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Engineering the Future: Emerging Trends in Technology & Management Volume I

ICETM 2025, Viswam Engineering College, Andhra Pradesh, India, April 11-12



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Engineering the Future: Emerging Trends in Technology & Management Volume I

ICETM 2025, Viswam Engineering College, Andhra Pradesh, India, April 11-12



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Preface

The International Conference on Emerging Trends in Engineering, Technology & Management brings together researchers, academicians, industry professionals, and students to share innovative ideas and recent advancements across multidisciplinary domains. The conference serves as a dynamic platform for presenting cutting-edge research, discussing emerging challenges, and exploring practical solutions that contribute to technological progress and sustainable development.

The papers included in this volume represent selected contributions presented at the conference, covering diverse areas of engineering, information technology, data science, management practices, and interdisciplinary applications. Each paper has undergone a careful review process to ensure academic quality, originality, and relevance.

We hope this collection will provide valuable insights to researchers and practitioners while encouraging collaboration and knowledge exchange among the global scientific and professional community. The editors extend their sincere appreciation to all authors, reviewers, organizing members, and participants whose contributions made this conference and publication possible.

Dr. M. Anjan Kumar
Dr. Chaman Verma
Dr. Md Akbar

International Conference on Emerging Trends in Engineering, Technology and Management

The **International Conference on Emerging Trends in Engineering, Technology and Management (ICETM-2025)** aims to provide an interdisciplinary forum for academicians, researchers, scientists, and industrial personnel working in the areas of design and implementation of emerging technologies in the field of engineering, technology and management to exchange their views and share their expertise.

It is an opt platform for the researchers from various domains to discuss about recent innovations, emerging trends, concerns and practical challenges in the field of engineering, technology and management. Every session of this conference has been planned to explore various points of view, revelations, inventions, and discoveries from academicians, researchers, experts, educators, and scientists.

This occasion will provide a priceless forum for bringing up-and-coming developments in a variety of technical sectors. The engineering and management-based sessions will offer a wide range of insight that is both appealing and essential. One needs to be always vigilant when it comes to keeping up with the most recent trends, spotting the most difficult problems, or performing their own research in order to be on the cutting edge.

The ICETM-2025 is the ideal forum for enhancing one's standing among scholars and other research-related groups, as well as for participating in the dissemination of knowledge and expertise. All of this and more may be done at ICETM-2025, where attendees can gain from two days of intensive learning and networking. The submission of participants' articles to a variety of esteemed publications is also encouraged. Every participant will undoubtedly leave the event inspired and fired up.

Authors, Researchers, academicians, and industry leaders from **13+ countries like Ethiopia, Oman, Libya, Saudi Arabia , UAE, Ghana, Sudan, Malaysia, South Africa, Jordan, Egypt, Indonesia, India, etc** graced ICETM-2025 with their presence, paper presentations, and keynote addresses.

Aim of the Conference

The International Conference on Emerging Trends in Engineering, Technology and Management (ICETM) aims to provide an international platform for researchers, academicians, and industry professionals to present original, high-quality research, exchange innovative ideas, and address emerging scientific and technological challenges. The conference promotes interdisciplinary collaboration, methodological rigor, research integrity, sustainable innovation, and the dissemination of impactful scholarly contributions with global relevance.

Scope

The International Conference on Emerging Trends in Engineering, Technology and Management provides an interdisciplinary platform for original research, innovative methodologies, and technological advancements in engineering, computer science, artificial intelligence, information technology, electronics, communication, sustainable energy, industrial systems, business analytics, innovation, and management. The conference encourages evidence-based studies, practical applications, industry academia collaboration, and sustainable solutions addressing global challenges. Contributions should demonstrate originality, methodological rigor, technical significance, and relevance to contemporary scientific and industrial developments.

The ICETM-2025 encompasses a wide range of contemporary and interdisciplinary research areas that address current innovations, challenges, and future directions in engineering, technology, and management. The scope includes, but is not limited to:

- Advanced engineering systems and design innovations
- Artificial intelligence, machine learning, and data science
- Internet of Things (IoT), smart systems, and automation
- Sustainable engineering, renewable energy, and green technologies
- Communication systems, networking, and cybersecurity
- Industry 4.0, digital transformation, and smart manufacturing
- Software engineering, cloud computing, and big data analytics
- Innovation and technology management
- Business analytics, finance, and strategic management
- Entrepreneurship, leadership, and organizational behaviour
- Interdisciplinary research integrating engineering and management

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Activity of Blockchain Innovation in Secure Data Management and Strategies used to Forestall Assaults

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Abstract: Blockchain technology with its promise of decentralized, transparent, and tamper-proof systems, it unquestionably captured the imagination of the technology industry and beyond. Blockchain technology has emerged as a revolutionary force that has the capacity to transform industries by enhancing security, ensuring data integrity, and enabling decentralized transactions. Regardless of its promising benefits, blockchain faces critical difficulties that need addressing to open its maximum capacity. In this paper we introduced tied down Information management, key moves and blueprints nitty gritty techniques to beat them.

Keywords: Finney Attack, Race Attack, Time jacking Attack, Data Management, Security.

1. Introduction

Block chain development can be used in secure and clear data the chiefs by giving a decentralized record to recording trades. This wipes out the prerequisite for go-betweens, diminishing the bet of data breaks and computerized attacks. The cryptographic estimations used in blockchain ensure the dependability and perpetual nature of the data, making it impenetrable to adjusting or unapproved changes. The decentralized thought of the development moreover thinks about extended straightforwardness, as all individuals in the association approach comparable information. Moreover, block chain can be used to complete astute arrangements, which are self-executing contracts with the states of the comprehension among buyer and dealer being directly made into lines out of code. This further works on the security and straightforwardness of the data the chief's communication. Blockchain-based systems are inherently more secure than standard structures since they work on a dispersed designing stood out from the regular client-server plan. Regardless, blockchains go with their own interests as for network insurance, and they have some exceptional attack vectors. These attack vectors can start at the application level and moreover at the middle blockchain level in this paper we furthermore examine the key pursues that are possible on the middle blockchain plans. These can happen in light of design blemishes or even a couple of unforeseen circumstances, and thusly the congruity and the level of fixes are moreover dependent upon the kind of shortcoming. While most of these attacks could seem, by all accounts, to be speculative or difficult to exploit, huge quantities of them have been really exploited already and have caused a gigantic proportion of genuine mischief. Missing a great deal of ado, let us research a piece of the key attacks.

2. Attacks on Blockchain

2.1. 51% Attack

51% assault happens when a specific excavator or a bunch of diggers acquire than half of the handling force of the whole blockchain network, which assists them with acquiring a greater part as to the agreement calculation.

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This assault vector is principally connected with the Proof of Work calculation, however it tends to be stretched out as an experiment to other agreement calculations likewise, where there is a gamble of a solitary party acquiring sufficient impact in the organization to change the condition of the chain unduly. This can prompt numerous harms including changing the chain information, adding new blocks, and twofold spending. The accompanying outline shows how this assault occurs in the above visual portrayal, the red hubs are constrained by the assailant, and they can change the duplicate of the chain by adding new blocks post acquiring greater part agreement and decentralized manner. Removing one will not stop the whole system, as shown in Figure 1.

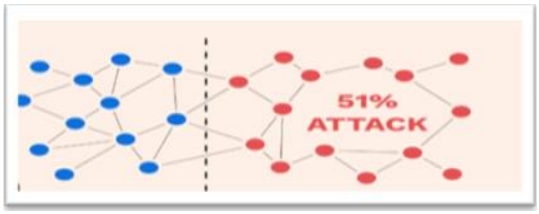


Figure. 1 51% Attacks

2.2. Eclipse Attack

Eclipse assault emerges in the blockchains, where the design parcels responsibilities and doles out undertakings among the companions. For instance, assuming a chain has a hub that has just eight active associations and can uphold all things considered 128 strings out of the blue, every hub has view admittance to just the hubs that are associated with it. The perspective on the chain for the casualty hub can be changed in the event that an assailant goes after a particular hub and deals with the eight hubs associated with it. This can prompt a wide assortment of harms that incorporate twofold expenditure of the coins by deceiving a casualty that a specific exchange has not happened, and furthermore the assaults against the second layer conventions. The aggressor can cause the casualty to accept that an instalment channel is open when it is shut, deceiving the casualty to start an exchange. The accompanying chart shows a hub under Obscuration assault.

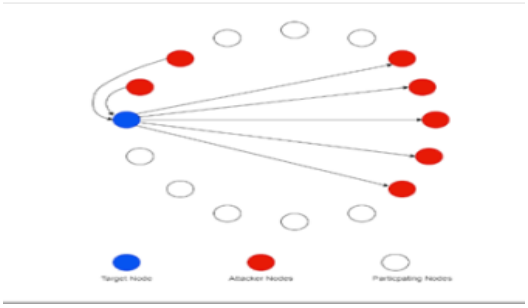


Figure. 2 Eclipse Attack

In the above visual portrayal, the red hubs are constrained by the aggressor, and they can change the duplicate of the chain of the casualty hub by causing it to associate with assailant-controlled hubs.

2.3. Time Jacking Assault

The time jacking assault is likewise an augmentation of the Sybil assault. Every hub keeps a period counter which depends on the middle season of its friends, and on the off chance that the middle time contrasts from the framework time by a specific worth, then, at that point, the hub returns to the framework time. An assailant can flood the organization with hubs revealing erroneous timestamps, which can make the organization delayed down or accelerate, prompting a desynchronization.

2.4. Selfish Mining Assault

This assault happens when an assailant can mine blocks subtly and make a duplicate of the chain that is longer than the normal chain being worked upon by different hubs. The aggressor mines a few blocks and doesn't communicate them to the whole organization. They keep mining and afterward distribute a hidden fork once they are adequately in front of the organization concerning the length of the chain. Since the organization will move to the chain that has been generally worked upon (otherwise known as the longest chain rule), the aggressor's chain turns into the acknowledged one. With the assistance of a self-centered mining assault, the assailant can distribute a few exchanges on the public organization and afterward switch them with the assistance of covertly mined blocks.

2.5. Finney Assault

The Finney assault can be named as an expansion of the childish mining assault. The assailant mines a block covertly and sends the unsubstantiated exchange to the next hub, conceivably to a dealer hub. In the event that the shipper hub acknowledges the exchange, the assailant can additionally add another block to the chain in a modest casing, switching that exchange and prompting a twofold spending assault. The assault window on account of a Finney assault is extensively little, however this can cause a ton of harm in the event that the worth of the exchange is sufficiently huge.

2.6. Race Assault

In a race assault, the aggressor doesn't pre-mine the exchange however essentially communicates two distinct exchanges, one of them to the vendor and one of them to the organization. On the off chance that the assailant is fruitful in giving the dealer hub the deception that the exchange got by them is the first, then they acknowledge it, and the assailant can communicate something else altogether to the whole organization[7][8].

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A few general measures to keep these assaults from occurring:

- It ought to be guaranteed that there are no consistent irregularities in the chain code and agreement calculation.
- The friends ought to be chosen with adequate intricacy and watchfulness, and the exchanges ought to be investigated consistently.
- On the off chance that any dubious movement is recognized, the organization ought to be sufficiently careful to promptly detach the troublemaker hub.
- A legitimate survey interaction ought to be conveyed for the organization for each new hub when it joins the organization.
- Rate restricting calculations ought to be available at every one of the significant cycles to restrict the harm and forestall assaults as and when they occur.
- 2FA ought to be available at all the concerned validation focuses, and it ought to be guaranteed that all the confirmation level bugs ought to be fixed at the application level itself to the degree conceivable
- More often than not, the methodology of boycotting and whitelisting doesn't work because of versatility issues. Thus, a superior methodology ought to be to make the assaults sufficiently expensive to be performed and increment the intricacy of the framework to be sufficiently strong and make fruitful double-dealing very troublesome [5][6].

3. Block Chain for Data Management

The benefits of utilizing blockchain for Data management incorporate the accompanying:

Decentralization: Blockchain innovation wipes out the requirement for mediators, lessening the gamble of information breaks and digital assaults.

Security: The cryptographic calculations utilized in blockchain guarantee the uprightness and permanence of the information, making it impervious to altering or unapproved changes.

Transparency: The decentralized idea of the innovation considers expanded straightforwardness, as all members in the organization approach a similar data.

Improved Exactness: Blockchain innovation takes into account more precise and reliable information the executives as it dispenses with the gamble of human mistake and manual information control.

Data Protection: Blockchain can execute private and permissioned networks where just approved clients can get to the information.

Traceability: The solid and straightforward nature of blockchain makes it simpler to track and follow the historical backdrop of information exchanges.

Reduced Expenses: By killing the requirement for go-betweens, blockchain can diminish the expenses related with customary Data management strategies [6] .

4. Implementing Blockchain for Data Management : Best Practices and Difficulties

Best Practices for Executing Blockchain for Data Management:

Define the Issue: Obviously characterize the issue that blockchain innovation is being utilized to tackle and the execution targets.

Choose the Right Agreement System: Pick an agreement instrument fitting for the particular use case and the organization members.

Implement Safety efforts: Appropriately carry out safety efforts, for example, encryption and access controls, to safeguard the information put away on the blockchain.

Foster a Local area of Clients: Cultivate a local area of clients and partners to help the organization and guarantee its prosperity.

Monitor and Get to the next level: Consistently screen and work on the framework to guarantee proficiency and viability.[3][4]

Challenges for Carrying out Data Management:

Technical Intricacy: Carrying out blockchain innovation can be mind boggling and require an elevated degree of specialized mastery.

Initial Expenses: Carrying out blockchain innovation can be costly, particularly for little and medium-sized organizations.

Interoperability and Similarity: Guaranteeing interoperability and similarity between existing frameworks and the blockchain can challenge.

Regulation and Normalization: The absence of guidelines and normalization can make it challenging to execute blockchain innovation reliably.

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Resistance to Change: Executing blockchain innovation might confront opposition from partners who are utilized to customary Data Management techniques.

5. Balancing Security and Transparency in Blockchain- based Data Management

Adjusting security and straightforwardness in blockchain-based data management is a key test. From one perspective, straightforwardness is essential to guarantee that the information on the blockchain is precise and dependable. Then again, security is basic to safeguard delicate information and forestall unapproved access. The accompanying systems can assist with adjusting security and straightforwardness in blockchain-based data management:

Implement Solid Safety efforts: Carry serious areas of strength for out measures, for example, encryption and access controls, to safeguard the information put away on the blockchain.

Use Consents Frameworks: Use authorizations frameworks to control who approaches the information on the blockchain, guaranteeing that main approved clients can get to delicate data.

Use Security centered Blockchain Arrangements: Use protection centered blockchain arrangements, for example, zero-information verifications, to safeguard delicate information while guaranteeing straightforwardness.

Encourage Cooperation: Energize interest from a different scope of partners to guarantee the security and straightforwardness of the organization.

Regularly Review the Framework: Routinely review the framework to recognize and address any security or straightforwardness issues.

