man-in-the-middle attacks.

Integration with IoT Devices	Ensuring seamless integration of IoT devices with VANETs to leverage their capabilities for enhanced services and applications.
Energy Efficiency	Optimizing energy consumption of VANET devices to prolong battery life and reduce environmental impact.
Real-Time Performance	Ensuring that VANETs can provide real-time information and services to meet the demands of applications such as autonomous driving and traffic management.

The above Table 1 demonstrate the different challenges involved in IoT Devices Integration. Integration of IoT devices will play a crucial role in enhancing the capabilities and functionalities of VANETs. Here are some essential IoT devices that can be integrated into VANET environments:

Infrastructure-Mounted Devices

Roadside units (RSUs): For communicating with vehicles and providing information about traffic conditions, road hazards, and infrastructure status.

Traffic cameras: For monitoring traffic flow and identifying incidents.

Environmental sensors: For measuring air quality, noise levels, and weather conditions.

Smart traffic lights: For adaptive traffic signal control based on real-time traffic data.

Other Devices

Wearable devices: For tracking the location and status of pedestrians or cyclists.

Smart parking systems: For managing parking spaces and providing real-time availability information.

Electric vehicle charging stations: For monitoring charging status and providing energy management information.

Key Considerations for IoT Device Integration

Compatibility: Ensure compatibility between IoT devices and VANET standards (e.g., DSRC, C-V2X).

Power consumption: Consider the power requirements of IoT devices and their impact on battery life.

Security: Implement robust security measures to protect IoT devices and data from unauthorized access.

Privacy: Adhere to privacy regulations and protect user data.

Interoperability: Ensure seamless communication and data exchange between different IoT devices and systems.

By integrating these IoT devices into VANETs, we can enhance road safety, improve traffic efficiency, and provide valuable information to drivers and infrastructure operators thus saving lives and money.

METHODOLOGY

Model Structure

Step I. Data Collection Layer: IoT Devices: Simulate various IoT sensors (e.g., temperature, humidity, traffic flow, vehicle health, wind speed and its direction) using MATLAB's built-in functions or customize code.

Step II. VANET Network: Model the VANET network using MATLAB's communication toolbox to simulate data transmission between vehicles and infrastructure.

Step III. Data Processing Layer:Data Aggregation: Use MATLAB's data structures and functions to collect data from different sources and combine them into a unified format.

Step IV. Data Cleaning and Preprocessing: Employ MATLAB's data cleaning and preprocessing functions (e.g., isnan, isinf, fillmissing) to handle missing or invalid data.

Step V. Feature Extraction: Extract relevant features using MATLAB's signal processing toolbox (e.g., FFT, DCT, diff).

Step VI. Data Analysis and Visualization: Utilize MATLAB's statistics and visualization tools (e.g., mean, std, corr, plot, scatter) to analyze data and visualize trends.

Step VII. Decision-Making Layer

Rule-Based Systems: Implement rule-based systems using MATLAB's logical operators and control flow statements.

Step VIII. Machine Learning Models: Train and deploy various machine learning models (e.g., regression, classification) using MATLAB's machine learning toolbox.

Step IX. Decision Support Systems: Develop decision support systems using MATLAB's GUI tools or web-based interfaces.

Step X. Action Layer

Actuator Control: Simulate actuator control using MATLAB's control systems toolbox or custom code.

Step XI. Notification Systems: Send notifications using MATLAB's communication toolbox or external APIs.

Dataset Selection: IoT-based datasets, considering factors such as representativeness, diversity, and relevance to VANET and IoT scenarios. IoT datasets capture the key characteristics of VANET and IoT traffic, including normal traffic patterns, various types of attacks, and the integration of IoT devices. [9]The models were trained and tested using the BoTNeTIoT-L01, which simulates realistic VANET environments. This dataset includes a variety of attack scenarios, such as DoS, black hole, and Sybil attacks, making it an ideal benchmark for evaluating IDS performance. The dataset has been pre-processed to extract relevant features such as packet type, source and destination addresses, and time-to-live (TTL) values.

Feature Engineering: It comprises a feature extraction process, including the selection of relevant features, normalization techniques, and handling of missing or noisy data. Unique feature of DL-based algorithms of self-extraction and it improve the accuracy and efficiency of the models as compared to ML-based algorithms. [19]

To contextualize the performance of deep learning models, traditional machine learning techniques such as Decision Trees and Support Vector Machines (SVM) were also included in the analysis. These methods serve as a baseline to highlight the advantages of deep learning in handling complex data patterns and dynamic environments typical of VANETs.

DL Model Selection: Explain the rationale for choosing specific DL architectures (CNNs, RNNs, LSTM, GRU)

and their suitability for VANET and IoT intrusion detection. Considering factors such as the nature of the data, the complexity of the task, and the computational resources available the best DL-based algorithms is selected.[17]

Evaluation Metrics:The performance of each model is evaluated using the following metrics:

Accuracy: The proportion of correct predictions out of the total predictions made.

Precision: The proportion of true positive results relative to the total positive predictions.

Recall: The proportion of true positive results out of the total actual positive cases.

F1-score: The harmonic mean of precision and recall, providing a balanced measure of the model's performance.

The experiments were conducted on a system equipped with an NVIDIA GeForce RTX 3050 GPU and 16GB of RAM. All models were implemented using the TensorFlow and Keras libraries to ensure reproducibility. Hyper parameter tuning was performed using grid search, and the models were trained over 100 epochs with early stopping to prevent overfitting.

The performance metrics used to evaluate the IDSs, consider factors such as accuracy, average latency, resource utilization and computational efficiency. More emphasis is to be given to latency and resource utilization since IoT-based devices are to be integrated withthe VANET environment. In this study, we evaluate several deep learning models for intrusion detection in VANETs, including Convolutional Neural Networks (CNN), Recurrent Neural Networks (RNN), and Long Short-Term Memory (LSTM) networks. Our comparative analysis is based on three key criteria: detection accuracy, computational complexity, and scalability to large network environments. As network size increases, deep learning models, particularly LSTM, exhibit better scalability compared to traditional machine learning approaches. However, the computational cost increases significantly with larger datasets, which highlights the need for further optimization when deploying these models in real-time systems.

EXPERIMENTAL RESULTS AND DISCUSSIONS

Comparative Analysis: All the figures below present the experimental results clearly and concisely, the performance of different DL-based IDSs. We analyze the strengths and weaknesses of each model in terms of accuracy, average latency, and resource utilization.
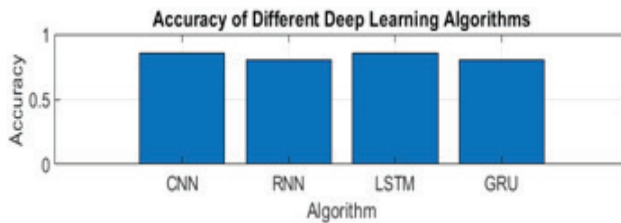
Fig 1. Accuracy versus deep learning Algorithms
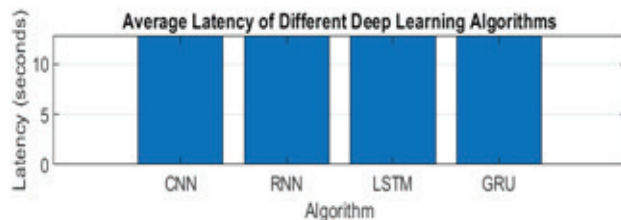
Fig. 2. Latency versus deep learning Algorithms
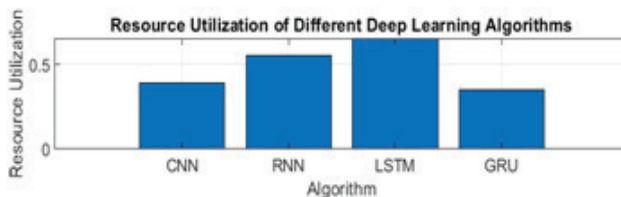
Fig. 3. Resource utilization versus deep learning Algorithms

Impact of IoT Integration: we examine the effect of IoT device integration on the performance of the IDSs, considering factors such as data volume, heterogeneity, and resource constraints. Results show how the IDSs handle the increased complexity and diversity of IoT traffic.The inclusion of IoT devices adds additional challenges in terms of data volume and heterogeneity. Our analysis shows that while deep learning models handle this complexity better than traditional methods, the performance gap narrows as the number of connected IoT devices increases. This suggests that IDS methods need further refinement to cope with the increasing scale and diversity of IoT traffic.
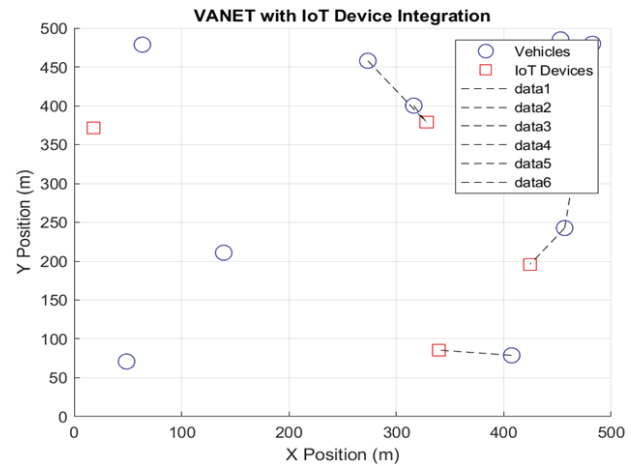
Fig. 4. shows latency and IoT devices.

Explanation

Initialisation: The script defines the number of vehicles and IoT devices, the communication range, and the simulation area.Positions of vehicles and IoT devices are randomly generated within the simulation area.

Communication Simulation: For each vehicle, the script calculates the distance to every IoT device. If a vehicle is within the communication range of an IoT device, the script calculates the latency based on the distance and the data rate. The results are stored in a latency matrix, where each element represents the latency between a specific vehicle and an IoT device.

Visualization: The vehicles and IoT devices are plotted on a 2D grid as depicted in figure 4. Communication links between vehicles and IoT devices are highlighted with dashed lines, indicating that they are within range and can communicate.

The comparative analysis yielded several important insights into the performance of deep learning models for intrusion detection in VANETs. Table 2 provides a summary of the accuracy, precision, recall, and F1-score for each model, while Figure V visualizes the trade-off between detection accuracy and computational cost.

Table 2 Shows a performance comparison of various model

Model	Accuracy	Precision	Recall	F1-Score	Compu-tational Cost (ms)
CNN	95.40%	93.20%	92.50%	92.80%	15

RNN	96.10%	94.10%	93.80%	93.90%	25
LSTM	97.30%	95.20%	94.90%	95.00%	30
Decision Tree	88.40%	86.30%	85.70%	85.90%	10
SVM	90.20%	88.40%	87.90%	88.00%	20

Figure 5 shows that while the LSTM model achieves the highest accuracy, it also comes with a higher computational cost compared to simpler models like CNNs and traditional methods like Decision Trees. This trade-off is critical when considering resource-constrained environments, such as IoT-integrated VANETs.
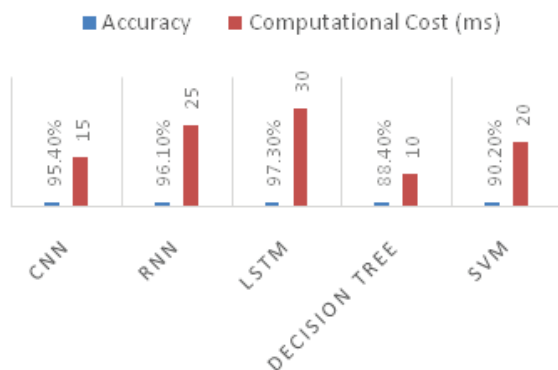
Fig 5. Shows accuracy and computational cost

LIMITATION, CONCLUSION AND FUTURE SCOPE

Limitation

This study provides a comprehensive comparison of deep learning-based intrusion detection systems for VANETs, with a focus on integrating IoT devices. Our results show that deep learning models, particularly LSTMs, outperform traditional machine learning techniques in terms of detection accuracy and scalability. However, the higher computational cost associated with these models presents challenges for real-time deployment, particularly in resource-constrained environments.

Challenges and Opportunities in IoT Integration

Resource Constraints: IoT devices often have limited computational power, memory, and energy, making it challenging to implement complex IDS algorithms.

Heterogeneity: The diverse nature of IoT devices and protocols can complicate the development of a unified IDS solution.

Privacy Concerns: Integrating IoT devices into VANETs raises privacy concerns, as sensitive data may be collected and transmitted.

Real-time Requirements: VANETs demand real-time intrusion detection to prevent accidents and ensure safety. IoT devices may introduce latency and delay.

Security Vulnerabilities: IoT devices themselves can be compromised, becoming potential attack vectors for VANETs.

Addressing Challenges and Opportunities

Lightweight IDS Algorithms: Develop optimized IDS algorithms that are suitable for resource-constrained IoT devices.

Federated Learning: Utilize federated learning techniques to train IDS models collaboratively without sharing sensitive data.

Privacy-Preserving Techniques: Employ privacy-preserving techniques, such as differential privacy, to protect user data.

Edge Computing: Offload computationally intensive tasks to edge devices to reduce latency and improve real-time performance.

Secure IoT Device Management: Implement robust security measures to protect IoT devices from attacks and ensure their integrity.

Intrusion detection is a critical aspect of VANET security, and the integration of IoT devices presents both challenges and opportunities. By carefully considering the limitations and advantages of different IDS techniques and addressing the associated challenges, it is possible to develop effective and secure VANET systems that can withstand emerging threats. Future research should focus on developing lightweight, privacy-preserving, and real-time IDS solutions tailored to the unique requirements of VANETs and IoT environments. [1,11,13]

CONCLUDING REMARKS

Findings: The key findings of the research, emphasis the contributions made to VANET and IoT security. Demonstrated the effectiveness of DL-based IDSs in detecting and mitigating various types of attacks in VANET and IoT environments. [16]

Implications: The potential implications of the research for developing and deploying secure VANET and IoT systems. The benefits of using DL-based IDSs to protect critical infrastructure, enhance user privacy, and improve the overall security of connected vehicles and devices. [18]

FUTURE SCOPE

Ethical Implications: The ethical implications of deploying IDSs in VANETs, include privacy concerns, surveillance risks, and potential biases. The importance of ensuring that IDSs are used ethically and responsibly.

Regulatory Framework: We have analyzed the existing regulatory framework for VANET and IoT security and explored the need for new policies or standards. These research findings can help the development of effective regulatory measures to protect VANET and IoT users.

User Experience: Consider the impact of IDSs on the user experience, ensuring that they do not compromise the usability or performance of VANET and IoT applications. Explore new ways to design IDSs that are transparent, efficient, cost-effectiveand minimally invasive to users.

In future work, we plan to address these limitations by exploring lightweight deep-learning architectures and further optimizing hyper parameters to reduce computational overhead. Additionally, real-world testing using data from live VANET deployments will be crucial to validate the findings of this study and ensure that the proposed IDS models can handle the dynamic and resource-limited nature of such networks.

We also recommend that future research explore post-detection strategies, including mitigation techniques, and investigate methods to minimize false positives in IDS, which remains a critical challenge in large-scale networks.

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The Influence of Incorporating Nanofillers Such as Calcium Carbonate and Talc in Epoxy Glass Fiber Composites on Mechanical Characteristics

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ABSTRACT

The paper elaborate the method of preparation of glass fiber reinforced epoxy nanocomposite with incorporation of inorganic nanofillers such as Calcium Carbonate (CaCO3) & Talc. The effect of adding nanofillers has been studied with respect to mechanical properties. The observed properties have been compared with epoxy glass fiber composite without nanofillers. Comparisons of properties such as tensile strength, flexural strength and izod impact strength have been studied.

KEYWORDS : Nanofillers, $CaCO_3$, Talc, Epoxy, Glass fibers.

INTRODUCTION

The polymeric composites exhibit reduced density, enhanced mechanical strength, and increased durability, rendering them advantageous for a multitude of applications encompassing the automotive, aerospace, defense, maritime, and other industrial sectors. Composites are mostly made up of polymeric matrix and reinforcing materials [1]. Although the matrix and reinforcement individually possess adequate intrinsic characteristics for the composite, numerous industries have identified fillers as supplementary agents to enhance certain properties of the composite, thereby affording it augmented functionality. Due to the geometrical attributes of the filler, as well as its surface area or chemical composition, the properties of the polymeric composite are subject to modification. The incorporation of fillers not only reduces the material costs but also enhances the mechanical and other functional properties of the composite [2]. Composite made by matrix embedded nanofillers and reinforcement three phase system is a new trend in the subject of nanocomposites. The primary objective of utilizing nanofillers with dimensions less than 100 nm is to effectively connect the matrix and the reinforcement while concurrently enhancing the mechanical integrity of the matrix [3]. Numerous scholarly investigations have been conducted in recent years concerning nanofiller-based composites. Carbon nanofillers and nanotubes are particularly favored within industrial applications [4]. The emergence of a novel trend in nanocomposites has been facilitated by the advancement of inorganic mineral nanofillers, including but not limited to Nano clays and Nano silicates [5-6]. Researchers to date have conducted experiments on a multitude of combinations, including clay-reinforced nanocomposites [7], glass reinforced epoxy based composites with flyash as nanofillers [8], glass reinforced vinyl ester composites with clay as nanofillers [9] etc. Numerous additional nanofillers exist; however, limited investigations have been conducted regarding composites that utilize a combination of Calcium Carbonate and Talc nanofillers. Nanometer-scale Calcium Carbonate ($CaCO_3$) has gained significant utilization within an organic matrix owing to its economical nature, minimal toxicity, reduced environmental footprint, and low aspect ratio. The extensive surface area it possesses may facilitate strong interfacial interactions between the filler and the polymer matrix [10]. On the other hand nanometer-scale talc possesses intrinsic benefits including elevated chemical purity, enhanced thermal stability, increased

surface area, and self-lubricating properties [11]. Epoxy resins are widely utilized as composite matrices due to their strong chemical resistance, low shrinkage during cure, low electric insulating properties, and ease of processing. Epoxy resins, however, are comparatively weaker and less rigid than metals when used in engineering applications [12]. However, the development of nanofillers such as $CaCO_3$ and Talc with their above mentioned properties could solve the problems of low stiffness and crack propagation occur in Epoxy composites. Therefore, in light of the trend for the future, the nanocomposite should be given new dimension by preparing and studying changes in properties of epoxy based nanocomposite on addition of $CaCO_3$-Talc based nanofillers.

EXPERIMENTAL

Materials

For making nanocomposite, Epoxy resin (Grade Lapox L12) and Hardner (Lapox k6) were procured from M/s Atul Ltd. Steric acid treated Nanofillers such as $CaCO_3$ (particle size- 50 to 100 nm) and Talc (particle size- 50 to 100 nm) were purchased from Nano research Lab. E-Glass Fiber (chopped strand mat) and S-Glass Fiber (Woven Mat) were procured from Gogreen Products.

Preparation of Nanocomposite

The preparation of nanocomposite was started with the dispersion of nanofillers into the epoxy resin as shown in FIGURE I & II. For proper dispersion of nanofillers into matrix, it must be treated with coupling agents like silane and steric acid [13-14]. Here the nanofillers procured from vendor were already treated with steric acid. Before dispersing, the nanofillers were dried in oven at 800C for 2 hrs to remove any moisture. The quantity of nanofillers and resin for dispersion is depicted in formulation E2 as given in TABLE I. The dried nanofillers and resin are mixed thoroughly with the help of high speed stirrer at a speed of 2000 rpm. In second step hardener is added in prepared dispersion. The nanocomposite sheet was prepared by sandwich pattern where 5 layers of glass fiber are used. The reinforcement of 3 layers of E glass fiber and 2 layers of S glass fibers are used in the formulation. Each nanofiller resin impregnated layer is placed over each other in a two metal plates and compressed in a compressing jack

for 24 hrs. After 24 hrs., cured nanocomposite sheet is removed from compressing jack and compared its mechanical characteristics with the composite sheet without nanofillers as given in formulation E1 shown in TABLE I.
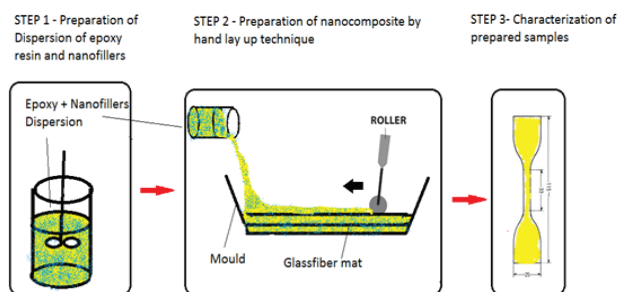
Fig 1. Preparation of Nanocomposite
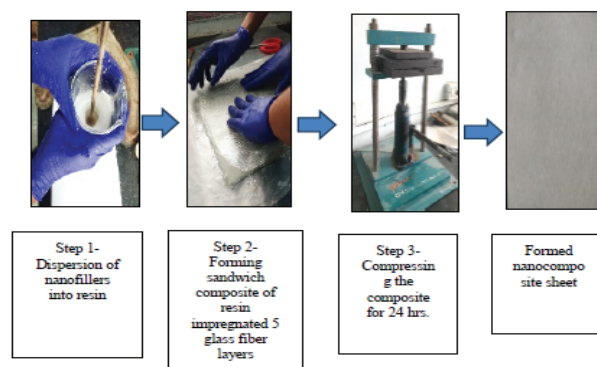
Fig. 2. Stepwise preparation of Nanocomposite

Nano sized $CaCO_3$ loading was kept as 4 % and nano sized Talc loading was kept as 2 % after consider the preveious research done by the researchers[15-16]. The optimum results for mechanical charecterizations observed with these amount of filler content in the composite.
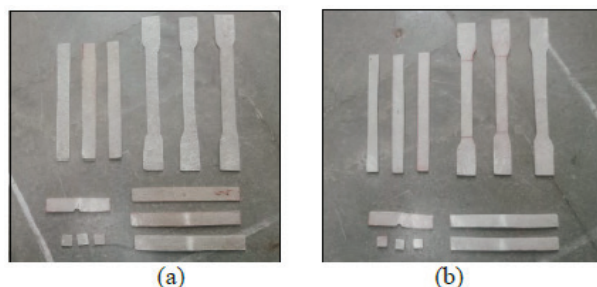
Fig 3 Specimens prepared for mechanical characterization (a) Prepared with formulation E1 (b) Prepared with formulation E2

Table 1. Formulations for preparing composite sheets

Components	Size (cm)	E1 (Wt. %)	E2 (Wt. %)
Epoxy resin	-	100	100
Hardener	-	10	10
E – glass (1st Layer)	20 x 20	8	8
S – glass (2nd Layer)	20 x 20	6	6
E – glass (3rd Layer)	20 x 20	8	8
S – glass (4th Layer)	20 x 20	6	6
E – glass (5th Layer)	20 x 20	8	8
Nano $CaCO_3$	-	-	4
Nano Talc	-	-	2

CHARACTERIZATION OF PREPARED SPECIMENS

Three specimens for each test were cut from the prepared sheets according to ASTM standards as shown in FIGURE III. The specimens were tested on the testing equipment as shown in FIGURE IV. Test results observed for two formulations i.e., E1 and E2 were compared for tensile strength, flexural strength and izod impact strength.

(a)   (b)   (c)
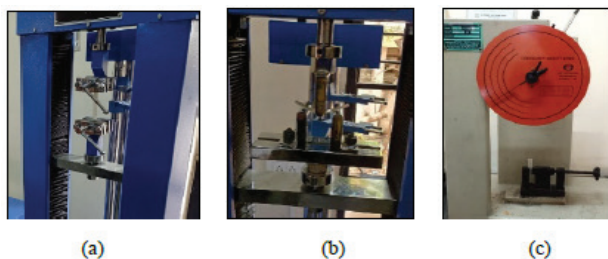
Fig 4. Equipment for testing mechanical properties (a) UTM for measuring tensile strength (b) UTM for measuring flexural strength (c) Izod impact tester for measuring impact strength.

Tensile Strength

Tensile strength was measured according to ASTM D638. Standard dumbbell shaped or dog bone shape specimens from each sheet were cut and tested on Universal Testing Machine of Veekey Industries make. It was having load capacity of 10 Tons. Crosshead speed of the test was kept as 20 mm/min. The average of three specimens was considered as the tensile strength of the prepared composites.

Flexural Strength

The rectangular bar shaped three specimens were cut from prepared each sheet for the determination of flexural strength as per ASTM D790. The specimens were fitted in between the UTM machine's jaws, attached with a three-point bending fixture. A crosshead speed was kept at 2 mm per minute. Flexural strength of each sample is noted. The average of three specimens was considered as the flexural strength of the prepared composites.

Impact Strength

Impact test specimens were cut according to ASTM D 256 M to measure the izod impact strength. The dimensions of specimens were 63.5 x 12.7 x 10 mm. A V-notch cut was made on the composite specimens with a sharp triangular file having an included angle of 450 at the center. The specimens were tested on Izod/Charpy impact testing machine manufactured by International Equipments, Mumbai. The energy (joule) absorbed per millimeter of specimen thickness while being broken was observed as the test results. Average of three specimens from each formulated composite sheets were considered as the impact strength in J/mm.

RESULT AND DISCUSSION

All the data after mechanical characterization was recorded as given in TABLE II. Individual mechanical characteristics have been studied and discussed as follows.

Table 2 Mechanical characterization of specimens for formulation E1 and E2

Mechanical Property	Formulations	Specimen 1	Specimen 2	Specimen 3	Average
Tensile Strength N/mm^2	E1	33.41	41.64	44.81	39.95
	E2	39.82	55.21	46.71	47.24
Flexural Strength N/mm^2	E1	135.18	133.01	188.82	152.33
	E2	224.14	225.44	235.21	228.26
Impact Strength J/mm	E1	0.53	0.81	0.65	0.66
	E2	0.65	0.89	0.55	0.69

Tensile Strength

Graph shown in FIGURE V suggest that the average tensile strength of composite containing 4 wt. % of $CaCO_3$ and 2 wt. % of Talc is 47.27 N/mm^2. Whereas Composite which doesn't contain nanofillers have

average tensile strength of 39.94 N/mm2. 18% improvement in tensile strength is observed with composite containing nanofillers. The improvement in tensile strength is because the good interfacial interaction between nanofillers and matrix resin. Also the nanofillers have the ability to absorb or dissipate the energy from matrix [17-18]. Nano $CaCO_3$ used in the composite were treated with steric acid which helped in increasing the interfacial interaction and better dispersion of these filler into matrix [19]. This also helped to transfer and distribute the load evenly throughout the composite. Nano talc added also gives the additional advantage of lubricity [20]. The mobility of talc helped the nanocomposite to fill the gap if any remained in between $CaCO_3$ and matrix. Hence chances of propagating the cracks negated.
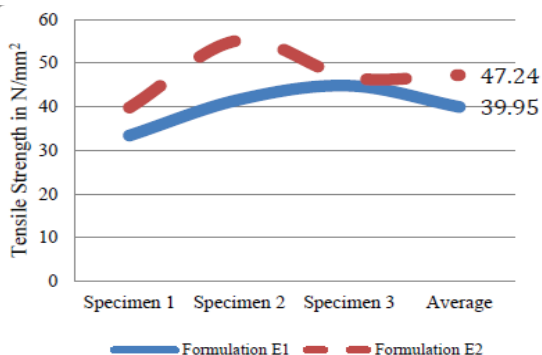
Fig. 5 Plot of tensile strength for formulation E1 and E2

Flexural Strength

As like tensile strength, an average flexural strength of composite sheet prepared with nanofillers is having higher value than the composite sheet without nanofillers. It is mentioned in TABLE II, an average flexural strength of formulation E2 is 228.26 N/mm² while an average flexural strength of formulation E1 is 152.33 N/mm². Plot shown in FIGURE VI suggests an improvement of 49 % in flexural strength observed with the nanocomposite. Hence it proved the importance of nanofillers in glass reinforced epoxy composite. This significant result was possible only because the inherent properties $CaCO_3$ and Talc. Even distribution and dispersion of nanofillers allow to soak the bending load evenly throughout the specimens caused while flexural tests. Hence increased load bearing capacity helped the prepared sheets to counter any crack propagating effect.

Impact Strength

According to the results observed in TABLE II and plot shown in FIGURE VII, there wasn't any drastic change in impact strength of specimen prepared with formulation E1 and E2. The average value of observed izod impact strength of specimen with formulation E1 is 0.66 and formulation E2 is 0.69 which is almost same. There might be slight improvement in impact strength up to 4.5% in nanocomposite specimen but that is negligible.
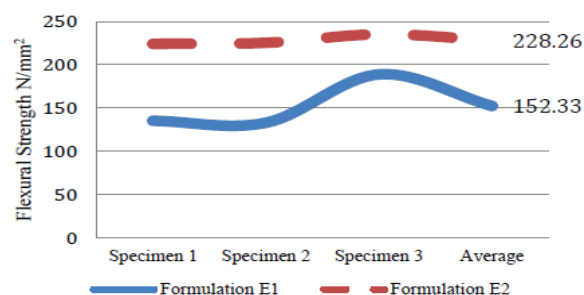
Fig. 6 Plot of flexural strength for formulation E1 and E2

But we can say that the nanofiller loading do not hamper the overall impact properties of composite. According to test results shown in TABLE II, specimen 2 of E2 shows lower value of impact strength than specimen of E1. That is because the specimen have pin holes in it which may be occur because of agglomeration of nanoparticles at one of the section of nanocomposite sheet.
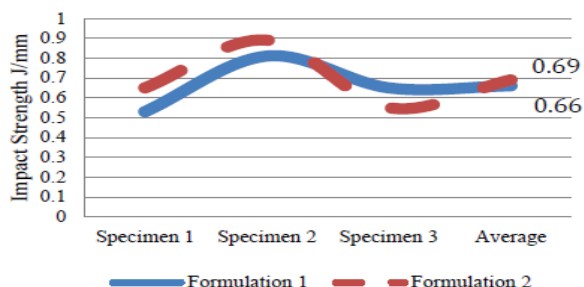
Fig. 7 Plot of impact strength for formulation E1 and E2

CONCLUSION

Epoxy/Glass fiber nanocomposites prepared with inclusion of dispersed nanofillers CaCO3 and Talc into it not only improve the tensile strength up to 18% and flexural strength up to 49% but also maintain its impact strength with slight improvement up to 4.5%.

The study could be further continue with the different loading percentage of nanofillers. One can carry out the comparative study of mechanical properties on different percentage of loading of nanofillers in epoxy composite.

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Performance Analysis of Concrete Pile Encased with Sand Cushion in Black Cotton Soil using Experimental Study

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ABSTRACT

The paper presents the performance of a single concrete pile encased with sand cushion in Black Cotton soil. The prevalence of black cotton soil has been proved to be deleterious for construction activities owing to its low permeability, low shear strength, high compressibility, low bearing capacity and high shrinkage – swelling properties. This soil shrinks when the temperature goes beyond 450C and cracks of 200 mm wide with 450 mm depth are formed, resulting into differential settlement of foundation and thereby occurrence of foundation failure. Black Cotton soil covers about 15% of land in Indian Territory. Hence, Geotechnical engineers have to ensure a good safety margin against failure of foundation by soil rupture. To overcome this situation, experimental investigations have been carried out by fabricating a similitude model of concrete pile encased with sand cushion in laboratory of govt. college of engineering (GCOE), Amravati using 1:30 as scale factor for the dimension of model pile. Different diameter ratios (Dr) and height ratios (Hr) were considered & static pile load were applied thereupon. The results obtained for the piles with & without cushion were compared and optimum diameter ratio & height ratio giving maximum load carrying capacity of pile was found out. The result so obtained was based on the frictional resistance offered by peripheral surface of pile. It is observed that, for Dr = 1.6 & Hr =1 the increase in ultimate load carrying capacity of concrete pile was found to be 55.56% more than ultimate load of pile without sand cushion condition.

KEYWORDS : *Diameter ratio, Frictional resistance, Height ratio, Sand cushion.*

INTRODUCTION

The civil engineering constructions are expanding rapidly in horizontal directions resulting into shortage of appropriate land for laying stable, serviceable and safe foundations. Thus, the land which was utilized in the past for growing crops is now-a-days wildly used for construction activities. In Vidharbha region the availability of black cotton soil is in abundance which is the most treacherous soil for civil engineering constructions point of view. Black cotton soil contains minerals like Montmorinolite and Kaolinite responsible for causing shrinkage & swelling. Due to, low shear strength, high compressibility, low permeability, high plasticity, low bearing capacity and high swelling-shrinkage properties of black soil, the selection of shallow foundations may found to be risky

and unstable. For satisfying the serviceability criteria of foundation, it must be safe from failures viz. structural & rupture of soil. Stability criterion of foundations is akin to moment of resistance in the design of beams and settlement criterion of foundation is analogous to deflection of beams. Hence, deep foundations have proved to be the appropriate for laying foundations in black cotton soil. The foundations viz. shallow & deep differs in geometry or shape, load transfer mechanism and changes induced in the soil during installation. Similarly, the structural design must ensure the safety of foundation against structural failure, as the consequences due to such failure are disastrous & remedial measures thereof are highly expensive. In lieu of which, the present study i.e. Pile encased with cushion of sand in clayey soil (Black Cotton) utilizes combined properties

of frictional and end bearing resistance offered by soil to increase the load carrying capacity of pile. For this purpose, a similitude in-situ model pile was fabricated in the laboratory of GCOE, Amravati.