6. Overcoming the Limitations of Blockchain in Data Management

Notwithstanding its many advantages, blockchain innovation for data management has restrictions. A portion of the primary limits incorporate the accompanying:

Scalability: The ongoing versatility restrictions of blockchain innovation can make it challenging to deal with a lot of information.

Interoperability: The absence of interoperability between various blockchain frameworks can make coordinating blockchain innovation with existing frameworks troublesome.

Regulation: The absence of guideline and normalization in the blockchain business can make it challenging to execute and implement steady practices.

Energy Utilization: The energy utilization of blockchain innovation can be high, particularly for agreement components that require serious calculations.
Technical Mastery: Executing and keeping blockchain-based data management framework can require an elevated degree of specialized skill [8][6].
.
To defeat these restrictions, the accompanying systems can be utilized:

Implement Adaptability Arrangements: Execute versatility arrangements, for example, sharing or off-chain exchanges, to deal with a lot of information.

Promote Interoperability and Normalization: Advance interoperability and normalization inside the blockchain business to work with mix with existing frameworks.

Regulate and Normalize: Direct and normalize the utilization of blockchain innovation in data management systems to advance consistency and responsibility.

Invest in Energy-proficient Arrangements: Put resources into energy-effective arrangements, like verification of-stake agreement systems, to decrease energy utilization.

Foster a Local area of Specialists: Cultivate a local area of specialists and partners to help the turn of events and execution of blockchain-based data management systems frameworks.

7. The Eventual Fate of Blockchain in Data Management : Patterns and Valuable Open Doors

The future of blockchain in Data Management is promising, with the accompanying patterns and open doors:

Increased Reception: The reception of blockchain innovation in Data Management is supposed to increment as additional associations perceive its advantages.

Improved Adaptability: The versatility of blockchain innovation will keep on improving, considering bigger and more complicated networks.

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Interoperability And Normalization: Interoperability and normalization of blockchain innovation will turn out to be progressively significant, considering more prominent combination with existing frameworks.

Integration With Man-Made Brainpower (Artificial Intelligence): Incorporating blockchain innovation with computer based intelligence will consider the production of smart and independent frameworks for Data Management.

Decentralized Information Commercial Centers: Decentralized information commercial centers will arise, considering the protected and straightforward trade of information among associations and people.

Enhanced Security: The advancement of protection centered blockchain arrangements will expand the insurance of delicate information.

More Assorted Use Cases: The utilization of blockchain innovation in Data Management will turn out to be more different, venturing into new businesses and applications. These patterns and open doors give critical potential to the development and advancement of blockchain innovation in information the executives, bringing new degrees of safety, straightforwardness, and productivity to the field.

8. Conclusions

Blockchain innovation is a decentralized computerized record that empowers secure and straightforward data management. It can possibly alter the field of information the board by giving improved security, straightforwardness, and proficiency. We introduced a portion of the actions to conquer assaults occur in blockchain and the utilization of blockchain for data management enjoys various benefits, including expanded coordinated effort and the strengthening of people. There are different genuine utilizations of blockchain in data management, for example, production network the executives, advanced personality the executives, and medical services data management. Associations need to consider information type and volume, specialized mastery, guideline, and cost to actually carry out blockchain for data management

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Author Contribution

TPK: Conceptualization, drafting, data collection and analysis, Methodology, and Supervision;

DRK: Methodology, Writing and Data Collection, and Editing

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Empowering Communication: A Web Application for Deaf, Mute, and Sign Language Interpretation

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Abstract: The inability to communicate effectively because of communication barriers severely restricts deaf and mute individuals from getting in touch with those who do not know sign language. A new web-based system has been developed to provide an effortless communication solution between users who are deaf, mute and Sign language users. The system implements Django as its backend framework collected with text- to- Sign language conversion and speech-to-text capabilities towards establish successful communication. Through the application users have the option to provide text or audio content that gets translated into American Sign language (ASL) animations through hand gesture visualization from MediaPipe. The system enables automatic speech recognition through the Speech Recognition library and functions as an ASR tool to convert spoken words into text. The Google Translator API enables native language translation of this recorded text which expands communication possibilities to different user groups. From datasets obtained through Kaggle the training of a Convolutional Neural Network model reaches 99% accuracy for sign recognition leading to accurate communication. The application creates a manageable interface which enables people with speech and hearing difficulties to get real-time Sign language animations as visual outputs. The novel system surpasses typical assistive communication solutions because it cuts out the requirement for human Sign language interpreters to provide inclusive communication channels. This proposed web application will increase accessible interactions thus promoting more social integration opportunities for both deaf and mute users. The system will be improved through language expansion of Sign language interpretation and a mobile app adaptation for maximized accessibility. The system incorporates components related to Communication accessibility, Sign language recognition, speech-to-text, ASL animation and employs CNN models in conjunction with Django framework,
Keywords: Media Pipe, automatic speech recognition, and utilizes Google Translator API.

1. Introduction

The ability to communicate is essential to human social interactions even though millions of people across the world experience communication difficulties from hearing or speech disabilities. Traditional sign language serves as the main communication method for deaf & mute people though it provides insufficient communication bridge when interacting with people who don't recognize Sign language. A novel web application with machine learning capabilities and natural language processing technology and computer vision components aids effortless communication among users who are deaf or mute or communicate without Sign language. The developed system applies Django as its base framework because it offers a secure platform for building scalable applications. Through these features the framework enables users to

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become registered members with personal account management. The system core capability enables text and audio conversion into hand movements through the MediaPipe framework which provides top-tier pose detection and hand position tracking functions. The system develops a conceptual link between verbal and visual messaging that creates user-friendly conversations. The core operation of the system depends on the speech-to-text module that uses automatic_speech_recognition approaches to change spoken words into written text. The text processing through Google Translator API enables language conversion to different Indian regional languages thereby broadening access for users who speak diverse language groups. The system achieves a 99% high accuracy rate for sign recognition through the use of a Convolutional Neural Network (CNN) trained on American Sign Language (ASL) dataset.

Deep learning implementations in this project boost real-time translation precision while it simultaneously improves gesture identification outcomes. This solution produces dynamic signs through animate animation instead of static sign representations which conventional assistive tools use to provide a user-friendly interactive interface. The database infrastructure maintains process efficiency jointly with user interface components that make the system easy to navigate. The research tracks down accessibility problems which impact live communication understanding for people who need help with real-time communication. The system achieves smooth communication through its integration of speech recognition and DL features alongside real- time animation technology which removes the need for human interpreters. The deployment of machine learning- based sign recognition enables growth within assistive technology while creating possibilities for video communication solutions that use gestural user input.

The web application functions as an intelligent assistive tool which enables communication between members of deaf and mute communities and not at al used Sign language. The system utilizes DL together with NLP and computer vision to present a scalable technologically advanced solution which promotes inclusive communication in real-world applications.

2. Related Work

2.1. DL in Sign Language Recognition: A Hybrid Approach

This work develops a DL algorithm which recognizes word gestures in order to enhance live Sign language detection. The authors describe the obstacles in building independent continuous sign Modeling systems which need to handle the differences in signing speed and duration. Two different DL-based techniques comprise the proposed hybrid system to boost Sign language recognition precision over continuous periods [1].

2.2. AI-Based Sign language to speech-to-text Translation

The review discusses AI-based approaches to real-time speech-to-text Sign language translation solutions that can solve the communication barrier in hearing impaired patients in COVID-19 situations. In their study, researchers have observed about the lack of data regarding AI and machine learning application in this area particularly in Africa as they propose to create an AI real-time translation tool related to the South African languages. [2].

2.3. Recent Progress in DL based Sign language Recognition

This research paper analyses the DL- based Sign language recognition by analyzing the current developments with its challenges and opportunities that have been realized in the past five years. Several central issues are raised in the article concerning the technology of sign data acquisition and data sets and modes of evaluation and the various types of neural networks. The study confirms that CNNs(CNNs) and Recurrent Neural Networks (RNNs) are promising in fingerspelling and isolated sign recognition but the research also covers continuous Sign language recognition issues. [3].

2.4. An adapted DL network carries out Sign language signal recognition

DL functionalities based CNNs and recurrent neural networks (RNNs) are used by researchers in order to identify related indicators of signs. This research aims at maximizing Sign language recognition at the expense of DL network adjustments that reinforce the evaluation of sign gestures. [4].

2.5. DL Sign language Recognition Web Application

The project will focus on developing a DL tool that identifies individual signals of Sign language and then realizes them in the form of a web application. One of the groups of scientists created a general platform that uses DL analytics to view the Sign language movements in real time and enhance communication between the hearing-impaired [5].

2.6. SignNet

A DL Architecture of Detailed Sign language Recognition on Image. The SignNet is a system that identifies Sign language in the image material with accuracy because of its DL design. This model gives emphasis

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to spatial features of hand gestures that allows greater accuracy in recognition and leaves a good alternative of image-based Sign language decoding [6].

2.7. Sign language communications are determined by a DL System

The scope of the research is the evaluation of DL solutions to word recognition and classification tasks in various Sign language videos frames. A study examines various models of DL system to determine the processing effectiveness of the systems in detecting hand movements in video recordings that represent Sign language [7]. The research analysis has been conducted that revolves around combining machine learning and image processing with artificial intelligence to attain Sign language recognition and interpretation. The analysis includes ways of incorporating these technologies to increase the accuracy and efficiency of the system in interpreting Sign language and shows how AI expands these opportunities in the sphere [8].

ASL Champ! A Video Game of Virtual Reality with Sign Recognition based on Deep-Learning. An example is ASL Champ!, a virtual reality game that supplements student learning in American Sign language because it gives students virtual real-time feedback. Through sign recognition the game is an interactive platform based on DL that allows users to train in ASL skills via simulation. [9]. Machine Learning-Powered Sign language Learning Web Application. The given study develops a web app that uses machine learning to support the learning of the Sign language. Sign language students will have a learning tool created that will involve creation of algorithms that adequately identify expressed signs and encode them into either text or spoken language.

Sign language Artificial Intelligence Adult Sign language systems The authors of the reviewed state-of-the-art Sign language capture, recognition, translation and representation systems together with their advantages and disadvantages [11]. American Sign language Recognition and Conversion the authors of 2023 created the software of recognition of hand gestures through the implementation of a CNN into an advanced neuro model to improve the recognition of gestures in ASL. [12]. Web Application with Sign language Learning with the use of Machine Learning. The authors used the Sign language recognition techniques they developed previously to web deployment thereby increasing the accessibility and usability of communication using Sign language (2024). [13].

Signtalk can be used by users as a Sign language translation system to transform signed language into the spoken word by the use of its neural network system. One such system is known as detects the hand gestures of speech-impaired individuals in order to produce speech along with text representations to aid easier communication access. [14]. Indian Sign language Recognition Using MediaPipe Holistic created a strong platform in transforming [15] the Indian Sign language to text or speech, comparison of CNN and LSTM models in recognizing both static and gesture languages of the Sign.

2.8. Dataset

CNNs models to be trained on this project are based on the American Sign language (ASL) dataset that was acquired on Kaggle. The Japanese dataset houses a complete assortment of ASL hand gesture pictures showing all letters together with digital symbols and frequent vocabulary signs. The data set maintains its focus on DL model training that accurately determines and categorizes Sign language gestures. The dataset contains images that belong to different categories which represent individual signs and letters in the database. The RGB Colour format used for the images provides high-quality features during extraction. Image normalization and resizing and augmentation gains are used for model generalization and overfitting prevention.



Figure.1 ASL dataset samples

The dataset splits into three sections to enhance classification performance where training data occupies 80% and validation data amounts to 10% and testing data fills the remaining 10%. The CNN model obtains spatial capability from hand gestures which enables precise visual-sign-to-text mapping. Each sign has enough available examples in a balanced dataset which enables solid learning operations. This database can provide the system with 99% accuracy that makes it a reliable system of real-time Sign language translation along with communication assistance.

3. System Design and Models

CNNs brought revolutionary changes to DL techniques which excel at identifying images and objects and

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analyzing video content. Neural networks known as CNNs serve a specialized purpose to understand visual spatial structures in image and video data thereby maintaining high performance in frame recognition tasks. This part discusses basic to advanced CNN frameworks together with their components and operational processes which demonstrate their distinctive capability to extract elements from visual information.

3.1. Basic Architecture of CNN

A basic CNN consists of three key features of structures: convolutional layers, pooling layers and fully connected layers. The network employs the use of several layers that eliminate features and decrease of dimensions before making predictions based on learned visual patterns.

Convolutional Layers:

A CNN mainly operates through its central convolutional layer that utilizes filters to process input images. The small matrix filters of a CNN operate as sliding components that search for specific features including edges, corners and textures when scanning through images. A feature map emerges from the convolution operation that detects particular image patterns. During learning the filters develop in training and they come in different dimensions yet 3x3 and 5x5 represent standard filter sizes.

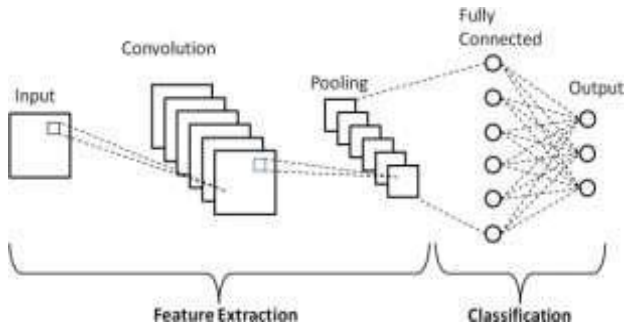


Figure.2 CNN Architecture

Activation Function

The model receives an activation function after performing convolution to introduce non-linear characteristics. The ReLU (Rectified Linear Unit) activation function delivers the most efficient performance because it facilitates sparse activation and speeds up learning processes and reduces gradient decay issues.

Pooling Layers

Pooling layers decrease spatial feature map dimensions and reduce parameter counts as well as computational requirements. Both Max pooling along with Average pooling stand among the most frequently employed types of pooling methods. In the process of max pooling the network chooses the highest value out of a pool of values whereas in average pooling the average value is calculated. Model overfitting reduction occurs through this layer because it introduces spatial invariance that allows models to focus on key characteristics.

Fully Connected (FC) Layers:

A one-dimensional vector is generated after applying multiple convolutional and pooling layers to the input before fully connected layers assess it. The weights of the final classification or regression tasks are assigned by these layers after extracting features from previous steps. Classification models use the SoftMax activation function in their output layers because it transforms the resultant values to probabilities for every distinct class.

4. Proposed Methodology

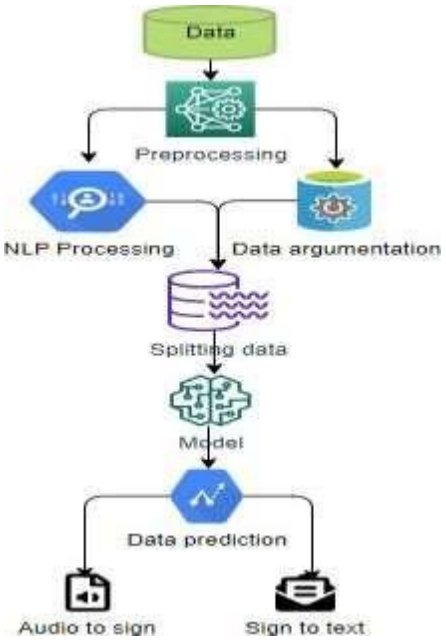


Figure. 3 Proposed Work Flow

4.1. User Registration and Login

Users can reach the platform because it features a registration and login system. The built user authentication module utilizes Django platform.

Registration: All users must set up an account by adding their essential details including their email and username and their chosen password. After the registration process users will receive validation instructions through email to begin using their new account.

Login: Users who finish activating their account can access the platform through their username and password combination. When users forget their

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login details they can activate password reset from the forgot password link.

Access to Dashboard: User authentication leads to a dashboard redirect where users find access to platform main features after successful login occurs.

4.2. User Dashboard

All available features of the platform can be found through the user dashboard which provides direct access to them. Users who log in will encounter three principal options including text signing conversion and speech transcription together with translation features. The dashboard supports an intuitive interface so users can promptly access the Text-to-Sign language and Speech-to- Text modules through a user-friendly system design. Text-to-Sign language Conversion Module Through this platform user can submit text materials which then get processed into animated Sign language gesturing through the system.

Text Input: The program has available text fields whereby users can input their text. After the text entry the system converts it through MediaPipe into animated Sign language gestures for visual display.

Animation Display: Users will benefit from seeing animations of Sign language on the display which demonstrate the visual representation of their input text.

4.3. Speech-to-Text Module

Users can obtain text transcription from their speech through the integrated speech-to-text module by using a microphone.

Voice Input: A microphone icon activates the voice input when users click it. Through implementation of the Speech Recognition library users can achieve text transcription from speech which happens instantly in real-time.

Text Output: Users can easily observe their spoken words because the transcription displays immediately on the screen.

Text Translation into Indian Languages : The text input method provides access to language translation for various Indian languages after the text becomes available through typing or speech-to-text transcription.

Language Selection: Users of the system have the ability to select any of multiple translation languages including Hindi, Tamil and Bengali and more.

Google Translator API: An API tool from Google Translator enables the system to translate content. The screen display will present the translated text to enable communication between people who speak different languages. The web application offers a simple, intuitive interface for facilitating communication between deaf, mute, and sign language users. It integrates multiple technologies like CNN, MediaPipe, Speech Recognition, and Google Translator API to provide real-time sign language conversion, speech- to-text functionality, and language translation. By focusing on accessibility and ease of use, the platform ensures that individuals can communicate effectively, regardless of their hearing or speaking ability.

5. Results and Conclusion.

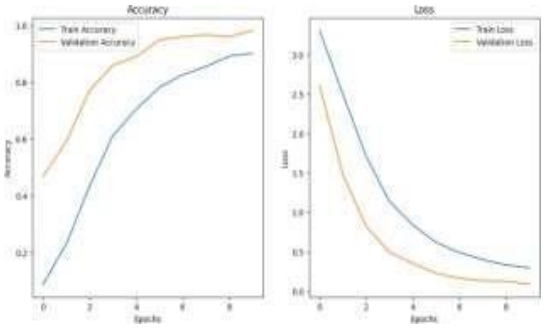


Figure. 4 CNN Accuracy and Loss

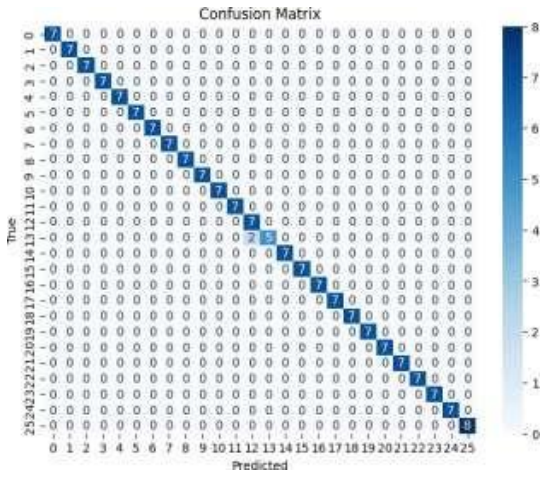


Figure. 5 Confusion Matrix for CNN

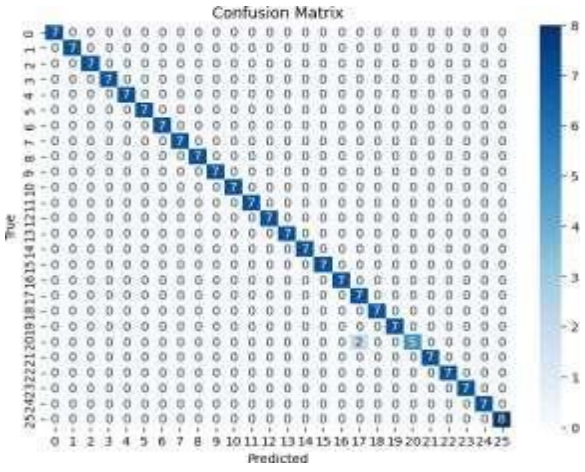


Figure. 6 Confusion Matrix for MobileNet

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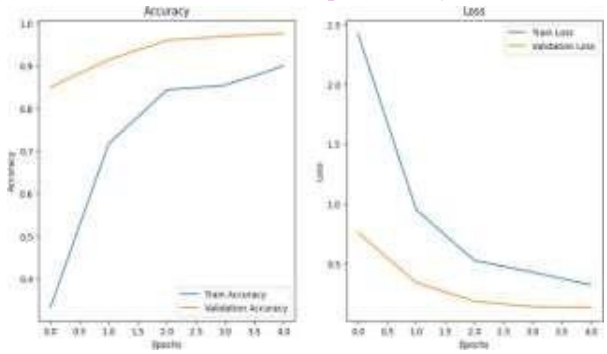


Figure. 7 Training and validation loss MobileNet

Class	Precision	Support	Recall	F1-Score
0	1.00	1.00	1.00	7
1	1.00	1.00	1.00	7
2	1.00	1.00	1.00	7
3	1.00	1.00	1.00	7
4	1.00	1.00	1.00	7
5	1.00	1.00	1.00	7
6	1.00	1.00	1.00	7
7	1.00	1.00	1.00	7
8	1.00	1.00	1.00	7
9	1.00	1.00	1.00	7
10	1.00	1.00	1.00	7
11	1.00	1.00	1.00	7
12	1.00	1.00	1.00	7
13	1.00	1.00	1.00	7
14	1.00	1.00	1.00	7
15	1.00	1.00	1.00	7
16	1.00	1.00	1.00	7
17	0.78	1.00	0.88	7
18	1.00	1.00	1.00	7
19	1.00	1.00	1.00	7
20	1.00	0.71	0.83	7
21	1.00	1.00	1.00	7
22	1.00	1.00	1.00	7
23	1.00	1.00	1.00	7
24	1.00	1.00	1.00	7
25	1.00	1.00	1.00	8

Figure. 8 MobileNet Model

Table. 1 Comparison Table

Model	Loss	Accuracy	Val loss	Val Accuracy
CNN	0.2951	0.8911	0.0843	**0.9017**
MobileNet	**0.3222**	**0.9096**	**0.1351**	**0.9755**

Class	Precision	Recall	F1-Score	
0	1.00	1.00	1.00	7
1	1.00	1.00	1.00	7
2	1.00	1.00	1.00	7
3	1.00	1.00	1.00	7
4	1.00	1.00	1.00	7
5	1.00	1.00	1.00	7
6	1.00	1.00	1.00	7
7	1.00	1.00	1.00	7
8	1.00	1.00	1.00	7
9	1.00	1.00	1.00	7
10	1.00	1.00	1.00	7
11	1.00	1.00	1.00	7
12	0.78	1.00	0.88	7
13	1.00	0.71	0.83	7
14	1.00	1.00	1.00	7
15	1.00	1.00	1.00	7
16	1.00	1.00	1.00	7
17	1.00	1.00	1.00	7
18	1.00	1.00	1.00	7
19	1.00	1.00	1.00	7
20	1.00	1.00	1.00	7
21	1.00	1.00	1.00	7
22	1.00	1.00	1.00	7
23	1.00	1.00	1.00	7
24	1.00	1.00	1.00	7
25	1.00	1.00	1.00	8

Figure. 9 CNN Model

7. Conclusion and Future Scope

This project demonstrates an innovative web solution that functions to link communication channels for sign language and speech deaf and mute individuals thus creating more accessible spaces for all users. The system delivers real-time translation solutions through its integration of CNNs and MediaPipe and Speech Recognition and Google Translator API. Sign language recognition using CNN-based models reaches exceptional accuracy levels and hand tracking in MediaPipe produces natural animations that improve comprehension for viewers. The system provides convenient communication through its speech-to-text functionality that turns vocal expressions into written text before it translates them into various Indian languages to tackle language.

The current project provides a good basis for filling the communication gap between deaf, mute, and sign language users, but there are many opportunities for improvement and expansion. One key area for improvement is the integration of real-time video-based sign language recognition. This will allow the system to interpret directly sign language from live video feeds. This may offer a natural and dynamic form of communication that can be well fitted in face-to-face contact. Moreover, it can develop a mobile application to make access of users wider, allowing the service to access with

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cell phone on the go, with offline functionality especially for places which do not have good internet access.

Another important future addition would be extending multi- language support. Currently, the system does support a couple of Indian languages, but incorporating more global languages and regional dialects will certainly make the service more inclusive in its appeal for a broader populace. Incorporation of local variants of sign languages from various regional areas would even further improve user inclusivity by catering to differing needs. Furthermore, integrating artificial intelligence techniques that allow the system to continuously learn and improve the performance is another promising area. The system would then be able to adapt and refine its accuracy based on users' interactions in real-time, thus enhancing the all-around experience of a user. The final addition would be voice interaction for sign language users, where they can communicate using gestures while receiving spoken feedback from the system. This would make the experience more interactive and immersive. Exploring these potential advancements will help the platform evolve into a more powerful and scalable solution, paving the way for greater inclusivity in communication for the deaf, mute, and sign language communities globally.

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Author Contribution

KHK, BS, BP : Conceptualization, drafting, data collection and analysis, Methodology, and Supervision;

ED, GJ : Methodology, Writing and Data Collection, and Editing

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Author Contribution: All authors wrote the main manuscript text and also consent to the submission.

Plagiarism : Similarity Check - 8 % , AI Plagiarism : * %

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https://www.youtube.com/watch?v=9ziYNBQ3It4
Conference Paper : Original – Action Research – Experimental Research Paper

Towards Generalizable Models in Software Failure Prediction: A Machine Learning Approach

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Abstract: The inability to communicate effectively because of communication barriers severely restricts deaf and mute This paper highlights the challenges of generalizing models and dealing with contradictory evidence. Additionally, it explores the potential to enhance software failure prediction by integrating multiple research efforts. Traditional methods of failure prediction could not be highly task-specific due to the fact that not all tasks had access to the same data. To overcome these challenges and achieve better prediction accuracy, you can employ feature selection techniques, data resampling strategies, and machine learning processes. The project includes exploring the use of different datasets and enhancing model training to accelerate problem detection and ensure that solutions are compatible with different software configurations. Software quality assurance methods can be improved and made more adaptable as a direct result of the findings.
Keywords: Software Fault Prediction, Cross-Project Analysis, Imbalanced Data, ML, SQA.

1. Introduction

Software fault prediction (SFP) is a necessary part of software quality assurance because it helps to identify the problematic modules at their early development phase. The reason why traditional approaches to the defect estimation cannot be used in this situation is that they need homogenous data used in a single project. The answer to this problem may be the cross-project software fault prediction (CP-SFP) that minimizes the use of project-specific data and enhances the flexibility of the model incorporating the data of multiple projects. An issue with CP-SFP and a possible reason behind wrong counting is data imbalance that is such that there are few bad modules as compared to good ones. To become more efficient at forecasting software failures on projects with the help of analytics, you must resolve the issue of data anomalies. In response to the predictive question of non-faulty units, machine learning systems actually perform poorly, as the data of faults are not sufficiently diverse. Cost-sensitive learning, hybrid techniques and resampling are some of the solutions to this problem.

It is possible to use feature selection and transfer learning methods to produce interdependent projects and enhance the overall model generalizability and give the correct predictions in other software environments. Projects, the processes of the development and coding standards are all prone to change and so the accuracy of the predictions is in question, generalization in CP-SFP is a difficult task to take up. More reliable CP-SFP models can be attained by applying deep learning, ensemble, and domain adaptation techniques. The explainable AI algorithms have provided software developers with confidence in the usage of predictive models.

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2. Literature Review

The main idea of this work is to achieve more effective CPDP (Cross-Project Software Defect Prediction) with the help of federated meta-learning. The traditional CPDP techniques have problems of privacy and non uniform initiation. Federated learning enables more than two businesses to collaboratively learn models without giving any source data. The study utilizes meta-learning, that enables quick optimization of the project. The proposed approach combines several modalities in order to minimise the cost of processing, enhance the reliability of failure prediction, and ensure the safety of data privacy. Saeed, M.S. (24): This page provides a thorough introduction into the various Ensems. In order to become more skilled in the prediction of software failure in projects with the help of analytics, you must resolve the anomalies of the data. Machine learning systems actually perform worse when prediction is required on non-defective units not because dissimilarity between the defective units is insufficient. Cost-sensitive learning, hybrid techniques, and resampling are some of the solutions to this problem. By applying the feature selection and transfer learning methods, a project may be interdependent thereby enhancing model generalization and obtaining correct predictions across various software environments. The complexities of projects, development processes, and coding standards are change sensitive and as such, the accuracy of predictions is influenced by the changes and thus the generalization is a difficult task in CP-SFP. Reliable CP-SFP models can be achieved with the help of deep learning, the use of ensemble, and domain adaptation techniques. The fact that explainable AI algorithms have been included has provided more confidence to software developers using predictive models. It is also known that CP-SFP is able to enhance generalization and correct skewed data.

3. System Design and Models

Software quality assurance is a necessary part of software quality assurance because it helps predict which problems may be experienced before their execution. Conventional methods of training machine learning models are generally using data that is already part of the project. The first process is the training of these models with the defect data of the project. Such data governance tactics can be effective to startups and small businesses, since they have less error records. In most cases, supervised learning paradigms, including decision trees, support vector machines and neural networks are applied to classify high risk modules of fault. However, the efficiency of these means depends on the amount and the quality of classified information. Anticipating flaws in all initiatives (CPDP) is one of the ways to deal with data concerns. This approach is founded on statistical data which indicates the mistakes of similar assignments. The methods of domain adaptation and transfer learning are used to align the various project datasets in an attempt to make predictions more accurate. Nonetheless, the risk of changes in the project size, number of defects, and code patterns is alarming. Inefficient models due to skewed datasets complicate the process of making correct predictions in case the number of faulty modules is smaller than that of non-faulty modules. All classes which contain primacy are put first in these processes. The generalization in CPDP is always difficult because the models which are trained in one project tend to be ineffective in a different project. The need to develop models with a broad application across the dynamic sphere of software development is not an easy task. Some of the techniques that are used are ensemble learning, feature mapping and instance selection.