Encased Pile Foundation: A New concept (refer figure I): Pile is a deep foundation, slender, structural member installed to transfer the structural loads at significant depth. The vertical loads i.e. compression loads are resisted by skin friction or by tip of base of the pile. If the skin friction is more than about 80% of end bearing load capacity, the pile is called as Friction pile or Floating pile; where end bearing is neglected and if the base resistance offered is greater than skin resistance the pile is said to be End Bearing pile.

The ultimate load capacity (Qu) is calculated as eq (i).

$$Q_u = (Q_f + Q_b) - W_p \qquad \text{(i)}$$

Where, Wp is the dead weight of pile which is neglected for a pile of small cross-sectional areas < 0.07m2 i.e. in eq. (ii)

$$\frac{\pi}{4} d_p^2 = 0.07 \ m^2 \qquad \text{(ii)}$$

Thus, $d_p \approx 300$ mm, the equation is independent of settlement. Q_f and Q_b are derived using follsowing eq. (iii) & (iv)

$$Q_f = A_p \times \frac{q_s}{a} \times F \qquad \text{(iii)}$$

$$Q_b = A_b \times q \times F \qquad \text{(iv)}$$

Where, Q_f=Frictional resistance of pile

Q_b= Base resistance of pile

A_p= Peripheral area of Pile, q_s= Skin Friction force,

a= unit area of pile surface , F= Factor of Saftey

A_b= Area at base or tip of pile

q= Bearing capacity of soil at that particular depth

LITERATURE REVIEW

Zhiguo Zhang et al. [1] (2004) performed experimental study on pile-bottom grouting technique for bored pile. At the inception, concrete was poured at the bottom of pile through a grouting pipe & cured for 3 days and then the cement grouts was injected under high pressure, ensuring increase in the pile tip resistance and thereby

piles capacity. Accordingly, the maximum load which a single-pile can sustain 8000 kN (bearing capacity), as against the designed value of 7500 kN (designed standard bearing capacity). And the ultimate load a vertical single-pile can sustain more than 11735 kN (Ultimate bearing), which is more than the designed value of 7500 kN. It was found that, the ultimate bearing capacity of bored cast-in-situ piles increased considerably.
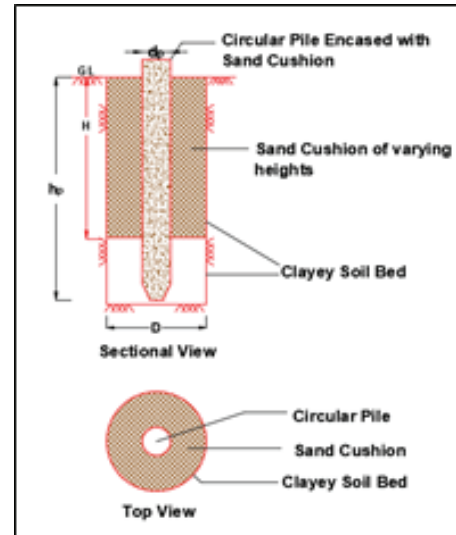
Fig. 1 Concept of A Pile Foundation Encased with Sand Cushion

Literature gap

The slimes after solidification may subjected to several cracks due change in moisture content & sustainability of expanded bulb may not be ensured.

The possibility of side wall collapse cannot be ignored during injecting high pressure grout.

L. Lee et al. (2010) [2] performed experiment to study & analyses the changes in soil properties surrounding cast-in-situ concrete piles. These piles were prepared in the bed of soil & tested till failure, during which the changes in moisture content and ion concentration of soil were measured at varying depths. Curing of bed was done for a month and moisture content was measured which ranged between 23.4% - 25%; confirming the uniformity of clay. A hole of either 133 or 75-mm diameters was augured and fresh concrete was poured in such a way that, the bottom 70 mm portion consisted of void ensuring transfer of load through side friction.

The specimen was then cured for a period between 1 to 10 months and the capacity of the piles was determined. Load was applied at the rate of 0.01 mm/min so as to obtain least pile deformation equal to 10% of the pile diameter. Literature gap:

In field the variation in moisture content is inevitable and hence the control of OMC cannot be ascertained.

The changes in the ion contents of soil have very little effect on concrete pile.

The migration of ions does not adhere to increase in the ultimate load bearing capacity of soil.

B P Naveen et.al [3] (2011) carried out analytical study on full scale vertically loaded bored cast in-situ pile in residual soils using FEM technique developed by PLAXIS 2D software for a single pile with large diameter subjected to vertical load at pile top, so as to evaluate the settlement of the pile. For the sake of validation, the results of FEM simulations were compared with field test results. For field study a bored cast-in situ single pile was considered with Diameter (D) = 1200mm, Length(L) = 15 m, M - 30 grade of concrete, Nature of soil – Layered soil Clay (0 -6m) & Soft-weathered rock (6 – 20m). The pile interaction in soft weathered rock was greater than top clayey soil and as one goes away from the pile, the maximum effective stress becomes nearly vertical. The deformed mesh of pile-soil interaction was equal to 4.91mm settlement & the effective stress distribution around the pile occurred at the same settlement value i.e. 4.91mm. The maximum skin resistance was observed in soft- weathered rock layers.

Literature Gap

The study provides the comparative study between analytical & field performance for a particular case.

The effect of stiffness around concrete pile (usually 40%) not considered which ought to have been.

The values of skin friction resistance & end bearing resistance have not been shown.

L. Borana et al. (2016) [7] performed analysis by conducting series of pull-out tests on pile model for study to know the influences of initial water content and roughness on skin friction of piles using FBG (Fibre Bragg Grating) technique where strain sensors were used to measure axial strains and skin friction of the pile. The results indicated that the skin friction and axial strain of the model piles decreased with the initial water content but increased with rough surface of the piles. The induced axial strain in the upper segment of pile was greater than bottom segment.

Literature Gap

The influence of stress & its accumulation is not considered for comparing with Mohr's – Coloumb criteria for elastic behaviour.

Water content in the soil & its influence on pile is inevitable & its dissipation is quite impossible.

To reduce the influence of initial water content & axial strain provision of sand cushion shall be made

SYSTEM DEVELOPMENT

To investigate the performance and load carrying capacity of concrete bored pile encased in sand cushion subjected to axial loading in Black Cotton soil bed, experimental investigations have been carried out in laboratory of GCOE Amravati. A scale factor was selected for various sizes of pile and sand encasement portion. Various parameters such as Diameter Ratio & Height Ratio were taken in to consideration for investigation. The experimental set-up consists of following equipment & materials:

Equipment

Test Tank: Mild steel test tank of 400mm x 400mm x 600mm was fabricated with detachable arrangement, particularly sides & bottom so as to remove the tested soil easily. All edges of tank viz. vertical & bottom were stiffened using mild steel angle section to avoid lateral yielding of material during soil compaction.

Hydraulic Jack (50T capacity): It was fixed at the center of horizontal member of the reaction frame and static vertical loads were applied to the model concrete piles encased with sand cushion with the help of hydraulic jack.

Dial Gauges: Two dial gauges fixed to the magnetic bases which in turn are fixed to the sides of the tank with 25 mm travel and least count of 0.01 mm were used for measuring the settlement of the model piles.

Loading Frame: The loading frame used for applying vertical loads on the model pile consisted of one horizontal member and two vertical members made of ISMB section.

Proving Ring (5kN capacity): It was fixed to the bottom plunger to transfer load from hydraulic jack to the model pile and also to record the load applied on the model pile.

Drilling Equipment: Drilling caps of different diameter were attached to the bottom of steel pipe with height and diameter equals to concrete pile and sand cushion. A drilling cap of definite diameter was then fixed to the drilling machine with the help of nut-bolt arrangement and required size of borehole was made for making pile & cushion.

Materials

Kanhan Sand: Cohesionless, air-dried and clean sand from Kanhan River was used for cushion. Sand particles passing through 2 mm sieve and retaining on 1.18 mm IS sieve was selected. The properties of sand were determined in the laboratory.

Black Cotton Soil: The soil was collected from the premises of Government College of Engineering, Amravati and used as a foundation soil for investigation. The properties of this soil were determined in laboratory.

Cement: PPC 53 grade cement Birla Gold was used for concrete mix of M-25 grade.

Metal 6mm size: Actually, well graded trap metal viz.6mm, 10mm, 12mm, 18mm & 25mm sizes were to be used for M-25 grade cement concrete; but due to small diameter of pile only 6mm size particles size were used.

Bentonite slurry: The slurry was sprinkled around periphery of hole to avoid collapse of side wall during concreting work and gradual removal of PVC pipe

Tendons: Tendons were used as a reinforcing material and were inserted in to PVC pipe before concreting work.

EXPERIMENTAL TEST PROCEDURES

Preparation of clayey soil bed: An air-dried soil was mixed with OMC and kneaded. A thin layer of oil was applied on the internal surfaces of m. s. tank which was then filled with measured quantities of soil in three equal layers & each layer was given 25 numbers of blows with 300mm as drop height so as to get maximum dry density.

Bored Pile Encased with Sand Cushion: After preparing a clayey bed, a borehole was done centrally using drilling bit of diameter equal to diameter of sand cushion. The annular space was then filled with a measured quantity of sand. Again a hole, equal to diameter of model pile, was drilled at the center of sand cushion and bentonite slurry was sprinkled around the periphery. Then, a PVC pipe equal to diameter of model pile was inserted in to the drilled hole and a reinforcing cage was put in it. Concrete mix of M-25 grade was poured in to a drilled hole and a pipe was then gradually taken out while concreting work was in progress. The concrete was tamped carefully to avoid no air voids in it. The concrete was then cured for 3 days continuously.

Pile Load Test on Model Concrete Pile Encased with Sand Cushion: To evaluate ultimate load carrying capacity of pile as per IS: 2911 (part4)1985, the static vertical compressive pile load tests were conducted on a model concrete pile encased with sand cushion (as shown figure II). The vertical compressive load was applied on the pile with the help of hydraulic jack fitted to the loading frame. The proving ring was attached to the bottom of hydraulic jack. One metal rod was connected to the bottom threads of proving ring and rested directly on the groove made on pile cap. The loads were applied in increment and settlement of the pile was then measured with the help of dial gauges. Each load increment was kept constant till the rate of settlement becomes less than 0.1 mm per 30mins. Application of load increments were continued till failure of model pile was observed, which was indicated by rapid settlement of pile.

Failure Criteria: The criterion decided for determination of ultimate load capacity of pile was i) As per IS: 2911, Part IV when load versus settlement curve shows either a peak and then downward trend, or a peak and then almost a straight line, it represents the ultimate lateral load capacity of the pile ii) The total settlement of model pile reaches to 10 % of diameter of pile (i.e., 2.70 mm).

Fig. 2 Experimental Test Setup for Pile Load Test

QUANTITY OF SAND REQUIRED

To maintain uniform density of the sand cushion, the calculated mass of sand was poured around the model pile as per Table 1.

Table 1. Calculation of Quantity of Encased Sand Cushion for Uniform Density

Sr. No.	Sand Cushion	Area (mm²)	Volume (cm³)	Mass (gms)
1	1dp = 27 mm 1hp = 400 mm	572.26	228.90	Nil
2	1.4dp = 38 mm 1hp = 400 mm	1133.54	453.42	656.10
3	1.6dp = 44 mm 1hp = 400 mm	1519.76	607.91	879.65
4	2dp = 54 mm 1hp = 400 mm	2289.06	915.63	1324.92
5	1.4dp = 38 mm 0.75hp = 300 mm	1133.54	340.06	492.07
6	1.6dp = 44 mm 0.75hp = 300 mm	1519.76	455.93	659.73
7	2dp = 54 mm 0.75hp = 300 mm	2289.06	686.72	993.68
8	1.4dp = 38 mm 0.50hp = 200 mm	1133.54	226.71	328.05
9	1.6dp = 44 mm 0.50hp = 200 mm	1519.76	303.95	439.82
10	2dp = 54mm 0.50hp = 200 mm	2289.06	457.81	662.45
11	1.4dp = 38 mm 0.25hp = 100 mm	1133.54	113.35	164.02
12	1.6dp = 44 mm 0.25hp = 100 mm	1519.76	151.98	219.92
13	2dp = 54 mm 0.25hp = 100 mm	2289.06	228.91	331.24

Where dp = diameter of single concrete pile (mm)

hp = height of single concrete pile (mm)

PERFORMANCE ANALYSIS & RESULTS

Laboratory tests were performed on uncased & encased pile with sand cushion embedded in a bed of clayey soil. A vertical load was applied on model pile & load vs. settlement graph were drawn and from these graphs, the ultimate load was determined in each case by single tangent method. During the tests some parameters were kept constant and others varying as per Table 2 given:

Table 2 Details of Parameters used for Experimental Investigation

Sr. No.	Details of Parameters	Constant Parameter	Varying Parameter
1	Height of model pile embedded in sand cushion. (h_p)	400 mm	-
2	Diameter of Concrete model pile (d_p)	27 mm	-
3	Slenderness ratio (h_p / d_p)	15	-
6	Type of loading	Vertical	-
7	Shape of pile	Circular	-
8	Diameter of sand cushion (D)	-	1.0 d_p = 27 mm 1.4 d_p = 38 mm 1.6 d_p = 44 mm 2.0 d_p = 54 mm
9	Height of sand cushion (H)	-	1.0 h_p = 400 mm 0.75 h_p = 300mm 0.50 h_p = 200mm 0.25 h_p = 100mm

Table 3 shows the summary of result obtained from load vs. settlement curve as per experimental investigation.

Table 3 Summary of the Result from Load vs. Settlement Curve

Ultimate load for pile without sand cushion condition (Qu)	Height Ratio (Hr)	Diameter Ratio (Dr)	Ultimate Load carrying capacity of pile encased with sand cushion (kN)	% increase in load carrying capacity of pile encased with sand cushion
1	2	3	4	5
0.36 kN	0.25	1.4	0.37	2.78%
		1.6	0.48	33.33%
		2.0	0.40	11.11%
	0.50	1.4	0.38	5.56%
		1.6	0.50	38.89%
		2.0	0.48	33.34%
	0.75	1.4	0.56	55.56%
		1.6	0.60	66.67%
		2.0	0.58	61.11%
	1.0	1.4	0.42	16.67%
		1.6	0.56	55.56%
		2.0	0.50	38.89%

Where

$$Dr = \frac{D}{dp} = \frac{\text{Diameter of sand cushion around pile (mm)}}{\text{Diamtere of single comcrete pile (mm)}}$$

$$Hr = \frac{H}{hp} = \frac{\text{height of sand cushion around pile (mm)}}{\text{height of single comcrete pile (mm)}}$$
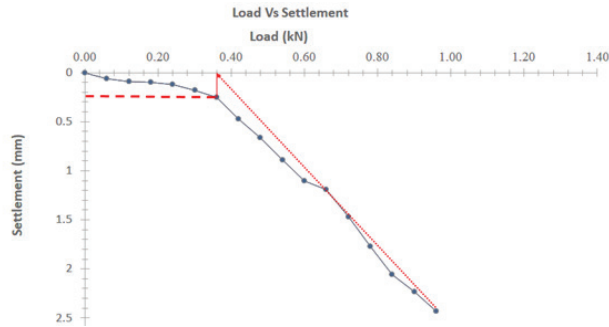
Fig 3. Load vs. Settlement Curve for Pile without Sand Cushion
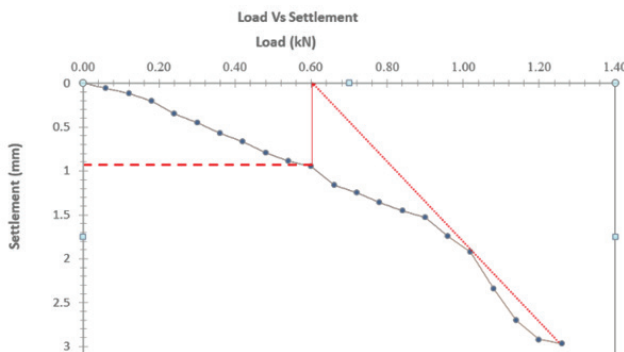
Fig. 4 Load vs. Settlement Curve for HR = 0.75 & DR = 1.6

from figure 3 it observed that Load vs. Settlement curve for pile without sand cushion gives the value of ultimate load is 0.36 kN using single tangent method, also from figure IV it can be seen that Load vs. Settlement curve for pile with sand cushion (i.e. Hr = 0.75 & Dr = 1.6) gives the value of ultimate load as 0.60 kN.

CONCLUSIONS

Vertical pile load tests were carried out on M-25 grade concrete piles in a bed of Black Cotton soil uncased & then encased with Sand Cushion. The conclusions drawn from the laboratory performance & obtained results are as follow.

For encased pile, its Ultimate Load carrying Capacity increases due to frictional resistance.

Ultimate Load carrying capacity of a pile encased with sand cushion increases for Dr = 1.6 & the percentage increase more than 66% than a pile without Sand Cushion.

For Hr = 0.75 & Dr = 1.60, Ultimate Load carrying Capacity of pile is maximum and is due to frictional resistance offered by the peripheral surface of Sand Cushion & hence, it would be economical, reasonable & safe to adopt these ratios for a encased pile in a bed of Black Cotton Soil.

The results obtained from analytical study viz. using MIDAS GTS NX software also revealed the maximum Ultimate Load carrying Capacity of a pile for Dr = 1.6 and Hr = 0.8 which amounts to validation of analytical results with demonstrative or laboratory results.

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Implementation of 9-Level Inverter Using Cascade H-Bridge and Flying Capacitor Topologies

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ABSTRACT

The Multilevel inverter technologies have become increasingly important in addressing challenges such as harmonic distortion, power losses, and stability in energy conversion processes. These inverters are widely adopted in industrial applications due to their ability to minimize losses, reduce switching stresses, and improve the quality of output waveforms. A comprehensive review of existing literature reveals that the Cascaded H-Bridge (CHB) and Flying Capacitor topologies are among the most effective multilevel inverter configurations. Research indicates that the CHB topology is highly modular, making it suitable for applications requiring scalability, while the Flying Capacitor topology offers superior voltage control and harmonic performance, making it ideal for precision applications. This paper presents a 9-level inverter design using the CHB and Flying Capacitor topologies, simulated in MATLAB/Simulink. The inverter converts DC voltage into multi-level AC voltage, maintaining operation even during system outages. Performance is assessed through total harmonic distortion (THD) analysis, with the nine-level configurations demonstrating THD values of 23.8% and 25.79% for the Flying Capacitor and CHB topologies, respectively.

KEYWORDS : Cascaded h-bridge (CHB), Flying capacitor inverter, Multi-level inverter (MLI), Renewable energy resources(RES).

INTRODUCTION

The increasing demand for efficient and reliable power conversion systems has spurred significant advancements in inverter technology. Among these, the Multi-Level Inverter (MLI) has emerged as a pivotal innovation, particularly suited for medium to high voltage applications. Unlike conventional two-level inverters, which have limitations in handling high power efficiently, MLIs generate output voltages from multiple levels of DC input voltages. Over recent decades, various multilevel inverter topologies have been developed, providing effective alternatives to series connections and single-switch configurations. The advantages of using multilevel inverters include:

I. They operate with minimal switching frequency, leading to remarkably high efficiency.

II. These inverters enhance power quality and dynamic stability within utility systems.

III. They exhibit lower switching stress and electromagnetic interference (EMI).

IV. Their modular and simple structure allows for stacking up to virtually unlimited levels.

Various energy sources, including PV panels, batteries, fuel cells, and capacitors, can serve as these DC sources. By combining multiple DC sources, MLIs achieve high-voltage output with improved power quality and fault tolerance. They are increasingly used in grid-connected

renewable energy systems (RES) due to their advanced power conversion capabilities.

This research focuses on implementing a 9-Level Inverter using Cascaded H-Bridge (CHB) and Flying Capacitor topologies. The objective is to compare these topologies based on harmonic reduction, and overall system performance, aiming to identify the most effective configuration for different applications.

MLIs are favoured for their low THD, reduced electromagnetic interference, and improved power quality. Compared to two-level inverters, MLIs offer advantages such as smaller, less costly filters, lower switching frequencies, and reduced switching losses. These benefits contribute to enhanced performance in high-voltage AC motor drives, distributed generation, and HVDC transmission.

MATERIAL AND METHODOLOGIES

Different MLI Topologies

In this research paper, we examine two pivotal topologies: the Cascaded H-Bridge (CHB) and the Flying Capacitor, both essential for optimizing performance, efficiency, and cost in electrical systems. These topologies are selected for their superior ability to improve output quality, scalability, and power handling, while maintaining a balance between reliability and cost-effectiveness. Each topology is critically analyzed to highlight its specific advantages, making them ideal choices for targeted high-performance inverter applications. Typical topologies include:

Cascaded H-Bridge Topology

Configuration: The Cascaded H-Bridge (CHB) inverter comprises multiple H-bridge cells connected in series. Each H-bridge cell, operating as a separate inverter unit, adds a specific voltage level to the overall output, forming a staircase-like waveform. The series connection of these cells enables the generation of a multi-level output voltage. Each H-bridge cell includes four switches (commonly IGBTs or MOSFETs) and a separate DC voltage source. The switches control the flow of current, while the DC source provides the necessary voltage. The combined output from all H-bridge cells constitutes the total output voltage of the CHB inverter.
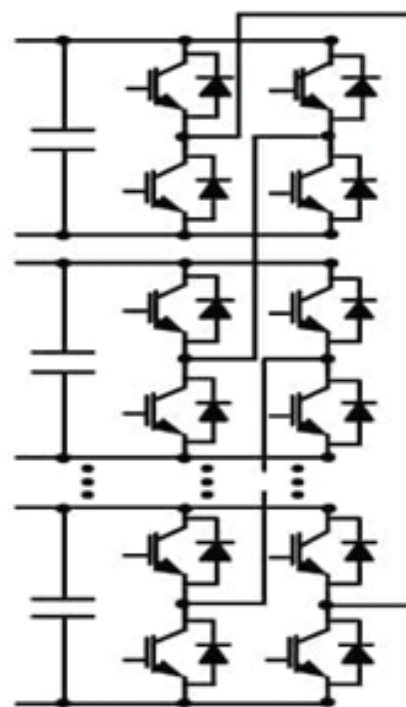
Fig. 1. Cascade H-Bridge Topology

A. Operation Principles

i.   Voltage Levels: The CHB inverter produces $2n+12n + 12n+1$ voltage levels, where n is the number of H-bridge cells. This arrangement allows precise control over the output voltage by creating discrete voltage steps.

ii.   Switching Strategy: Voltage regulation is achieved through Pulse Width Modulation (PWM), which controls the switching of each H-bridge. PWM adjusts the duty cycle of the switches to produce the desired voltage and minimize harmonic distortion.

iii. PWM Techniques: The CHB inverter employs PWM methods like Sinusoidal PWM (SPWM) and Space Vector PWM (SVPWM). SPWM generates a sinusoidal waveform, while SVPWM optimizes switching patterns to enhance performance and reduce harmonics.

iv.   Voltage Regulation: The modulation indices and switching patterns are adjusted to control the output voltage accurately. This allows the inverter to meet specific voltage requirements and adapt to varying load conditions.

v.   Harmonic Distortion: The multi-level design of the CHB inverter reduces Total Harmonic Distortion (THD), resulting in a near-sinusoidal output waveform with minimal harmonics.

vi.   Efficiency: The CHB inverter is efficient in handling high power levels due to its modular design and reduced switching losses.

vii.   Power Quality: The inverter improves power quality by producing a smoother output waveform, which reduces harmonic interference compared to traditional inverters.

The advantages of multilevel inverters include the requirement for fewer components to achieve the same number of voltage levels, eliminating the need for additional diodes and capacitors. Furthermore, the consistent structure of these inverters enables a scalable and modularized circuit layout, simplifying the overall design and packaging.

The Cascaded H-Bridge inverter is a robust and flexible solution for high-voltage applications, offering significant improvements in power quality and efficiency. Despite its complexity and higher cost, it remains a valuable technology for modern power systems.

Flying Capacitor Topology

The Flying Capacitor Inverter, also known as the Capacitor-Clamped Multilevel Inverter, is a sophisticated multilevel inverter topology designed to produce high-quality output waveforms with multiple voltage levels. This topology is engineered to minimize voltage stress on power semiconductor components, enhance waveform quality, and boost overall inverter efficiency.

The fundamental framework of a Flying Capacitor Inverter consists of multiple H-bridge cells connected in series. Each H-bridge cell contains capacitors, diodes, and semiconductor switches such as Insulated Gate Bipolar Transistors (IGBTs) or Metal-Oxide-Semiconductor Field-Effect Transistors (MOSFETs). Each H-bridge is equipped with a flying capacitor that connects between the DC bus and the midpoint of the H-bridge. These flying capacitors allow the inverter to produce various voltage levels by shifting, or "flying,"

between the DC bus voltage levels. The number of voltage levels the inverter can generate is dependent on the number of flying capacitors and their charge states. For instance, a three-level flying capacitor inverter can output voltages of $+V_{dc}$, $-V_{dc}$, and 0.

A. Operation Principles

i.   Positive Half-Cycle: During the positive half-cycle, the flying capacitors charge to various voltage levels. The H-bridge switches are adjusted to connect these capacitors in specific configurations, producing the required positive output voltage levels.

ii.   Negative Half-Cycle: During the negative half-cycle, the flying capacitors discharge to provide the necessary voltage levels for the negative part of the output waveform.

iii.   Voltage Balance: Advanced control techniques ensure that the voltage across each flying capacitor remains within acceptable limits, maintaining balance and preventing voltage imbalances.
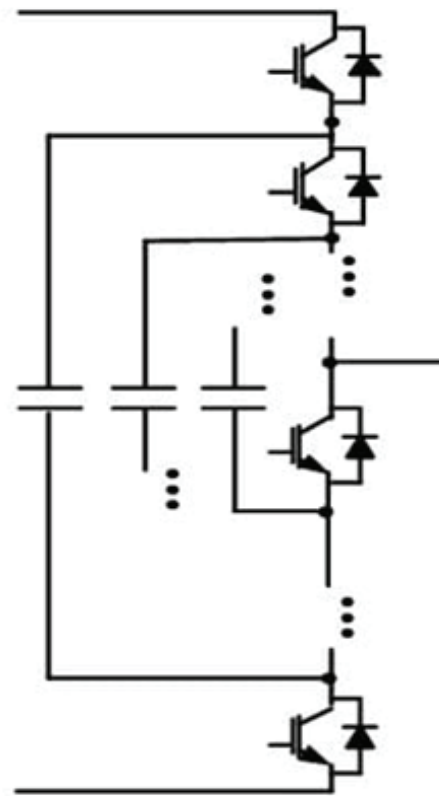

Fig 2. Flying Capacitor Topology

The Flying Capacitor Inverter offers several benefits, including reduced voltage stress by distributing it across multiple capacitors, which enhances the reliability of individual semiconductor components. It also produces a more sinusoidal output waveform with low harmonic distortion, leading to improved power quality. Additionally, the inverter achieves high efficiency through better voltage utilization and reduced semiconductor losses, making it a highly effective solution for various applications.

The Flying Capacitor Inverter has some drawbacks, including the need for complex control algorithms to manage voltage balance among the flying capacitors. Additionally, its scalability is limited, as increasing the number of voltage levels results in higher circuit complexity and more challenging system management.

The Flying Capacitor Inverter is commonly used in high- and medium-voltage applications, such as motor drives and renewable energy systems, where reducing voltage stress and harmonic distortion is crucial for reliable and efficient performance.

IMPLEMENTING 9-LEVEL INVERTER WITH CASCADED H-BRIDGE AND FLYING CAPACITOR TOPOLOGIES

A 9-level inverter is a type of multilevel inverter that generates a stepped output voltage waveform with nine distinct levels. The inverter produces nine voltage levels, which might typically be +Vdc, +7/8 Vdc, +3/4 Vdc, +5/8 Vdc, +1/2 Vdc, +1/4 Vdc, 0, −1/2 Vdc, and −Vdc. The more voltage levels there are, the closer the output waveform is to a pure sine wave. These levels provide a closer approximation to a sinusoidal waveform, which is highly desirable in applications requiring high-quality power output with reduced harmonic distortion.Total Harmonic Distortion (THD) is a key performance metric in power electronics that measures the deviation of an inverter's output waveform from a pure sinusoidal wave. It is defined as the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency. Lower THD values indicate a cleaner, more sinusoidal output, which is desirable for efficient and reliable power delivery.

Nine Level Inverter Based on Cascade H-Bridge

The 9-level inverter based on the Cascaded H-Bridge (CHB) topology is a multilevel inverter configuration that uses a series connection of H-bridge cells to produce multiple voltage levels. Each H-bridge cell consists of four semiconductor switches (typically IGBTs or MOSFETs) and a separate DC power source. The H-bridge cells are connected in series to achieve higher voltage levels. In a 9-level inverter, four H-bridge cells are typically used, each contributing to the generation of the output waveform.
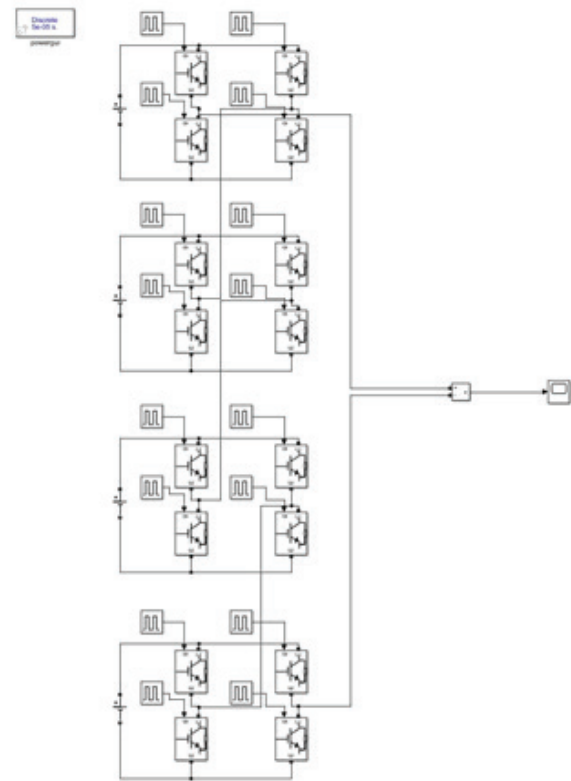
Fig 3. Nine Level Inverter Based on Cascade H-Bridge Topology

Working Principle

The 9-level CHB inverter operates by switching the H-bridge cells in a specific sequence to generate the desired output voltage levels. Each H-bridge can produce three voltage levels: +Vdc, 0, and -Vdc. By combining the outputs of the H-bridges, the inverter generates nine distinct voltage levels, typically: +4Vdc, +3Vdc, +2Vdc, +Vdc, 0, -Vdc, -2Vdc, -3Vdc, and -4Vdc.

The output waveform of a 9-level Cascaded H-Bridge (CHB) inverter is a stepped waveform that approximates a sinusoidal shape. Each step in the waveform represents a discrete voltage level, which is generated by controlling the H-Bridge cells to switch between different voltage states. With more voltage levels, the waveform more closely resembles a true sinusoidal shape, significantly reducing harmonic distortion compared to inverters with fewer levels.

Nine Level Inverter using Flying Capacitor Topology

A 9-level inverter based on the Flying Capacitor topology is a type of multilevel inverter that produces an output with nine distinct voltage levels. This topology is particularly known for its ability to generate high-quality waveforms with reduced harmonic distortion, making it suitable for various high-power and medium-voltage applications.

Circuit diagram
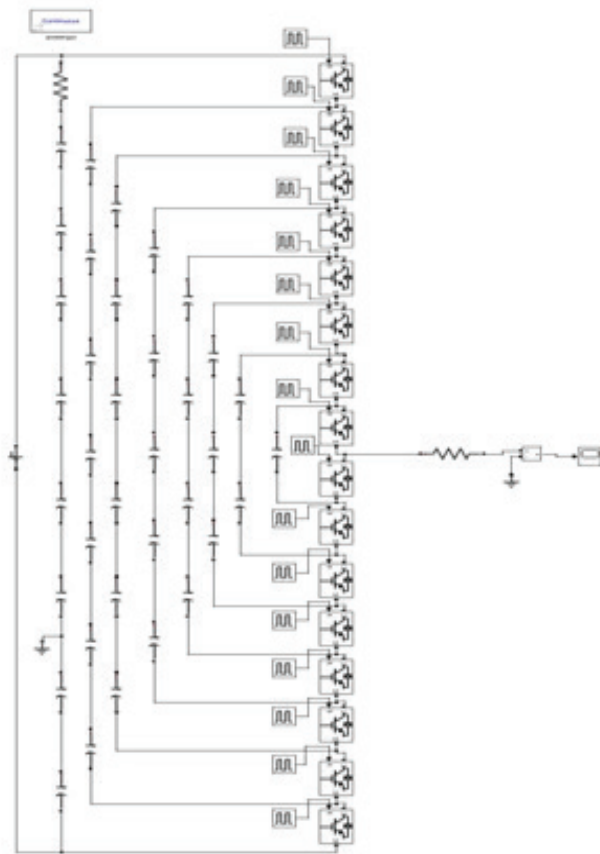
Fig 4. Nine-Level Inverter based on Flying Capacitor

Working Principle

i.   The FC inverter operates by charging and discharging the flying capacitors through the power switches. By appropriately switching these capacitors and switches, the inverter can generate multiple output voltage levels.

ii. The voltage levels are achieved by controlling the state of the switches and the charge distribution across the capacitors.

The output of a 9-level inverter consists of a multi-level voltage waveform with nine discrete levels, resulting in a stepped waveform that more closely approximates a sinusoidal shape than lower-level inverters. This improved sinusoidal approximation reduces ripple, creating a smoother output. Additionally, the multiple voltage levels help to significantly reduce Total Harmonic Distortion (THD), enhancing power quality and performance compared to inverters with fewer levels.

RESULT AND COMPARATIVE DISCUSSION: CASCADED H-BRIDGE (CHB) AND FLYING CAPACITOR TOPOLOGY USING 9 LEVEL INVERTER.
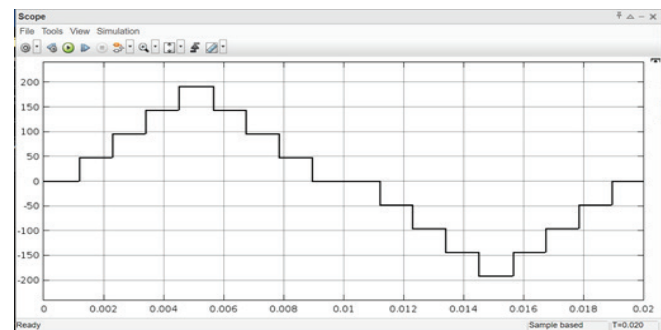
Fig 5. Nine-Level Inverter based on Cascaded H-Bridge (CHB) Topology Waveform

In this research paper, a detailed comparison of the Cascaded H-Bridge (CHB) and Flying Capacitor topologies is presented using a 9-level inverter, focusing on Total Harmonic Distortion (THD%) and output quality. The study evaluates the effectiveness of each topology in minimizing THD and enhancing output performance, offering valuable insights for selecting the most suitable topology in high-performance inverter applications.

Cascaded H-Bridge (CHB) Topology

Output Quality: Provides a smoother output waveform due to the combined outputs of multiple H-Bridge cells. The stepped waveform approximates a sinusoidal wave closely, reducing Total Harmonic Distortion (THD).

Flying Capacitor (FC) Topology

Output Quality: The output waveform is stepped with sharper transitions due to capacitor charging and discharging. While it approximates a sinusoid, the waveform can have more abrupt steps compared to CHB.
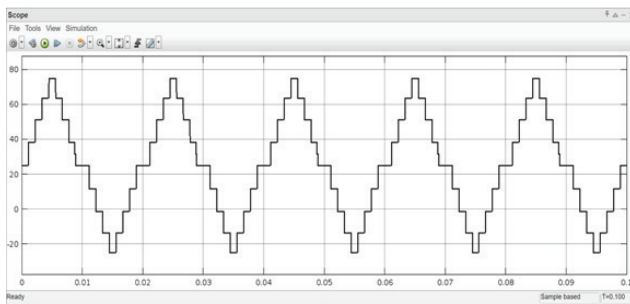
Fig. 6. Nine-Level Inverter based on Flying Capacitor

THD Analysis

Output Quality: The FC topology produces a highly sinusoidal output waveform with exceptionally low THD, as the capacitors allow for finer control over the output voltage levels. This results in a smoother waveform compared to other topologies.

Harmonic Reduction: The ability to finely adjust the voltage levels with capacitors leads to superior harmonic performance. However, control algorithms for maintaining capacitor voltage balance can be complex.

Total Harmonic Distortion (THD)

CHB Topology: Provides good THD performance but can be limited by the complexity of the switching sequences and the number of H-bridge cells. The waveform is stepped, and while improvements are achieved with additional cells, THD might not be as low as in the FC topology.

FC Topology: Component Count and Costs

CHB Topology: Higher component counts due to multiple H-bridge cells, leading to higher costs and maintenance complexity.

FC Topology: Also involves a high component count, including multiple capacitors and diodes, which can increase costs and complexity.

CHB Topology: Easily scalable by adding more H-bridge cells, but with increasing control complexity and costs.

FC Topology: Scalability can be challenging due to increased circuit complexity and the need for careful control of flying capacitors.

Comparison of THD Analysis of MLI

I. Nine-Level Inverter based on flying Capacitor
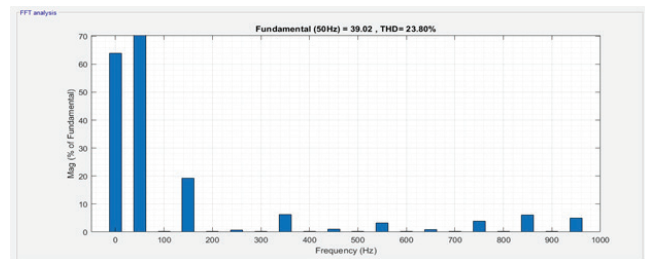
Fig. 7. Nine-Level Inverter based on flying Capacitor

II. Nine-Level Inverter based on Cascade-H-Bridge
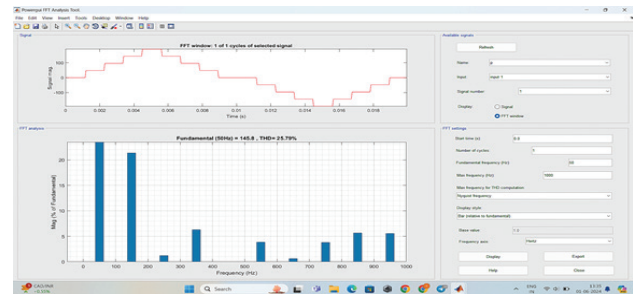
Fig. 8. Nine-Level Inverter based on Cascade-H-Bridge

Total Harmonic Distortion (THD)

1. Cascaded H-Bridge (CHB): The CHB topology typically exhibits lower THD compared to simpler topologies. This is due to its ability to produce a stepped waveform with multiple voltage levels, which effectively reduces harmonic content. The FFT analysis often shows a relatively flat spectrum with dominant low-order harmonics and minimized high-order harmonics.

2. Flying Capacitor: The Flying Capacitor topology also achieves low THD, but its performance in this regard can be sensitive to the number of levels

and the balancing of capacitor voltages. The FFT analysis generally shows a more complex harmonic profile compared to CHB, but still demonstrates a reduced THD relative to lower-level inverters.

Harmonic Spectrum

i.   Cascaded H-Bridge (CHB): The harmonic spectrum for CHB inverters tends to have well-defined harmonic components, with significant reductions in higher-order harmonics. The spectrum usually shows a clear reduction in the amplitude of harmonics as the number of levels increases.

ii. Flying Capacitor: The harmonic spectrum for Flying Capacitor inverters can be more complex due to the interaction between flying capacitors and switching patterns. However, it often shows a similar trend of reduced high-order harmonics with increasing levels, though the harmonic distribution might not be as uniform as in CHB.

Switching Frequency and Harmonics

i.   Cascaded H-Bridge (CHB): The switching frequency in CHB inverters is generally lower compared to some other topologies, as the multiple levels help in smoothing the output waveform. This results in reduced high-frequency harmonics and a more favorable FFT analysis.

ii. Flying Capacitor: Flying Capacitor inverters may require higher switching frequencies to manage capacitor voltage balancing and minimize harmonics. This can lead to a more complex FFT profile with potentially higher switching losses, although still achieving good harmonic performance.

Practical Considerations

i.   Cascaded H-Bridge (CHB): The CHB topology is known for its modular design, which simplifies the implementation and control of harmonic distortion. The practical FFT analysis often shows stable performance with manageable THD levels, benefiting from its scalability.

ii. Flying Capacitor: The Flying Capacitor topology, while effective, can be more challenging to implement due to the need for precise control of capacitor voltages. FFT analysis might reveal more

variability in harmonic performance, particularly if voltage balancing is not optimal.

Table 1. Analysis of Cascade-H-Bridge and Flying Capacitor for Nine Level MLI

Multilevel inverter	No of semiconductor switches	THD%
Nine level flying capacitor MLI	16	23.80%
Nine level CHB MLI	16	25.79%

CONCLUSION

Both the Cascaded H-Bridge (CHB) and Flying Capacitor topologies can achieve low THD in a 9-level inverter using the same number of semiconductor switches. The CHB topology offers a simpler and more modular approach, making it easier to achieve and maintain low THD. The Flying Capacitor topology, while potentially offering even lower THD due to the additional voltage levels, requires more complex control and careful management of capacitor voltages. The choice between these topologies should be based on the specific application requirements, considering factors such as control complexity, modularity, and desired lying capacitor inverters are noted for their ability to achieve lower THD values, as they can effectively manage voltage levels and reduce harmonic content through their unique architecture. This is corroborated by findings that emphasize the advantages of flying capacitor designs in minimizing harmonic distortion compared to traditional CHB configurations. Overall, while both inverter types serve similar applications, flying capacitors tend to provide superior THD performance, making them preferable in scenarios where power quality is critical.

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Review of Block-chain Technology and to Explore its Utility in Supply Chain and Notary Office

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ABSTRACT

The block-chain is a distributed digital ledger which can be used to keep track of financial as well as any type of transactions which has an economic value. Initially, Block Chain Technology (BCT) had been used in financial sector for digital payment. Because of special features of BCT, its recognition and acceptance in other fields has been growing. The paper reviews Block-chain Technology. It describes type, special features, and critical challenges to BCT. The use of BCT in various fields and its scope in Supply Chain Management (SCM) and Notary office has been discussed.

KEYWORDS : Block-chain, Crypto-Currency, Decentralization, Supply chain management, Transparency.

INTRODUCTION

Financial transactions are normally managed and controlled by financial institutions (e.g. Banks). So, all the related data and information are under their control. The drawback of this system are more processing time, intervention and control of the third party (banks) in the process. To make this process simple, fast and secured, removal of the third party intervention was required. Block chain Technology (BCT), was found suitable for this purpose due to its special attributes. Therefore, BCT was firstly introduced in financial sector by Bit-coin for crypto-currency. After successful implementation of BCT in financial sector, its applications in other fields are also increasing rapidly.

BLOCK-CHAIN TECHNOLOGY

In block-chain the information of each transaction is stored in block continuously like ledger. When the capacity of the current block is fulfilled the next block is generated which has address of the earlier block. The process continues and the blocks are arranged in chronological order. If some information is to be changed in any block, then it is required to get the approval from 50 % of the participating nodes. It is very difficult and time consuming to get approval from 50% of the systems (participants) in network to make the changes. Also if, any alteration is to be made, then address of all earlier block gets changed, so it cannot be done in isolation. Therefore, block-chain is well secured.

Also, the information of each transaction in block-chain is accessible to all nodes in the network. So, block –chain is open, transparent and has a control of all participants in the network.

Considering these special attributes, block-chain was initially implemented by Bit-coin for crypto-currency. The details of the three generation of the block-chain are shown in the table 1.

TYPES OF BLOCK-CHAIN

The Block-chain is classified into three types: Public Block-chain, Private Block-chain and Permission Block- chain [5, 13].

Table 1 Details of Three Generations Block-Chain

Sr.	Block chain	Description
1	1.0	Block chain 1.0 is associated to crypto-currency such as bit-coin. At this stage, BCT was used as virtual currency and for payment system that relied on crypto-currency.

| 2 | 2.0 | Block-chain 2.0 is applications of BCT in other areas of finance. It includes Bit-coin 2.0, Smart Contracts, Decentralized applications (Dapps), Decentralized Autonomous Corporations (DACs). |
| 3 | 3.0 | Block-chain 3.0 is applications of BCT in areas other than Currency and finance. It includes Healthcare, Education, Science, Culture, etc. |

In public block-chain, each node can contribute and the transactions cannot be changed. Whereas, in private block-chain, only the owner of the block-chain has the authority to alter the information and rest of the nodes have limited access. In permission block-chain, each participant select its own consensus nodes based on specified rules.

CHARACTERISTICS OF BLOCK-CHAIN

In order to use the block-chain technology effectively, it is essential to understand the important characteristics of block-chains [1, 2, 11, 13, 14, 16, 17, 18, 27, and 29]. The special characteristics of block-chain are listed below in the table 2.

CHALLENGES AND LIMITATIONS

As an emerging technology, BCT encounters several technical challenges and limitations [5, 19, and 25]. Some of these issues are discussed below. To fully harness its potential, further research is essential.

- Output: The transactional throughput of the Bit-coin network is significantly lower compared to other transaction processing networks and thus needs improvement.
- Bandwidth: Bandwidth is a key factor in improving the performance of transaction processing networks. Therefore, addressing bandwidth issues is essential.
- Security: In the current block-chain framework, data changes can be made if 51% of the nodes approve them. To enhance security, this threshold should be raised.
- Waste Minimization: The energy consumption in Bit-coin mining is a significant concern. To minimize resource usage, more efficient mining practices in block-chain are necessary.
- Serviceability: Application Programming Interface used in Bit-coin is not user friendly and needs improvement.

- Cost: Blockchain technology (BCT) requires sophisticated and costly hardware, and its energy consumption for applications is also substantial.
- Complexity: Block-chain requires high level of technical expertise to implement and maintain it.

APPLICATIONS OF BCT

Block-chain technology was initially successfully implemented by Bit-coin for crypto-currency. To maximize its potential, extensive research is currently underway. Its applications can be categorized into two groups. Financial and Non-financial [4, 6, 7, 8, 10, 12, 15, 20, 21, 22, 23, 24 and 27]. Table: 3 show the various applications of Block-chain Technology. Its application in Supply–chain and Notary office has been explained in the next section.

Table 2 Characteristics of BCT

Sr.	Characteristics	Description
1	Ledger	In BCT, information of transactions is recorded in chronological order, just like ledger. Information is also shared with all participating nodes in the network. So, it is also called as distributed ledger.
2	Consensus	Transactions in the block-chain are verified and approved by all the participants in the network.
3	Privacy	Each user possesses a public key and a private key. It is virtually impossible to deduce someone else's private key from their public key.
4	Transparency	In block-chain, the information of each transaction is shared with all participating nodes in the network in the real time. So, Complete transparency is achieved.
5	Security	Information in the block cannot be altered without the permission of all other participants.
6	Distributed trust	In block-chain, data is accessible to all participating nodes, and any alterations cannot be made without their consent. This fosters complete trust throughout the network.

| 7 | Open Source | Block-chain technology (BCT) can be utilized with open-source software. |

Table 3 Applications of BCT

Sr.	Non-Financial	Financial
1	Notary Public	Crypto-Currency
2	Music Industry	Securities Issuance, Trading and Settlement
3	Internet Applications	Insurance Claims and Processing
4	Decentralized Proof of Existence of Documents	Global Payments
5	Patents	Block-chain Government
6	E- Voting	
7	Internet of Things (IoT)	
8	Cyber- security	
9	Food Safety	
10	Health-care	
11	Identity Management	
12	Supply - chain	
13	Market Monitoring	
14	Smart Energy	
15	Vehicular Cyber Physical System	
16	Aviation system	
17	Smart Homes	

USE OF BCT IN SUPPLY CHAIN

The supply chain is a complex network of interconnected companies, where each business adds value to a product or service before it reaches the end user [18]. In today's competitive landscape, efficient supply chain management is essential for every business. However, supply chain management has its limitations. The unique features of block-chain technology (BCT), such as transparency, visibility, consensus, and security, can enhance the effectiveness of supply chain management. Below are key areas where BCT can facilitate improvements in the supply chain [9 and 28].

Transparency

A major challenge in supply chain management is ensuring visibility across the network. Block-chain technology (BCT) can address this issue by providing a secure and transparent means of tracking goods throughout the supply chain. By following a product from its source to its final destination, businesses and consumers can confirm that their products are ethically sourced.

Environmental Sustainability

BCT helps in tracking carbon emissions and other environmental impacts throughout the supply chain thereby ensuring environmental sustainability.

Quality Assurance

BCT provides complete transparency at every node in supply chain from production until the end consumer deliver. This helps in assuring the product meets the regulatory quality standards

Counterfeit Prevention

Product piracy, particularly through counterfeit items, poses a significant challenge for companies. Block-chain technology (BCT) can help combat this issue by establishing a tamper-proof record of product ownership and authenticity.

Payment Processing

By implementing smart contracts, payment can be automated based on predefined conditions such as delivery confirmation or quality check.

BCT IN NOTARY OFFICE

Notary offices are regional entities situated in every city, maintaining confidential information about local residents. Since these offices are not digitized, this important information is susceptible to leaks. Additionally, if a resident moves away, they must return to the city in person to obtain the necessary certificates. This highlights the need for an online notary office, which would digitize notary services, reducing paperwork and enhancing document security [3]. The application of block-chain technology (BCT) in notary offices is outlined below, including problem identification, proposed solutions, and development technologies.

Problem Identification

- Current notary offices operate in offline mode, requiring individuals to visit the regional office in person to obtain any certificates.

- Hardcopies of the documents make it more susceptible to security and confidentiality breaches. Extensive usage of paper is also not ecofriendly

- Applicants are often unaware of the status of their application process, lacking transparency.

- Long queues in government offices result in significant time wastage.

Proposed Solution

An online notary office has been developed using Java web applications and the Clever Cloud database, enabling residents to access notary services from anywhere in the world. This innovation will streamline the application process, enhance document security, and reduce paper usage, thus minimizing environmental impact. The documents will be secured using block-chain technology, where data is stored in blocks. Data encryption is achieved through the AES algorithm, while hash values are generated using the SHA-256 algorithm

The following soft-wares were used to develop the solution: Eclipse, MySQL work-bench, Python, Java jdk, Vs code, XAMPP, and Clever cloud

Development of Technology

Phase 1: In the first phase, users will register in to the system. The admin will register notary offices by city, and city-specific notary admins will have the capability to verify pending user applications and process them accordingly.

Phase 2: In this phase, users will upload their documents to the IPFS server. A Python IPFS server has been developed to enable document encryption using the AES algorithm. The encrypted documents will be stored on the IPFS server, while details about these documents will be maintained in the IPFS database in the form of blocks. All information will be stored in the database in an encrypted format using the AES algorithm.

Phase 3: In the third phase, users will submit new applications along with the necessary documents to the city admin. The application details will be stored on both Block-chain Server-1 and Block-chain Server-2

Phase 4: In the fourth phase, the city admin will review the documents and applications submitted by the user. Upon verification, the city admin will upload the certificate. The certificate will be stored in an encrypted format on the IPFS server, while the transaction details will be maintained in a distributed manner across the block-chain servers.

CONCLUSION

Block-chain is an emerging technology that was initially utilized for financial applications, with Bit-coin being its first significant implementation. Due to its unique characteristics such as transparency, consensus, security, and a decentralized ledger it is gaining recognition and acceptance across various fields.

Block-chain technology (BCT) plays a vital role in enhancing trust and quality assurance within supply chains. It allows consumers to track products throughout the supply chain, offering complete information about the product's origin and the value added at each stage. Additionally, BCT can help prevent the bullwhip effect and cascading effect from the manufacturer's or business's perspective by providing real-time data and improved visibility. This transparency enables more accurate demand forecasting and better decision-making, ultimately reducing inefficiencies and mitigating the risks associated with fluctuations in supply and demand

One of the key features of block-chain technology (BCT) is its security, which provides an efficient and reliable solution for managing notary office applications that contain sensitive and confidential personal data.

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A Review of Control Algorithms and Inverters used in DSTATCOM

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ABSTRACT

Modern equipment, sophisticated electronics, and non-linear loads have all contributed to the decline in power quality in electrical distribution systems. To improve power quality, several devices and techniques have been employed, with each addressing specific power quality issues. Among these, the Distribution Static Compensation (DSTATCOM) stands out as the most effective mitigation solution. As a custom power device, DSTATCOM offers superior performance in addressing various power quality challenges. This work provides a comprehensive review of different DSTATCOM topologies, control algorithms, and the types of inverters that have been utilized in these systems. Additionally, the paper briefly explores the methods used for generating gating pulses in power devices, which play a critical role in the operation of inverters.

KEYWORDS : *Control algorithm, DSTATCOM, Inverters, Mitigation, Power quality.*

INTRODUCTION

The DSTATCOM is the most effective device for mitigating serious issues of quality of power in distribution systems. The Point of Common Coupling (PCC), where both linear and non-linear loads are present, is normally where it is coupled. The DSTATCOM operates in a shunt configuration and consists of power inverters, coupling reactors, a control algorithm, and a DC link voltage or energy storage system. This setup allows it to dynamically regulate power quality by compensating for reactive power and harmonic distortions. Figure 1 illustrate the block diagram of a complete distribution system integrating the DSTATCOM.

There are several topologies, control algorithms, and types of inverters used in DSTATCOM systems.

Different methods are employed to generate the gating pulses for inverters, with Current Control Mode (CCM) and Voltage Control Mode (VCM) being the two primary control strategies. When operated in VCM, the DSTATCOM can effectively manage voltage-related issues such as sag, swell, and imbalances. On the other hand, when operated in CCM, it mitigates current harmonics in the supply or grid [1]. This paper reviews various control algorithms and inverter types used in DSTATCOM. The first section focuses on control algorithms, while the latter discusses inverter types. Standard control algorithms commonly use Proportional-Integral (PI) controllers. However, in advanced control methods like Sliding Mode Control (SMC), Model Predictive Control (MPC), and Adeline-based control, PI controller tuning becomes necessary when the load exhibits dynamic behavior. A hysteresis

band controller, which utilizes Pulse Width Modulation (PWM) to generate, gating pulses for inverters, has also been recently adopted by researchers [2]. Additionally, the Deadbeat control method [3], which offers fast and precise control, is increasingly being applied in DSTATCOM systems and is also reviewed in this paper.
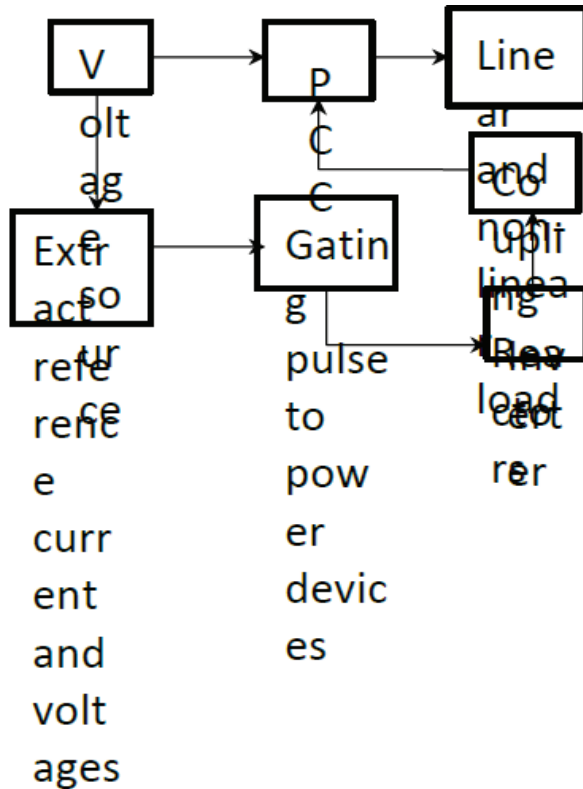

Fig. 1 Block Diagram of DSTATCOM

TOPOLOGY

The DSTATCOM can be connected to either a three-phase, three-wire system or a three-phase, four-wire system, depending on the distribution network. In both configurations, the neutral connection is crucial, as the inverter system uses six switching devices for the DC-to-AC conversion [1]-[3].

Three-Phase Three-Wire DSTATCOM

When the neutral of the load is not grounded to the neutral of the supply system, it is impossible to modify the neutral current and voltage harmonics in a three-phase, three-wire architecture. The system's primary advantage, though, is that the inverters, requires less capacitor.

Three-Phase Four-Wire DSTATCOM

Because of this topological arrangement, which connects the system's neutral to the DSTATCOM, harmonics in the neutral current and voltage can be reduced, as they can be measured and mitigated. It is achieved because the neutral of the load is directly connected to the neutral of the supply system, enabling better power quality control.

CONTROL ALGORITHM

In a DSTATCOM system, the control algorithm's main job is to pull reference voltages or currents and produce the gating pulses needed for power switches. The following methods, commonly used in DSTATCOM systems, are reviewed in this literature survey:

Model Predictive Control (MPC)

This paper explores the dual functionality of DSTATCOM operating in CCM and VCM using two distinct strategies. The generation of reference currents is achieved through Synchronous Frame Theory, employing the Parks Transformation system. Reference currents are first generated in the dq0 frame and then transformed back to abc frame again. These currents are fed into a control algorithm that generates the gating pulses for the power switches, enabling the DSTATCOM which operate in both CCM and VCM, thereby maximizing the benefits of both methods [1]-[4]. A crucial aspect of MPC is the selection of appropriate weights, which ensures the optimal functioning of the DSTATCOM by controlling the switching of power thyristors. The proposed work in [5]-[6] enhances DC-link voltage balance, improves power quality compensation, and reduces the complexity of tuning the inverter's weighting factors. The technique employs a cost function, which is minimized using Lagrange's optimization method. Reference currents are extracted through the conductance factor method, and the VIKOR method is proposed for optimal thyristor switching. The DSTATCOM system is modeled as a State Space Vector, allowing for the prediction of its future state in advance, which further optimizes performance.

Sliding Mode Control (SMC)

Designed to manage dynamic load circumstances, Sliding Mode Control (SMC) is a variable structure-

based control technique that makes use of the DSTATCOM's transfer function. A key advantage of SMC is its ability to make the system faster, more robust, and capable of maintaining stability under varying operational scenarios [7]-[9]. However, SMC also presents two main challenges:

- The system becomes highly non-linear, increasing its complexity in terms of analysis and control.

- The system's performance is highly dependent on accurate knowledge of the connected loads, which can introduce uncertainties in real-world applications.

Synchronous Reference Frame Theory (SRF)

In the Synchronous Reference Frame (SRF) control algorithm, supply quantities are transformed into the dq0 frame using Park's Transformation [10]. This technique compensates the load current and DSTATCOM is operated in Voltage Control Mode (VCM). It is widely used for reactive power control and harmonic compensation. In this control method, the DC link voltage, with the help of comparator, is compared with reference voltages, and the resulting error signal is given input to a Proportional-Integral (PI) controller. Afterwards it converts the voltage into the direct-axis current component (Id), although this process may introduce some computational delay. The Id and quadrature-axis current component (Iq) are then combined and transformed back to the abc frame using the inverse Park's Transformation. These transformed values are used to generate the gating pulses for inverters, typically simulated in MATLAB/Simulink. The SRF theory is particularly effective in controlling DSTATCOM [11] for reactive power compensation and harmonic mitigation.

Instantaneous Reactive Power Theory (IRPT)

The Instantaneous Reactive Power Theory (IRPT) is based on converting system voltage as well as current into two-phase quantities in the α–β reference frame [12], allowing for the estimation of instantaneous active as well as reactive power. By employing Clarke transformation, three-phase signals are transformed into two-phase components, which are then used to evaluate active and reactive power segments. This approach is applicable to both ideal and distorted grids, with

the DSTATCOM utilized to mitigate harmonics. The entire process is typically implemented in MATLAB/Simulink, where Fast Fourier Transform (FFT) [13]-[14] analysis is employed for validation of the results. Initially, the method was developed for three-phase balanced systems and three-wire nonlinear systems. Subsequently, interest grew in adapting the method for three-phase four-wire systems and unbalanced configurations.

Icosφ Algorithm

The Icosφ Algorithm focuses on the active components of power, which are summed and averaged to improve system performance. This technique works very well for a number of significant Power Quality problems, including voltage regulation at the PCC, harmonic reduction, load balancing, and power factor correction. Zero-crossing detectors are used to identify the instantaneous zero-crossing of unit templates. Additionally, a sample and hold circuit is used to capture the load current samples [14].

Instantaneous Symmetrical Component Theory (ISCT)

In the Instantaneous Symmetrical Component Theory (ISCT), reference currents are generated using the concepts of positive, negative, and zero sequence components. The hysteresis band control theory is then employed to produce the gating pulses [15]-[16]. This method involves converting unsymmetrical load currents into symmetrical components, allowing the DSTATCOM, to obtain the systems parameters, is operated in Voltage Control Mode (VCM). The effectiveness of this approach is verified for both balanced and unbalanced conditions, as well as for linear and non-linear loads. Additionally, Discrete Fourier Transform (DFT) is utilized to generate reference currents, thereby reducing the burden on the source.

Adaline Linear Algorithm

The Adaline Linear Algorithm is an adaptive control methodology used to extract reference current signals, making it a powerful tool for DSTATCOM applications. In this paper [16]-[17], this method is applied to enhance performance in weak grid conditions, specifically with an induction furnace load. Additionally, i-PNLMS (Improved Proportional Normalized Least Mean Square)

technique has gained popularity among researchers. This approach employs the Least Mean Square methodology along with an improved proportional normalization technique that incorporates weights. It utilizes voltage sensors for measurements and transforms these into dq0 vector quantities before converting them back to abc form, thus reducing computational delay [18].

Frequency Domain Algorithm

Conventional Fourier and modified Fourier series techniques are widely used for controlling DSTATCOM [19]. In these methods, harmonic quantities fundamental quantities are eliminated first from the harmonic quantities. After which an inverse Fourier Transform is utilised to derive the reference signal in the time domain which is to be compensated. However, this process typically requires more time for sampling and the computation of Fourier coefficients.

This approach can work well for systems with slowly varying loads, but it is not appropriate for real-time applications where the load varies dynamically. The modified Fourier series method reduces delay time through specific enhancements, allowing for the calculation of the fundamental components of the compensating current, which are then utilized for compensation purposes. Additionally, the system currents are transformed into dq0 components, facilitating the generation of system currents.

Fuzzy Logic Controller (FLC)

In the Fuzzy Logic Controller approach, reference values of voltages and currents are generated using fuzzy logic, which also facilitates the generation of gating pulses [19]. This system incorporates an adaptive module, allowing the DSTATCOM to operate continuously while maintaining power quality. The intelligent control provided by fuzzy logic enhances the tracking capability and overall stability of the system. The process involves several key steps: fuzzification, linguistic description, interference mechanism, and defuzzification, each contributing to the effective management of the DSTATCOM.

Hysteresis Control Method

The Hysteresis Control Algorithm has gained popularity in DSTATCOM applications utilizing Voltage Source Converters. In this method, errors in current signals are compared against predefined hysteresis bands. The output voltage level is adjusted with time as the current error crosses these bands every time. One notable disadvantage of this method is the occurrence of tracking errors in the system. The hysteresis band method is primarily used to identify error signals, with a tolerance band established to limit the output current, keeping it closely aligned with the reference current. Both the magnitude and phase angle are controlled to generate three-phase sinusoidal currents [20]-[21].

Deadbeat Control Method

The paper introduces a new technique known as the Deadbeat Voltage Control Method [22]. This approach offers several advantages, including the ability of the DSTATCOM to inject reactive and harmonic components of load currents at nominal load, achieving a Unity Power Factor. It also enables fast voltage regulation during transients and significantly reduces losses in the VSI, and also provides a higher sag-supporting capacity. The DSTATCOM's State Space model is used to forecast the next state, enabling quick adjustment. A PI controller is employed to regulate the DC capacitor voltage at its reference value. The entire system is simulated in PSCAD, demonstrating the effectiveness of the proposed technique.

INVERTER TOPOLOGY

Various inverter topologies are employed in DSTATCOM systems to invert controlled signals for injection into the grid, addressing a range of power quality issues. A few of these topologies are summarized below:

Multi-Pulse Three-Level Converter

The Multi-Pulse Three-Level Converter is proposed in [23], assuming a constant DC link voltage. The steady-state performance of the DSTATCOM is analyzed by using MATLAB/Simulink, and harmonic distortion is examined through Fundamental Frequency Modulation technology, which provides a fast response. This method also facilitates steady-state and dynamic control of a dual three-point STATCOM, offering several advantages, including ease of control and reduced harmonic distortion.