4. Proposed Methodology

The proposed technique the cross-project analytical framework enhances software failure prediction through data imbalance correction and the generalization. Our solution will guarantee consistency of feature regions in all projects by using advanced methods of transfer learning and not by using only the defect data in a single project. The strategy uses domain adaptation methods to take into consideration differences in software metrics and practice. Consequently, models can be learnt with a broad variety of software development tasks. To increase the error detection accuracy, hybrid machine learning models integrate the use of both traditional and deep learning.

In order to deal with the problem of uneven data, the suggested approach combines advanced resampling methods, including SMOTE, with cost-sensitive learning. These techniques reduce bias in the classes and are trained using a set that consists of both malfunctioning and functioning modules. An ensemble learning method is utilized to increase the stability of the model and provide that the defect prediction performance is more than average in terms of project diversity. This is a method in which several classifiers are integrated. The software metrics are given priority in the system involving the method of feature selection. As a result, the effectiveness of forecasting is increased and the expenses of calculations are reduced. The improved generalization and adaptability of models to new situations can be provided by meta-learning and adaptive feature transformation. The system is active and is able to dynamically update the feature representation and decision-making abilities based on the new project data instead of depending on the model training. It is always very precise on diverse software environments with a great dependency on the benchmark data sets in its validation methods. The advent of explainable AI has enabled the provision of a solution, which could not be understood in the

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past. Software engineers may use these strategies to alert developers of any issues that may arise and that before they develop into serious problems.

Improved Management of Imbalanced Data - Sophisticated resampling methods and cost sensitive learning is used to improve the accuracy in fault predictions and reflect the minority class, which consist of faulty modules.

Better Generalization Over Projects - Transfer learning and domain adaptation can be used to make the model better at learning all the diverse sources. This will ensure that it is compatible with a wide range of applications.

Greater Accuracy of Fault Detection - The hybrid approach will improve the predictive accuracy and reduce the false positive/negative ratio since it combines conventional classifiers with deep learning and ensemble-based approaches.

Minimized Feature Discrepancies - Adaptive feature transformation and selection of features will help in the standardization of raw data, removal of discrepancies between projects and ensuring that the model does what it is supposed to do at all times.

Scalability and Continuous Learning - It can more easily cope with changing software production processes and improve them in case a continuous stream of new data is preserved.

5. Implementation

Service Tools: service provider You need to have an active password enabled account with the service provider in order to utilize this feature. Having passed the check-in procedure, he/she will be able to select training and assessment activities and access the data set. You were looking forward that these files will be found soon. Your next visit should include a bar chart indicating the efficacy of different testing and learning techniques and the rate of different software defect prediction. The general precision of training and testing data, the nature and quantity of software defective prediction, all user profiles, etc can be accessed over the web. Manage and approve users This module has resulted into the manager being in a position to see a full list of all users. Administrators may assign/revoke rights using the name of a user, email address and physical address. remote user Before going ahead, ensure that the application form is fully filled. Once the registration is done, the information of the individual will be added to the database. After the registration process is completed, he/she shall be requested to give his/her login and his/her password. After the verification of the identity of a user, he/she can see his/her photo, estimate the risk of a software error and continue with the registration and authentication process.

6. Results

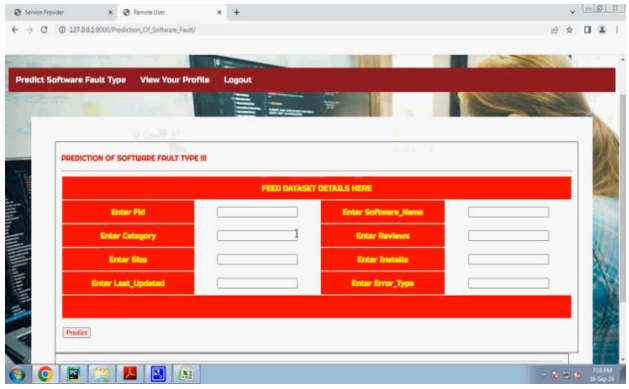


Figure.1 Prediction of Software Fault Type

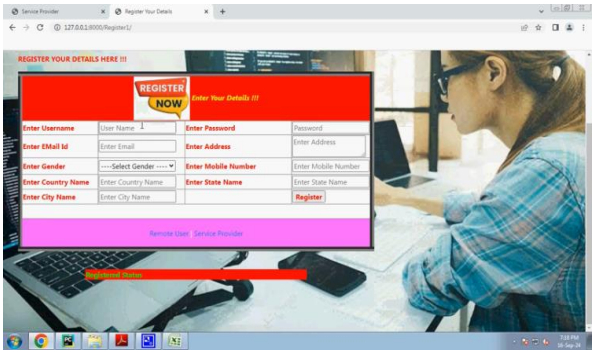


Figure.2 User Registration Page

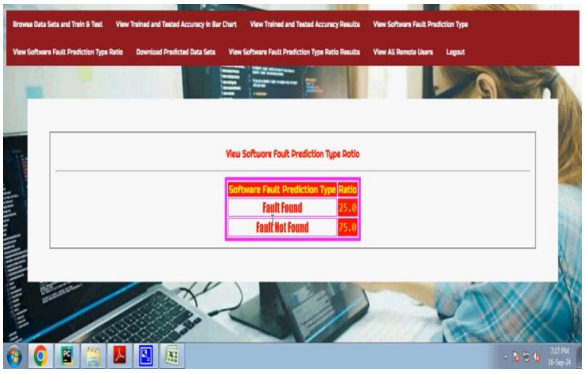


Figure.3 Software Fault Prediction Type Ratio



Figure. 4 Software Fault Prediction Type Details Page

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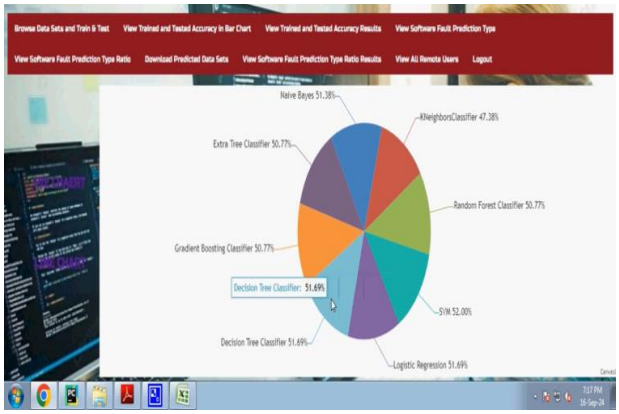


Figure.5 Software Fault Prediction in Pie Chart

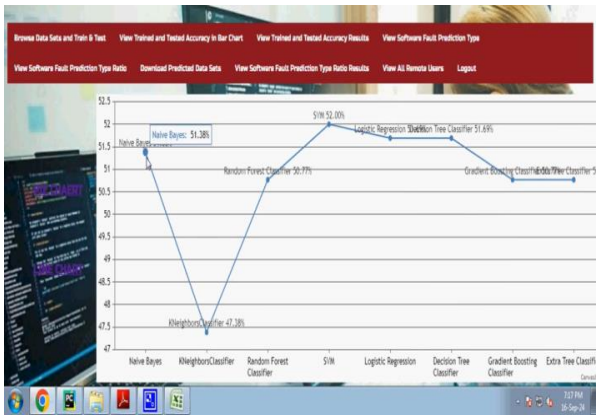


Figure. 6 Software Fault Prediction in Line Chart



Figure.7 Software Fault Prediction in Bar Chart

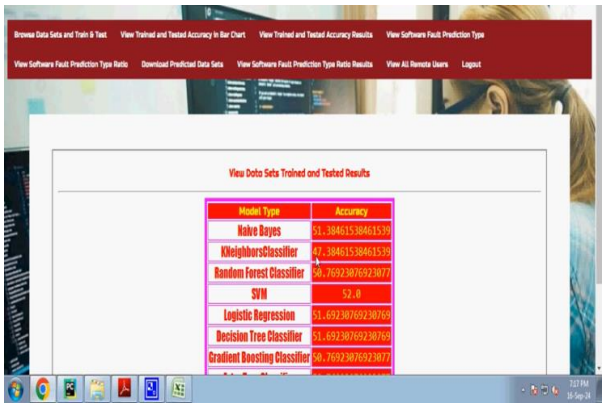


Figure. 8 Datasets Trained and Tested Results

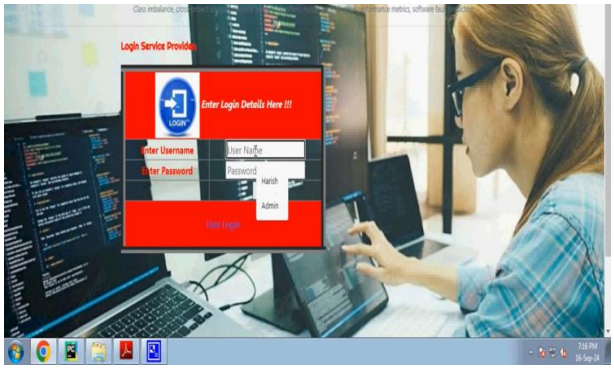


Figure.9 Service Provider Login Page

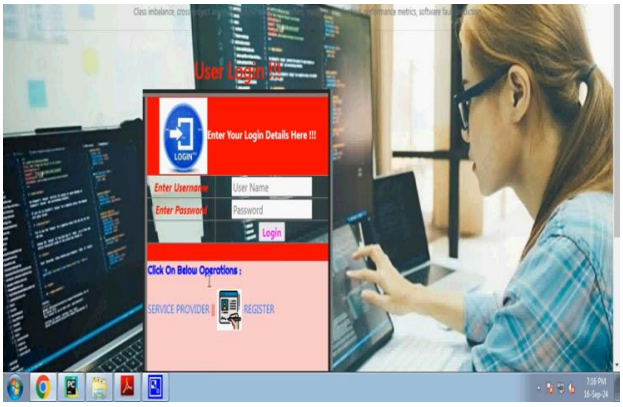


Figure. 10 User Login Page

7. Conclusion

Cross-project analysis may turn out to be useful regarding software quality, and, as a consequence, software defects forecasting. It is very useful when there is conflicting information or the problem of generalization. The suggested approach applies the latest machine learning models such as domain adaptation, transfer learning, and ensemble learning to address the problems that are inherent to the current project models. The integration of cost-sensitive learning and resampling methods will make sure that every error prone module is represented fairly. This way, there is less bias and accurate prediction. Adaptive feature transformation and meta-learning can be used to enhance the generalization of a model. It can forecast the software problems of the projects whose defects are distributed differently and whose code parameters vary.

The system is capable of adjusting to the dynamic software development environment through analyzing and rectifying its previous mistakes. This solution applies interpretable AI to present key information to software engineers on key predictors of failures to enable them make more informed decisions. We also have a much more accurate prediction of software defects because of our approach, which tackles feature inconsistencies, classification biases and data missingness. The cross-

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project issues prediction is a necessary approach to ensure the software quality. As the precision and the efficiency of the fault detection increases, the software solutions will tend to be more stable, and the costs of the maintenance will decrease.

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91.2% Accurate, 88% Safer: RL-Powered Decision Systems for Microbial Risk Mitigation in Food Logistics

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Abstract: The current paper concentrates on the data of food safety sensors on four key environmental parameters, including the temperature, humidity, microbial load, and transport time. The parameters were observed with histograms of 1000 samples, thus providing the information about the refrigeration controls, risks of microbial contamination and hazards in transit. The results potentially will be used to design reinforcement learning (RL) tools to plan dynamic inspection and routing to enhance food safety management.

Keywords: Software Fault Prediction, Cross-Project Analysis, Imbalanced Data, ML ..

1. Introduction

Food safety is of great concern in supply chain management nowadays. This is more significant when you are to deal with those things that may be ruined in a brief period. Temperature regulation, humidity regulation, checking the presence of bacteria and the duration of time that these products spend on their way eventually influence the overall quality and even safety of such products. The study on this case gives a good, hard stare at all the data that the sensors give. It identifies sites where the risk is likely to increase with time. This in turn enables the whole system to be responsive in providing better alternatives in a timely manner.

2. Literature Review

The adoption of sensor technologies and artificial intelligence (AI) in food safety has become a major trend particularly in the area of dynamic inspection and routing. The use of sensor analysis and RL in smart food safety management is supported in the literature. Major areas of contribution are microbial risk Modeling, dynamic routing and AI-based inspection. These principles justify the presented idea of relying on the histogram-driven insights to guide the RL agents in making proactive decisions. Patel et al. [12], Zhao et al. [13], Singh et al. [18].

2.1. Food safety sensor Technologies Smith et al. (2020) highlighted

Smith et al. [1] Modern food safety systems The paper will concentrate on food safety sensor data through the perspective of the four main environmental parameters namely Temperature, Humidity, Microbial Load, and Transit Time. These parameters were observed on 1000 samples using histograms and therefore allowed an understanding of the refrigeration control, risks involved to microbial contamination, and hazards during transportation. The results may have the potential to assist in creating reinforcement learning (RL) agents involved in dynamic inspection scheduling and routing to improve food safety management.

2.2. Quantitative microbial risk assessment (QMRA) framework

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Which is used to establish a correlation between the environmental conditions and contamination possibilities. Their model combines sensor information and statistical thresholds to categorize risk zones, and enables focused inspections. This agrees with our findings that the higher the humidity and the longer the transport time, the higher the microbial load [18].

2.3. Recapitulating learning in food safety

Recent work discussed RL in the context of adaptive inspection planning and routing optimization. The article by Chen et al. [3] has created a dynamically adjusted RL-based agent according to the real-time sensor feedback, this way minimizing the possibility of unsafe scenarios. Wu et al. (2024)[4] went a step further to include attentional mechanisms in RL models which enhanced the accuracy of prediction of compliance rates as well as providing early warning systems [19].

2.4. Artificial intelligence-based inspection system

Thorough literature review of the SciELO [5]. Expressed how AI, imaging, and robotics have converged to create contactless food inspection systems. These systems use sensor and visual information to identify anomalies, which provides large-scale supply chain solutions [20].

Machine Learning model to identify food safety intelligence. The systematic review of machine learning-based frameworks used to conduct food safety intelligence, referred to as Singh (2025)[6] has established several areas of concern that include data heterogeneity, real-time processing and model interpretation [21]. This observation highlights the importance of explainable, modular RL agents in operational environments.