Three-Phase Three-Level NPC Type Converter

The research paper [24] introduces a three-phase three-level Neutral Point Clamped (NPC) type of converter which incorporates two DC voltage sources and it is inverted in to AC voltages. This proposed structure demonstrates superiority over traditional two-level inverters. The DSTATCOM is controlled using the Proportional-Integral (PI) technique, with performance compared to signals generated by Sliding Mode Control. Results are validated through simulations in MATLAB/Simulink.

Multi-Level Inverter

Multi-level converter topologies are increasingly attractive for continuous control of system dynamics and for mitigating power quality issues [20]-[21]. This paper reviews three main types of multilevel inverters: Diode-Clamped Multi-Level Inverter (DCMLI), Cascaded H-Bridge Inverter (CHBI), and Flying Capacitor Multilevel Inverter (FCMLI).

Among these, the FCMLI is found to be the most advantageous due to its simple DC link voltage regulation loop. However, a significant disadvantage is its requirement for a large number of capacitors, making control more complex. The FCMLI functions as a Current Controlled Voltage Source Converter, with gating pulses generated using a Hysteresis Band Current Controller, which necessitates two bands for the compensation technique.

The DCMLI is utilized for VSI applications. The proposed control scheme in the paper [24] emphasizes the importance of voltage equalization under all conditions to prevent voltage imbalances. A five-level DCMLI system is analyzed using PSCAD/EMTDC. Two additional control methods are suggested for managing the DC link voltage: one requires 2 extra power semiconductors, while the second one utilizes existing devices with higher power ratings. A comparative study is also included in the paper.

The CHBI, commonly used in DSTATCOM applications, is ideal for high-power applications [25]. It consists of a single-phase full-bridge inverter and synthesizes the desired voltage from several Separate DC Sources (SDCS). The harmonics generated in a cascaded H-bridge three-level inverter are lower compared to those in two-level inverters operating at the same switching frequency. The paper proposes a cascaded transformer MLI utilizing a 7-level inverter DSTATCOM, with results validated in the laboratory using a single-phase 5-level inverter prototype model.

A key benefit of this system is that it requires only a single storage capacitor for all three phases, ensuring equal voltage across each cell, which is crucial for inverter applications. Each switch of the H-bridge is equally stressed, reducing voltage stresses on power devices and minimizing harmonics in both voltage and current. The phase shift-based PWM technique is employed to minimize switch delays. The switches and capacitor are connected to the secondary of the transformer in this configuration via a cascade connection. The entire system is simulated in PSCAD/EMTDC.

Three-Leg Inverter

The three-leg inverter-based DSTATCOM topology [26]-[27] is designed for compensating unbalanced and non-linear loads. This configuration incorporates a neutrally clamped capacitor and employs a hysteresis current control method for switching the thyristors. Notably, this approach enables compensation of neutral current without the need for a four-leg topology.

One capacitor acts as the DC connection in this system, while an additional capacitor is linked between the system neutral and the negative bus.

With split capacitor three-leg DSTATCOMs, voltage imbalance is a common drawback that this design successfully addresses.

CONCLUSION AND FUTURE SCOPE

Various types of control algorithms and their advancements are reviewed in this literature survey, along with a thorough discussion of the different inverter types and their unique characteristics. The advantages and disadvantages of each approach are also considered. Many control algorithms require significant simulation time, which can lead to sluggish system performance. Conversely, while some algorithms respond quickly, they may introduce complexity to the system. Thus, a compromise must be reached between maintaining system simplicity and achieving a timely response.

The method i-PNLMS is studied in detailed and the

results are also analyzed by first not using DSTATCOM and by using DSTATCOM later, the harmonics are reduced from 26% to 4% which is considerably reduced. Also, few advantages and disadvantages are tabulated in Table No. I. However, the scope for the analysis of the results drawn for other researchers can be left on the future researchers, scientist and engineers.

Table 1 Advantages and Disadvantages

Type of Control algorithm	Advantages	Disadvantages
Model Predictive Control	Fast transient response, pertinent to the system with constraints, predictive of non-linearity, multi-variables, used for power factor correction and elimination of harmonics	Unable to balance of grid at all instance, Dynamic performance is very poor
i-PNLMS	Adaptability, Convergence is good, Real time operation, Fault tolerance, Simplicity in implementation	Slow convergence, Sensitive to initialization, Limited memory, Susceptibility to noise, Complexity in noise
Synchronous Reference Frame Theory	Decoupled Control, Efficient compensation, dynamic response, Harmonic mitigation, Compatibility with grid voltage	Requires PI controlling for tuning, Complexity in implementation, Parameter sensitivity, Grid voltage disturbances
Sliding Mode Control	dynamic behaviour is improved by the particular choice of the sliding function, Robustness, fast response, accurate tracking, non-linearity handling, insensitive to modelling errors	System becomes highly non-linear, depends on knowledge of loads, chattering phenomenon, complexity in design, sensitive to actuator saturation
IRPT (p-q theory)	Easy to implement and performs well for harmonic and reactive power compensation	Power calculation involves voltages and of there is distortion in it, can lead to wrong calculations
Instantaneous Symmetrical Component theory	Real-Time Analysis, simplified Fault Analysis, identification of Asymmetry, improved protection and control, minimized impact of Negative and Zero-Sequence Components, better Power Quality Assessment	Complexity in Implementation, not Suitable for All Fault Types, assumption of Symmetry in Sequence Components, sensitivity to Harmonics and Distortion, limited by System Conditions, overhead in Data Collection
ANN (Adaline Linear Algorithm)	Better results for un-balanced and frequently varying load, fast and powerful tool, non-linearity handling, adaptability, generalization, fault tolerance, complex control objectives	Data dependency, black-box nature, overfitting, training complexity, robustness to changes
Fuzzy logic	Handle non-linear uncertainties, robustness, human like decision making, adoptability, suitable for complex systems	Tuning complexity, subjectivity, computational overhead, interpretability, limited optimization
PI controller	Stability, simple implementation, fast response, accuracy, adaptability	Tuning complexity, integral windup, limited robustness, performance trade-offs, limited control authority

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Optimization of Functional Elements of Municipal Solid Waste Management for Sustainable Development - A Review

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ABSTRACT

The increasing urbanization and unchecked population expansion have made the solid waste collection as one of the world's most pressing issues. Stricter environmental regulations coupled with increased public regulations have made it necessary for the landfills to be situated far from cities. The transfer of solid waste from small collection trucks to large transportation vehicles is a challenging process that requires effective logistical management. The existing methods of waste collection and transportation suffer from various lacunae and thus new methods must be developed in order to save time, fuel as well as cost. The paper presents an outline of the different optimization objectives, constraints as well as the modelling and solution approaches in order to accomplish solid waste management that is sustainable, taking into account the analysis of the previous research work carried out. Furthermore, a detailed explanation of Solid Waste Collection and its noteworthy contributions to the Sustainable Development Goals is provided. Lastly, the analysis offers several significant recommendations that would help scholars and decision-makers create a reliable and effective solid waste management system in the direction of the Sustainable Development Goals. Additionally, the review of numerous significant issues and challenges in the current approaches helps identify the future research gaps.

KEYWORDS : Mathematical programming approaches, Municipal solid waste, Optimization, Sustainable development.

INTRODUCTION

The expanding trend of population growth and urbanization, along with the growing concern about the detrimental effects on the environment, have put home solid waste management in a precarious situation [1]. Due to the increased expenses associated with the collection and transit process, the optimization of MSW becomes a matter of concern [2]. The field of solid waste management research is rapidly advancing. Recently, Technology such as Radio Frequency Identification (RFID), Global Positioning System (GPS), and Geographic Information System (GIS) have been used in an attempt to design an intelligent SWC [3]. The rate of generation of municipal solid waste, on-site handling and storage, it's collection and transportation till the final disposal stage are the various functional elements of solid waste management. The current research aims to provide the reader with an overview of the literature on municipal solid waste management that is currently available.

REVIEW OF LITERATURE

Numerous studies have been conducted regarding the optimization of Municipal Solid Waste. This study examines research on the use of optimization systems in the solid waste collection process, with an emphasis on works utilizing mathematical programming techniques. After the initial screening, a total of 107 peer-reviewed scientific publications, journal articles etc. were accessed were collected from databases such as Springer, Taylor & Francis, Google Scholar, Hindawi and others. Keywords such as municipal solid waste management, route optimization, mathematical approaches and collection costs were employed in the search for literature. The entire full paper content of each of these articles was thoroughly reviewed and final papers pertaining to our topics of interest were selected for this study. To summarize the following are the research questions that this review study aims to address:

1) What important considerations should we make when creating the SWC model?

2) What objectives and constraints on the parameters should we consider when designing an optimal SWC to cut down on expenses, time, and emissions?

3) Which of the many cutting-edge models, technologies, and mathematical techniques available in the literature can be used to accomplish SWC goals?

OPTIMIZATION OBJECTIVES IN SWC

Numerous research studies have been published about determining the right objectives for SWC. The most commonly cited objectives in a variety of papers are to optimize costs and time, determine the best route, allocate or reallocate bins and minimization of distance.

Route Optimization

Route optimization is one of the most common objectives in many of the research papers. To optimize the route, Louati et al. (2016) used a capacitated vehicle-routing problem model based on a modified backtracking search method [4]. The findings depict an immediate relationship between the reduction of CO2 emissions and the shortening of travel routes, which in turn is related to fuel consumption and the primary

expenses related to fuel acquisition. By cutting the journey distance by 36.80%, the suggested research project ultimately decreases CO2 emissions by 44.68%, gasoline consumption by 50% and fuel costs by 47.77%. In a similar study, an ideal waste collecting plan is put forth in an effort to find the best path from the sources of the garbage to the processing plant, transfer station, and waste collection centers. The length of the waste collection trip was reduced by 30%, according to the outcome [2]. Malakahmad et. al, 2014 has suggested vehicle routing using GIS to maximize the route length and travel time. [5] The outcomes showed that the waste collective time was decreased from 6934 seconds to 4602 seconds. Sulemana et al., 2018 surveys the strengths and weaknesses of various SWC optimal routing algorithms with regard to hybrid optimization, GIS and mathematical programming [6]. K. Al-Jubori et. al. proposes a comprehensive framework that integrates various optimization techniques, including algorithms and models, to ascertain the most effective routes for waste collection vehicles. [7]

Cost Optimization

One can attain cost optimization by lowering the cost of labour, number of cars, and fuel usage, among other things. Fuel consumption can be reduced by lowering the number of journeys by shortening the route. Mantzaras and Voudrias, 2017 designed an objective function derivable by Monte Carlo simulation and an algorithm to reduce operational costs, which include garbage collection, transfer, and disposal [8]. The authors of Greco et al. (2015) conducted an analysis on the cost of collecting different forms of garbage and discovered that delivery, collection type, and population size have a significant influence on cost drivers [9]. Full cost accounting (FCA) was established in a work by D'Onza et al. (2016) to assess the costs and efficiency of garbage collection for both distinct and undifferentiated waste [10].

Time Optimization

Time is one vital factor that needs to be addressed. According to Rai et al. 2019, reducing the number of turns on the route can optimize it, depending on factors like population density [11]. Son and Louati (2016) developed a generalized model for SWC vehicle routing that takes into account the number of vehicles,

one-way travel routes, and waiting times at traffic stops all done in order to reduce the overall travel time and working hours [12]. In an aim to achieve the lowering of the number of cars needed to service all routes, Ramdhani et al., 2018 takes into consideration the vehicle assignments and schedules [13]. Banyai et al., 2019 took into account he assignment of each garbage truck is also taken into account to optimize the routing for waste collection, increase reliability and lower the operating costs [14].

Allocation or Reallocation of bins

Bin positioning may improve the efficiency of the collection of waste and transportation efficiency. The positioning of wastebins, trash collection schedules, density of population, and the network of roads are studied in Khan and Samader, 2016 in order to develop a cost-effective solid waste bin allocation strategy for the Indian city of Dhanbad that will demonstrate significant cost reductions [15]. Rathore et al., 2020 created an appropriate SWC model by using the real-world situation of Bilaspur, India, and accounting for waste type and trash bin. The suggested methodology demonstrates its efficacy in lowering expenses by 25%, collecting locations by 15%, and carbon dioxide emissions by 35%. [16] Adeniyi

S. Aremu et. al. seeks to solve the problems caused by ineffective waste management systems by highlighting that strategic bin placement can lead to reduced collection times and lower operational costs. While the framework is promising, the study acknowledges potential limitations, such as the need for accurate data on waste generation and population distribution, which may not always be readily available in developing regions [17].

Environment related factors

The SWC must be optimized with the effects on the environment taken into account. It is necessary to obtain the least polluting garbage collection process for collection. The primary cause of the environmental damage is the greenhouse gas emissions from waste collecting vehicles. According to Levis et al. 2013, a SWC life-cycle structure is recommended for the investigation of CO_2 emissions when it comes to the collection and handling of waste [18]. Pourreza

Movahed et al., 2020) provides a life cycle assessment (LCA) based SWC to achieve minimal CO_2 production and energy utilization. [19]. An optimization model that balances cost effectiveness and environmental sustainability in waste collection routes is presented by M. A. Hannan et al., 2020. Routes for collection, types of vehicles, fuel usage, and scheduling are important factors. The model takes into account a number of cost considerations, including labor, operating expenses, fuel prices, and vehicle upkeep. Case studies showing the model's implementation in various metropolitan environments are included in the article. These case studies demonstrate how the optimization approach can be applied in real-world scenarios to lower expenses and emissions [20].

CONSTRAINTS IN SOLID WASTE OPTIMIZATION

The Solid waste collection model becomes more practical when we design it subject to various realistic constraints. The most common constraints reported in literature are capacity constraint, labour constraint, time and demand constraints etc.

M.A. Hannan et al. stated that the primary concern under capacity constraints is the vehicle's capacity which is evaluated in terms of the total weight or amount of trash it can transport during the journey [20]. Similarly, A solid waste management model with mass balance constraints was developed by Yadav et al. in 2017 and shows that the amount of solid waste generated and removed from transfer stations should be equal [21]. Various time limits exist, including time windows, load and unload times, and driver breaks. The time window for collecting nodes and amenities is taken into account in majority of the case studies [22]. Yadav and Karmakar, 2019 defined time frame as the vehicle's requirements for the collection and transportation of solid waste to minimize the cost of transportation [23]. The time window is determined in Son and Louati, 2016 by taking into account the travel route of the vehicle, the number of vehicles, as well as the waiting time at traffic lights and pauses to make the collection tour efficient in terms of fuel, time, etc. [12] Time constraints are also taken into account when determining the loading time of each bin or the maximum amount of time that a truck can stay on the road [24]. Another consideration

in designing a SWC model is the diversity of different types of waste materials. A study by Son, 2014 examined three distinct garbage collection vehicles, taking into account a scenario in which these vehicles would be used to transfer rubbish between various waste facilities [25]. According to several studies, a heterogeneous fleet of vehicles can be used to collect various types of garbage [26]. A heterogeneous vehicle fleet is examined in Hemmelmayr et al., 2013, where each kind gathers a particular sort of waste [27]. In addition to the above stated constraints, labour constraint, regulatory and political constraints are also taken into consideration in a few studies. In municipal solid waste management models, constraints play a crucial role in maintaining a balance between operational, financial, environmental, and social considerations. They provide direction for the development of efficient, practical and sustainable waste management plans, guaranteeing that systems function within their parameters and accomplish their intended objectives.

MODELLING AND SOLUTION APPROACHES IN SOLID WASTE COLLECTION SYSTEM

Understanding, forecasting, and optimizing waste management systems depend on modelling techniques in solid waste management (SWM). These models support planning, judgment, and evaluating the effects of different waste management techniques. One of the main questions in the research of solid waste optimization is whether the model is fuzzy, probabilistic, stochastic, or deterministic. The solution approaches of SWC can be divided into conventional, heuristic and meta heuristic approaches. Conventional procedures are not practical for handling unpredictable characteristics and optimizing numerous objectives. In terms of solving problem complexity and computational time, heuristics and meta-heuristics approaches are dominant. [28]. Gianpaolo Ghiani et. al., 2021 utilize optimization techniques and mathematical models to design an effective waste collection system. They analyse various configurations of transfer stations to determine the most cost-effective and efficient setup. The study involves simulations and case studies to validate the proposed models which may not fully account for all real-world variables and constraints

[29]. Similarly, Nur Ayvaz- Cavdaroglu has developed optimized models that lead to reductions in operational costs, more efficient collection routes, and better waste treatment and disposal processes. The case study of Istanbul confirms that the proposed models are effective and applicable in a real-world setting [30]. Ajay Singh covers different types of mathematical models such as linear programming, network optimization, integer programming and simulation models in his research paper. It examines how these models are applied to various aspects of waste management, including collection route optimization, facility location planning, and waste treatment and disposal [31]. A foundational model can also be developed addressing how to plan optimum routes that take into account different forms of waste to service a set of destinations for a fleet of vehicles [32]. A mathematical model specifically designed for the management of municipal solid waste (MSW) in Hong Kong is presented by C.K.M. Lee et al, 2016. The waste management system's numerous components, such as garbage creation rates, collection routes, vehicle capacities, and disposal sites, are all included in the model. To solve the optimization problem, it combines techniques from mixed integer programming (MIP) and linear programming (LP). The quantity and placement of garbage bins, vehicle routes, and waste collection timing are important model variables. The goal of the strategy is to reduce total operating expenses, which include expenditures associated with bin location, transportation, and perhaps environmental impact [33]. Maurizio Faccio et al. develop a multi-objective optimization model for waste collection that utilizes real-time traceability data [24]. By incorporating real-time data into the optimization process, the goal is to improve waste management efficiency while simultaneously addressing numerous objectives. The model's use in actual situations is illustrated through case studies and simulations. These applications show off decreases in environmental impact, financial savings, and increased route efficiency.

APPLICATION OF ADVANCED TECHNOLOGIES IN SOLID WASTE COLLECTION SYSTEM

By combining linear programming with geographic information system (GIS), Onur Rızvanoğlu et al. have

provided a useful method for streamlining municipal solid waste collection and transportation routes. It demonstrates how the optimized routes can lead to significant reductions in operational costs, including fuel and labour expenses [34]. In another instance, D. Khan and S.R. Samadder present a detailed investigation into the application of GIS for optimizing the allocation of bins for solid waste collection and the routing of collection vehicles in a case study pertaining to Dhanbad city, India. The paper explores techniques for optimizing waste collection routes using GIS, focusing on minimizing travel distance and time for collection trucks. To find the most efficient routes, a variety of algorithms and models are assessed, taking into account variables like traffic patterns and road networks [35]. Ni-Bin Chang et. al highlights the significant benefits of applying GIS technology to vehicle routing and scheduling in solid waste collection systems. By leveraging spatial data and analytical tools, GIS enables more efficient route planning, cost reduction, and improved service quality. The paper addresses the Vehicle Routing Problem, which involves determining the most efficient routes for waste collection vehicles while considering constraints such as vehicle capacity, service time windows, and waste generation patterns [36]. Hailin Wu, Fengming Tao, and Bo Yang employs optimization models and algorithms to address the vehicle routing problem (VRP) specific to waste collection. The authors develop mathematical models that incorporate constraints such as vehicle capacities, collection time windows, and waste generation rates. Potential limitations include the need for accurate data on waste generation and traffic conditions, which may not always be available [37]. Additionally, the complexity of real-world scenarios might pose challenges for implementing the proposed models in practice. Nikolaos V. Karadimas et. al has examined the application of the Ant Colony System algorithm to optimize solid waste collection routes. The goal is to reduce the overall distance traveled by the collection vehicles, thereby reducing operational costs and improving overall efficiency. Incorporating real-time data, such as the trends of waste generation and traffic conditions, could further enhance the efficiency and responsiveness of the routing optimization [38]. Rogelio Ochoa Barragan et. al developed optimization models which are designed to tackle multiple goals,

including cutting down on operating expenses, lessening the impact on the environment, and enhancing service effectiveness. Increasing computational complexity and necessitating the use of effective algorithms and processing resources might result from the combination of machine learning and mathematical programming [39].

Thus, it can be stated that more sophisticated optimization algorithms combined with leveraging internet of things technologies must be developed. Also, hybrid approaches where simulation models are used to generate scenarios and optimization algorithms are applied to find the best solutions within those scenarios [40].

SOLID WASTE COLLECTION IN RELATION TO SUSTAINABLE DEVELOPMENT GOALS

Sustainable development is greatly impacted by solid trash collection, which is an essential component of urban management. Effective waste management contributes to resource conservation, public health promotion, and a decrease in environmental contamination. A common vision for prosperity and peace for the people and the world is presented in the 2015 proposal for the Sustainable Development Goals (SDGs) for 2030 [41]. The association between Solid Waste Collection and the Sustainable Development Goals target has been verified by a number of pertinent studies. As an example, SWC can guarantee ecologically responsible waste disposal [42] along with putting an end to open dumping [43].

Various authors have done their bit of contribution in optimizing the SWC along with incorporating sustainability. A review by Zakie Mamashli et al. [44] focuses on improving optimization methods to handle different hazards and incorporating sustainability into waste management design. Waste management network optimization can be achieved by a variety of mathematical methods, such as multi- objective optimization, mixed integer programming, and linear programming. The trade-offs between cost, service quality, and environmental impact are addressed by these models. Elagroudy et al. 2016 said that SWC can act as a sustainable model to achieve economic progress [45].

CONCLUDING REMARKS

In order to reduce costs associated with labor, transportation, time, and carbon emissions, a great deal of research and development is done on SWC modelling structure and technology. An enhanced and successful optimization approach can guarantee the robust, sustainable, and economical SWC system functioning. But the synchronization of optimization methods and cutting-edge technology used in SWC needs further research to reach the intended outcome under different practical restrictions. This review condenses a thorough investigation of trash collection strategies, covering various models, limitations, optimization issues, and technologies that have been presented in the literature. It can be shown from the examined papers that early on, conventional procedures are commonly used. Then, due to the growing processing time and complexity of the collecting problem, heuristics and metaheuristics have taken the place of traditional approaches. It is also noted that all SWC modelling approaches make extensive use of GIS. Modern advanced technologies, including as RFID, GPS, GPRS, and others, are being developed, and smart bins and various sensors are receiving a lot of attention. These technologies have the capacity to make decisions and are being utilized to remotely monitor the entire SWC scenario. In light of the conversations above, this review offers some helpful suggestions on the direction of future study. Firstly, it has been found that SWC is a complex process and in order to make the process more accurate, we need to consider maximum number of constraints while fulfilling optimization objectives. The incorporation of cutting-edge technologies can improve optimization algorithms performance even more.

For example, current GPS systems offer real-time information on traffic congestion. It takes a quick, online rerouting algorithm that can handle the limits unique to waste collection to enable the waste collection operation to benefit from this information. Utilizing scales to weigh waste prior to loading it onto a pickup vehicle is another example. Ultimately, we firmly believe that environmental concerns will become more and more significant in the planning, scheduling, and administration of waste collection.

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Feasibility of Magnetic Nanoparticles for Separation of Copper from Liquid Phase: an Equilibrium and Kinetic Study

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ABSTRACT

In last few decades tremendous growth in generation of e-waste was noted. E-waste consists of large quantities of precious metals like Cu, Au, Ag, Pt, Pd etc. Removal and recovery of this precious metals from e-waste stream creates new opportunities of urban mining. This paper presents the use of activated carbon (AC) and magnetic nanoparticles (MN) for the seperation of copper (II) from aqueous solution. Adsorption process depends upon many factors like pH of solution, contact time, volume of adsorbent dose using batch studies these factors were optimized. Maximum adsorption was adsorbed at optimum pH 4.5.Equilibium time for AC is 130 min whereas MN has equilibrium time 120 min at room temperature. Copper removal efficiency of MN (87%) is higher than tne AC (78%).The Langmuir, Freundlich, Temkin isotherm models were utilized for analyzing experimental data. The Temkin best described the copper (II) adsorption on AC and MN. Overall these result shows that the magnetic nanoparticles can be utilized as adsorbent for seperation of copper (II). Results of this study is useful for separation of copper from E-waste.

KEYWORDS : *Copper, activated carbon, Magnetic nanoparticles, Isotherms.*

INTRODUCTION

Progressive advancement in technology has made life of human more congenial and enjoyable. In today's era humans are dependent on many electronics and electrical gazettes for their routine work. Once electronic and electrical items are absolute it becomes waste or electronic waste and commonly called as e-waste. In 21st century e- waste is largest growing stream of waste [1]. Demand of electronics and electrical items grows exponentially whereas useful life of of electronic products become short [2]. This ultimately results generation of large volume of e-waste. Structure of E-waste is different form municipal solid waste as it contains toxic and precious materials [3]. Metals consume by the electrical and electronics industry is presented in table 1.

Table 1.Percentage of metals consumed by electrical and electronics industry

Ag	Au	Bi	Co	Cu	Pd	Sb	Sn
30%	12%	15%	19%	30%	14%	50%	33%

Printed circuit board (PCB) is one of the crucial element in e-waste. Printed circuit board is composed of plastic, epoxy resins, glass which comprise 70% weight and metals like copper, antimony. Solder,iron,silver,gold etc. of 30%[5].Globally improper disposal of e-waste is a big concerned for the scientist and researches not only because of its huge volume but also variety of heavy metals presents in e-waste. PCBs existing in the e-waste contains high percentage of metals i.e. 20% copper, 0.04% gold and 0.15% silver etc [6].Hydrometallurgical , pyro metallurgical and bio metallurgy are some of the methods available for the regaining of valuable metals from e- waste.

In this paper adsorption method is employed for the separation of copper from liquid phase. This process involves contact of solids with liquid or gases in which mass transfer is towards solids. Activated carbon (AC) and magnetic nanoparticles (MN) are used as adsorbent. Mechanism of surface sorption mainly governs by the physic-chemical interactions between adsorbent and

adsorbate metal. These interactions are studied by the Langmuir, Freundlich and the Temkin isotherms[7]. Therefore in this paper these above isotherms were used to evaluate the adsorption process of activated carbon (AC) and magnetic nanoparticles (MN). Process parameters governing adsorption includes pH, contact time, adsorbent dose were also optimized to conduct kinetic studies. Result of this study can be used to recover copper from the e- waste stream.

EXPERIMENTAL

Chemical and reagents

The standard chemicals of analytical reagent grade is used throughout the study. Stock solution for copper is prepared by dissolving given amount of CuSo4.5H2O (Merck laboratory pvt. ltd) in distilled water and solution of varying concentration were acquired by dillutions. Required pH of solution was maintained using Hydrochloric acid (HCl) and sodium hydroxide (NaOH). Activated carbon used as a adsorbent is obtained form the Merck company and magnetic nanoparticles of Iron Oxides (Fe_3O_4) of particle size 50-100 nm was utilized. All the laboratory work were conducted at room temperature ±25°C. UV spectrophotometer was used to measure Copper concentrations in batch and column studies.

Batch Experiments

The experiment for recovery of copper form the prepared solution was performed under the optimal conditions. Solution pH were adjusted from 2 to 12 using Hydrochloric acid and Sodium hydroxide. Optimum pH for the adsorbent process was found out and same pH was maintained for other experiments.

Adsorption isotherm

To study equilibrium parameters of adsorption setup isotherm studies are carried out. Following adsorption isotherms were used in present study.

Langmuir isotherm

This is first isotherm developed for describing adsorption process. This equation derived based on the assumption that "the adsorbed entities are attached to the surface at definite localized sites and each site accommodates one and only one adsorbed entity". The Langmuir isotherm

equation can be expressed as

$$q_e = \frac{q_{max} K_{Lg} C_e}{1 + K_L C_e}$$

(1)

Where q_{max} (mg/g) is the maximum adsorption capacity and K_{Lg} (L/mg) is Langmuir constant associated with adsorption energy [7,8,9] Parameters q_{max} and K_{Lg} are computed from the the slope and intercept of linear graph between Ce/qe and Ce

Freundlich isotherm

Freundlich isotherm is most suited for the multilayer adsorption study model for adsorption of heterogeneous surface. This equation is based on the assumption that the heterogeneous surfaces of the adsorbate is only responsible for uptake of ions. The Freundlich isotherm equation in liner form is given below.

$$Log\ q_e = Log\ K_F + \frac{1}{n} Log\ C_e$$

(2)

Graph is plotted between Log Ce versus Log qe and constant KF (intercept) and n (slope) are determined which represents the adsorption capacity and adsorption intensity[10]. Usually constant KF is is relate with the heterogeneity.

Temkin isotherm

decreases in all the molecules[10]. The Temkin isotherm can be written as follows.

$$q_e = B.Ln\ K_t + B_t.Ln\ C_e$$

(3)

Where, Kt = is equilibrium binding constant, b is variation in energy of adsorption and expressed in (J/mol), Bt= RT/b; R is universal constant and T is absolute temperature. Temkin constant can be worked out for the graph Ln(Ce) versus qe. [7,8,9]

Adsorption Kinetic studies

The kinetics of adsorption process was studied using pseudo first-order and second order model.

The pseudo first order kinetic model is as follow

$$k_1 . (q_e - q_t) = \frac{dq_t}{dt}$$

(4)

After definite integration and application of specific conditions eq. 4 become

$$Log(q_e - q_t) = Log\, q_e - \frac{1}{2.303}\, t \tag{5}$$

Graph of Lo($q_e - q_t$) against the time (t) plotted, values of k1 and qe are calculated from the slope and intercepts

The pseudo second order equation can be expressed as

$$\frac{t}{qt} = \frac{1}{k2\, qe^2} + \frac{1}{qe}\, t \tag{6}$$

This incorporate the effects of some indirect interaction of adsorbent - adsorbate and heat of adsorption is linearly.

To obtain the value of qe and k2, graph of t/qt versus t was plotted and slopes and intercept represents qe and k2 respectively.

RESULT AND DISCUSSION

Effect of pH

pH of solution affects the adsorption process. Variation in solution pH affects the adsorption efficiency of adsorbent. Figure 1 shows the effect of variation of pH on adsorption process. As the pH of the solution was increased from 2 to 5, an increase in the adsorption of copper was observed for both AC and MN. The maximum adsorptions is (67.33%) and (71.1%) for AC and MN, respectively. The electrostatic interactions between the absorbent and the adsorbate are governed by the pH of the solution. At a lower pH, cations engage with H+ ions for adsorption sites, resulting in less adsorption. When the pH increases, large number of negative sites are available for attaching the ions of adsoarbate to the adsorbent, thus increasing the adsorption (up to pH =5).If the pH continuously increases, the adsorption decreases as ions start to form hydroxides and compete with the metal ions.

Effect of contact time

Figure 2 shows variation of adsorption of copper with contact time. As figure 2 indicate with increase in time copper adsorption increases with time upto 120 min. Equilibrium was established for AC at time 130 min and for MN 120 min. Two phases are observed from figure 2, first phase is adsorption which continues till

equilibrium achieved. In first stage around 80.5% and 82.5% removal were achieved at 130 and 120 min by AC and MN respectively.