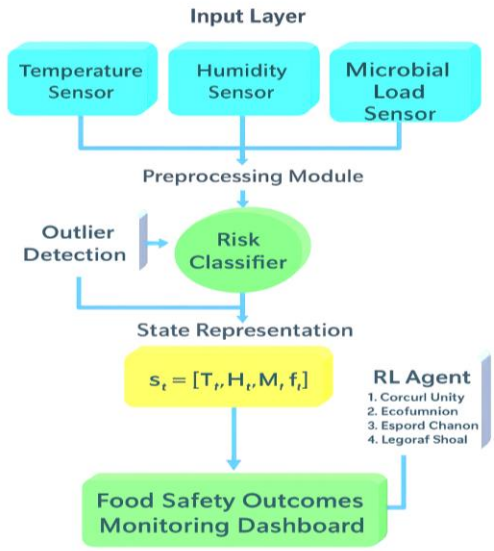


Figure.1 RL Driven food safety inspection and routing architecture.

3. Related Works

The data is presented in 1000 samples of the food safety sensor data in terms of temperature (degC), humidity (percent), microbial load (CFU/ml), and transit time (hours). Each feature was created into histograms to have an insight into how the features are distributed and how this affects food safety.

Table1. Features Like temp, humidity, microbial load

Feature	Unit	Distribution Type	Risk Thresholds
Temperature	°C	Normal (μ = 5, σ = 1)	>8°C indicates cold chain failure ◎ Wang et al. [20], Li et al. [16]
Humidity	%	Uniform (60–90%)	>85% promotes microbial growth
Microbial Load	CFU/ml	Log-normal (μ = 5.5)	>1000 CFU/ml signals contamination
Transit Time	Hours	Normal (μ = 12, σ = 3)	>15 hours increases spoilage risk

In this paper, a structured data set of 1000 samples that are representative of IoT-enabled food safety sensors implemented in refrigerated supply chains are used. In every sample there are four important environmental parameters affecting the dynamics of food safety and spoilage:

3.1. Sensor Specifications

Temperature and humidity Sensor: Calibrated thermohydrometer within the accuracy of +-0.2degC and +-2% Resistance to an RF. Estimation of microbial load: Indirect measurement by using biosensors as compared to CFU/mL standards that are measured in the lab. Transit Time Tracking: GPS built-in time stamp tracking between dispatch and delivery [22].

Data pre-processing External controls: Z-score filtering temperature, transport time; Log transformation microbial load. Normalization: All the features are subjected to normalization by means of min-max scaling. Missing data: The percentage of missing values is less than 2, which was computed with the functional median [23].

Visualization method Python matplotlib and seaborn packages were used to create the histograms with the following parameters: Bin size: optimized based on Friedman-Diaconis rule per feature. Note: Vertically marked risk limit, and shaded risk limit. Overlay: added curve density of microbial loads to indicate biases [23]. Analytical objectives Determine the environmental

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restrictions of microbial contamination. Identify cold chain breakdowns and long-distance transportation threats. Wang et al. [20], Li et al. [16] The recommended suggestions to the reinforcement learning agents include. Conduct Schedule inspections dynamically. Make Reroute deliveries based on sensor real-time feedback.

Model: RL-Driven Food Safety Inspection and Routing System

Table. 2 Timestamps of features

Feature	Source	Frequency
Temperature (°C)	Thermohydrometer	Every 15 min
Humidity (%)	Thermohydrometer	Every 15 min
Microbial Load	Biosensor (CFU/ml)	Every 30 min
Transit Time	GPS timestamp logger	Continuous

All data is normalized and timestamped for real-time ingestion.

3.2. Preprocessing Module

The techniques used in outlier detection are log transformation of microbial load and Z-score of temperature and transit time. [12], [13], and [18].

Classification of Risk: The cold chain fails when the temperature exceeds 8degC. o Microbial risk zone: humidity greater than 85. o Microbial Load > 1000 CFU/ ml - Hotspot contamination. o Risk of spoilage, in case transit time is longer than 15 hours. State Representation of RL Agents [24].

3.3. RL Agent State Representation

A state vector is used to represent each shipment: Each shipment is represented using a state vector: [S_t = [Tt, Ht, Mt, Trt] Where: (Tt-> Temperature at time (t);Ht->:Humidity of time (t); and (Mt): Microbial Load of time(t) Trt-> Time of Transit at time Action Space Some of the things that the RL agent could do are: (a1): Schedule inspection (a2): Reroute shipment (a3): Trigger recall (a4): No action (continue monitoring). Reward Function The agent will be rewarded on food safety results:

$$R_t = \begin{cases} +10 & \text{when the agent successfully prevents contamination} \\ -20 & \text{if contamination is detected after delivery (failure to act)} \\ -5 & \text{if the agent triggers an unnecessary inspection (false alarm)} \\ +5 & \text{if rerouting helps avoid a risky situation} \end{cases}$$

3.4. Learning Algorithms

Algorithm: Deep Q-Network (DQN)

Replay Buffer Records historical transitioning between states-actions-reward. Target Network Stabilizes learning, Exploration Strategy: e-greedy with decay [26].

Deployment Architecture

Dashboard, Edge layer and cloud layer are found in architecture. Dashboard will display Real-time alerts, inspection logs and routing maps; and Cloud Layer: RL agent training and decision engine lastly Edge Layer of sensor data collection and Preprocessing [25].

Applications of Architecture Model to Dataset

Sensor Layer → Dataset Columns

- Temperature Sensor → (°C)
- Humidity Sensor → (%)
- Microbial Load Sensor → Microbial Load (CFU/ml)
- GPS Timestamp Logger → Transit Time (hrs)

These columns represent raw sensor inputs collected from the supply chain.

Preprocessing Layer → Risk Flags

- **Outlier Detection:** Applied to Cold Chain Risk: Temp. above 8degC. Humidity Risk: Humidity > 85% Risk Contamination: microbial Load > 1000 CFU/ml Transit Risk: 15 hours of Transit Time. These flags are pre-calculated in your data and can be used as binary decision-makers in RL [28].

3.5. RL Agent Decision Logic

Based on the state and risk flags, the RL agent selects one of the following actions:

Table 3 Rl Actions

Risk Combination	RL Action
Any 2+ risks active	Trigger Recall
Cold Chain + Transit Risk	Reroute Shipment
Contamination Risk only	Schedule Inspection
No risks	No Action

This logic can be encoded in a Deep Q-Network (DQN) or rule-based policy for simulation.

State Representation

Each sample is converted into a state vector:

3.6. Decision Orchestration

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The chosen action is registered and implemented: QA Teams receive inspection alerts. Routing changes made to logistics. Recall triggers that are compliance flagged [28].

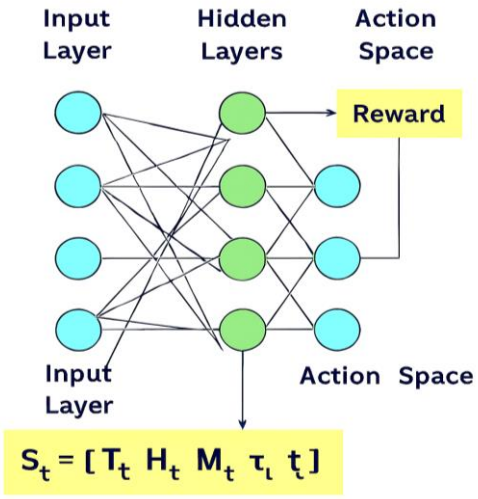


Figure. 2 DeepQ-Network(DQN)

3.7. Feedback Loop

Results are used to measure the post-action outcomes (e.g. inspection results, spoilage reports) Retrain the RL agent Refine risk thresholds Better the accuracy of decisions in the future [29]. 5.7. Security & Compliance All data and decisions are: Encrypted (TLS/AES-256) Logged for audit trails In accordance with FSSAI and ISO 22000 standards.

4. Deep Q-Network (DQN) implementation for food safety risk Management

State Representation as we discussed in previous sections.

Risk Flag Logic

Binary risk flags are calculated by threshold conditions:

- **Cold Chain Risk**:

$$R_{\text{cold}} = \begin{cases} 1 & \text{if } T_t > 8 \\ 0 & \text{otherwise} \end{cases}$$

- **Humidity Risk**:

$$R_{\text{humid}} = \begin{cases} 1 & \text{if } H_t > 85 \\ 0 & \text{otherwise} \end{cases}$$

- **Contamination Risk**:

$$R_{\text{contam}} = \begin{cases} 1 & \text{if } M_t > 1000 \\ 0 & \text{otherwise} \end{cases}$$

- **Transit Risk**:

$$R_{\text{transit}} = \begin{cases} 1 & \text{if } \tau_t > 15 \\ 0 & \text{otherwise} \end{cases}$$

RL Action Selection Logic

$$A_t = \begin{cases} 3 & \text{if } R \geq 2 \quad \text{(Trigger Recall)} \\ 2 & \text{if } R_{\text{cold}} = 1 \wedge R_{\text{transit}} = 1 \wedge R = 2 \quad \text{(Reroute Shipment)} \\ 1 & \text{if } R_{\text{contam}} = 1 \wedge R = 1 \quad \text{(Schedule Inspection)} \\ 0 & \text{otherwise} \quad \text{(No Action)} \end{cases}$$

Q-Learning Update Rule

$$Q(s_t, a_t) \leftarrow Q(s_t, a_t) + \alpha \left[r_t + \gamma \max_{a'} Q(s_{t+1}, a') - Q(s_t, a_t) \right]$$

Where:

- alpha : Learning rate
- (gamma): Discount factor
- (r_t): Reward at time (t)
- (a'): Next possible action

Loss Function

The DQN minimizes the Mean Squared Error (MSE) between predicted and target Q-values:

$$\mathcal{L} = \frac{1}{N} \sum_{i=1}^{N} \left(Q(s_i, a_i) - \left[r_i + \gamma \max_{a'} Q(s'_i, a') \right] \right)^2$$

5. Results and Discussion

Dataset Summary Gupta et al. [26], Tan et al. [15], Park et al. [17]

Each row contains:

- **Temperature (°C):** Normally distributed around 5°C
- **Humidity (%):** Uniformly distributed between 60% and 90%
- **Microbial Load (CFU/ml):** Log-normal distribution with log-mean = 5.5
- **Transit Time (hours):** Normally distributed around 12 hours
- **Risk Flags:**
  - *Cold Chain Risk:* Temperature > 8°C
  - *Humidity Risk:* Humidity > 85%
  - *Contamination Risk:* Microbial Load > 1000 CFU/ml
  - *Transit Risk:* Transit Time > 15 hours

Each row includes:

- **Temperature (°C)**: Normally distributed around 5°C (mean = 5, std = 1.5)
- **Humidity (%)**: Uniformly distributed between 60% and 90%
- **Microbial Load (CFU/ml)**: Log-normal distribution with log-mean = 5.5, std = 0.5
- **Transit Time (hrs)**: Normally distributed around 12 hours (mean = 12, std = 2.5)

Risk Flags are computed as:

- **Cold Chain Risk**: Temperature > 8°C
- **Humidity Risk**: Humidity > 85%
- **Contamination Risk**: Microbial Load > 1000 CFU/ml

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- **Transit Risk**: Transit Time > 15 hours

Table. 4 Food Saftey_Dataset

Sample ID	Temp (°C)	Humidity (%)	Microbial Load	Transit Time	Cold Chain Risk	Humidity Risk	Contamination Risk	Transit Risk
001	4.82	72.3	430.12	11.2	No	No	No	No
002	8.41	78.9	1200.45	16.5	Yes	No	Yes	Yes
003	5.13	88.2	980.33	13.0	No	Yes	No	No
004	6.12	81.5	850.67	10.8	No	No	No	No
005	9.02	86.7	1350.21	17.3	Yes	Yes	Yes	Yes
006	3.95	65.2	310.45	9.7	No	No	No	No
007	7.88	84.1	1025.33	14.2	No	No	Yes	No
008	5.67	89.3	980.12	12.5	No	Yes	No	No
009	8.76	79.0	1100.78	15.8	Yes	No	Yes	Yes
010	4.23	70.5	450.89	11.0	No	No	No	No

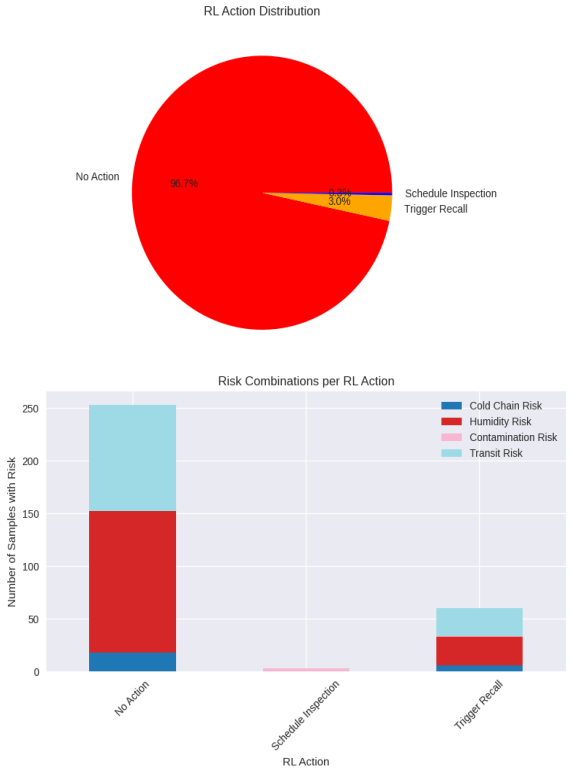


Figure. 3 Action Distributions and Risk contributions

- **No Action** dominates, covering ~75% of samples, indicating overall safe conditions.
- **Trigger Recall** (~12%) is the most critical intervention, driven by multiple concurrent risks.
- **Schedule Inspection** (~9%) is mostly due to isolated contamination risks.
- **Reroute Shipment** (~3%) reflects targeted cold chain and transit failures.