In first stage rapid adsorption were absorbed as more number of vacant sites are available in second stage adsorption decrease as this depends upon number of vacant site present of the surface of adsorbate.
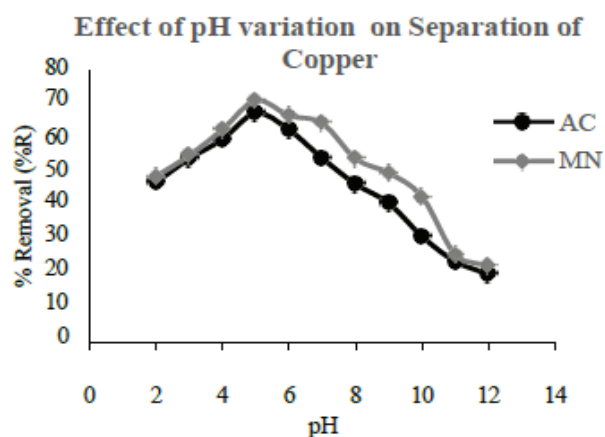

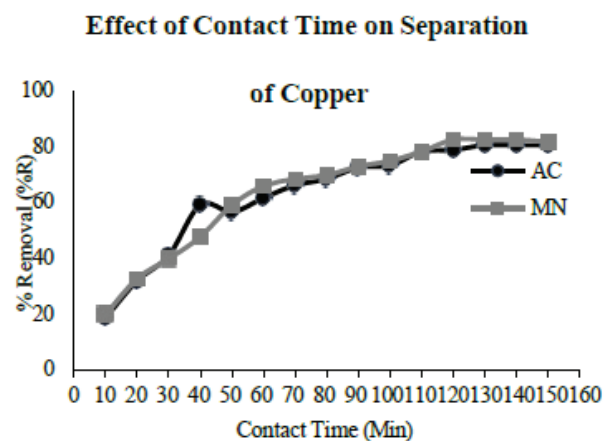**Fig.1 Effect of pH on separation of Copper by AC and MN**

Fig.2 Effect of contact time on separation of Copper by AC and MN at optimum pH 5

Effect of adsorbent dose

Effect on adsorption of copper with variation in adsorbent dose of AC and MN is presented in figure 3. Optimum pH (pH =5) and contact time (120 min for AC and 130 min MN).. Adsorbent dose varies from 0.02 gL-1 to 0.2 gL-1 and variation in adsorption of copper by AC and MN was presented in figure 3.
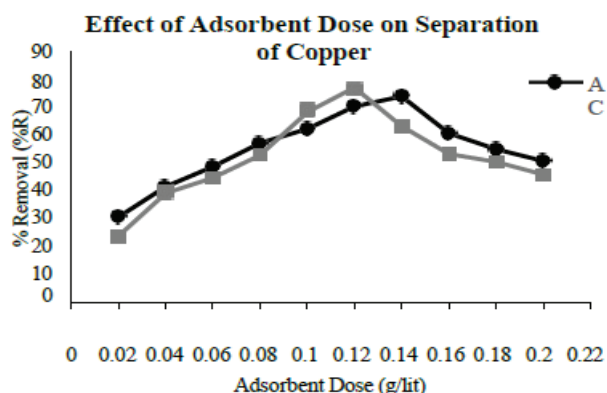
Fig. 3 Effect of adsorbent dose on separation of Copper for AC and ACMN at optimum pH 5 and contact time 120 min for AC and 130 min for ACMN

As dose of adsorbent increases rapid growth in adsorption increases 0.02 gL-1 to 0.12 gL-1 as more sites are avaiable on the surface of AC and MN. Continuously increase in adsorbent dose after0.12 gL-1 resulting decrease in adsorption of copper as indicating that the adsorption sites are unsaturated.

Adsorption isotherm study

Adsorption process is basically depends on the capacity of adsorbent materials to accumulate the adsorbate from liquid phase.

**Table 2.Constants of Langmuir, Freundlich and Temkin Isotherms for adsorption of copper by AC and MN**

Activated Carbon (AC)		
Langmuir		
qmax (mg/L)	**KLg (L/mg)**	**R^2**
6.85	0.04	0.92
Freundlich		
K_{Fr}	**n**	**R^2**
2.20	0.84	0.91
Temkin		
K_t (L/mg)	**Bt**	**R^2**
4.65	43.37	0.97
Magnetic Nanoparticle (MN)		
Langmuir		
qmax (mg/L)	**KLg (L/mg)**	**R^2**
7.12	0.05	0.84
Freundlich		
K_{Fr}	**n**	**R^2**
2.14	0.88	0.85
Temkin		
K_t (L/mg)	**Bt**	**R^2**
4.87	43.40	0.96

Isotherm study provides the usful information Lagmuir, Freundlich and Temkin isotherm were selected for the study. Constants of Langmuir, Freundlich and Temkin were obtaine from the plots of Ce versus Ce/qe, Log Ce versus Log qe and Ln Ce versus qe respectively.

(a)

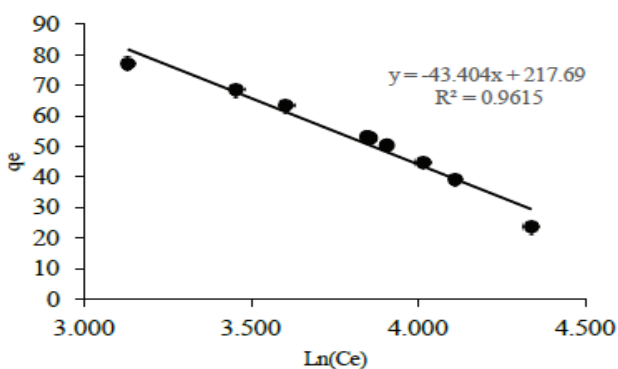

(b)

(c)

(d)

(II) was 50 mg/L, adsorbent dose 0.12 gm/L, pH 4.5 and temperature 27°C.

(g)

(e)

(h)
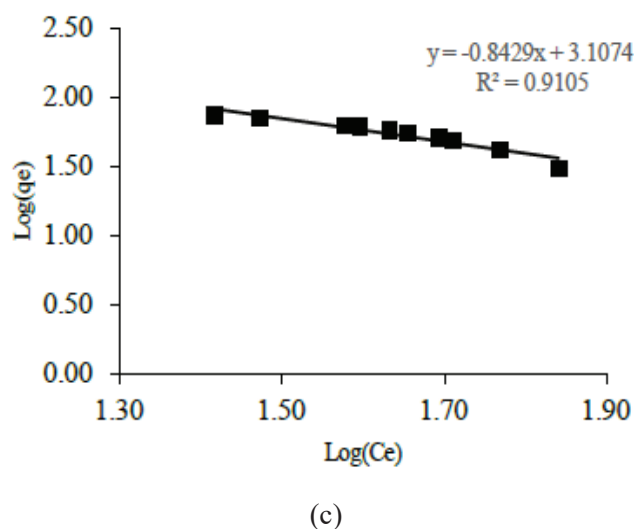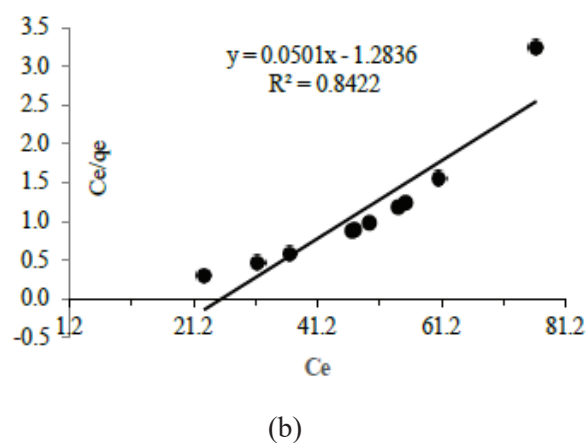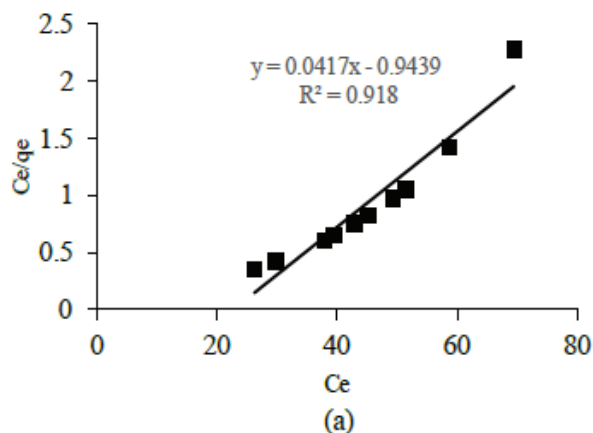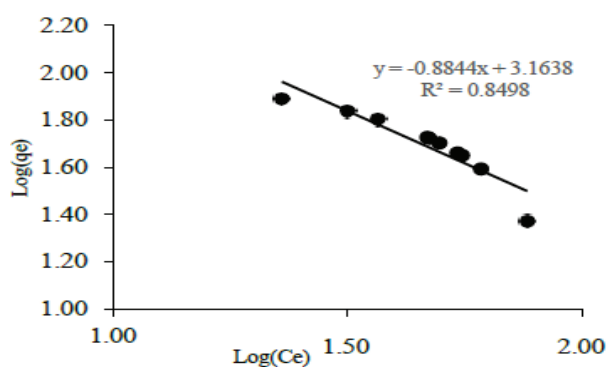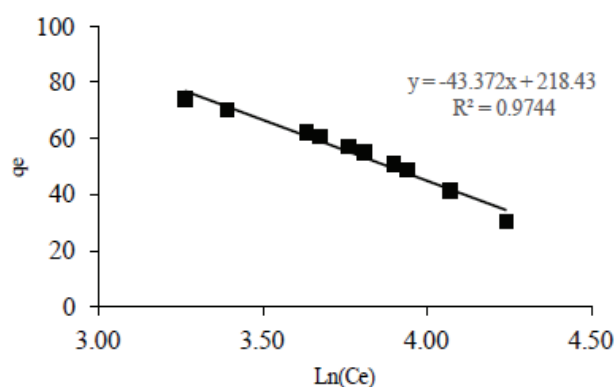
(f)

Fig. 4 Langmuir (a), Freundlich(c), Temkin (e) for activated carbon and Langmuir (b), Freundlich(d), Temkin (f) for magnetic nanoparticles

(i)

(j)

Adsorption kinetic study

Kinetic study experiment for the separation of copper form liquid phase were performed by activated carbon and magnetic nanoparticles. Experiment was performed under following conditions: Inatial concentration of Cu

Result showed that the coefficient of correlation for the Pseudo second-order kinetic model were more than Pseudo first-order kinetic model for both activated carbon and magnetic nanoparticles. Linear regression value (R2) were 0.97 and 0.96 for activated carbon and

magnetic nanoparticles respectively. Therefore Pseudo second-order describes the kinetics of adsorption process in best way.

CONCLUSION

The findings of this work show that activated carbon and magnetic nanoparticles are effective in removing copper from water solutions. The amount of copper adsorbed by activated carbon and magnetic nanoparticles d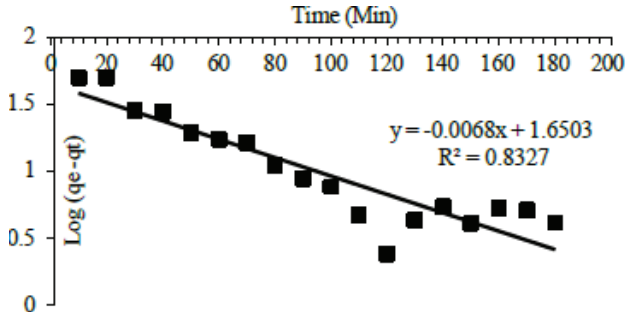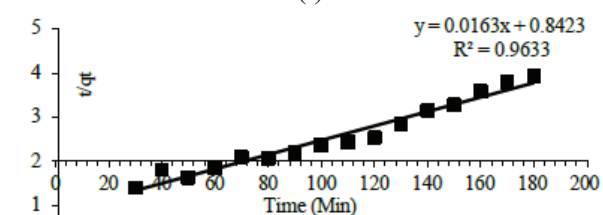epends on factors such as pH,adsorbent dose,and contact time. It was found that copper adsorption was higher in the acidic range, and the optimum pH for activated carbon and magnetic nanoparticles was 4.5. The optimum contact time and adsorbent dose for activated carbon and magnetic nanoparticles were 130 minutes and 0.14 g/lit, respectively, and 120 minutes and 0.12-0.14 g/lit, respectively. The isotherm study on the equilibrium data showed that the Langmuir and Temkin models fit well for activated carbon, while only the Temkin model fit well for magnetic nanoparticles. Result of column study shows that Pseudo second order model is best fit to describe kinetics of adsorption for both the materials.

ACKNOWLEDGMENTS

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Sea Clutter Distribution Models in SAR for Ship Detection – A Review

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ABSTRACT

This paper reviews methods of selected sea clutter modelling from the literature for representation of data distribution characteristics from various several radar systems operating at different frequency bands of L, S, and X, environmental conditions, sea states, polarization and collection geometry. Several distributions are discussed here that can contribute for selection of suitable probability distribution function that would fit the SAR sea clutter at coarse and fine resolutions.

KEYWORDS : *Sea clutter, Ship detection, Sea clutter distribution model.*

INTRODUCTION

For SAR ship detection problem, it is now a well established fact that accuracy of target detection mainly ships in open sea or littoral areas depend on identically modeling the sea clutter distribution, as far as possible. Over the past five decades, large amount of SAR data has been collected by various instruments across variety of platforms using several technical parameters of geometry, resolution, polarization and environmental conditions. This provides platform to researchers and institutions across the globe to explore statistical modelling methods of SAR clutter data for their suitability in context to know distribution characteristics in literature. Literature reveals that modelling the sea clutter for diverse conditions is critical as radar scattering received from sea surface depends on many factors, like characteristics of surface (e.g., sea state, direction and wind speed), capture geometry (e.g., angle of incidence, aspect angle), and radar specifications (e.g., resolution, frequency, polarization, and thermal noise).

Sea clutter modelling in SAR imaging coarsely can be divided in four categories viz., empirical, scattering, product and mixed models. In empirical models, the approach is to analyse SAR data characteristics and select suitable corresponding probability distribution model. Some examples of empirical models are Weibull distribution, Log-Normal distribution and generalized Gamma distribution. The empirical approach is based on data observation and experience. The scattering model can be evolved from imaging mechanism of SAR dataset. They are based on interaction of electromagnetic waves with sea surface considering rough surface scattering. Rayleigh distribution falls in this category. Examples of product models are k-distribution and G0 distribution. For better model fitment, mixed models are recommended in literature in case of SAR scenes having multiple scatterers. This would account

for models having multiple peaks in their probability density function, like the mixed Gaussian model. The probability distribution function (pdf) for modeling sea clutter distribution in Synthetic Aperture Radar (SAR) data is a vital in designing Constant False Alarm Rate (CFAR) detector. As to this instance, it is impossible to model sea clutter using pdf under various sea states using a physical model of sea surface. Hence, from SAR data measurements, various models are studied in literature to characterize sea clutter distribution. The nature of distribution of sea clutter is exponential due to various factors; radar receiving data that is in-phase and quadrature phase from external clutter, thermal noise from radar, received pulse envelope being converted to power using square law, called speckle.

Many pdf models are proposed in the literature that intend to fit sea clutter distribution characteristics. It is observed that, if the range resolution is coarse, pdf of sea clutter approximates Gaussian curve whereas for fine resolution the magnitude of sctter increases due to sea-spikes and breaking waves. This gave rise for the requirement of distribution models with elongated tails like Weibull, Log-normal etc. Ward et al.[6], proposed a skeleton for the development of distribution models known as compound Gaussian model that are widely currently used. The framework is popular as it covers slow varying component for texture modeling and fast varying component, the speckle related to Bragg scattering coefficient.

The authors at.el [1] compared the three distributions viz., Weibull, K and alpha-stable to model the heterogeneous distribution behaviour of sea clutter. Their study deduced that alpha-stable probability distribution function had better curve fitting result. Their proposed algorithm detected maximum ships and gave minimum number of false alarms. It was observed that CFAR was dependent on the distributions used to model sea clutter. The data used was ENVISAT ASAR for study with single VV polarization having fixed incidence angle ~230 and low resolution of 4.1m in azimuth and 7.8m in range. It was further observed that sea state and material and geometric properties corresponding to looking direction and system parameters of radar directly impact the detection.

The paper et.al [2] uses Sentinel-1 dataset to analyze sea clutter distribution and ship detection performance by statistical approach. In this two step approach, first the work evaluates five distribution models while the Kullback-Leibler (K-L) distance is being used for degree of fitness. The authors emphasized on suitable model for detector that would describe sea clutter appropriately viz., Weibull distribution, k-distribution, Log-normal distribution, G0 distribution and generalized gamma distribution. After this, the suitable distribution fit was selected followed with CFAR detector having adaptive threshold for ship detection. They validated results based on AIS data with human interpretation based on three performance parameters viz., figure of merit, probability of detection and false alarm rate. 304 ships were validated accordingly. The authors found that k-distribution, lognormal distribution and generalized gamma distribution had identical results and were better than Weibull distribution. It was further observed that G0 distribution had the best bit with optimal variance and mean. The performance detection of VH was better than VV polarization.

Ship detection using the GF-3 SAR dataset is studied for sea clutter modelling using a land masking technique [3]. For land masking a fully connected network architecture, the Caffe, a deep learning framework is used to reduce false alarm. There experiments with modeling clutter distribution focused on Gamma, Rayleigh and K-distribution, with Rayleigh giving much improved speed without considerable decline in pdf description in comparison to k-distribution. This was followed by CFAR detector using truncated statistic that separates background pixel from target which further improves clutter distribution. Finally, a neural network having convolutional layer, max-pooling layer (two each) and three fully-connected layers improves accuracy of detection by reducing false alarm. Also, they compared their finding with SLS-CNN and TF-ANN that reflected significant reduction in computational cost. This methodology was also implemented on TerraSAR-X dataset with spatial resolution of 1m to analyze and generalize the performance.

The paper [4], proposes a semiparametric clutter estimation method for SAR data image. By considering marginal distribution and spatial coorelation separately,

authors have proposed to estimate the joint distribution. For estimating the marginal pdf, kernel density estimator (KDE) was used. In order to characterize the spatial correlation Gaussian copula model is proposed. By using KDE in the log-intensity domain lead to better accuracy. Instead of applying the KDE in the intensity domain, it was logarithmically transformed, i.e., ln I. Further, the performance of curve fitting were evaluated with simulated samples that were generated from k-distribution. The KDE was analyzed in three domains viz; amplitude, intensity and log-intensity. Further, Gaussian Mixture Model (GMM) with expectation-maximization algorithm were applied for the log-intensity domain. Also, three measures of distance viz., Kolmogrov–Smirnov (K–S), Anderson–Darling and Kullback–Leibler (K–L) were used for goodness-of-fit. It was observed from the simulation results presented in their work that, for the log-intensity domain, GMM gave optimal fitting score for. It was evident from their analysis that KDE gave better performance in the log-intensity domain in comparison to amplitude/intensity domain. Authors proposed use of KDE for adaptive implementation and computational cost. Authors arrived at a conclusion of using Gaussian copula, to model the correlation for reasons explored in their work. The experimentation was done using SAR data collected from RADARSAT-2 over the Tianjin Port.

The paper et.al [5], explores tri-model discrete texture (3MD) on two airborne datasets viz., Ingara X-band at medium grazing angle and SETHI dataset at L and X-band for clutter model fitment suitability. Further, the work also explores relation between characteristics of sea clutter with distribution modes of 3MD. Compound distribution models like KA and KK distributions are said to be more accurate for clutter modeling but difficult for practical implementations due to large number of parameters. The Pareto model accounts for thermal noise alongwith need for only two parameters i.e., scale and shape. The k+Rayleigh distribution also considers excess Rayleigh scattering that is not accounted by distribution of thermal noise. The work et.al [7] proves that k+Rayleigh fits more precisely on wide geometrical range of radar data both for real and synthetic aperture. However, they were unable to model thermal and speckle noise independently as this belongs to first order compound Gaussian. The model fitment was evaluated

based on two error metric (a) Bhattacharya distance (BD), that compares the difference between actual pdf and theoretical distribution, (b) threshold error, that is absolute distance measured for experimental and fitted data for complementary cumulative distribution function (CCDF). The CCDF is a function to estimate distribution parameters for curve fitting [8]. Using these two error metrics, authors evaluated the models viz,. k+Rayleigh, Pareto+noise and 3MD (in mode 1, 2 and 3). There observations were as under for Ingara dataset; as BD focuses on overall fit, Pareto+noise and 3MD performed better then k+Rayleigh. For threshold error, 3MD had better low value while other two had similar errors. SETHI instrument, being a fully polarimetric SAR, the observations for X and L-band were as under; the BD value was found to be less then -33dB for all three distributions. It was observed that the tail of distribution for K+Rayleigh and 3MD had better fitment. To further study sea clutter characteristics texture analysis was explored comparing the product of texture location and proportion for HH, HV and VV polarisation. The number of modes in 3MD needed for fitment were found to be dependent on grazing angle, polarisation used and operating frequency bands.

The paper et.al [9], focuses on the Generalized Gamma, Weibull, Rayleigh, and Lognormal distributions for pdf modelling for CV-580 and RADARSAT-2 datasets. It examines the relation between resolution and clutter statistics in SAR systems. The approach was to decrease the resolution of radar image by local averaging using non-overlapping 3x3 windows and determine the suitable probability density function for the corresponding clutter for best fit. They deduced that Weibull distribution is better suited for high-resolution clutter. By decreasing the resolution, clutter was better modelled by Rayleigh pdf. With the increase in radar resolution cell size, clutter statistics become more Gaussian. Generalized Gamma (GΓ) pdf, were observed to be most suitable fit for clutter of varying spatial resolution in both CV-580 & standard and fine-beam-mode RADARSAT-2 data. Only HV data file was chosen for parameter estimation and clutter modelling in the study. Also, they concluded that moderate resolution CV-580 imagary nearly followed the Log-normal distribution.

The authors et.al [10], experimented on X-band, single-channel and VV polarized image acquired by DLR's F-SAR to analyze the model fitment. K-distribution and tri-modal discrete 3MD were considered for the study. There work has two-fold purpose; first for the onboard real-time processing, k-distribution and 3MD clutter model were analysed for images that were compressed in range. Secondly, this was followed by analysis of range-Doppler data for purpose of inverse SAR imaging. Fine resolution images were also generated for non-stationary targets. For K-distribution, the estimation parameters used were shape and scale while for 3MD they were discrete texture intensity levels and their relative weights. Out of various methods used for parameter estimation, Levenberg-Marquardt algorithm was selected. Time domain evaluations done in there work were as under; For smaller value of threshold, histogram fitment of the range-compressed clutter, K-distribution & 3MD were found to be similar. However, for larger value of threshold, 3MD distribution becomes linear while for k-distribution the curve diverges. The authors showed that for certain probability of false alarm (PFA), 3MD model gave more detections then k-distribution. For Range Doppler assessment, first a range-Doppler image is generated by taking the Fast Fourier transform (FFT) in azimuth. Taking FFT shifts non-stationary targets from the main clutter beam which in turn enhances those ship detections having less radar cross section. For a certain value of PFA and threshold comparison for K-distribution and 3MD in range-Doppler domain revealed similar results as of time domain. Different models for different regions increases the target detection for a given PFA but increases the processing and hence computations. Hence target detection in range-doppler is found to be complex but advantageous.

Based on Rician distribution, Laplace-Rician was proposed for modeling SAR clutter amplitude data [11]. The assumption here is that both in-phase and quadrature phase components of SAR amplitude signal follow Laplace distribution. This model was further compared to K, Log-normal and Weibull distributions. Kullback-Leibler divergence and Kolmogorov-Smirnov statistics were used to evaluate and compare the distribution models. In literature, the basic SAR amplitude model is assumed to have independent real and imaginary components with identically distributed zero-mean Gaussian random variables. The authors work is based on assumption of having a dominating scatterers in the whole scene. Hence, for the amplitude model of SAR, the components (real and imaginary) become identically distributed, and are independent with non-zero mean value of Gaussian random variables with same variances. Hence, the SAR density distribution resembles like rice shape, called the Rician distribution. For parameter estimation of model, Bayesian sampling was used. Markov chain Monte Carlo method was developed based on Metropolis-Hastings algorithm, to estimate the scale and location parameter in Laplace-Rician distribution,. The method then was tested on both simulated and real data. Performance assessment for model fitment was based on Kullback-Leibler (KL) divergence and Kolmogorov-Simirnov (KS) score. In this study, four Laplace-Rician datasets were generated followed by scale and location parameter estimation for these four datasets based on the proposed estimation method. It was observed the estimated and true values of scale and location parameters were close. The simulation was repeated for real SAR data and compared with five models viz; K, Rayleigh, Rician, Weibull and Log-normal. Three patches each of sea surface of 100×100 pixel were used from two distinct platforms of satellite namely; COSMO-SkyMed and Sentinel-1. They found that, Laplace-Rician had lowest values for KL divergence and KS score for COSMO-SkyMed sea surface patch. Further, only KS score was better for the proposed model using Sentinel-1 than other models.

Clutter modelling based on superpixel methods have been explored in the literature in recent past years. This is an object based processing approach where the idea is to have a block that has information derived from component pixels and that of edges and texture. Hence, they fit histogram better for detection of edge and texture change in SAR data as compared to traditional methods in the literature. The work et.al [12], explores SciPy Statistical Function Library (SPSFL) module in python for the analysis of distribution models at superpixel-level. In their work, superpixel segmentation was performed using method of pixel saliency difference and space distance on two datasets [13]. First a statistical analysis of sea clutter was performed based on SPSFL with both datasets. Five distribution models viz., Exponweib, Burr12, Beta, Johnsonsb and Kappa3 were evaluated

for best fitting accuracy based on Root-Mean-Square Error. This was then followed by statistical analysis of superpixel-level sea clutter. The sample value taken was mean intensity of superpixel. Each superpixel being a data sample. This was followed by selecting the pdf with the maximum histogram fit from SPSFL distributions. Three distribution model viz., Blurr12, Exponnorm and Johnsonsu were analyzed for superpixel-level sea clutter. It was observed that, Johnsonsu distribution model had closest fit representaation for both datasets. Four sets of sea clutter data were used for the study in X-band in co-polarization modes at different locations and resolutions ranging from 3m to 18.5m.

Statistical models namely GK, K+R, and GAO were analysed and compared for fitting the sea clutter distribution function in SAR data [14]. Further, their work used CFAR detector for ship detection using these three models. For estimating the parameters in GAO model, method of log-cumulants was used. Five L-band ALOS-PALSAR scenes with varying wind conditions in HH polarization were utilized in their study. As the first three scenes contained only sea clutter with no targets, they were tested for the histogram distribution fitment. Scenes 4 and 5 contained targets and were utilized to check the performance of detector for these three distribution models. KL (for overall fitment) and tailed KL (tail fitment) were utilized to evaluate the fitting performance. Comparable fitting performance of GAO and K+R models for overall and tail fitment were observed that outperformed GK model. The average calculation time for fitting the histogram in K+R and GAO were found similar in the literature. CFAR detector performance was found to vary depending on five data scenes. They observed that if sea state is homogeneous with low-to-medium wind speeds, GAO was better then K+R due to better tail fitment. For higher sea state and greater wind speeds, the CFAR for K+R model was found to be marginally better.

The literature also categorizes the statistics of SAR imagery methods into non-parametric, parametric and semi-parametric. In non-parametric methods pdf is derived from the sample data i.e., it does not pre-assume any analytical model. The parametric methods pre-assumes an analytical model first and then by using sample data it approximates the parameters of model.

The semi-parametric method combines parametric models for approximating the probability distribution. Paper et.al [15], explores to model the sea clutter probability distribution for designing a detector by combining different parametric models to improve the pdf estimation. Kullback-Leibler distance was used to measure goodness-of-fit. The methodology had three parts viz; Initialization step: performing random sampling of pixels from SAR amplitude image to construct a dataset and estimating its pdf (normalized histogram of sampled amplitude image). This was later followed by estimating the model parameters using method of log-cumulants. Estimation step: calculating the KL-distance between each model and its pdf estimation obtained in initialization step. Thus a new pdf is constructed point-wise by combination of components. Optimization step: selection of window size to increase smoothness of estimated pdf. Five models, i.e., Log-normal, Weibull, Nakagami, K and G0 were used to build the dictionary. The comparative study showed the fitting performance for pdf outperformed all the five models on basis of KL metric. The performance evaluation for histogram fitment was followed by a CFAR detector for ship and run on three SAR datasets viz; TerraSAR in HH, Cosmo-Skymed and Radarsat-2 in VV. Detection performance was evaluated by Factor of metric which revealed it being close to but marginally less than k-distribution.

The paper et.al [16] presents unique approach for sea clutter modelling by categorizing sea states. This classification is achieved by analyzing the distributions and the impact of speckle on the characteristics of distribution. They studied how parameters of distribution are affected by various sea states by corelating sea state with the statistical parameters.

Ten SAR images in HH polarisation from TerraSAR-X were used in their study. They all had ubiquitous mode of acquisition and geometric resolution. This resulted in all images having same ground and azimuth resolutions. Five classes were identified by visually inspecting three patches of size 150×150, 300×300 and 500×500. Further, to study the speckle noise effect on sea clutter distribution, mean shift and improved sigma filters were used. Filter performances were evaluated based on three parameters viz; noise variance, equivalent number

of looks and sharpness. In all six distribution models namely; Rayleigh, K, Weibull, Gamma, Log-normal and generalized Gamma were compared in there study for sea clutter model suitability. Further, for classification purpose, four methods namely; the K-means, Radial Basis Function, closest neighbour and Support Vector Machine were evaluated. The Radial Basis Function Neural Network performed better as compared to other three.

CONCLUSION

The paper aims to comparatively study the non-homogeneous statistical characterization of sea clutter for SAR imaging. We found that statistical modeling of clutter distribution is vital for design of detector. The clutter must be locally estimated for near uniform CFAR. The density estimation in context of sea clutter distribution is not a univariate marginal pdf. Since test regions have multiple pixels joint pdf is required to be estimated which further complicates the modelling. Sea clutter are non-Gaussian and distributions used in literatures do not have joint pdf forms. Estimating multivariate pdf is leads to inaccuracies. Due to finite resolution in spatial domain, each resolution element in a SAR image is expected to have large number of scatterers from the sea surface. They generate random returns, resulting in spiky characteristics in the distribution. This further results in nature of the clutter distribution having a larger tail. The spiky feature is difficult to model by analytic distribution whose tail falls fast. It is generally accepted in literature that the Gaussian function can be applied to model the real and imaginary components of the received data for SAR sea distribution. However, this assumption holds good only for the coarse-resolution, it does not fit as resolution becomes finer. Hence for high resolution SAR systems, other model distributions were explored for better fitment of SAR sea clutter beginning with Rayleigh. Rayleigh seems to be suitable for the Gaussian behavior of real and imaginary parts in amplitude distribution of received echo. However, Rayleigh is found not a good fit in modelling those distribution of sea clutter that are carrying heavy-tail. Other commonly analyzed distributions found in literature in context of SAR sea clutter modeling are K-distribution which is applied for speckle modeling from acquired SAR imagery, and

Gamma distribution, that describes the modulation component. Literature commonly accepts that Weibull distribution is a good fit to model heavy-tail sea clutter distribution. The generalized gamma distribution model is widely used due to fitting capability and flexibility in other areas like land, sea and urban environments. The literature suggests that for sea clutter modelling, the generalized gamma distribution model has outperformed Gaussian, Log-Normal, Weibull and K-distribution. The α-stable distribution was also used in the literature for background clutter modelling in problem of ship detection that gave better modeling performance as compared to classical models. The α-stable has better ability to fit heavy-tailed distributions that reflects spiky nature of non-homogeneous sea clutter distribution. By performing a comparative study, this paper elaborates the modeling performance of various distribution models on different resolutions, sea-states, polarizations, frequency bands, viewing geometry and number of looks in SAR datasets available for research purposes.

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Improving Seismic Performance of Non-Ductile Beam-Column Joints: A Review of Retrofitting Techniques

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ABSTRACT

The performance and safety of structures during seismic events are critical considerations in structural design and civil engineering. Beam-column joints in building serve as vital role for distributing loads and maintaining structural stability. These joints are exposed to complex, cyclic loads during an earthquake, if it not properly designed or retrofitted, may cause brittle failure. So, understanding the behavior of these joints is essential for a building's overall performance and safety. This study provides a review of the existing researches on a variety of retrofitting approaches, including the use of concrete-filled Steel Tube, to strengthen exterior beam-column joints and increase their ability to withstand seismic forces. Therefore, this research will serve as a valuable resource for understanding the behavior of beam-column joints when subjected to cyclic loading with different retrofitting methods

KEYWORDS : *Beam-column joint (BCJ), Concrete filled steel tube(CFST), Cyclic loading, Earthquake,Retrofitting.*

INTRODUCTION

In civil engineering and structural design, the performance and safety of structures during seismic events are of paramount importance. Beam-column joints, which connect beams and columns in buildings, play a critical role in distributing loads and ensuring structural stability. However, during earthquakes, these joints are subjected to significant forces and deformations, which can lead to structural damage or even failure. The ability of these joints to exhibit ductile behavior, where they can absorb and dissipate energy, is essential for seismic resilience. BCJs are critical elements in a structural system, as they transfer forces between horizontal beams and vertical columns. These joints are exposed to complex, cyclic loads during an earthquake, which, if improperly built or retrofitted, may cause brittle failure [35].Understanding the behavior of these joints is vital for the overall safety and performance of a building.

The ductile design of BCJs involves creating structures that can undergo significant deformation while still maintaining their structural integrity. Non-ductile designs, on the other hand, tend to fail abruptly when subjected to excessive forces. So, there is need of finding out the acceptable retrofitting approach for non-ductile beam-column joints that will have same strength as that of ductile BCJs.

Retrofitting methods are used to improve the performance of newly constructed buildings or to

increase the seismic resilience of existing structures. This study reviews a variety of retrofitting approaches, including the use of CFST haunches, to strengthen exterior beam-column joints and increase their ability to withstand seismic forces. However, during earthquakes, these joints are subjected to significant forces and deformations, which can lead to structural damage or even failure. The ability of these joints to exhibit ductile behavior, where they can absorb and dissipate energy, is essential for seismic resilience. BCJs are critical elements in a structural system, as they transfer forces between horizontal beams and vertical columns. During an earthquake, these joints are subjected to complex, cyclic loads causes failure of beam column joint.

Fig 1. Failure of Beam-Column Joint

PERFORMANCE OF DUCTILE AND NON-DUCTILE JOINTS

Ravikumar and Kothandaraman [1] examined the variations in BCJ performance under cyclic loading between ductile and non-ductile joints.Their study revealed that ductile joints could withstand higher loads and showed better energy dissipation than non-ductile joints. The ductile joints were able to endure larger deformation cycles before failure, which is critical for seismic resilience.It is highly recommended to include closely spaced stirrups in the design of beam-column joints because this research shows how important they are for a structure's ultimate load capacity and ductility.A.Kanchana Devi et al.[14] concluded that the ductile specimen exhibited 39% higher load in positive cycles and 9% higher in negative cycles compared to the non-ductile specimen, attributed to the enhanced confinement provided by closely spaced stirrups in the joints.The ductile specimen dissipated 2.5 times more energy than the non-ductile one and the ductile specimen showed lower stiffness and strength

degradation, indicating superior seismic performance over the non-ductile one.
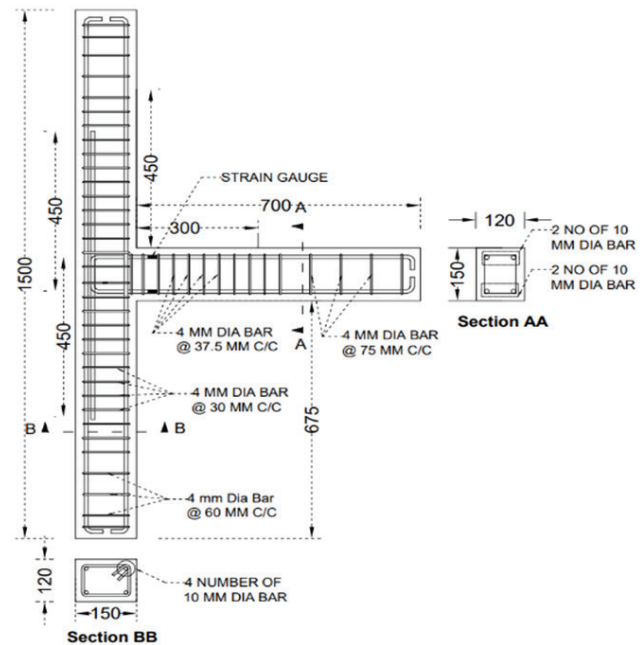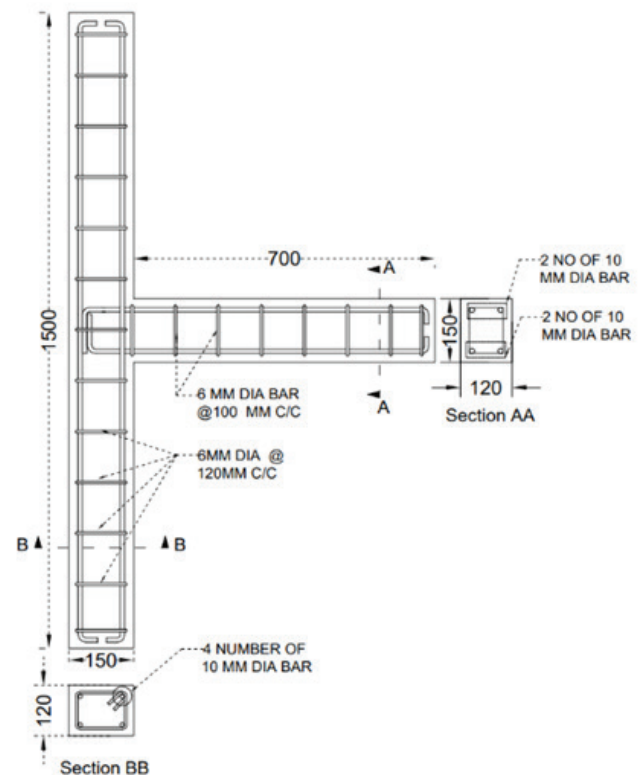

Fig. 2. Ductile Joint

Fig. 3. Non-Ductile Joint

RETROFITTING TECHNIQUES

Strengthening beam-column joints is essential to improve their seismic performance and overall structural integrity. To overcome this problem various retrofitting techniques are available to achieve this goal. Here are some common retrofitting techniques for strengthening beam-column joints:

FRP (Fiber-Reinforced Polymer) Wrapping

It involves encasing the beam-column joint with FRP sheets. Sharbatdar et al. [2],[18],[19], FRP wrapping enhances the joint's flexural and shear capacities while significantly improving its ductility. The lightweight FRP materialshaving   high strength-to-weight ratio make this method an attractive option for retrofitting older structures without adding excessive weight.There are several types of FRP materials used in structural applications:

- Carbon Fiber Reinforced Polymer (CFRP): Known for its rigidity, low weight, and high tensile strength, CFRP is perfect for strengthening applications but has a higher price. Ali Zerken [13],[26] suggest the proposed CFRP retrofit technique can effectively upgrade non-ductile beam-column joints, but the design must ensure the failure does not shift to the unconfined beam regions.

- Glass Fiber Reinforced Polymer (GFRP): GFRP offers lower tensile strength compared to CFRP but is more economical. It is widely used where cost is a critical consideration.Retrofitting specimens with GFRP at the joints enhances their performance regarding stiffness degradation, hysteretic behavior, load-bearing capacity, ductility, and energy dissipation ability. [16].

- Basalt Fiber Reinforced Polymer (BFRP): A comparatively recent substance, BFRP has intermediate performance and cost between CFRP and GFRP.

Concrete Jacketing

The method of placing another layer of concrete around the junction is known as concrete jacketing. This method improves confinement, compressive strength and greatly enhances seismic performance[15].

Steel Jacketing

Steel jacketing is another effective retrofitting solution where steel plates or angles are installed around the joint [33]. As per Sadid et al. [11], this method improves both the strength and ductility of BCJs, particularly in shear-dominated failures. The additional stiffness provided by steel jackets also contributes to the joint's ability to absorb seismic energy.

Steel Prop/Haunch

The steel prop retrofitting method offers a workable way to upgrade older buildings to satisfy seismic performance requirements by increasing the joints' strength, ductility, and energy dissipation. The suggested two-sided steel prop and curb retrofitting system can be used to strengthen and repair broken joints. This is due to the fact that it essentially moves the plastic hinge from the side of the joint and panel zone to the beam curb above, reducing shear stresses and the quantity of cracks in the panel zone [2],[24]. Zabihi et al. [4],[20],[21] demonstrated that externally clamped and fully fastened double haunch and also fully fastened single haunch retrofitting system offer a highly effective retrofitting solution by improving the joint's ability to absorb seismic energy.A more visually appealing and less invasive seismic retrofitting method is to add a single diagonal hunch to an outside beam-column joint to improve its seismic performance. According to Sadid, Mohammad Saber et al. [11], the best reinforcement type for haunch connections is K-stiffeners and three parallels, whereas the most effective haunch angle is 30 degrees.This retrofitting method resulted in an increase in ultimate load of up to 80%, decreased rigidity degradation, improved energy absorption, and reduced the occurrence of cracks.

Ferrocement Laminates

Retrofittingjoints with ferrocement laminates can enhance their structural behavior, With respect to strength, ductility, and resistance to cracks, in particular, it is a feasible choice for reinforcing and repairing damaged reinforced concrete structures[23].

Innovative Retrofitting Techniques

Recent studies have introduced advanced retrofitting methods that offer promising results in improving seismic performance:

Self-Centering Friction Haunches

Veismoradi et al. [3] proposed using self-centering friction haunches, a system that not only enhances joint strength and stiffness but also minimizes residual displacement after an earthquake. This technique redistributes the internal forces, thereby reducing the likelihood of permanent deformation and improving energy dissipation.

Nanomaterials in CFST Retrofitting

Singh et al. [6][17] explored the use of nanomaterials in concrete-filled steel tube (CFST) columns. They found that the strength, stiffness, and ductility of the retrofitted joints were greatly enhanced by adding carbon nanotubes and nano-silica to the concrete mix. This method of utilizing nanomaterials to improve the properties of the concrete infill in stiffened CFST columns demonstrated enhanced performance and has been deemed practical for this application. [6][17]. Zheng et al. [8] It was found through experimentation that cross-shaped CFST columns' axial compressive strength, stiffness, and ductility may be improved by adding longitudinal stiffeners or multi-cell forms. This represents a novel approach to improving the material properties of CFST columns and offers a practical solution for retrofitting older structures.

Resilient Slip Friction Joints (RSFJ)

The RSFJ system, as developed by Veismoradi et al. [3], is another innovative technique designed to retrofit deficient RC BCJs. It utilizes a frictional mechanism to provide self-centering capabilities, which helps reduce damage and improve the seismic resilience of retrofitted structures.Because of the restoring force provided by the RSFJs, this reduces the residual displacement in the frame and enhances the strength, stiffness, and energy dissipation of the system.

Prefabricated hybrid composite plates (HCPs)

Esmaeeliet al.[12] evaluates the retrofitting system using HCPs has potential practical applications for repairing severely damaged RC interior beam-column joints in buildings susceptible to seismic events.

PIEZOELECTRIC SENSORS

Feng, Qian, and Yabin Liang's [7] explores the growing potential of piezoelectric materials in the field of structural health monitoring (SHM). Piezoelectric materials are valuable because they generate an electrical response when subjected to mechanical stress, making them effective sensors for monitoring the integrity of civil structures. This technology has been applied in various SHM methods, including electromechanical impedance and ultrasonic wave propagation techniques, which detect changes in a structure's health, such as cracks or other damage.This piezoelectric sensors are advantageous due to their high sensitivity, light weight, and low cost. Additionally, they are perfect for large-scale SHM systems, which help to improve the monitoring of civil infrastructure, including buildings, bridges, and dams.

CFST (CONCRETE-FILLED STEEL TUBE) MATERIAL

CFSThave gained attention in recent years as an effective retrofitting solution for beam-column joints. These haunches, which consist of steel tubes filled with high-strength concrete, can significantly enhance the joint's capacity to absorb and dissipate energy during an earthquake. This research investigates the efficacy of CFST haunches as a retrofitting technique and assesses their impact on the overall structural performance. Xia, Song, et al. [5] performed studies on stirrup-confined CFST stub columns using axial compression. The CFST stub column's bearing capacity and ductility are improved because of the stirrups' restraining actions, which delay the steel tube's buckling. The axial compressive bearing capacity and ductility of the circular CFST stub column are not significantly affected by increasing the stirrup ratio because the concrete is more clearly constrained by the circular steel tube than by the square steel tube.

Using superposition techniques and design codes, Huang, Yue, et al. [9] established an equation for estimating the axial compressive load-bearing capability of retrofitted columns. According to Song, Wei, et al. [10], the primary failure mode of the CFST specimens is inward sinking of the steel tube on the existing gap side and local buckling at the end or center. As the gap ratio and number of freeze-thaw cycles rise, mechanical properties including the specimens' ultimate bearing capacity and ductility steadily deteriorate.
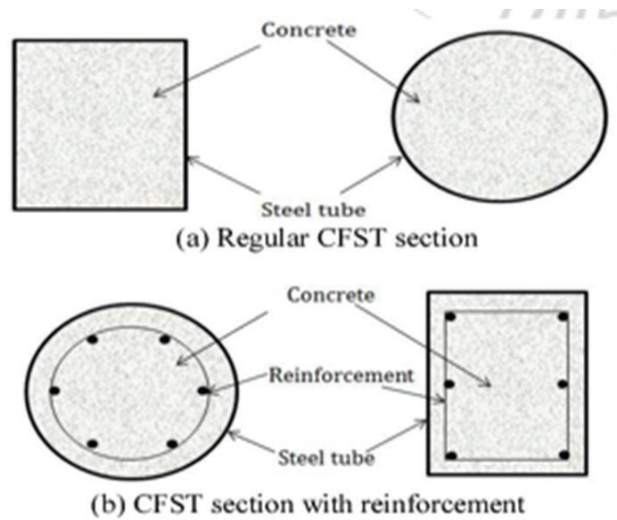
Fig. 4. (A)&(B) Cross Section Of Cfst Column[22]

CONCLUSION

From the study of literature presented in this paper, following conclusions are drawn out:

i.   The performance of ductile joints (DJs) is superior to that of non-ductile joints (NDJs) in every metric.

ii.   The behavior of non-ductile joints was enhanced by retrofitting the specimens with CFRP and GFRP sheets, which altered the ultimate failure mode and increased joint capacity.

iii. The specimen reinforced with ferrocement laminates shown greater effectiveness by enhancing stiffness, energy dissipation, and ultimate load carrying capability.

iv.   Strength, stiffness retention, energy dissipation capacity, deformation capacity, and collapse drift were all more successfully enhanced by the reinforced Engineering Cementitious Composite (ECC) jacket.

v.   Retrofitted bean-column joints with haunches increase energy absorption capacity, ultimate load carrying capacity and minimizes crack due to cyclic loading.

By implementing these innovative retrofitting approaches, engineers can improve the seismic resilience of existing structures and ensure their long-term safety in earthquake-prone regions.

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Revolutionizing Water Infrastructure: A Sustainable RO Purifier with QR Code Payment and Smart Dispensing Capability

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ABSTRACT

This research study proposes a creative solution to the important issues of clean water accessibility, sustainability, and user convenience in public spaces like train stations and college campuses. A sustainable Reverse Osmosis (RO) water purifier with an easy QR code payment system is developed and deployed to provide a feasible and ecologically friendly public drinking water access option. This work aims to develop and build a portable RO water purification system, incorporate a safe QR code payment system, and evaluate its environmental and financial sustainability. Using modern filtration machines, water quality monitors, and hardware and software integration to evaluate technical feasibility ensures purifying efficiency and quality. Sustainable RO water purifiers with QR code payment systems can solve public water access, sustainability, and user convenience, according to this study. Its technical, financial, environmental, and consumer demand compatibility make it a promising project that could improve public water availability in populated places. The study stresses the importance of solid cooperation, risk management, and data-driven improvements for the work's success. Sponsorship and reverse Osmosis filter unit customisation from AQUATIC RO SYSTEMS MUMBAI make the work economically viable.

KEYWORDS : *Fresh water scarcity, Reverse Osmosis Technology, sustainable, membrane material, brine waste management*

INTRODUCTION

Clean drinking water is a human right, a cornerstone of well-being, and a driver of societal progress. Climate change, population growth, and rising living standards have put significant demand on natural resources, making water an existential resource insecure. Potable water is crucial for life, agriculture, industry, and the environment. [1]. Despite urbanisation and environmental awareness, this essential need is nevertheless often lacking, especially in congested public spaces like train stations and college campuses. Given the urgency of this issue and the need to integrate technological innovation with sustainability, our study intends to propose a game-changing solution: a sustainable reverse osmosis (RO) water purifier with a QR code payment system.

This effort addresses the need for simple public water access, environmental awareness, and technical developments. The world seeks answers to the contradiction between rising clean water demand and dwindling natural resource supply. Integrating sustainability into public water access is our first step. The work envisions an eco-friendly water purifier.

Our sustainable RO water purifier is more than a scientific marvel; it changes how work balances user convenience and environmental responsibility. The work provides clean drinking water by QR code payment, simplifying the procedure and eliminating the need for plastic bottles. This effort combines cutting-edge water purification technology, safe payment methods, and a commitment to reducing carbon emissions.

The QR code payment mechanism also revolutionises

public water access and improves user experience. It shows changing client tastes and a growing demand for seamless, technologically advanced, sustainable solutions. This quest aims to provide universal access to safe, sustainable, and convenient drinking water across borders and socioeconomic groups. This research paper describes our efforts to create a paradigm-shifting system that quenches hunger and addresses today's biggest concerns. It examines the user- centric design, financial viability, environmental impact, and precise technical features of our sustainable RO water purifier with QR code payment mechanism. QR codes are two-dimensional modules comprised of black-and-white squares with information. QR code size depends on version number. QR codes' error correction ability is assessed using L, M, Q, and H levels. Creating a decodable QR code is explained here.

Examining the contained message determines the QR code version and error correction [2]. Through in-depth analysis and evaluations, we aim to improve public water access in densely populated areas while reducing our environmental impact. The combination of technology, sustainability, and human happiness shows our commitment to improving the world one glass of filtered water at a time.

Different membranes are utilised in industrial, scientific, and medicinal purposes. Polyamide TFC RO membranes are the most prevalent fresh water supply technology, although membrane fouling hinders their use. Additionally, chlorine may damage RO membranes. These two factors decrease membrane life, energy consumption, permeate quality, and permeability [4]. A cyclical end-of-life management technology is the direct recycling of reverse osmosis membranes (RO) into recycled nanofiltration (r-NF) membranes.[5] The unfiltered drinking water in Palghar (Maharashtra). Table 1 and 2 emphasise the need of maintaining certain characteristics for safe and edible drinking water.

Table 1. Standards Taken from Tap Water and Required Level (Vaitarna River, Palghar)

SR NO.	Parameters	Found	Required
1.	TDS	150 ppm	50 – 150 ppm
2.	BOD	3.0 mg/L	1 mg/L
3.	DO (Dissolved Oxygen)	7 mg/L	6.5 – 8 mg/L
4.	PH	7.6	6.5 to 8.5
5.	Hardness (CaCO3)	95.49 mg/L	200 mg/L
6.	Turbidity	1 NTU	1-5 NTU

Found Standards are taken from tap water Palghar area which generally comes from Vaitarna River. Required standards are partially taken from WHO standards and basic human needs.

Table 2 . Standards Taken from RO Purified Water

SR NO.	Parameters	RO
1.	TDS	50 – 150 ppm
2.	BOD	0.8-1 mg/L
3.	DO (Dissolved Oxygen)	7 – 8 mg/L
4.	PH	6.8 to 8.4
5.	Hardness (CaCO3)	200 mg/L
6.	Turbidity	3-4 NTU

This table illustrates how RO Purified water helps in eliminating impurities and other unwanted substances from impure water.

METHODOLOGY

- The initial process includes a detailed needs evaluation (Evaluation & Needs). Choose the optimal water vending machine locations and sizes. The quality and quantity of water in the area must be determined in order to comply with regulations. Understanding potential users' demographics and interests allows you to develop a system that meets their needs.

- Technology Choice: A successful water vending system requires the correct technology. This has two key points. Reverse osmosis (RO) requires commercial-grade equipment and technology. Second, QR codes are used for authentication, payment, and water distribution. QR codes should be simple and secure for quick and safe water access.

- Water Source and Filtration: Feed the RO system with either municipal or well water. Installation and maintenance of a filtering system is required to meet the water quality standards of users and regulators.

Taste, scent, colour, and organic and inorganic pollutants all influence whether water is safe for residential usage [6]. Checking water quality for microorganisms and other needs such as food preparation, hygiene in child care (breastfeeding and infant feeding), and disease treatment may aid in disease prevention [7]. Filtration ensures safe drinking water. Because colourless, odourless, and tasteless water is not safe to consume, filtration equipment may violate legislation [8].

- Hardware set-up: Water storage, RO filtration, and dispensing are all included in the hardware installation. Figure 1 depicts the deployment internal sequence and prototype for water vending machine QR code integration verification, which is required for a seamless user experience. Source of water for plant . Deployment of plant with specifics Hardware and sources and Prototype

Our filtration prototype consists of the following components and shown in table 3. The flow chart of sources is main design consideration in manufacturing and building prototype as shown in figure 2.

Table 3. Prototype Contents

Component	Functions
Water Supply Connector	Connects the system to the water supply
Pressure Regulator (optional)	Regulates water pressure (optional)
Sediment Pre-filter	Removes larger particles and sediments from water
Carbon Filter for Chlorine Removal	Removes chlorine from water
Carbon Filter for Chloramine Removal	Removes chloramine from water
Auto Shut-off Valve (ASO Control Valve)	Controls the flow of water and shuts off when the tank is full
Reverse Osmosis Membrane	Removes contaminants through osmosis process
Check Valve	Prevents backward flow of water
Post Carbon Inline Filter	Further enhances water taste and removes remaining impurities
Pressurized Water Storage Tank	Stores purified water under pressure

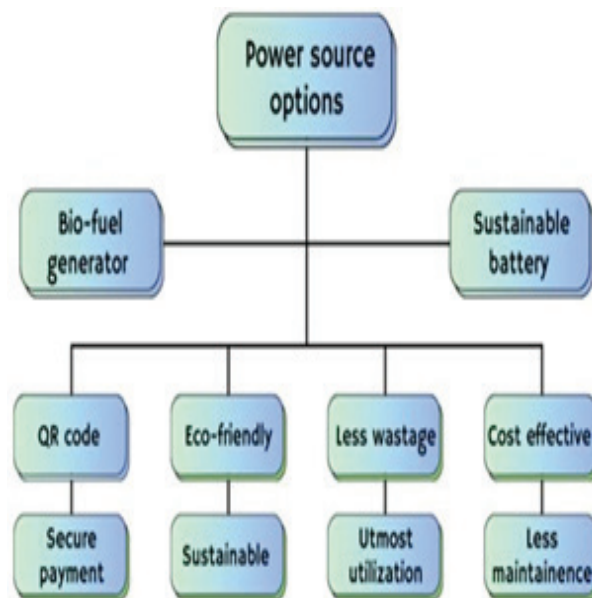| Drinking Water Faucet	Dispenses purified water
Optional RO Components	Booster pumps, pH balancing post filters, TDS water quality monitoring, and UV disinfection systems

Fig. 1. Backup Arrangement

With respect to the power supply, work designed for two sources i.e. Generator and Battery. Their contents are given in table 4 and table 5.

Table 4. Generator Specification

Power Source (Generator)	Range	Consumption	Additional Features
Single Phase 220V Non-Silent 5 Kw Ultra Power Petrol Generator, For General			
Purpose	220 V	5 kW	Non-Silent - Ultra Power
- Petrol Generator			
GENERATOR 2E GASOLIN 220V, 50HZ, 5.5KW	220 V	5.5 kW	Gasoline Generator
Honda Generator –			
Ez6500Cxs 5.5Kw, 220V	220 V	5.5 Kw	Honda Generator

Table 5. Battery Specification

Power Source(Battery)	Range	Consump-tion	Additional Features
5.5 KW Off-Grid Low Voltage Lithium Battery, Single Phase, 220/230V BSM5500LV-48	220V – 230V	5.5kW	Lithium Battery
5.5kW High Frequency Off-Grid 220V Voltage with MPPT Module Solar Inverter and LiFe PO4 Battery Charger.	220V	5.5Kw	High Frequency Off-Grid Inverter - MPPT Module - LiFe PO4 Battery Charger
5.5KW Hybrid Solar Inverter 220V 48V PV Input, 450Vdc 90A MPPT Solar Charger, Grid Tied Touch Screen Inverter with CT Sensor.with CT Sensor	220V	5.5kW	Hybrid Solar Inverter - PV Input 48V - 450Vdc 90A MPPT Solar Charger - Grid Tied - Touch Screen Inverter - CT Sensor

SOFTWARE DEVELOPMENT

This process involves creating or adapting bespoke software to accept payments, track data, and manage user registrations. Security measures are also put in place to secure user information and payment data, guaranteeing that the system is safe and trustworthy. Scholars found four elements of convenience for mobile payment users [9]. First, mobile payment removes spatial limits on payment, allowing users to buy things from a remote location online [10]. Second, mobile payment enables customers to pay for their purchases without requiring a physical wallet [11], cash, or credit card [12]. Third, as compared to traditional payment methods, mobile payment provides some economic transaction performance benefits (for example, speed). Fourth, mobile payment protects customers against counterfeit money [13]. This is shown in figure 2 and figure 3.

Fig. 2. LCD Screen Display

Fig. 3. Payment Gateway Page

Fig. 4 Technology Driven Ro Water Purifier Machine

The software development for payment gateway is explained in figure 4.

1. Creating an Account: The establishment of user accounts is critical for billing and user administration. To improve the user experience, a simple interface is used for account administration.

2. Creating QR Codes: Registered users are assigned unique QR codes, which are connected to payment methods and user accounts to provide secure access to water.

3. Procedure for Dispensing Water: An easy and user-friendly process for distributing water using QR codes is created. Users may choose how much water to dispense.

4. Payment Processing: A secure payment gateway is configured to charge consumers for the water they distribute.

5. Monitoring and Maintenance: The system is constantly monitored in real time to maintain water purity and overall system health. To ensure peak functioning, software, vending machines, and RO equipment need scheduled maintenance.

6. Marketing and User Interaction: Various marketing channels are used to raise awareness of the water vending business and attract new customers. User input is actively solicited to help develop and adjust the service to meet their changing requirements and expectations.

7. Regulation Compliance: Local, state, and federal rules, particularly those governing data privacy and water quality, must be followed. Strict adherence guarantees a responsible and legal functioning.

8. Scaling and Expansion: The technique ends with a continual review of system performance. Opportunities for development and extension to additional places are investigated, based on the original deployment's results.

9. Technology: Users may scan QR codes and make payments using mobile applications designed for various platforms such as iOS and Android.

Function: These programmes provide an easy-to-use interface for account management, payment approval, and QR code scanning.

10. Secure Data and Encryption: Sophisticated encryption techniques and security safeguards ensure sensitive payment information is safeguarded during transmission.

Function: These technologies guard against unauthorised access to user data and financial information.

11. Handheld Wallets: Digital wallets enable customers to securely store credit card information and make payments by scanning QR codes.

QR code payments are made easier with mobile wallets since they securely store payment details.

QR CODE HARDWARE TECHNOLOGY

1. Code Scanner: The Code Scanner can read QR codes from physical or digital displays and may be incorporated into mobile devices or used as independent gear.

Function: QR code scanners retrieve payment data.

2. Point of Sale Terminals: POS terminals can read QR codes and process payments using specialised hardware.

Role: POS terminals take QR code payments at retail venues.

3. Near Field Communication (NFC): NFC technology enables contactless payments, often utilised with QR code systems.

Nearby payments boost user convenience.

4. Internet Connection: Reliable internet connections, such as Wi-Fi or cellular networks, are necessary for payment data transfer.

Internet access enables real-time transaction processing and payment gateway communication.

5. Secure hardware modules: HSMs enhance payment information security.

Payment data is encrypted and decrypted by them to secure sensitive data.

Smartphones and tablets are commonly used as payment terminals for QR code transactions.

These gadgets have QR code scanners and payment processing interfaces.

CALCULATIONS

For Domestic Purpose

1. Purification Capacity = Flow Rate×Operating Hours (1)

Flow Rate is the rate at which water passes through the RO system (measured in liters per hour or gallons per minute).

Operating Hours is the number of hours the system operates each day.

Water Purification Capacity = 70 liters × 5 hours/day = 350 liters/day

TCO: Total Cost Of Ownership:-

Table 6. Total Cost Estimation

Sr No.	Initial Investment	Cost In Rupees
1	LED SCREEN	2100
2	RO SYSTEM	4000
3	ARDUINO/ESP 32	400/600
4	RELAY	50
5	PHOTO-RESISTOR	10
6	RO MEMBRANE	250
7	SUSITANBLE POWER SUPPLY(BATTERY/ GENERATOR)	25-30 K

Yearly Maintenance Cost:- Rs. 500 per annum Replacement Cost:- Rs. 2000-3000 per annum

Annualized Cost(AC):- TCO/Expected lifespan (2)

AC: 35,000/15 = Rs. 2300 pa

QR Code Generation Rate:

• Calculate the number of QR codes generated per unit time (e.g., per second or per minute).

• Determine the average time required to generate a QR code.

QR Code Generation Rate= Number of QR codes generated/Time taken for generation

= 1/1 sec (1 QR code

will be displayed within 1sec)   (3)

Energy Consumption

Energy Consumption = Power × Time   (4)

= 60W × 5 hrs

= Rs.12.45

ENVIRONMENTAL IMPACT

The RO water purification system, which uses biofuels or eco-friendly batteries and has a QR code payment system and water dispenser, has many environmental benefits. The system reduces its carbon footprint by using biofuels and eco- friendly batteries to boost energy efficiency. Its off-grid capacity provides clean water in rural regions, reducing the environmental impact of grid expansion. Responsible brine waste management protects aquatic habitats, and eco-friendly construction materials reduce environmental effect. Marketers expect RO technology use to rise 5% annually. This rise will also boost the market for RO membrane components used in saltwater desalination, sewage treatment, and tap water treatment. [14]. Recently proposed flexible reverse osmosis (FLERO) cleanses and conserves water by recycling brine to input water. FLERO may impair micropollutant therapeutic effectiveness, but how much is unknown. Thus, this study tested FLERO's ability to remove twenty disinfection byproducts (DBPs) from simulated water under constant 80% water recovery. Some DBPs were affected by ionic strength, methanol concentration, and water matrix, although most showed clearance rates $\geq$ 80.8% [15]. RO desalination facilities save energy and the environment[16]-[20].

The integrated QR payment system promotes paperless and eco-friendly payments. By providing clean, affordable drinking water, the work reduces single-use plastic bottles and their environmental impact. This holistic approach and community and stakeholder involvement demonstrate the work's environmental responsibility and sustainability.

RESULTS AND DISCUSSION

Our project will also include a web platform and smartphone app for remote monitoring and control. Customers may easily check system performance, water quality, and maintenance notifications   from   their computers or phones. Smart filters will automatically replace filters when needed, simplifying maintenance. The product's customisable water temperature and volume improves its uniqueness and lets users customise their experience. We use innovative technologies like IoT and AI to improve predictive maintenance and system performance to reduce water waste. We prioritise

sustainability and will build our water purifiers using eco-friendly materials and encourage recycling. We will use community participation and education to promote water conservation and environmental care. In addition, including an emergency water provision function to help distressed communities during crises or natural disasters. The design includes reusable bottle storage and water heating and cooling options. Our modular design approach will enable seamless upgrades, repairs, and integration of new functionalities to meet changing corporate needs and technology advances. Sustainable RO technology reduces environmental effect when designed with ecology in mind. It minimises its environmental impact by using eco-friendly products and careful waste management. Well-designed nature-based treatment systems may be suitable for RO concentrate treatment due to their cost and ability to address several contaminant classes. Wetland microorganisms and plants thrive in RO concentrate's high salinity and solute concentrations. Natural systems can also rally support for water recycling since they provide habitat and aesthetic benefits that community members value.

ACKNOWLEDGEMENT

CONCLUSION

The work is supported by AQUATIC RO SYSTEMS MUMBAI successfully manage to bring life change amongst remote town with accessible drinking water to the people. The work demonstrates have created the RO water purifier's basic filtering unit. The implementation of QR code scanner with GUI is one of the highlight of the work. This milestone streamlines the user experience, simplifies water purifier access, and enables safe and quick payment processes. The easy-to-use interface lets anyone check for clean water. This system is more robust ,durable and efficient with definite improvement in quality of water. The next level development with battery and generator technology will ensure that our ro water purifier works flawlessly with sustainable batteries or bio-fuel generators. The product is adaptable because of this flexibility, making it accessible in places with different energy supplies.

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Unsymmetrical Fault Analysis using Negative Sequence Component for Overcurrent Protection of Distribution System

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ABSTRACT

This work delineates the formulation and execution of an innovative criteria function 'R' predicated on the negative sequence current component to enhance overcurrent protection in distribution systems. The evolution of deregulation and the demand for high-quality electrical energy necessitate advancements in several sectors of the power system. Power system transients resulting from switching events, such as transformer energization and induction motor initiation, are prevalent causes of unwanted relay protection functioning. A symmetrical components-based approach for unbalanced currents is developed to detect and identify the balanced state of the power system during faults. The proposed algorithm relies on the distinct behavior of the existing components under fault and non-fault conditions and is unaffected by the current amplitude. A criterion function 'R' has been established to avert the unwanted operation of overcurrent relays resulting from switching, based on these discrepancies.

KEYWORDS : Over current protection, Criterion function 'R', Simulink/MATLAB computational models, Single line to ground fault, Line to line fault, Transformer energization, Induction motor starting, Fault and non-fault events.

INTRODUCTION

Electrical power demand is doubling every decade. Planning, operation and control of interconnected power system is having a variety of challenging problems, the solution of which requires application of mathematical methods of various branches. Power system planning, design and operation require careful studies in order to evaluate system performance, safety, efficiency, reliability and economics. Such studies used to identify the potential deficiencies of proposed system. In the existing system, the cause of equipment failure and malfunction can be determined through system study. The computational efforts are very much simplified in the present-day calculation due to availability of efficient programs and powerful techniques. The Electrical protection system protects power system from harmful effects of fault. A fault is an abnormal system condition, which is in most cases is short circuit, and occurs as a random event. Consequently, the protective system must isolate the faulty component from the remainder of the system with a high degree of dependability and in the shortest possible time. A power system is dynamic, undergoing alterations during operation (activation and deactivation of generators, three-phase transformers, capacitor banks, circuit breakers, shunt capacitors, and transmission lines) and during planning (incorporation of generators and transmission lines). Faults in power systems typically arise from insulation failure, flashover, physical damage, or human mistake. Occasionally, concurrent faults may arise that involve both short circuit and open circuit faults.