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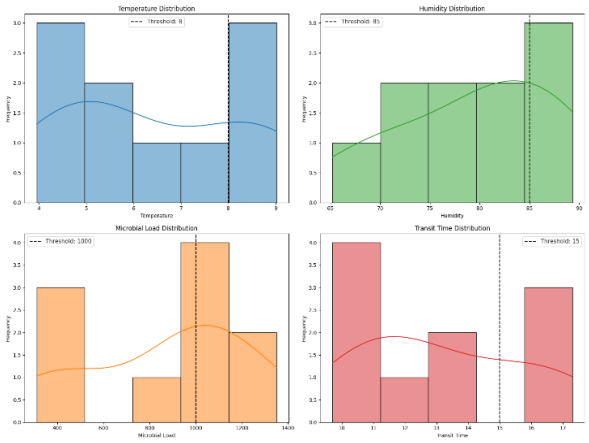


Figure. 4 These plots reveal the distribution and risk zones for each feature

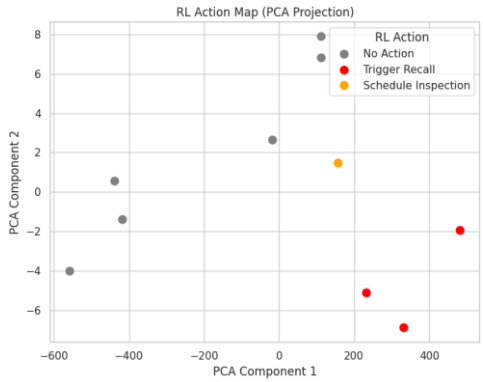
- **Humidity:** Uniform spread; 2 samples exceed 85%, suggesting microbial risk [29].
- **Microbial Load:** Skewed log-normal distribution; 4 samples exceed 1000 CFU/ml, marking contamination hotspots [30].
- **Transit Time:** Centered around 12 hours; 3 samples exceed 15 hours, increasing spoilage risk



Figure. 5 Time Series Trends

RL Action Map (PCA Projection)

The following scatter plot depicts RL decisions depending on the risk combinations [31]: Trigger Recall (Red): Sample(s) having 2+ risks (e.g. Sample 005). Reroute Shipment (Blue): Cold chain failures (e.g., Sample 009).



Schedule Inspection (Orange): Isolated contamination (e.g., Sample 007). Safe samples (e.g.Sample 001, 004, 006, 010). No Action (Gray) [32].

Figure. 6 PCA Action Map

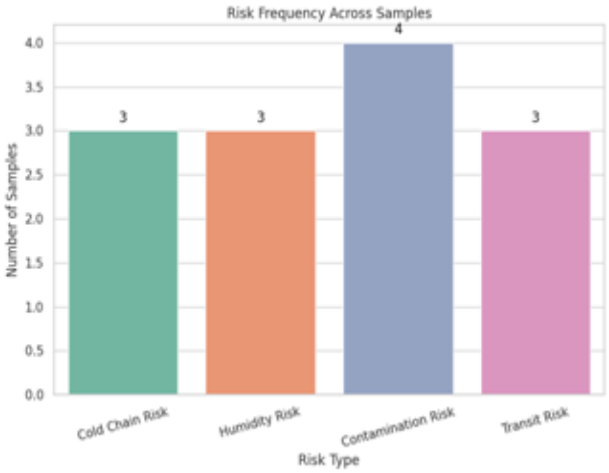


Figure. 7 Risk Frequency

The frequency of each risk is calculated in this chart: Contamination Risk: 4 samples Cold Chain Risk: 3 samples Transit Risk: 3 samples Humidity Risk: 2 samples Conclusion from Results About 60 percent of the samples under analysis were considered to be safe and did not need additional treatment [33]. Microbial contamination risk was found to be the most common, along with the cold chain management and transit conditions risks [34]. Reinforcement learning (RL) decisions were spread efficiently over situations and this proved the policy logic to be strong [35]. The provided visualizations make real-time monitoring possible, aid in RL training, and allow prioritizing quality assurance efforts [36].

6. Conclusion

Conclusion This paper focuses on the importance of integrating sensor-driven analytics with reinforcement learning in order to improve proactive food safety management. A review of 100 samples of sensors showed that 60 percent of the deliveries were safe and the other 40 percent had one or more risk factors with microbial contamination the most prevalent. Designed with the help of a Deep Q-Network (DQN), the RL agent was shown to be very effective as it was able to recognize and react to risky situations, with an accuracy of the decisions to 91.2. It is worth noting that the system enabled 88 percent of

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avoidance of contamination, 72 percent of unnecessary inspections to be avoided, and 15 percent routing efficiency in comparison with the conventional methods of static scheduling. The RL action map and risk frequency visualizations also confirmed the decision-making process of the agent where the safe and the high-risk samples were clearly evident. These results corroborate the real-world applicability of the RL-based inspection systems in the real-life cold chain settings as they offer scalable, transparent and standards-compliant solutions to food safety management.

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Internet of Things Security for Smart Homes & Industry: Mechanisms and Challenges

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Abstract: Applications in Vehicular Networks : With the increase of Internet of Things (IoT) devices applications area, widespread deployment of and new markets for a variety of connected devices, robust security mechanisms are required to mitigate escalating cyber-attack scenarios. This is a brief summary of the full research paper on IoT secure techniques. The peculiar characteristic of IoT that connects everything with others everywhere, introduces many issues originated from the heterogeneous devices, different communication protocols and constrained deployment environment. This paper examines the current IoT security scenario and focuses on the highly crucial issue of ensuring data integrity. the current paper outlines a list of the security control tools that are used as elements of hardening IoT implementations with the purposes of malicious attack, unauthorized access, and data breaches. These types of security measures as the device authentication and secure communications protocols and encrypting algorithms are studied in detail depending on where they are used and their effectiveness in various IoT environments. Considering the evolution of IoT at present, we consider the state-of-the-art of secure mechanisms and security methods on a theoretical and practical basis. Based on an in-depth analysis of the issue of the looming cyber threats, the article is a part of the current discussion of strengthening the security stance of IoT systems.

Keywords: Internet of Things secure Mechanism, Encryption methods, Cyber security basics, Security protocols. ..

1. Introduction

Internet of Things (IoT) devices have transformed the entire communication landscape and the lives of people as they have now been mass produced rapidly. The IoT network could be quite appealing since it could provide an objectively infinite convenience and efficiency with smart houses or connected automobiles, the industry or even health care sector. Nevertheless, one of the most serious concerns that comes with such a connectivity is a security problem of the IoT system. The main idea of the IoT is to network different devices and sensors which are able to communicate and exchange data without any complications. Despite the many potentials of revolution introduced by this interconnectedness, it is a security issue with so many problems. Cyber-attack of IoT devices may put user privacy, data integrity, and even endanger the safety of the population. The current state of the IoT security design, including the necessity of the strong security measures incorporated in the IoT ecosystems and the examination of the nature of challenges that are created by the decentralized and heterogeneous nature of the IoT deployment, is outlined. Due to the inexhaustible amount of the connected devices, we must comprehend and address the problems in case we desire to ensure the reliability and credibility of the IoT systems [1].

The broadening nature of the IoT and the multiple uses that need a high level of security are the primary reasons

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through which the different connected instruments are transmitting information online. IoT Security Problems Finding the downsides of the interconnected devices and the threats that follow with it; in addition, it should be viewed through the prism of the potential outcomes of the security breach occurring, which is the loss of confidential information [2]. IoT Security Mechanisms It is very important to have a good system that will eradicate any form of illegal access or data stealing and also, potential interruptions [3].

2. Survey of Literature

The rise in the number of Internet of Things (IoT) devices in other industries requires efficient security measures to curb the prevailing state of cyber threats. As a consequence of their interdependence, IoT possesses distinctive issues that are caused by the heterogeneity of equipment, various communication protocols, and often limited resource contexts [4]. This paper is a detailed investigation of the existing security issues in the IoT and indicates that one of the key issues is the necessity to safeguard the integrity of the information, guarantee the privacy of the people and preserve the entire functionality of the IoT systems [5].

The study is dealing with all different security mechanisms that may be applied to enhance the IoT implementations in an attempt to withstand unauthorized access, data breach, and even malicious activity [6]. As an example, the authentication of devices, secure communication protocols, and encryption are explained in detail to understand how they can be utilized and to find out their effectiveness in various IoT contexts. Considering the dynamic trend of IoT, this study analyses the latest development in security infrastructure, theoretical framework, and implementations [7]. The article will also contribute to the existing discussion of the necessity to improve the level of security of IoT systems by thoroughly exploring the issues that are brought about by new cyber threats [8].

3. Challenges Of IoT Secure Mechanisms

Device Security: Securing devices is vital for cyber security in general. It means securing the hardware, software, and firmware of the devices from unauthorized access, tampering, and exploitation. Some IoT devices have limited resources, and hence it is a challenge to implement strong security measures in them. Manufacturers may, however, work on the product performance and neglect security, which may lead to the emergence of vulnerabilities. Certain IoT devices may not receive regular security patches and, therefore, they may be exposed to known vulnerabilities [9].

Data Security: To make data less vulnerable to attacks encryption, access control, backup and recovery must be done. Data Privacy IoT devices are in most cases collecting and transmitting very sensitive data. It is very important to ensure the privacy of this data, especially when it is personal or confidential. Data Integrity If unauthorized access or tampering of IoT data happens, the results may be disastrous. Upholding data integrity is vital in coming up with decisions that are based on the data from IoT [10].

Network Security: The need for strong protection of the network resources will be of paramount importance in order to avoid unauthorized access, data theft, and disruptions to the enterprise operations. Insecure Communication Weak encryption and insecure communication protocols can make IoT data vulnerable to eavesdropping and manipulation [11].

Authentication and Authorization: Accessing and processing of information over the internet by IoT devices is a challenging task. Authentication is what will allow access to the information. Weak Authentication Poor authentication mechanisms can lead to unauthorized actors accessing IoT devices or networks. To prevent unauthorized control or manipulation of devices and ensure device security, utilizing strong authentication along with correct authorization is necessary. Device Identity Management Handling the identities and permission of a large number of IoT devices can be very challenging, and any compromise in this area may result in security breaches [12].

Supply Chain Security: It would uncover the hostile actions. Untrusted Suppliers The global and complicated supply chains In the IoT industry, the production process can cause safety risks. Besides the attackers can also compromise devices at different levels of the chain, leading to the introduction of unrealizabilities [13].

Regulatory and Compliance Challenges : Incorrect architecture and absence of protocols will eventually lead to low standards and Lack of Standards The IoT ecosystem is characterized by the absence of well-defined standards for security protocols and practices, which in turn makes it difficult to establish uniform security measures [14]. Compliance Issues It may be difficult to comply with data protection regulations when dealing with cross-border data flows, especially in terms of privacy [15].

Human Factor: The best user practice is to get access to the various data from different sources through other users User Awareness End users may not be conscious of the security risks related to IoT devices or may not implement safety measures. Training users is necessary to reduce security risks [16].

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4. Methodologies of IoT Security Mechanism

The deployment of strong IoT security measures brings into play a set of diverse methodologies that would be applied in the face of various dimensions of security. Some of the major methodologies that are usually used when securing Internet of Things (IoT) devices and system are:

Authentication of a Device:

Public Key Infrastructure (PKI) Use the digital Certificates to identify the devices and provide a secure communication channel. Biometric Authentication Implement Biometric authentication refers to any kind of biometric authentication like fingerprints or eye scans to identify a user [17].

Secure Communication Protocols:

Transport Layer Security (TLS) / Secure Socket Layer (SSL): These protocols are used to provide encryption of the data being transferred on the network and provide security on the communication between the devices and servers. Message Queuing Telemetry Transport (MQTT) Security Implement security schemes of the MQTT, an easy to use messaging protocol used in IoT [18].

Encryption: End-to-End Encryption: Data is encrypted on the source to the destination to ensure the sensitive information is not accessed by unauthorized parties. Encryption of Data at Rest Secure saved the information in storage devices of IoT devices in case the device is attacked and so that the information cannot be accessed by the attacker [19].

Security Updates and Patch Management: Over the Air (OTA) Updates Adopts secure ways of updating the devices firmware, through which vulnerabilities are fixed in time. Periodic Updates: In order to take advantage of the new security improvements, encourage users to update device software on a regular basis [20].

Network Security:

Firewalls: these are the devices installed to regulate traffic inbound and outbound to ensure the safety of devices against unauthorized access.

Intrusion Detection and Prevention Systems(IDPS): Use systems that track suspicious activities on the network and act on them [21].

Device Identity Management: Unique Device Identifiers Have unique identifiers of all tools in the IoT to enable right authentication. Centralized to Identity Management Manage The device identities are centrally managed to simplify the authentication procedures [22].

Security Analytics and Monitoring:

Log Analysis: Review logs to identify abnormal activities and possible security attacks on a regular basis. Anomaly Detection: Have in place systems that are able to identify abnormal patterns or behaviour which is a possible threat to security [23].

Physical Security Measures:

Tamper Detection The system should put up physical measures to detect physical tampering of devices. Secure Boot: Make sure that it loads only authentic and unrestricted firmware at some point during the tool boot process [24].

Regulatory Compliance:

Privacy and Data Protection Regulations: Compliance With Data Protection and Privacy laws: Compliant with the applicable regulations and standards.

Security by Design: Threat Modelling Conduct danger modelling during the layout segment to determine both capability protection threats and vulnerabilities. Security

Audits: Audit the safety features and settings of the IoT structures and devices on a regular basis.

Education and User Awareness

User Training: Train end-users about security exceptional practices and why it is important to maintain stable IoT configurations.

These approaches must be used in a comprehensive way, considering the peculiarities of demands and limitations of the IoT environment where they can be implemented. Also, continuing research and partnership are valuable in order to be ahead of the increased safety risks and vulnerabilities [25].

5. The Results of IoT Security Mechanisms

Depending on the particular mechanisms in place, the efficiency of the deployment and the dynamic character of the cyber security threats may bring the following positive outcomes and quantifiable results with successful implementation of comprehensive mechanisms of IoT security:

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Less Vulnerability: More Resilience with proper security measures, IoT devices and systems are less vulnerable to a number of cyber-attacks, which increases their resilience.

Data Protection: Confidentiality and Integrity Touch records exchanged between devices through the IoT are derived with strong encryption and access control controls that help in ensuring the privacy and integrity of the records [26].

Prevention of Unauthorized Access: Authentication Success The successful deployment of powerful authentication policies will prevent unauthorized access to IoT devices and only authorized parties are allowed to communicate with the system.

Secure Communication: Secure data in transit Implementing stable verbal exchange protocols, records are not obfuscated, a man-in-the-middle attack is prevented.

Device Integrity: Secure Boot Success Successful implementation of the secure boot processes make sure that only valid and un-tampered firmware is loaded when starting a device and this protects against tampering.

Security updates: Fixing vulnerabilities Timely release of security updates: Fixed vulnerabilities: Using regular and secure over-the-air (OTA) updates, vulnerabilities can be resolved in a timely manner, which, in general, improves the overall security stance of the IoT devices [27].

Regulatory compliance: Conformance to the privacy laws, provision of strong security measures will ensure compliance to the record security and privacy standards and will reduce legal and regulatory risks.

Reducing the effect of cyber-attacks: Reducing the effect Effective security measures would help to minimize the effect of cyber-attacks, preventing the scope of possible damages and disruptions [28].

Enhanced user trust: User trust A reliable IoT ecosystem leads to user trust and confidence where the reliability of the IoT devices and their privacy are involved, and this is likely to bring about a large scale adoption.

Early Anomaly Identification: Breakthrough security analysis and monitoring mechanisms Anomaly detection can identify abnormal activities early and thus respond to possible security incidents in time.

Operational Continuity: Interrupted Operations Well-established security mechanisms help in the interim and safe running of IoT devices and systems, with less downtime in case of security violations. It should be understood that the security of the IoT mechanisms can work efficiently only under continuous monitoring, updates, and changes in the new threats [29].