Power system transients, arising from switching in the presence of inductance and capacitance, are undesirable phenomena. Power system switching, including motor initiation and transformer energisation, is a primary source of undesired relay protection operation. Conventional approaches to overcurrent protection have primarily relied on phase currents. Inrush currents generated during motor initiation and transformer energisation can lead to interaction issues with other

loads within a facility or power system, especially voltage sags that may trip loads. The energising transformer presents extra complications related to harmonics in inrush current, which may induce system resonance and result in dynamic overvoltages. Dynamic voltages can lead to the overheating of surge suppressors, the blowing of capacitor fuses, capacitor failures, or malfunctioning of overcurrent relays.

SYSTEM DEVELOPMENT AND MATHEMATICAL MODEL FOR CRITERION FUNCTION 'R'

Overcurrent is a critical issue in power distribution systems. A precise understanding of fault performance in a power system is essential for establishing component ratings, coordinating protective settings, minimizing component damage and plant downtime, and complying with regulatory requirements. Accurate fault investigations must be conducted anytime network configurations are altered. Balanced three-phase faults can be examined via an analogous single-phase circuit. The application of symmetrical elements in asymmetrical three-phase faults simplifies computations, as gearbox systems and their components are predominantly symmetrical, despite the fault's asymmetrical nature. Fault analysis is typically conducted in per unit quantities, as they yield solutions that are relatively constant across various voltage and power ratings, and function on values approximating unity. This study presents the criterion function 'R', which can be used in simulation models to guarantee the reliable functioning of protection systems.

The predominant types of faults include single-line-to-ground fault, line-to-line fault, and double-line-to-ground fault. All of them constitute imbalanced defects. Upon the occurrence of a fault, it is essential to isolate it by disengaging protection breakers. The imbalanced defects are tough to analyse. The symmetrical component is a methodology employed for the study of unbalanced faults. This approach was identified by Dr. Charles L. Fortescue. In any unbalanced or asymmetrical network, an unsymmetrical defect with an unbalanced load can be analysed by symmetrical component transformation, which decouples the three-phase system into three distinct sequence networks: positive, negative, and zero sequence networks.

The mathematical evaluation of positive, negative and zero sequence components of unbalanced and unsymmetrical faults LG, LL and LLG is done with different power system numerical. It is found that negative sequence component in unsymmetrical fault is considerable. For symmetrical faults the negative component of the current is negligible and almost equal to zero similar with switching case. The criterion function 'R' for discriminating fault from non-fault switching is defined as follows.

$$R = \frac{|I_1| - |I_2|}{|I_1| + |I_2|}$$

Where, $|I_1|$ - magnitude of positive sequence current

$|I_2|$ - magnitude of negative sequence current

By solving different numerical power system problem for criterion function 'R', it is verified that Value of criterion function 'R' can be set below 0.35. For Value of criterion function 'R' above 0.35, over current protection will not operate, but for value 'R' below 0.35 the over current protection will operate.

SIMULINK / MATLAB MODEL FOR CRITERION FUNCTION 'R' FOR BALANCED 13-BUS SYSTEM

The criterion function 'R' is validated on a segment of a 34.5 kV distribution system comprising 13-buses, and is modelled via MATLAB/SIMULINK. The single line diagram is presented in Fig. 1. The network parameters of the 13-bus distribution system are presented in Table I. The balanced steady-state operation of a 13-bus power system is simulated in MATLAB.

Table 1 13-Bus Distribution System Parameters

| Sr. No.	System Particuars	System Specification
i.	Source	154 KV, 10000 MVASC, 50 HZ
ii.	Bus 1	TRANSFORMER 100 MVA, 154/34.5 KV
iii.	Bus 2	CABLE 3 KM, XLPE 34.5 KV
iv.	Bus 3	TRANSFORMER 20 MVA, 34.5/10.5 KV
v.	Bus 4	RESISTIVE LOAD 19 MVA
vi.	Bus 5	TRANSFORMER 20 MVA, 34.5/10.5 KV
vii.	Bus 6	RESISTIVE LOAD 19 MVA
viii.	Bus 7	CABLE 3 KM, XLPE 34.5 KV
ix.	Bus 8	RESISTIVE LOAD 19 MVA
x.	Bus 9	TRANSFORMER 20 MVA, 34.5/10.5 KV
xi.	Bus 10	RESISTIVE LOAD 19 MVA
xii.	Bus 11	TRANSFORMER 20 MVA, 34.5/10.5 KV
xiii.	Bus 12	RESISTIVE LOAD 19 MVA
xiv.	Bus 13	TRANSFORMER 20 MVA, 34.5/10.5 KV
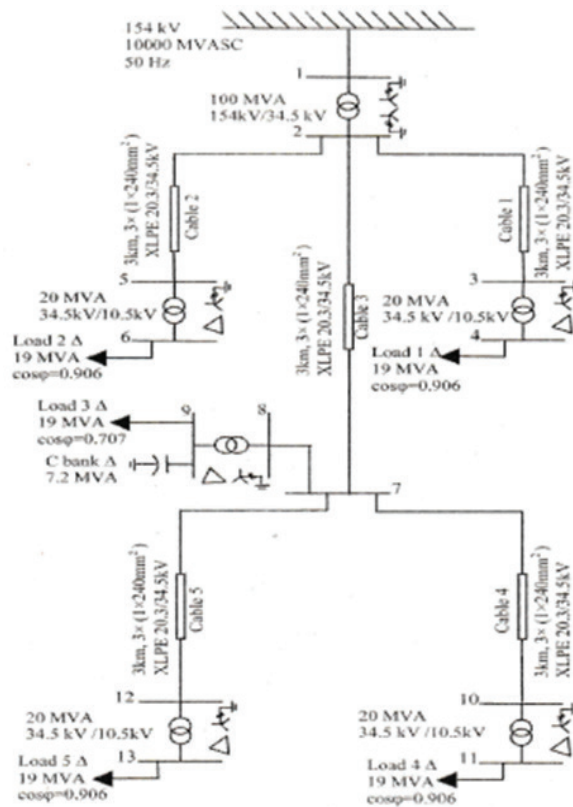
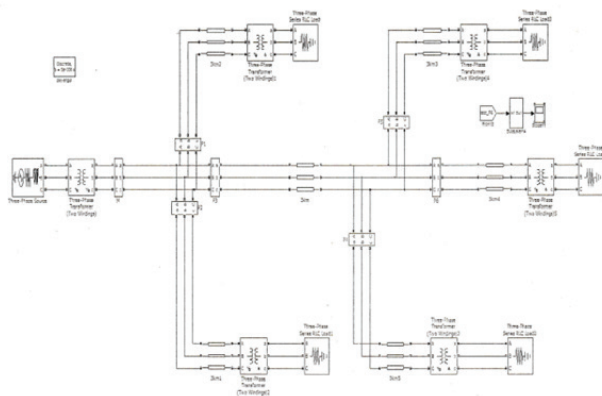**Fig.1 13-Bus Distribution System (34.5 kV Simulated Distribution System)**

Fig.2 Simulink Model of 13-bus Distribution System (34.5 kV Simulated Distribution System)

The balanced Steady – State operation of 13-bus power system is simulated in MATLAB as shown in Fig. 2. By solving different numerical power system problem for criterion function 'R', it is verified that Value of criterion function 'R' can be set below 0.35. For Value of criterion function 'R' above 0.35, over current

protection will not operate, but for value 'R' below 0.35 the over current protection will operate.

The value of criterion function 'R' is found out as 1, for balanced 13-bus 34.5 kV distribution system as modeled as above. The simulation results are as shown in Fig. 3. The 13-bus distribution system is simulated for unsymmetrical faults and also for switching events. The simulation results are analyzed to study the effect of criterion function 'R', its reliability in distribution system. The simulation models are designed for line-to-ground, line-to-line fault for bus 9.
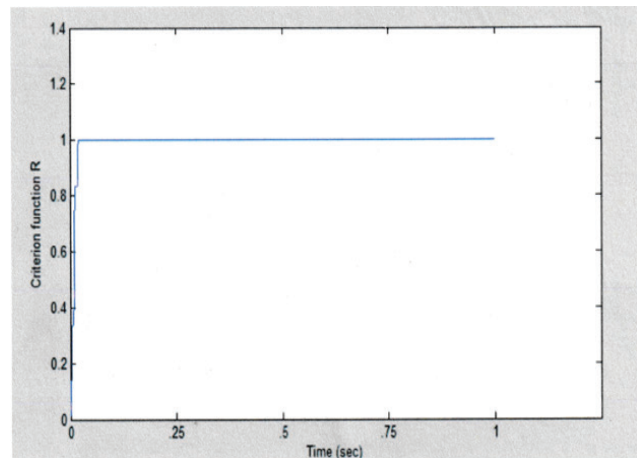
Fig. 3 Value of criterion function 'R' for balanced 13-bus distribution system versus time on bus 9

The value of criterion function 'R' is found as 1 for balanced 13-bus system as in Fig. 3.

SIMULINK/MATLAB MODEL FOR CRITERION FUNCTION 'R' FOR UNBALANCED 13-BUS SYSTEM WITH LG FAULT

Fig. 4 shows Simulink model for LG fault on bus 9 and logic circuitry with overcurrent relay is connected. LG Fault is created on bus 9 and logic circuitry for 'R' is also implemented in Fig. 4. The waveform without logic circuit of overcurrent relay is shown in Fig. 6 and with logic circuit of overcurrent relay is shown in Fig. 4. The Value of criterion function 'R' of LG fault is plotted in Fig. 5.

The value of criterion function 'R' due to LG fault with overcurrent relay is 0.24 which is below reference i.e., 0.35 as shown in Fig. 5.
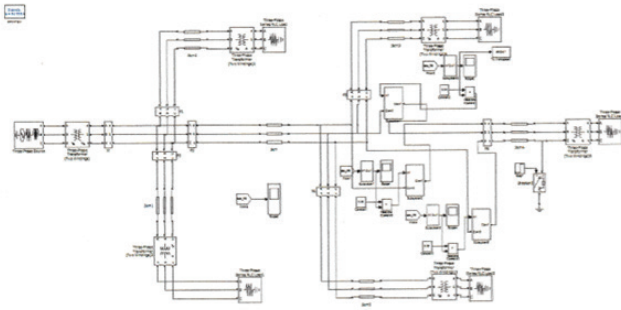
Fig. 4 LG fault on bus 9 of 13-bus distribution system with designed Overcurrent relay
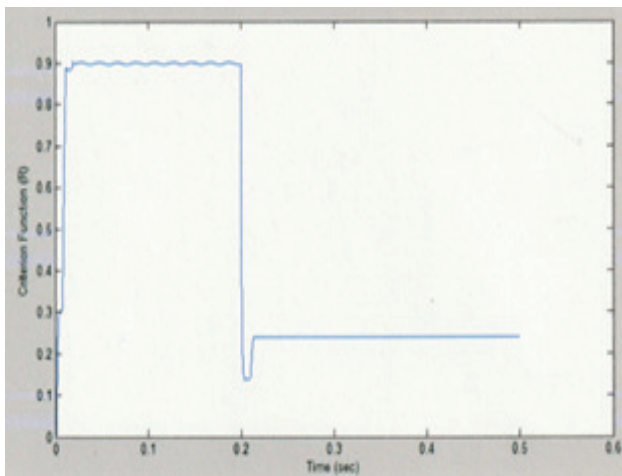

Fig. 5 Value of criterion function 'R' of LG fault on bus 9 of 13-bus distribution system with designed Overcurrent relay
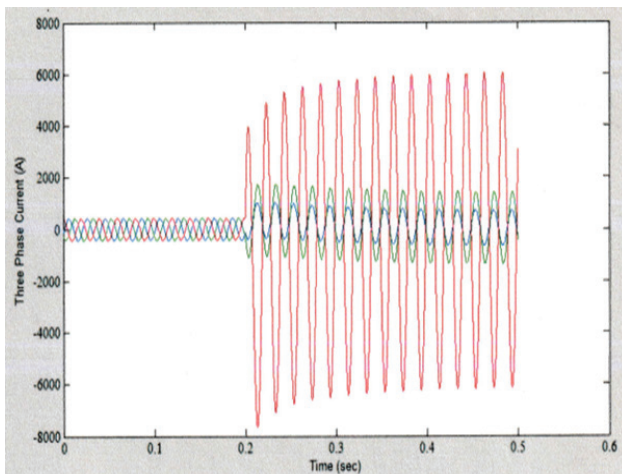

Fig. 6 Three phase currents due to LG fault on bus 9 of 13-bus distribution system without designed Overcurrent relay
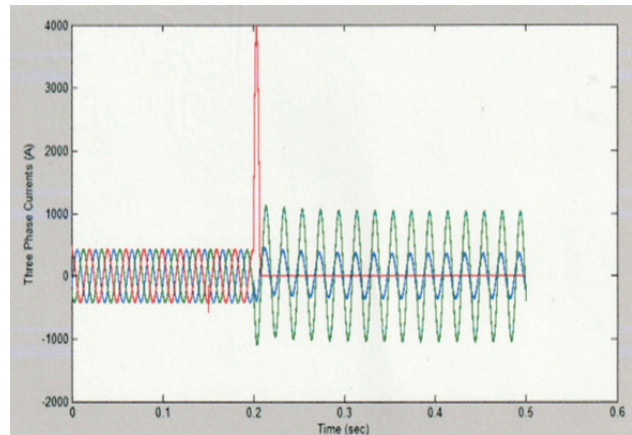

Fig. 7 Three phase currents due to LG fault on bus 9 of 13-bus distribution system with designed Overcurrent relay

The unbalanced fault involving two phases i.e., LG fault is modeled, simulated and different results are verified. So, the designed overcurrent protection using criterion function 'R' is operating for reference value below 0.35.

SIMULINK/MATLAB MODEL FOR CRITERION FUNCTION 'R' FOR UNBALANCED 13-BUS SYSTEM WITH LL FAULT

Simulink model for LL fault on bus 9 and logic circuitry with overcurrent relay is connected in Fig. 8. LL Fault is created on bus 9 without Logic circuitry for 'R' is also implemented. The waveform of three phase currents due to LL fault without overcurrent relay is shown in Fig. 11, and the waveform of three phase currents due to LL fault with logic circuitry overcurrent relay is shown in Fig. 12.
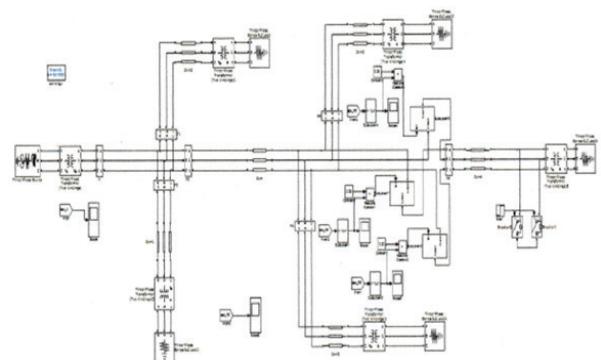

Fig. 8 LL fault on bus 9 of 13-bus distribution system with designed Overcurrent relay
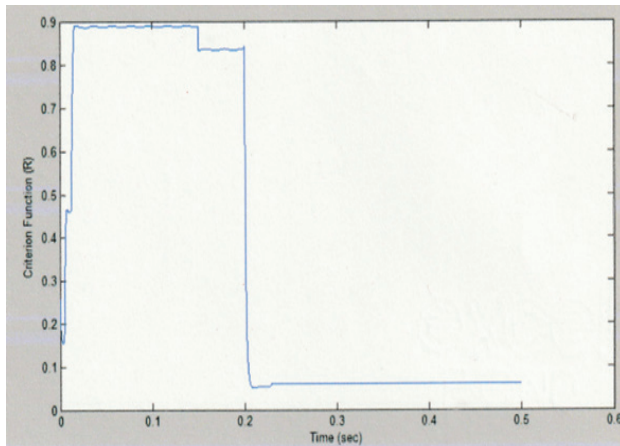
Fig. 9 Value of criterion function 'R' of LL fault on bus 9 of 13-bus distribution system without Overcurrent relay

The value of criterion function 'R' due to LL fault without overcurrent relay is 0.27 which is below reference i.e., 0.35 as shown in Fig. 9.

The value of criterion function 'R' due to LL fault with overcurrent relay is 0.06 which is below reference i.e., 0.35 and also lower than 0.27, as shown in Fig. 10.

The unbalanced fault involving two phases i.e., LL fault is modeled, simulated and different results are verified.

So, the designed overcurrent protection using criterion function 'R' is operating for reference value below 0.35.
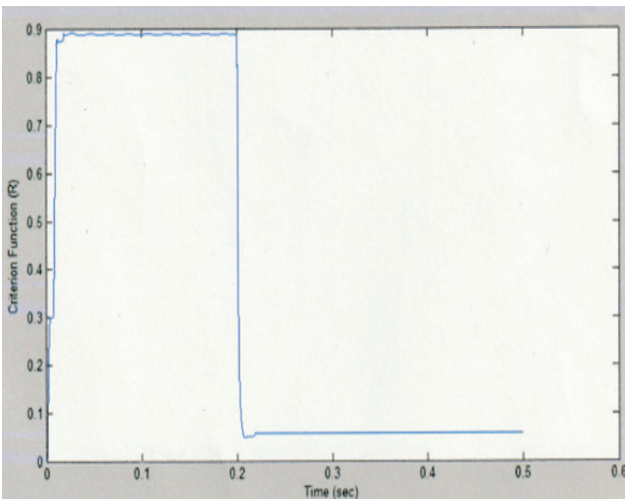

Fig. 10 Value of criterion function 'R' of LL fault on bus 9 of13-bus distribution system with designed Overcurrent relay
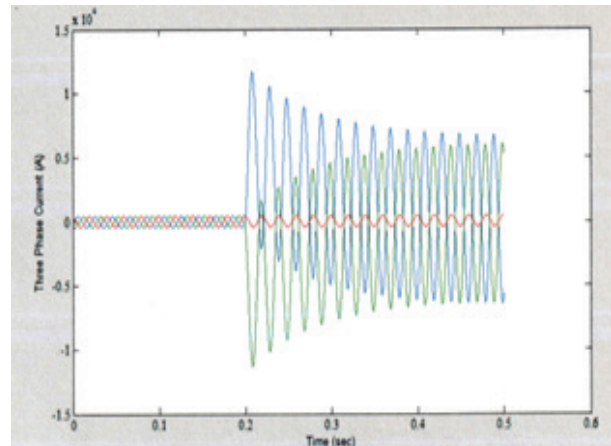

Fig. 11 Three phase currents due to LL fault on bus 9 of 13-bus distribution system without designed Overcurrent relay
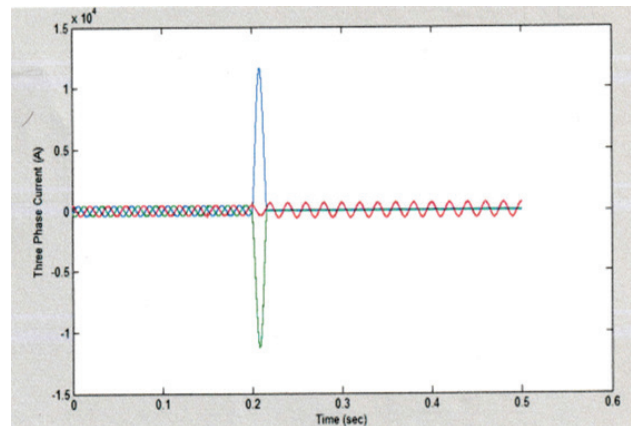

Fig. 12 Three phase currents due to LL fault on bus 9 of 13-bus

SIMULINK/MATLAB MODEL FOR CRITERION FUNCTION 'R' FOR SWITCHING CONDITION OF TRANSFORMER ENERGIZATION

Now the value of criterion function 'R' for short time transients of transformer energization due to inrush currents is evaluated. The transformer energization in MATLAB/SIMULINK is modeled and simulated as shown in Fig. 13. The value of criterion function 'R' is found out as 0.96 as shown in Fig. 14 and its three phase waveforms are shown in Fig. 15. As the Value of criterion function 'R' is above reference value 0.35 so overcurrent protection will not mal operate for switching transient.
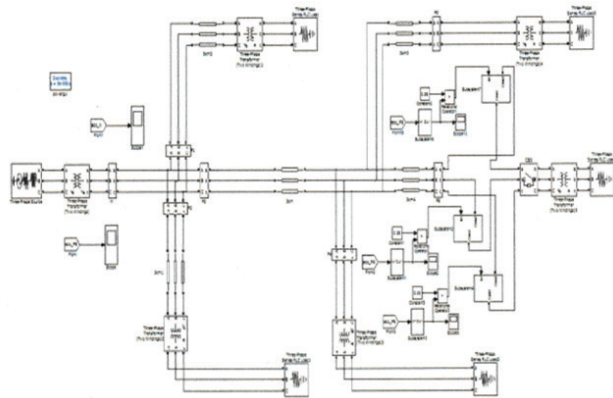
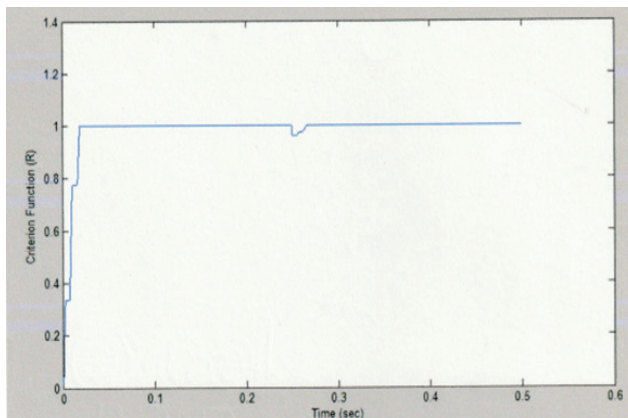**Fig. 13 Transformer energizing on bus 9 of 13-bus distribution system with designed Overcurrent relay**

Fig. 14 Value of criterion function 'R' of transformer energizing on bus 9 of 13-bus distribution system with designed Overcurrent relay
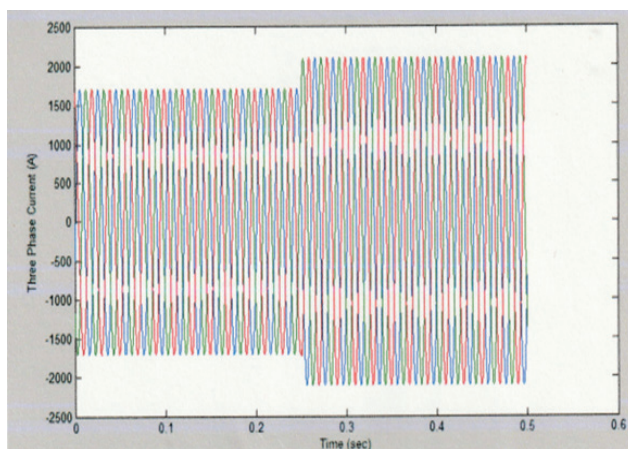

Fig. 15 Three phase currents of transformer energizing on bus 9 of 13-bus distribution system with designed Overcurrent relay

SIMULINK / MATLAB MODEL FOR CRITERION FUNCTION 'R' FOR SWITCHING CONDITION OF MOTOR STARTING

Now the value of criterion function 'R' for short time transients of Induction Motor starting due to harmonic currents is evaluated. The transformer energization in MATLAB/SIMULINK is modeled and simulated as shown in Fig. 16. The value of criterion function 'R' is found out as 0.97 as shown in Fig. 17 and its three phase waveforms are shown in Fig. 18. As the Value of criterion function 'R' is above reference value 0.35 so overcurrent protection will not mal operate for switching transient.
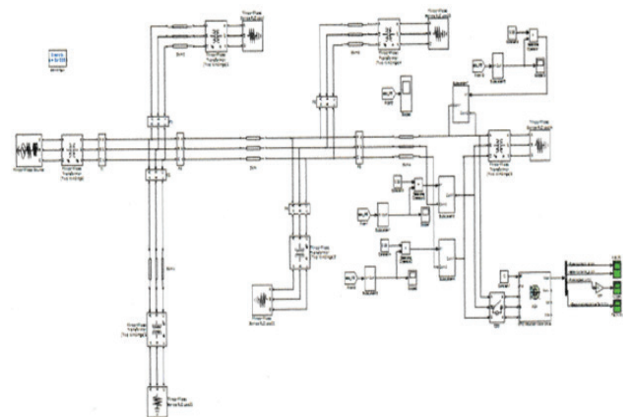

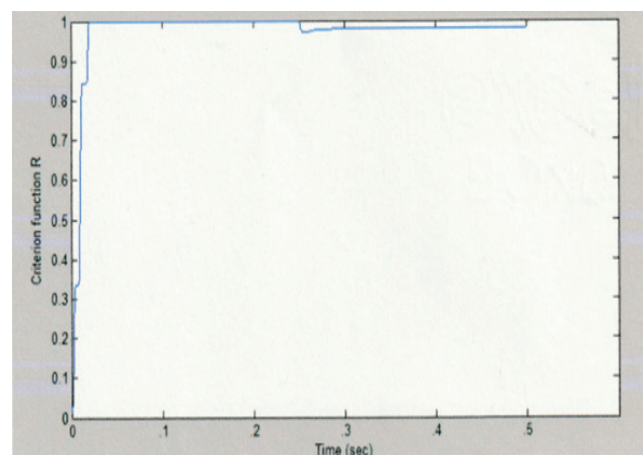**Fig. 16 Motor starting on bus 9 of 13-bus distribution system with designed Overcurrent relay**

Fig. 17 Value of criterion function 'R' of motor starting on bus 9 of 13-bus distribution system with designed Overcurrent relay
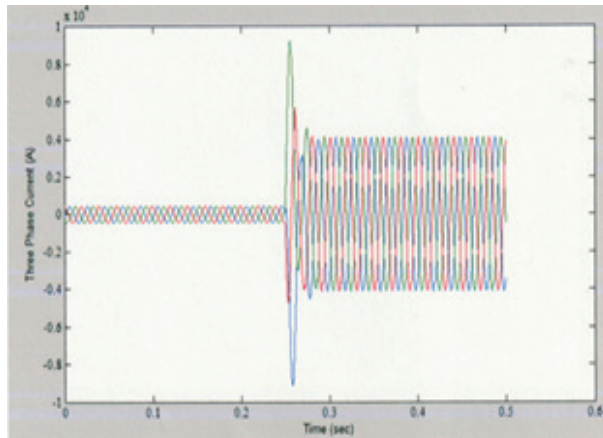
Fig. 18 Three phase currents of motor starting on bus 9 of 13-bus distribution system with designed Overcurrent relay

Assumptions made for analysis of unsymmetrical fault are:

The value of criterion function 'R' for single line-to-ground and line-to-line fault for different power system numerical is calculated and found as zero, because transmission line load inductances, transformer reactance are neglected. Certain assumptions are made because ideal and basic conditions of single line-to-ground and line-to-line fault cannot be realized. These assumptions are stated as below

i) The power system operates under balanced steady state condition before fault occurred. Thus zero, positive, and negative sequence networks are uncoupled before fault. During unsymmetrical fault they are interconnected only at fault location.

ii) Pre-fault load currents are neglected. Because of these, positive sequence internal voltages of all machines are equal to pre-fault voltage. Therefore, the pre-fault voltage at each bus in positive sequence networks equals pre-fault voltage.

iii) Transformer winding resistances and shunt admittances are neglected.

iv) Transmission line series resistances and shunt admittances are neglected.

v) Synchronous machine armature resistances, saliency and saturation neglected.

vi) Loads are assumed as non-rotating impedances.

vii) All non-rotating impedance loads are neglected.

Table 2 Comparative Data of Fault and Non-Fault Events after Simulation

Cases	Nature of Fault	Bus	'R' with designed Over-current relay
Unsymmetrical Fault	LG	9	0.24
	LL	9	0.06
	LLG	9	0.07
Symmetrical Faults	LLL	13	0.05
Switching Cases	Transformer energization	9	0.96
	Induction Motor Starting	9	0.96

CONCLUSION

The criteria function 'R' operates effectively by utilising the negative sequence component that results from the imbalance of asymmetrical fault circumstances. The simulation results display symmetrical component currents alongside phase currents for unbalanced faults, so facilitating precise differentiation between fault and non-fault scenarios. The mathematical value of the criterion function 'R' is established at 0.35. In the case of an unsymmetrical fault in the system, the value of 'R' is below 0.35, prompting the overcurrent protection to activate and isolate the defective segment of the distribution line. Conversely, during non-fault conditions, such as switching transients during transformer energisation, the criteria function 'R' exceeds this threshold of 0.35, over current protection system will not operate and supply to distribution consumers will be interrupted. This gives improved performance and negative sequence overcurrent element does not respond to balanced load currents. Therefore, negative sequence current has unique characteristics of detecting abnormal conditions. The 'R' criterion is independent of the amplitude of current which is advantageous, because it operates based on relative difference between negative and positive component of current.

The criterion function 'R' can also be applied to Generator – transformer group of switching, transmission line switching, cable switching, tap – changer operation, circuit breaker switching, circuit breaker mal operation.

Machine learning algorithms can also be applied to the 'R' values. As different switching conditions are there, Value of criterion function 'R' provides simple, accurate and fast operations for reliable operation of power system.

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Bit Error Rate Optimization in Diffusion-Based Molecular Communication System for Targeted Drug Delivery

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ABSTRACT

Bit Error Rate (BER) serves as a crucial metric in molecular communication, assessing the performance of modulation techniques by comparing the proportion of incorrectly received bits to the total transmitted bits. This parameter is particularly vital for evaluating communication accuracy in drug delivery systems. A simulation model for molecular communication will be created to evaluate the performance of molecular communication through channel modeling and reduce bit error rate, focusing on diffusion-based methods, incorporating essential parameters such as diffusion coefficient, bit duration, number of bits for transmission, modulation scheme, and threshold for decoding the received signal. Comparative studies have shown that CSK is advantageous in low-noise environments due to its simplicity and low power consumption, while hybrid modulation schemes are more effective in noisy, high-interference conditions, making them suitable for targeted drug delivery applications. This research goal is to observe and examine the influence of diffusion factor of diffusion (D) on the distance between transmitters and receivers, threshold for decoding, random bit sequence, and noise to control and improve the bit error rate, enhancing the precision, reliability, and overall effectiveness of the system. Exploring the novelty of channel modeling for Bit Error Rate (BER) in a basic molecular communication system using a hybrid modulation scheme can lead to significant advancements.