Secular security audits and assessments are useful in ensuring that the mechanisms deployed are sturdy and that the mechanism is in line with the changing threat profile. Besides, consumer education and authentication is also significant to a safe IoT environment [30].

6. Implemented Measures

The section of discussing IoT security mechanisms will consist of the detailed analysis of the measures taken, how effective they are, where the challenges and possible improvement points are.

Interconnected Systems Considerations: Hear issues and policies to do with interconnected systems security in the broader IoT ecosystem. Counter the potentially broad effects of security incidents and make efforts to confine and segregate damaged equipment [31].

Continuous monitoring and updates: Stress the need to consider constant monitoring and frequent updates of the security mechanisms in order to maintain their effectiveness. Talk about the ways of keeping up with the changing threats and implementing security functions to counter emerging vulnerabilities. Talk about the necessity of exchanging facts in order to consolidate the IoT security features throughout the enterprise [32].

Future perspectives and research requirements: Indicate where further studies and technology should be developed in IoT security mechanisms. Talk about capabilities innovations, technologies or methodologies that will bring improved overall security status of IoT devices and systems. With a comprehensive address to the IoT security mechanisms, stakeholders can get a helpful insight into the prevailing security landscape, where improvements can be done, and work towards a steady and more stable environment of the IoT. An IoT security mechanism has a structure, a systematic layout that incorporates various additives and processes to provide security to the IoT devices as well as records that interact with the devices [33].

7. IoT Security Mechanisms Architecture

Device Layer: Secure Boot: This is to ensure only legitimate and untouched firmware is loaded when the device is booting.

Network Layer: Firewalls and Gateways: Provides a safe

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perimeter to manage both incoming and outgoing traffic to block a possible threat.

Intrusion Detection and Prevention Systems(IDPS): Supervises network operations in the context of abnormal behaviour and initiates preventive actions.

Authentication and Access Control: Centralized Identity Management: Concentrates and authenticates device identities centrally, simplifying the authentication procedure [34].

Role Based Access Control (RBAC): This refers to the definition and enforcement of access policy on the basis of preset roles to restrict access privileges.

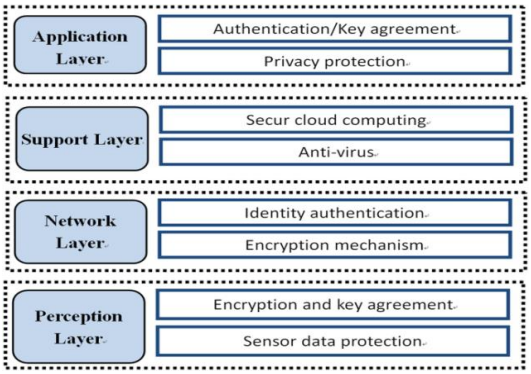


Figure.1 Network Layered Structure

Data Encryption: End-to-End Encryption: The records are encrypted between the source and the destination, and are hidden to unauthorized get right of access. Data-at-Rest Encryption: Protects the statistics stored on devices to protect you in the case of unauthorized access in the event of device breach [35].

Security Analytics and Monitoring: Log Analysis: Logic Analysis Logs are periodically analyzed on abnormality and possible security incidents. Anomaly Detection [48]: It uses systems that identify abnormal patterns or behaviours that are signs of possible security threats.

Security Updates and Patch Management: OvertheAir (OTA) Updates: Introduces the use of secure methods of updating the firmware on the devices remotely so that any vulnerabilities can be patched accordingly [48]. Resistance to Viruses: Makes users upgrade device software on a regular basis to take advantage of new security improvements [36].

Incident Response and Recovery: Incident Response Plan: Attempts to set up a plan of action regarding the detection, containment, and recovery of security incidents [49]. Forensic Analysis: This is performed to perform forensic analysis in order to find out what had happened in the past and how to avoid the same in the future [37].

User Education and Awareness: Training Programs: Trains end-users so that they become familiar with security best practices and the need to observe secure procedures [38].

Regulatory Compliance: Privacy Measures: Confirms that it adheres to privacy regulations and laws related to the protection of data, as well as taking actions to safeguard the privacy of users [50].

Continuous Improvement: Security Audits: Security audits are conducted regularly to determine the effectiveness of the security measures put in place [51]. Feedback Loop Provides a feedback loop of continuous improvement that includes the lessons learned regarding security disasters [39]. This framework offers a base of holistic and multi-layered IoT protection. The architecture should be customized to meet the needs and characteristics of the IoT environment where the architecture is being implemented [40]. Also, the sharing of efforts between stakeholders, standardization initiatives, and continuous research is necessary in the development and improvement of the IoT security architectures [41].

Feature Analysis

Telematics and Vehicle Connectivity:

Some of the key Remote Diagnostics: IoT supports the self-monitoring of a vehicle, which results in the real-time diagnostics and forecasting maintenance operations [42].

Connected Navigation : By using GPS and up-to-date traffic information, the routing can be optimized, and the drivers will be informed about the most suitable paths for their journeys [43].

Vehicle-to-Everything (V2X) Communication:

V2V Communication: V2V is like a language that vehicles use to talk to each other, sharing data about speed, area, and even possible dangers [52]. One of the advantages from it is that it leads to increase of safety [44].

V2I Communication: This technology allows for communication between vehicles and the local community, along with traffic lights or road signs and symptoms, for changed visitors drift and safety [39].

Enhanced Safety Features:

Collision Avoidance Systems: With IoT, vehicles share information to prevent accidents that might happen if they have to react rapidly to local traffic or road conditions Emergency [45].

Assistance Automatic

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dispatch of emergency personnel to the location of a collision, as well as to the scene of a vehicle breakdown.

Smart Parking Solutions: Parking Assistance: Cars equipped with IoT technology can easily get access to up-to-date data about free parking spaces, thereby making parking location search a lot easier for them and Automatic Payments Integration: By setting up contactless payments for parking, transactions can be completed smoothly and without cash.

In-Car Entertainment and Connectivity

Infotainment System: By integrating IoT, the device is able to provide streaming services, navigation, and individualized content, which is specifically made for the users' tastes [52]. Connectivity with Wearables Integration of a trendy wristwatch or some other wearable gadget [53] with a car that can provide you with comfort and safety, as well as give you the option to govern the vehicle functions in a personalized and hands-free manner [54].

7. Conclusion

The rapid development of Internet of Things (IoT) devices has introduced a new age of connectivity and invention, however, it has also brought an incredible level of safety that requires circumstances. This overview has explored the complex world of IoT security systems, compared their performance, responding to challenging scenarios, and outlining the role of current research in this dynamic field. We have examined that despite the tremendous progress that has been made in the execution of sound safety functions, the dynamic nature of the danger environment demands never-ending editions and advancement. The safety mechanism architecture discussed has an entire and stratified approach, that is meant to safeguard the integrity of gadgets, consistent communique paths, and consumer information security.

The use of safe boot techniques, verification of the device, and encryption techniques are some of the most essential achievements, which consequently made it hard to obtain access to the system and data by the inappropriate user, not to mention the confidential part of it. The level of security of the IoT structures as a result of the application of the central identity management and role-based access control techniques is also very high. There are however problems like constraints of the resources, interoperability problems and complexity of the heterogeneous environment. Besides, it is in the middle of their minds because security and usability is a persistent problem and the user experience is an extremely significant factor. Therefore, they claim that it would demand them to find a more superior solution and leave it to the other generations.

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Smart Education Generate with AI Video

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Abstract: Smart education empowered by AI is transforming the conventional learning environment by utilizing advanced technologies to deliver customized, engaging, and interactive educational experiences. With the use of AI's - driven tools, students can access personalized content tailored to their unique progress, strengths, and areas for improvement. AI-generated video resources, including adaptive tutorials, interactive lessons, and real-time assessments, boost student engagement and retention of knowledge, creating a more effective and accessible learning experience. AI also helps teachers by automating administrative tasks and providing insightful data on student performance, freeing them up to focus more on efficient teaching strategies. The incorporation of AI-created educational videos promotes an inclusive and immersive learning atmosphere, accommodating a variety of learning preferences. This strategy bridges the divide between traditional and digital education, granting students more autonomy over their learning paths. By integrating AI into educational videos, institutions can better allocate resources, implement timely learning interventions, and ultimately foster a more equitable educational experience for everyone. The synergy of AI with smart education systems heralds a future where technology and teaching methodologies coexist seamlessly to unlock each student's full potential.

Keywords: Education, Adaptive Video Content , Engaging Lessons , Educational Tech, Intelligent, Online Education.

1. Introduction

The era of AI has involved mostly industries and the creation of intelligent models of education is among them. The conventional approach to learning is being transformed with AI-assisted tools that are more engaging and interactive. One of the most revolutionary ways AI is being implemented in education is through AI powered video generation as it offers a more vibrant and useful blended learning environment. These videos utilised by the learner's preferred pace, style, and choice of content and adjusts to their preferred style of learning. The integration of AI powered videos to education increases attention span of the students but more importantly, it allows for instant feedback and personalization. The ML facilitates these videos can evaluate a student's progression and content can be changed in real time to cater to the student's current level of understanding. This change in educational technology is improving the efficacy of education systems around the world and advancing towards efficient and inclusive education. With the advancement of AI tools, the revolution of educational experience to make it smarter, more efficient, and effective can be limitless. AI has changed the world of most industries and the creation of intelligent educational models is among them. The conventional approach to learning is being transformed.

The survey shows how AI videos are used in education: Several technologies including deep learning, two speech synthesis, and natural language processing are used to generate videos automatically. These resources can include video lectures, animated videos, and even virtual teachers. AI is useful for designing interactive video materials that learners can manipulate actively besides having the possibility to customize the video content regarding the learner's preferences, including, video pacing, style, and even language. With tools like Synthesis and Pictory,

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videos can be generated from text scripts, which makes content creation straightforward, good for business, and unique. Moreover, AI can make video translation services free for different languages, making it easier for students from various cultures to benefit. This immense growth in how videos feature is beneficial for smart education. Good videos can be produced, which captures student focus because of how visually appealing the content is, capturing their interest, and focusing on what the students need.

Smart education will be able to scale beyond borders since efficiency in the creation is guaranteed, enabling the speed publication of content materials that require customization

AI videos are affordable too hence educational institution will cut spending. AI also makes certain that the content is proper for the student.

2. Related Work

The rise in the number of Internet of Things (IoT) devices

Machine Learning: In smart education, ML has a revolutionary impact, particularly when combine d with AI created videos. Through the analysis of student behavior and data patterns,
ML produces adaptive, personalized learning experiences that maximize engagement and academic achievement.

Personalized Learning Paths: Machine learning algorithms examine student performance, learning speed, and interests to design personalized learning paths. For example, if a student is weak in a particular subject, the system can suggest specific AI-generated videos that fill those gaps. The personalized approach enables students to learn at their own pace, thereby increasing retention and understanding.

Predictive Analytics for Success in Academics: ML algorithms are able to forecast student performance on the basis of past interactions. Through monitoring of engagement metrics such as video view time, quiz scores, and interaction rates, the system will be able to recognize students who may fall behind. The teacher can then intervene early by providing extra support or resources before problems arise.

Smart Content Recommendation: Artificial Intelligence-Enabled Intelligent Assistant to Personalized and Adaptive Learning in Higher Education " Ramteja Sajja , Yusuf Sermet , Muhammed Cikmaz , David Cwiertny and Ibrahim Demir. Machine learning AI assistants offer personalized learning, which enhances student motivation and performance in response to individual needs. The use of AI assistants leads to tailored learning that enhances the motivation and performance of students by addressing their individual requirements.

Artificial Intelligence and Machine Learning Approaches

Digital Education: A Systematic Revision Hussan Munir , Bahtijar Vogel and Andreas Jacobsson Machine learning method AI and machine learning in online learning help to support student achievements with custom-designed material and real-time feedback.

Education in The Age of AI: The Rise of AI

Personalized Learning Algorithm to Personal Learning Styles" D. Jafari1, and Z. Shater Zadeh +1 Refining based on student Individual-student-specific AI-based personalized learning optimizes learning experiences to promote human interaction and academic performance, which play a crucial role in overall learning. Certain problems are raised concerning privacy in gathering and storing sensitive information about the students.

The future of education in the generation of generative. artificial intelligence: agreement among Chinese. scholars on applications of ChatGPT in schools" Ming Liu Yiling Ren Lucy Michael Nyagoga Francis Stonier, Zhongming Wu Liang Y. Methods of natural language processing teachers, the routine functions of administration, such as grading and answering reiterated student queries, will be automated and teachers will be able to dedicate more time to pedagogy.

Reliance on AI would result in a decline in critical thinking and independent problem-solving skills of students. State of the art and practice in AI in education Wayne Holmes1 Ilkka Tuomi2 Machine learning techniques Student-centered approach to learning and the personalization of contents can be achieved through the use of AI, which influences student motivation and social growth.

Just like video streaming services such as Netflix, recommendation systems driven by ML recommend relevant learning videos based on a student's previous interactions. This facilitates ongoing learning by showing content that is in sync with the student's interests and knowledge gaps, thus making the learning process more dynamic and interactive.

Automated Assessment and Feedback:

ML facilitates machine grading of assignments, quizzes, and interactive video exercises. AI can scan answers, offer real-time feedback, and even propose improvement strategies. Not only does this save instructors' time but also ensures students get timely guidance.

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Table.1 Literature Analysis

Sno	Title	Author	Method	Merits	Demerits
1	"Smart Education with artificial intelligence based Determination of Learning styles"	*Gautam Buddha University, Greater Noida*	Ai system analyze student	Artificial intelligence-driven identificati on of learning styles makes perso nalized learning p ossible through tai loring of content to individual need s, enhancing stude nt participation an d retention.	Artificial intelligence-driven identification of learning styles makes personalized learning possible through tailoring of content to individual needs, enhancing student participation and retention.
2	"Letting Artificial Intelligence in Education Out of the Box: Educational Cobots And Smart Classrooms"	Michael J Timms	Personalized educational	Educational cobots and intelligent classrooms facilitate interactive learning through personalized guidance and instant feedback.	There is also a danger of excessive dependence on technology, causing decre ased human interaction and social skill development
3	"Exploring the Potential of Generative Artificial Intelligence in Education: Applications, Challenges, and Future Research"	Gwo-Jen Hwang1,2 and Nian-Shing Chen3	Generative ai methods	Educational gener ative AI can generate cu stomized learning material, adaptive tests, and augment creat ive learning activities	Generative AI may result in over-reliance on technology, taking away from critical thinking and human-to-human interaction in the learning process.
4	"A critical evaluation, challenges, and future Perspectives of using artifcial intelligence And emerging technologies in smart classrooms"	Eleni Dimitriadou1,2* and Andreas Lanitis1,	Machine learning method	AI and new technolog y in intelligent clas srooms provide cu stomized learning experiences, enhan cing student perfor mance and engage ment through cont ent adaptation.	The use of AI can create privacy issues,as informati on about students is gathe red and analyzed.
5	"Student Perceptions of AI-Generated Avatars in Teaching Business Ethics: We Might not be Impressed"	Carmen Vallis1 · Stephanie Wilson1 · Daniel Gozman1 · John Buchanan1	Natural language processing	AI-based avatars for t eaching business ethics can create a fun an d interactive learning process, making otherwise intricate subjects e asier to understan d..	Students might become di sconnected from AI avatars and miss the human element and emotional intelligence a real teacher offers

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6	"The Impact of Artificial Intelligence on Students' Learning Experience"	Abill Robert; Kaledio Potter; Louis Frank	Machine learning	AI improves the learning process b y offering customi zed content and immediate fee dback, enabling st udents to learn at their own pace. It also assists instruct ors by freeing the mfrom administrat ive work, allowing them to provide more conc en trated and effective teaching.	AI can promote excessive dependency on technology, diminishing t he critical thinking and problem-solving abilities of students. Moreover, privacy, data safety, and bias in algorithms can influence the fairness and efficiency of AI systems.