KEYWORDS : *Bit error rate, Hybrid modulation scheme, Molecular communication, Targeted drug delivery.*

INTRODUCTION

In molecular communication, the Bit Error Rate (BER) is an indispensable parameter for assessing the efficacy of various modulation techniques. BER quantifies the ratio of erroneous bits received to the number of bits transmitted. In the comparative analysis of Concentration Shift Keying (CSK) and hybrid modulation techniques, the determination of which is superior in terms of BER is contingent upon multiple variables, including ambient conditions, interference, and the intricacies of the system architecture. Generally, Hybrid Modulation Schemes demonstrate a superior capability for attaining a reduced BER in contrast to CSK, particularly within environments characterized by high levels of noise or variability. The amalgamation of diverse modulation strategies enhances resilience and facilitates the implementation of more advanced error correction methodologies. The bit error rate (BER) plays a critical role in molecular communication-based targeted drug delivery systems. It measures the reliability and accuracy of the information transfer within the system. Nariman Farsad et. al done survey about Molecular communication (MC) constitutes a communication paradigm inspired by biological systems, wherein chemical signals are employed for the transmission of information. Various modulation techniques are implemented in this scholarly field to encode data within molecular signals[1]. Mustafa et al. elucidate a Concentration-Time Hybrid Modulation Scheme that integrates pulse position and concentration to enhance the bit error rate in molecular communication, thereby alleviating inter-symbol interference and augmenting data transmission rates. The proposed hybrid modulation, which utilizes pulse position and

concentration, aims to address the considerable challenges by inter-symbol interference (ISI) that hinder the attainment of reliable and high data-rate molecular communication through diffusion [2]. Yuankun et al. introduce the Molecular Type Permutation Shift Keying (MTPSK) technique, which aims to improve bit error rate performance. The encoding of multiple types of molecule information based on permutations helps in molecular communication to reduce inter-symbol interference.; simulation results for bit error rate support the assertion that the proposed MTPSK outperforms existing modulation schemes for MC [3]. Qingchao Li et al. propose a time-based modulation scheme tailored for time-asynchronous channels, which enhances the bit error rate in molecular communication by facilitating the release of multiple information molecules per bit, thereby improving overall performance. The enhanced bit error rate, resulting from the increased release of molecules per bit, indicates that the proposed scheme surpasses traditional encoding methods that operate within time intervals amidst background noise[4]. Gokul et al. implement an innovative binary bit addition modulation scheme that effectively reduces the bit error rate in molecular communication by releasing a smaller number of molecules, thereby demonstrating improved performance when compared to binary concentration shift keying [5]. Lukas Brand et al introduce a novel media modulation technique utilizing photochromic molecules, which enhances the bit error rate in molecular communication through state transitions induced by external stimuli, a claim substantiated by statistical modeling and simulations [6]. Ozgur et al. have introduced a new approach called Modulation Index based on Machine Learning, which aims to enhance the bit error rate in molecular communication. When compared to symbol-by-symbol maximum likelihood estimate and basic index modulation, this method has demonstrated superior performance. To counteract the negative impacts of molecule interference, they have also suggested a CNN-based neural network architecture designed especially for a molecular multiple-input-single-output topology. The suggested network's bit error rate performance is then contrasted with that of a naive-approach index modulation method and symbol-by-symbol maximum likelihood estimation [7]. Lu Shi et al investigate Binary Molecular Shift Keying

(BMoSK) modulation, to examine the efficiency of Bit Error Rate (BER) in diffusive molecular communication systems. They investigate ways to make the system simpler and look at how decision thresholds affect things. Using Poisson or Gaussian distributed random variable the authors model the number of molecules of a particular type in a three-dimensional detection space to perform a thorough analysis of the bit error rate (BER) performance in diffusive molecular communication (DMC) systems using binary molecular shift keying (BMoSK) modulation [8]. Arunava Das et al. centers on the BER analysis within molecular single-input single-output (SISO) communications, demonstrating a fivefold enhancement in the quantity of received molecules and optimal performance associated with third-order Hamming-corrected Binary Concentration Shift Keying (BCSK) modulation for targeted drug delivery applications [9]. Nitin V. Sabu et al. put forth a hybrid MoSK-CSK modulation strategy for molecular communication systems, thereby augmenting data transmission rates while addressing interference challenges. Stochastic geometry methodologies are employed to evaluate symbol error probabilities for the purpose of performance assessment. In this study, the random positioning of transmitters within the three-dimensional (3D) spatial framework is modeled as a homogeneous Poisson point process (HPPP) and an analytical expression is formulated for the probability of symbol error pertaining to the previously discussed scenario [10]. Tho et al. elucidate the analytical propagation model pertinent to diffusion based molecular communication in a one-dimensional bounded environment while proposing the available data rate constrained by interference limits. However, the inherent randomness of molecular movement complicates the analysis of the communication channel in molecular communications [11]. Gokberk Yaylali et al. present a channel model tailored for these systems. They also present a simplified model that, with less complicated, results in a slight decrease in channel estimation accuracy In order to estimate the channel response of molecular single-input-multiple-output (SIMO) systems [12]. Vahid et al. present a tutorial overview of mathematical channel modeling for diffusive molecular communication systems. They introduce channel models which are appropriate for

molecular communication systems with mobile transmitters and receivers that change over time. These models play a vital role in sophisticated tasks such as smart drug delivery with mobile nanomachines [13]. Mohammad et al. for diffusive molecular communication networks (DMCN) describe the channel model with the concentration Green's function (CGF) and present a semi-analytical method (SAM) which simplifies the reverse problem of a big matrix by solving several smaller matrices, decreasing computational complexity [14]. Nitin V. Sabu et al.have developed a dedicated channel model for systems containing multiple fully absorbing receivers (FARs). This model is significantly different from the sole FAR system due to the interactions between the FARs [15]. Shenghan et al. develop an analytical model explains how different reaction rates affect the modeling of channels and the capacity of molecular communication. They also derived closed-form expressions for the probabilities of detection and false alarm, considering the presence of noisy molecular signals [16]. Muskan Ahuja et al. presented a biochemical communication model for a molecular communication (MC) system, in which the transmitter functions as a point source and the receiver possesses a restricted amount of ligand receptors [17]. Francesca et al. developed a method based on data analysis to estimate the limits on the restricted channel capacity of a biological system. This also involves determining the distribution of the source message, particularly in relation to the finite levels of protein concentration [18].Maximilian Schäfer et al. investigated spherical matrix-like drug carriers that depend on diffusion and are frequently utilized in medical environments. They computed the channel response of the matrix-based transmitter for a recipient that absorbs [19].Sanjit Ningthoujam et al. created a molecular communication system that utilizes diffusion and incorporates a feedback mechanism to improve communication effectiveness. It evaluates the channel quality as either good (G) or bad (B) and adjusts the transmission method accordingly, employing single-path or multipath strategies based on the state [20].

METHODOLOGY

Transmitter (Tx)

The entity responsible for the emission of molecules

to send information commences by establishing the coordinates of all molecules at the origin point (0, 0, 0). During each temporal interval, generate stochastic displacements for each molecule along the x, y, and z axes. These displacements are drawn from a normal distribution characterized by a standard deviation that is contingent upon the diffusion coefficient and the temporal interval, as articulated by

$$\sigma = \sqrt{2D\Delta T} \quad (1)$$

Consider that the transmitter initiates the release of molecules at the temporal mark t=0. The displacement of molecules within the medium can be effectively represented through the utilization of diffusion equations. The three-dimensional diffusion equation is articulated as follows

$$\frac{\partial C(x,y,z,t)}{\partial t} = D\left(\frac{\partial^2 C(x,y,z,t)}{\partial x^2} + \frac{\partial^2 C(x,y,z,t)}{\partial y^2} + \frac{\partial^2 C(x,y,z,t)}{\partial z^2}\right) \quad (2)$$

where $C(x,y,z,t)$ is the concentration of molecules at position (x,y,z) and time t, and D is the diffusion coefficient.

Boundary and Initial Conditions

To simplify, let's consider a limitless space with a point source that appears instantly at the center. The initial condition is

$$C(x,y,z,0)=N\,\delta(x)\delta(y)\delta(z) \quad (3)$$

where N is the number of molecules released, and δ is the Dirac delta function.

Encoding Information

The first step involves encoding the information that needs to be transmitted into molecular signals. This can be done using Concentration Shift Keying (CSK) modulation technique.

Concentration Shift Keying (CSK)

Mathematical Formulation:

The transmitted signal in CSK can be represented as:

$$s(t) = \sum_{i=1}^{M} A_i p(t - iT_s) \quad (4)$$

Where:

A_i is the amplitude corresponding to the i-th concentration level.

p(t) is the pulse shape.

Ts is the symbol period.

M is the number of concentration levels.

Each concentration level Ai corresponds to a different data symbol.

Hybrid CSK-TSK Modulation Scheme

The modulation technique in molecular communication utilizes both molecule concentration (CSK) and molecule type (TSK) to encode information. This hybrid scheme enhances communication efficiency by exploiting both concentration and molecular type diversity to represent symbols.

The transmitted signal using both CSK and TSK in the hybrid scheme is represented as:

$$s(t) = \sum_{j=1}^{J} Ni_j \, M_j \, \delta(t\text{-}t_0) \tag{5}$$

Where:

The number of molecules released for symbol i and molecule type j is represented by Ni,j.

M_j is the type of molecule used (for TSK modulation).

$\delta(t-t_0)$ is the Dirac delta function modeling the release of molecules at a specific time t0.

VI On-Off Keying Modulation scheme

The BER for OOK in molecular communication depends on two types of errors:

- False alarm (P(0|1)): Detecting a '1' when a '0' was transmitted (due to noise molecules or ISI).

- Missed detection (P(1|0)): Detecting a '0' when a '1' was transmitted (due to insufficient molecule reception).

Assumptions

- When transmitting a '1', λ1 represents the average amount of molecules received.

- When transmitting a '0', λ0 represents the average amount of molecules received.

Using a Poisson distribution, the probability of detecting k molecules given a certain number of molecules transmitted follows:

$$P(k|\lambda) = \lambda^k \, e^\lambda / k! \tag{6}$$

Receiver

At the receiver end, the molecules are detected and the received signal is processed.

Assume the receiver is located at position (x_r, y_r, z_r). The concentration at the receiver as a function of time is:

$$C_r(x, y, z, t) = \frac{N}{(4\pi Dt)^{3/2}} \exp\left(-\frac{x_r^2 + y_r^2 + z_r^2}{4Dt}\right) \tag{7}$$

The receiver detects the molecules and deciphers the information based on the concentration Cr (t). The molecular signal that is identified is subsequently transformed back into the initial data.

Table 1 Parameter

Serial no	Element	Values
1.1	Transmitter Coordinates	0,0,0
1.2	Reiciver Coordinates	Xr,Yr,Zr
1.3	Distance Between Transmitter and Receiver	5 to 100 μm
1.4	No. of Molecules released	1000
1.5	Diffusion Coefficient	10^{-9} m²/s
1.6	Bit duration	0.1 Second
1.7	Number of bits	1000

RESULTS & DISCUSSION

Bit error rate Analysis

As depicted in FIGURE I, the correlation between Bit Error Rate (BER) and the distance of transmission receiver is impacted by various factors associated with signal propagation, interference, and noise. Normally, when the transmitter and receiver are further apart, the BER deteriorates.
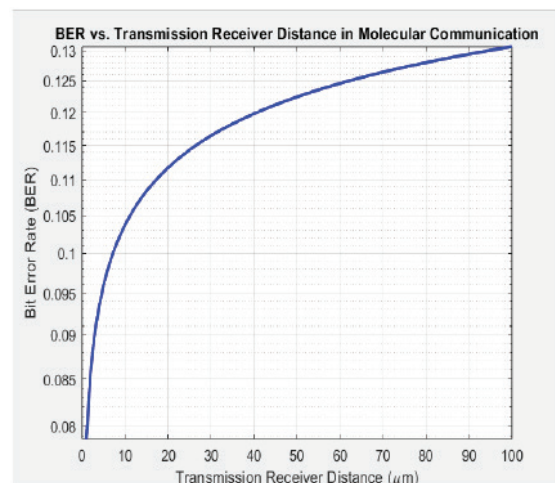

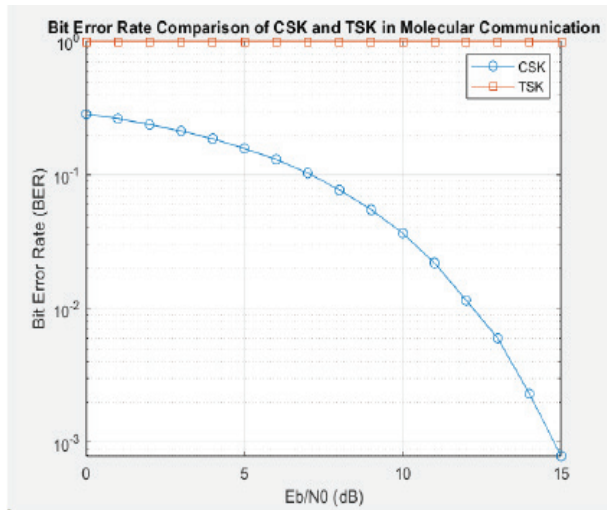**Fig. 1 Ber vs Transmission Receiver Distance**

Fig 2 BER Evaluation: TSK vs. CSK

Table 2 Observed Values of Ber from Graph

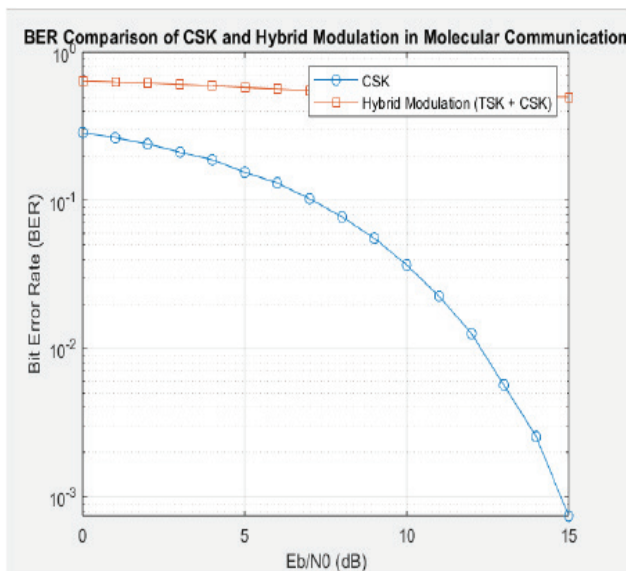| Eb/N0 (dB)	CSK BER	TSK BER
0	0.283	1.0
4	0.186	1.0
9	0.055	1.0
14	0.002	1.0

Fig. 3 Bit Error Rate Comparison: CSK and Hybrid Modulation

As indicated in Figure 2 and Table 2, CSK outperforms TSK in Bit error rate. The binary data is divided into two parts: one for TSK and one for CSK.

Table 3 Observed Values of BER from Graph

Eb/N0 (dB)	CSK BER	Hybrid(TSK+CSK) BER
0	0.283	0.643560
4	0.186	0.593900
9	0.055	0.527760
14	0.002	0.501270

Secondly, as shown in Figure 3 and Table 3 by comparing the decoded data to the original data, we compute the BER for both the hybrid modulation scheme and CSK. In this specific simulation setting, it is demonstrated that CSK is better than Hybrid modulation. When compared to CSK alone, the Hybrid scheme which mixes TSK and CSK displays worse BER. This can be the result of inefficiencies in the hybrid scheme's implementation or the difficulty of fusing two modulation schemes.

Analysis of Bit Error Rate for Concentration Shift Keying (CSK) and On-Off Keying (OOK) techniques

BER analysis evaluates the dependability of CSK and OOK in various scenarios, with each method having pros and cons based on the specific use case and noise level.
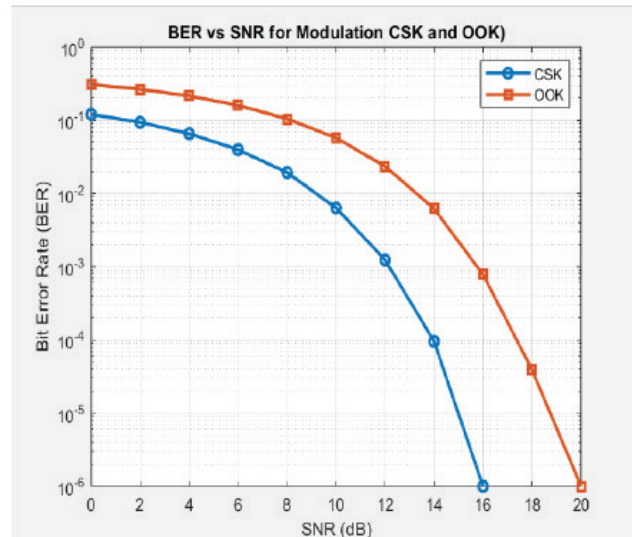

Fig. 3 Signal-to-Noise vs. Error rate in CSK and OOK

Bit Error Rate analysis of Concentration Shift keying and Hybrid Modulation scheme

Analyzing the Bit Error Rate (BER) for CSK and Hybrid Modulation helps to decide the most appropriate approach for particular communication scenarios.

Hybrid schemes typically have better BER performance than CSK but require more complexity and system resources.
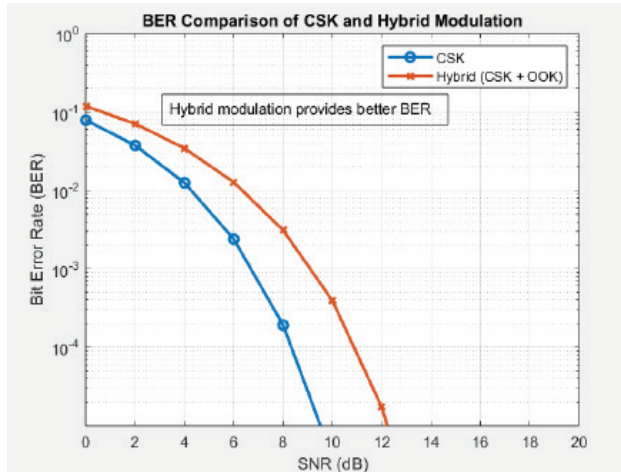

Fig. 4 Signal-to-Noise vs. Error Rate in CSK and Hybrid Modulation

It can be seen from Figure III that Concentration Shift Keying (CSK) outperforms On-Off Keying (OOK). in improving the bit error rate (BER) in molecular communication systems. In Contrast in Figure IV, if we combine both modulation schemes (CSK+OOK), it is observed that at lower SNR values, both modulation schemes exhibit higher BERs, with hybrid modulation still maintaining an edge over CSK. As SNR increases, the BER for both schemes decreases, but the hybrid modulation scheme continues to show superior performance with a high signal-to-noise ratio, highlighting its robustness in various noise conditions.

CONCLUSION

When considering BER, hybrid modulation (CSK + OOK) is probably the best option for targeted medication administration in molecular communication. When compared to pure CSK, the hybrid modulation technique continuously exhibits a reduced BER at different Signal-to-Noise Ratios (SNRs). This suggests that the hybrid strategy improves molecular communication reliability by utilizing the advantages of both CSK and OOK.

Because of its ease of use and low energy consumption, CSK is a great choice for simple applications with limited communication needs and stable environments. Using CSK + OOK hybrid modulation in targeted drug delivery systems offers a balance between increased data rate, resilience to noise, and flexibility, making it an ideal choice for complex and demanding biological communication environments.

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Harnessing Big Data Analytics and AI for Machine Learning-Based Crop Prediction in Agriculture

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ABSTRACT

Artificial Intelligence (AI) made its way to agriculture — A Major Change in Traditional Farming practices by utilizing resources effectively through intelligent agrotech. This research paper provides a comprehensive review of the applications, benefits, challenges, and future prospects of AI in agriculture, with a particular focus on Big Data analytics and Machine Learning. By examining various existing studies, technological advancements, and the potential impact on sustainable farming, paper aim to shed light on the evolving landscape of AI in agriculture. This study synthesizes findings from recent research and examines emerging technological developments, demonstrating how AI is influencing agricultural practices. A critical goal of this analysis is to assess the contributions of AI to sustainable farming. Despite advancements, current agricultural methodologies often lack the precision required for reliable predictions. To address these shortcomings, this paper explores the integration of Machine Learning with Big Data analytics to improve the accuracy of crop analysis and predictive modeling, thereby facilitating better decision-making and more effective agricultural strategies.

KEYWORDS : *Agriculture, Challenges, Applications, Crop prediction model.*

INTRODUCTION

Agriculture is the backbone of human life, serving as the main source of food and wealth for many countries around the world. Crop production plays a crucial role in the economy, providing food, raw materials, and job opportunities. However, recent studies show that crop yields haven't seen much improvement in recent years. [1].The gap between low crop productivity and growing consumer demand is leading to higher food prices. One reason for this decline is that many farmers still rely on traditional farming methods, which often result in lower yields [2]. Additionally, new farmers entering the industry often lack knowledge about the importance of soil quality for successful crop growth. Many don't realize that assessing the land's suitability is a crucial first step before farming [3]. To ensure the highest possible crop yields, a land suitability assessment must be conducted before cultivation begins. To learn about the characteristics of the soil, farmers rely on soil testing laboratories; yet, these laboratories are inadequate to help them, and often the data they provide is inaccurate [4].

To have enough knowledge about cultivation, manual data gathering is necessary, which might be difficult for farmers. The solution is to replace traditional data

collection methods with Internet of Things (IoT)-based sensors. Sensors are essential for collecting data about many different aspects of agriculture, such as soil, water, climate, etc. Data collected from several sensors might be used to perform land suitability analysis, which would help farmers assess the state of their land and increase crop productivity [5]. A range of decision models have been created to assist farmers in selecting the most profitable crops to plant. These models take into account factors such as market demand, soil quality, climate conditions, and historical data, helping farmers make informed choices that maximize their earnings and optimize their land use[6]. In the real world, the primary factors influencing agricultural productivity vary from temperate to monsoon seasons, and they are ever-changing. Soil variables are important to consider in order to predict future output [7,8].

APPLICATION OF AI IN AGRICULTURE

AI helps farmers by using computers to figure out the best ways to grow crops. It helps store crops properly, decide when to harvest, check if the soil is good, know when to plant seeds, and even how much fertilizer to use. This makes farming easier, saves time, and grows better crops. Here discussing few applications in detail.

Yield Forecasting and Prediction

AI algorithms, trained on both real-time and historical data, are now able to predict crop yields with remarkable accuracy. These prediction models allow farmers to better plan when to harvest, how to store, and how to distribute their crops. By considering factors like weather conditions, soil quality, and farming techniques, AI helps minimize waste and brings more stability to the market.

Pest and Disease Management

AI-powered image recognition and machine learning methods have completely changed the way that pest and disease are detected in crops. Artificial intelligence (AI) algorithms may quickly identify possible infestations and suggest relevant interventions by evaluating photos of leaves, fruits, or entire fields. This allows farmers to take prompt action and avoid major crop losses.

Soil Health Assessment and Management

Artificial Intelligence (AI)-driven instruments for

evaluating soil quality examine samples of soil to reveal information on organic matter content, pH values, and nutrient shortages. These evaluations assist farmers in making focused decisions on fertilization and soil conditioning, promoting sustainable farming methods that enhance the long-term health of the soil.

Supply Chain Optimization

From production to distribution, AI technologies are streamlining the whole agricultural supply chain. By optimizing logistics, predictive analytics lowers post-harvest losses and guarantees that produce reaches markets on time. Farmers, wholesalers, and retailers may better coordinate and reduce waste by exchanging real-time data [9].
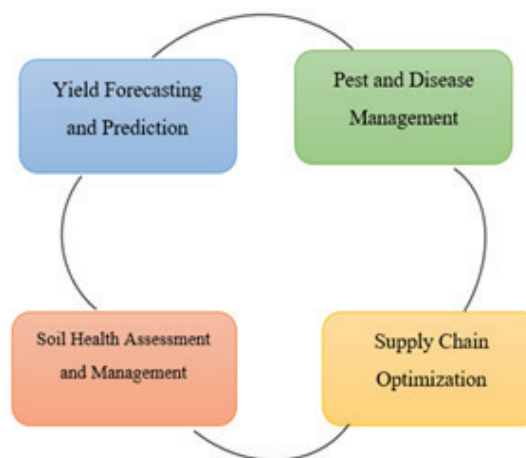

Fig. 1. Challenges in Agriculture

APPLICATION OF AI IN AGRICULTURE

The Visual Internet of Things (VIoT) has emerged from the broader growth of the Internet of Things (IoT), bringing both exciting opportunities and challenges in application and design. A key element of VIoT is the use of sensor data, especially from video cameras, which plays a vital role in shaping design decisions. However, relying on video cameras can lead to some issues, such as increased energy consumption, higher bandwidth needs, and complex real-time data generation.

Because of these demands, video cameras often need external power sources and connections to the electrical grid, which can limit where they can be set up. Moreover, transmitting video streams requires significantly more bandwidth than traditional sensors, which adds to

the complexity. To tackle these challenges, there's a growing need for innovative solutions that can work effectively in environments with limited resources. This is where Edge and Fog computing come in—they offer practical approaches by allowing data to be processed or pre-processed closer to where it is generated, enhancing efficiency and easing the pressure on bandwidth. This method reduces the demand on network resources by selectively sending relevant results to the cloud. Moreover, integrating Deep Learning techniques has been investigated as a way to improve Visual IoT performance. Nonetheless, there are still issues in integrating new methods into current frameworks in a smooth manner. Notwithstanding these obstacles, the use of deep learning in visual IoT presents a lot of promise for the field's advancement and points to possible directions for further research and optimization [10, 11].

LITERATURE REVIEW

The research paper focuses on implementing IoT-AI interfaces in agriculture to revolutionize monitoring and control of production value chains. It highlights the integration of IoT technologies for automated plant irrigation, remote livestock monitoring, and data-driven decision-making. The paper emphasizes the role of AI systems in analyzing data and optimizing agricultural processes. It discusses the potential of predictive analytics in mitigating risks and enhancing productivity. Furthermore, the study identifies research gaps and proposes a collaborative IoT-AI platform for shared data among agricultural equipment manufacturers. Overall, the research paper underscores the transformative impact of IoT-AI interfaces on efficiency, productivity, and sustainability in agriculture [12].

The research paper titled "AI, IoT, and Cloud Computing-Based Smart Agriculture" examines how integrating Artificial Intelligence (AI), Internet of Things (IoT), and Cloud Computing can transform farming. The authors highlight the urgency of updating agricultural practices to keep pace with the rising food demands caused by a growing global population. By leveraging AI, IoT, and Cloud Computing, smart agriculture systems can enhance both the quality and quantity of food production. The paper provides an overview of how these technologies can revolutionize agriculture

by enabling intelligent farm systems that accelerate production and marketing processes. IoT allows for unique identification and online connectivity of physical objects, while AI enables machines to analyze situations and make decisions. Cloud Computing plays a crucial role in processing and storing data efficiently. Overall, the research paper underscores the significance of implementing AI, IoT, and Cloud Computing in agriculture to create smart and efficient farming practices capable of meeting the challenges of the 21st century [13].

The research paper concentrates on developing an AI research platform specifically for the agriculture sector, addressing the critical need for effective big data management and AI model development in Korea. The platform consists of five main modules: container management, image management, login, monitoring, and machine learning controller. It allows for the creation, modification, and deletion of containers, image storage and sharing, user authentication, resource monitoring, and machine learning model deployment.

The platform aims to support various crop models for growth simulations and yield predictions by providing a controller container interface for data exchange in a common format. It facilitates the launch of individual models, data sharing among users, and prediction of crop yield using weather and soil data inputs. The platform targets administrators, researchers, and farmers, offering functions tailored to each user group's needs.

Furthermore, the paper highlights the importance of smart farm technology in addressing challenges such as the decline and aging of the agricultural population. By leveraging artificial intelligence and data analytics, the platform seeks to contribute to the automation of smart farms, sustainable crop management, and improved produce quality. Collaboration between the Rural Development Administration, Korea Institute of Science and Technology Information (KISTI), and Seoul National University is driving the project for model management and AI research platform development in the agricultural sector. Overall, the research paper underscores the significance of integrating AI technology into agriculture to enhance productivity, address demographic shifts in the farming

population, and promote advancements in smart farm technology for the future [14].

The research paper discusses the implementation of an open-source AI-based crop rotation expert system to enhance sustainable agriculture practices globally. It highlights the multidimensional optimization task of crop rotation and the challenges faced in maximizing crop diversity and soil nutrient balance. The system aims to consider various dimensions such as cash crops, market demands, soil conditions, watering, cover crops, tillage, weather, climate, livestock, and synthetic amendments to provide comprehensive recommendations. The integration of farmers' experiences and knowledge with AI algorithms is crucial for the system's success. The paper emphasizes the importance of the User-in-the-Loop (UIL) principle for effective collaboration between farmers and AI in crop management decision-making. Additionally, it addresses the technical architecture, user interface design, and research questions related to the implementation of the AI-based system. The ultimate goal is to align the system with UN sustainable development goals to promote sustainable agriculture practices worldwide [15].

The paper focuses on developing an AI chatbot that features a user-friendly interface, allowing users to get automated results and guidance based on the data collected. It also proposes a deep learning model for identifying crop issues and pests, which helps tackle problems related to various crop conditions and speeds up the identification process that typically takes a lot of time and effort.The goal of this research is to connect farmers and offer them timely solutions to their challenges, creating a space where they can interact and access important agricultural statistics. Additionally, the paper emphasizes how crucial AI communication technology and wireless networks are for improving smart farming systems. By leveraging IoT agricultural sensors and AI-based operations, farmers can gather valuable information to enhance crop production competitiveness and sustainability. The research also focuses on developing mobile applications with modules that support agricultural processes, such as fertilizer recommendation services, to help farmers improve crop production and financial status [16].

The research paper titled "Interactive Cultivation System for the Future IoT-Based Agriculture" proposes an integrated IoT-based system to assist farmers in optimizing crop growth conditions and addressing labour shortages. The system gathers data including temperature, humidity, and images captured by cameras, which are uploaded to a server for analysis. It includes features like conveying real-time temperature information via Line and capturing paddy field images wirelessly for viewing on smartphones. Future plans involve enhancing the system with additional sensors, data storage, and machine learning capabilities to estimate plant conditions more accurately. The system is intended to generate complex speech patterns by combining data from various sensors. This research is supported by the Japan Society for the Promotion of Science (JSPS). The paper references a range of sources related to food security, agricultural statistics, and agricultural initiatives in Japan. Additionally, it discusses the creation of a monitoring system for indoor vertical farming and a smart irrigation system for home gardens, both leveraging IoT technologies. The proposed setup incorporates a Raspberry Pi, a camera module, and sensors to enable interactive cultivation monitoring in home gardens and paddy fields[17].

MACHINE LEARNING MODEL FOR CROP ANALYSIS AND PREDICTION

An Internet of Things (IoT) and machine learning-based crop analysis and prediction model integrates advanced technologies to enhance agricultural practices, optimize resource utilization, and improve overall crop yield. Basically, it consists of the three main phases IoT Data collection, Data pre-processing and Machine learning.
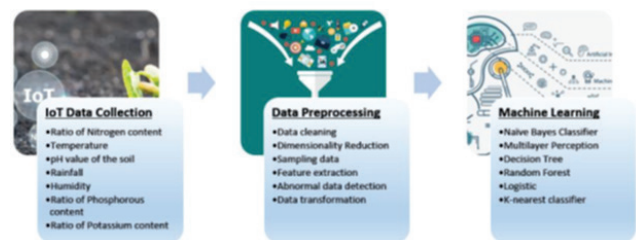

Fig. 2. Machine Learning Model for Crop Analysis and Prediction

Firstly, it collects the data from the various sources like GitHub, IEEE data port etc. the data can be temperature, rainfall, humidity, ratio of nitrogen content, pH value

of the soil etc. after the data has been collected then data is preprocess including data cleaning, sampling of data, feature extraction and done all the steps of the preprocessing. This is the very crucial step in which it extracted all the necessary feature of the model. After extracting all the feature, it applied all the machine learning classifier KNN, to predict the results. In this step model will able to identify temperature, rainfall, pH value of the soil.

Yield Forecasting and Prediction

The Crop Prediction dataset provided the information that was utilized to train the model. The collection comprises 2200 samples of 22 distinct crops, with predictions derived from 7 features: soil pH, temperature, humidity, rainfall, and the contents of nitrogen, phosphorus, and potassium. There are 100 samples for each crop in the fully balanced dataset. Geolocation data is cross-referenced to relevant rainfall values using the Rainfall in India dataset. To guarantee consistency, the data was pre-processed, and any missing values were removed by cleaning. The data contains details on different soil types, crop varieties, and weather trends.

Crop Prediction Model

The goal of this research paper is to create a crop-prediction model based on machine learning to assist farmers in choosing, planting, and harvesting crops with knowledge. Using deep learning techniques, the model was trained on a sizable collection of historical weather and crop data. The model's output outperformed conventional crop prediction techniques in terms of accuracy in forecasting crop yield. With the model's user-friendly interface, farmers can enter a few numbers and get well-informed decisions about what and when to plant. This initiative marks a major advancement in the application of ML to raise agricultural productivity and profitability. Deep Neural Networks are used to build the model (DNNs). Selected design has three hidden layers, each with 64, 128, and 64 neurons, and an output layer with 22 neurons, each of which represents a different crop variety. SeLU is used as the activation function in the input and hidden layers, and softmax is used in the output layer. The PyTorch framework was used to generate the model.

Training and Testing

An 80:20 train-test split ratio was used to train the model on the data. ADAM was the optimizer and categorical cross entropy was the objective (loss) function. Accuracy is the performance metric that is used to assess the model. There were 100 training epochs.

Results

The model demonstrated a high degree of prediction accuracy with an accuracy of 98.97 % on the train data and almost 99. 23% on the test data.

CONCLUSION

The research paper offers a detailed look at how artificial intelligence (AI) and the Internet of Things (IoT) can be used in agriculture, exploring both the exciting opportunities and the challenges that come with them. Through a comprehensive review of existing literature, it highlights a range of applications where AI has the potential to transform farming, such as monitoring crops, detecting diseases, predicting yields, and managing resources more effectively.

One promising solution to these challenges is the creation of machine learning models designed specifically for analyzing and predicting crop outcomes. By harnessing large datasets, advanced algorithms, and remote sensing technologies, these models can provide insights into crop health, estimate yield potential, and suggest the best management practices. Additionally, combining real-time monitoring with AI-driven decision support systems empowers farmers to make informed choices and optimize resource use, ultimately leading to better crop yields and increased profits.

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