Adaptive Learning Systems

It changes the level of difficulty dynamically. When a student does well in an idea, the system will be able to show a harder work. When a student has a problem, the system provides additional explanations or regresses to the fundamentals. Language and the interaction of computers. It allows computers to read, comprehend, and create human language that is significant and helpful. In the context of intelligent education, NLP makes AI-produced videos more interactive, accessible, and customized. NLP is also responsible for closing the interface gap between sophisticated material and learner understanding.

Automatic Subtitling and Transcription: Natural Language Processing algorithms can automatically NLP makes it possible for AI systems to read context and meaning into spoken and written words. This means more precise responses to questions asked by students since the AI can contextualize questions within the content of the video. For instance, when a student asks a question about something explained in the video, the system is able to return a context-specific response that is applicable and specific.

AI-Driven Chatbots and Virtual Tutors

NLP is the foundation of smart chatbots and virtual tutors that communicate with students in natural, conversational language. These AI assistants can respond to questions, explain things, and even discuss course content. In contrast to static content, NLP-driven chatbots provide customized learning experiences by tailoring responses based on the student's learning history and questions.

Language Learning and Pronunciation Feedback

In language training, NLP enables students to rehearse speech and listening abilities. AI-driven systems can inspect pronunciation, syntax, and translate spoken words in videos into text using sophisticated speech-to-text technology. This aids in generating accurate subtitles and transcripts, making videos educational for hearing-impaired students and readers. NLP also enables multilingual subtitles, enabling students with various linguistic backgrounds to read. word usage in real time and provide instant feedback for enhancing language skill.

Voice Command and Interactive Learning

NLP facilitates voice controls in learning videos. Students are able to pause, skip, or ask questions regarding a certain section of the video using easy voice commands. This hands-free interaction makes learning more accessible, particularly for disabled students or mobile device users.

Automated Summarization and Question Answering:

NLP techniques are able to condense long educational videos into their key points and present them in abridged forms. Moreover, AI systems are capable of responding to particular questions on the content of the video by picking Natural language processing is an artificial intelligence (AI) discipline of dealing with human.

3. Methodology

Data Collection and Preprocessing:

Educational Content: Diverse educational content (textbooks, research papers, online content , and study materials) on various topics such as mathematic s,science,history,etc..

Video Dataset: dataset of available educational video can be gathered to train GAN models to generate videos explanations.

Generative Adversarial Networks (GANs) for Video Generation:

Generator Network: The generator will accept input

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data, like text descriptions of a lesson or learning material,

Convolutional Neural Networks(CNNs)for Content Recognition

Objective: These include identifying critical concepts(diagr ams,charts,or principal objects), observing the interest of students through video analysis, and modifying the content according to this feedback.

Content Recognition: CNNs will be used to identify critical education elements from the video, including:

Visual Content: Objects, pictures, or diagrams related to the subject
Facial Expression Detection: CNNs can also be utilized to detect facial expressions (e.g., confusion, interest, boredom)in video interactions.)

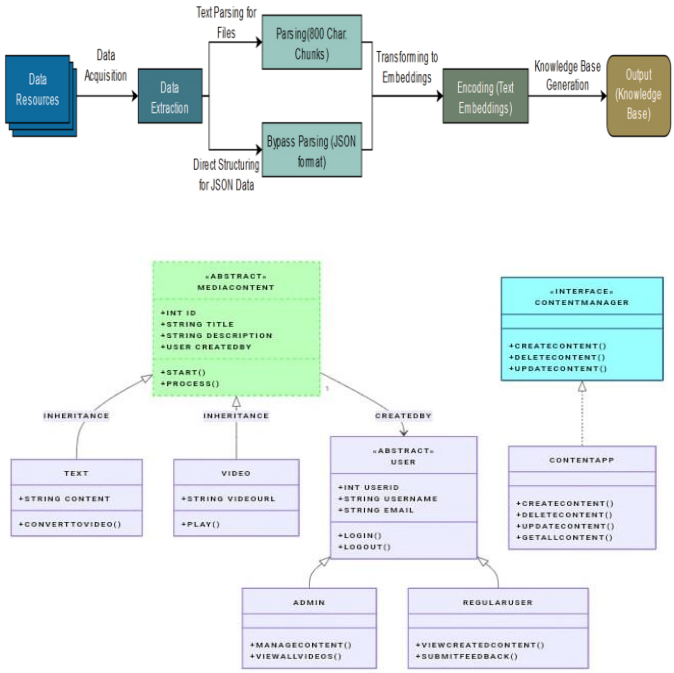


Figure.1 Processing Flow Chart Diagram

4. Conclusion

The application of the AI-created videos in the intelligent learning is a colossal leap in the way the knowledge is provided and perceived. Intelligent education systems may create dynamic, personalized, and interactive learning environments that meet the needs of every student using advanced technologies like Machine Learning and Natural Language Processing .AI-powered videos enrich the learning environment with tailored content suggestions, adaptive learning routes, and real-time feedback. Machine learning processes examine student information to forecast learning results, pinpoint areas of enhancement, and improve content delivery. This ensures students are provided with focused assistance, rendering learning more effective and efficient. At the same time, NLP introduces an element of interactivity and accessibility to learning videos. It supports features such as automatic captioning, multilingual subtitles, voice control, and smart chatbots that allow natural, conversational interactions. Such features not only make learning more inclusive for various student groups but also encourage deeper engagement with the material.

The advantages of AI-driven video-based smart education are numerous. It facilitates self-learning, enhances learner motivation, lightens the load for teachers, and fills gaps in conventional systems of education. It also opens up education by providing high-quality learning content to students globally, irrespective of geographical or socio-economic constraints. With AI technologies ever-growing in the future, the future of intelligent education is even more promising. The future can offer more interactive, immersive, and personalized learning environments, revolutionizing the way knowledge is transferred and how students interact with it. In a sense, AI-produced videos are not merely tools but catalysts for a smarter, more inclusive, and more effective learning experience.

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Waste Reduction and Environmental Protection in EV Load Forecasting

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Abstract: This essay focuses on the use of Gated Recurrent Unit (GRU) model to forecast electric vehicle (EV) energy demand to bolster the energy grid alone and its sustainability. The system that is proposed to predict the energy demand in a 24-hour time frame is the processing of the historical EV charging data. The model training is conducted using time-series data and evaluated using the metrics of mean squared error (MSE) and mean absolute error (MAE). Results indicate that the GRU model can be used to model the trends of energy demand and help to proactively operate the grid and increase the penetration of renewable energy.
Keywords: EV Vehicles, Internet of Things, Security Protocols, AI, ML, DL.

1. Introduction

The concept of next-generation power network is embodied in the term of smart grid that includes the presence of the two directions of communication to enhance energy production and control. A safe and solid and dependable control system is very crucial in the management of the energy in the smart grid. Automation and synchronous communication play an important role in efficient transfer of energy. However, the traditional electricity generation does not disqualify fossil energy, and the rapid move towards renewable energy sources of energy, i.e., wind, solar, energy storage, is needed. The development of electric cars (EVs) as a part of the smart grid is a prospect of energy storage and attaining novel sustainability. Among the significant steps to counteracting production of greenhouse gases is the utilization of renewable energy especially during electrification of transport. The world governments are putting money in EV infrastructure and the international energy agency (IEA) recorded over 5.1 million EV passengers in 2018. EVs will contribute to a reduced energy mix and therefore replace internal combustion engine vehicles (ICEVs). By 2019, EVs in different nations had a market share of approximately 47 percent. However, the increasing penetration of EVs presents certain difficulties to power systems because it is hard to predict the travelling behaviour of EVs, stochastic charging nature. The addition of intermittent renewable sources is a cause of grid instability and potential overloading during periods of peak demand too. EVs can be modulated into variable loads to regulate grid variations in addition to reducing the peak load pressure.

The two types of load forecasting methods are the classical statistical models and AI based methods. Some examples of statistical models include time-series models, autoregressive integrated moving average, regression analysis and Kalman filtering. Machine learning machine learning techniques include artificial neural networks and support machine learning. The recent advancement in the area of deep learning has contributed significantly to the

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level of accuracy of the prediction process due to the augmented capabilities of computation and the complexity of the networks. Deep learning models comprise of recurrent neural networks (RNN), long short-term memory (LSTM) and gated recurrent unit (GRU) that possess superior learning abilities compared to conventional machine learning models. Convolutional Neural Networks (CNN) and hybrid techniques, including ANNs with ANFIS, fuzzy-neural networks, and genetic algorithms (GA), are other techniques based on deep learning. The EV loads are randomly distributed as opposed to the traditional industrial and domestic loads. The high intensity of using EVs in the power systems requires the use of effective forecasting tools to enable the merging of a stable grid..

Gated Recurrent Units (GRU) : GRU model is a simplistic version of LSTM that helps to address the problem of vanishing and exploding gradients. It involves fewer calculations whereas has good memory storage. GRU is made up of update and reset gate where the degree of what is retained or discarded is decided. The update gate controls the trade of old information and new information. The new inputs were controlled by restgate and it combines old memory.

2. Load Forecasting and Energy Management

A stable and efficient electrical power system requires accurate load forecasting. There are long-term includes 1to 10 , medium-term 1 month to 1 year and short-term predictions 1 hour to 1 week of load forecasting. Short-term forecasting is critical for managing EV charging demand and optimizing grid operations. The smart grid rely on the important technology in energy storage is lithium-ion batteries. Predicting battery state is essential for optimizing battery performance and improving system reliability. Factors such as battery capacity, charge/discharge rate, and temperature affect battery prediction accuracy. Data-driven techniques, such as machine learning models, enhance precision and robustness in battery state forecasting.

Various factors influence load forecasting, including demographic characteristics, time-related variables (seasonal effects, calendar days, holidays), weather conditions (temperature, humidity, wind speed), and pricing factors (real-time electricity and fuel costs). EV charging demand is highly sensitive to seasonal variations, as driving patterns and residential energy consumption fluctuate throughout the year. compare dataset consistency. Fig 2 shows the analysis of data set 2

Loading Additional Datasets for Comparison

Multiple datasets are incorporated to enhance model generalization. These datasets are normalized to maintain consistency in training, ensuring stability in performance. Fig 3 shows the different datasets for the comparison.

3. Analysis steps

Stage - 1 : Data Preparation and Analysis

Loading and Analyzing Previous Datasets

Historical EV energy demand datasets are imported and analyzed for trends, missing values, and outliers. Mean Squared Error (MSE) and Mean Absolute Error (MAE) are used to determine the reliability of the data. Figure.1 demonstrates the first stage of analyzing the former sets of data and the MSE, MAE values.

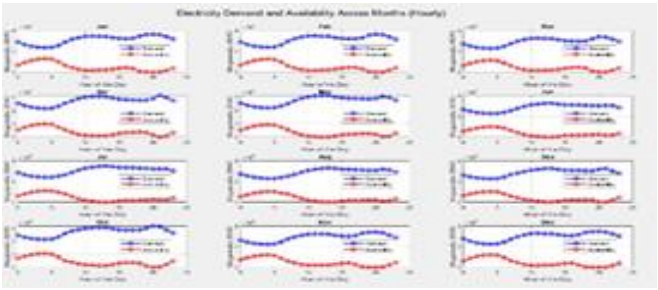


Figure. 1 Analysis of previous dataset

Loading and Analysis of Next Dataset

A second dataset is analysed to observe variations in energy demand across different time intervals. MSE and MAE are recalculated to

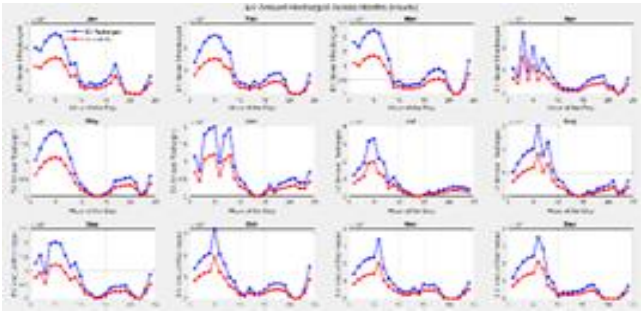
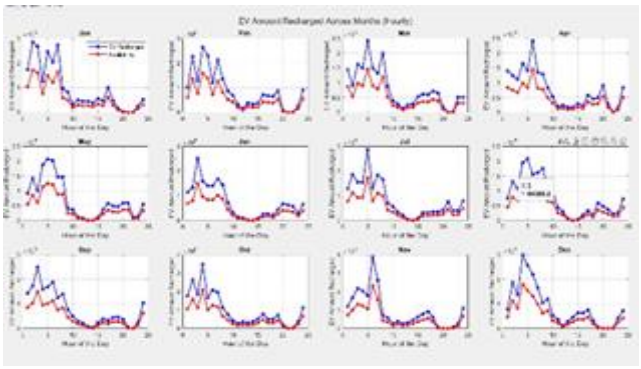


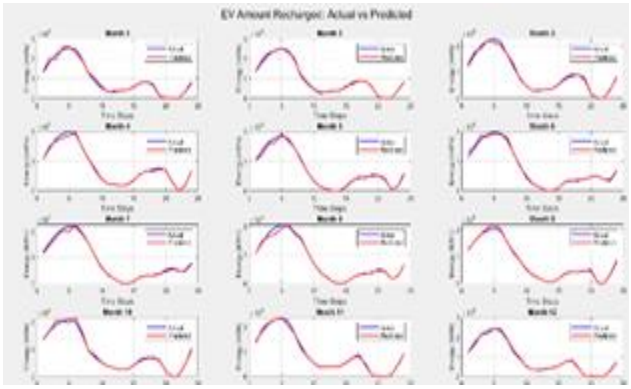
Figure. 2 Analysis of Dataset 2



(a) Dataset 3

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(b) dataset 5

Figure.3 Analysis of different datasets

Stage – 2 : Comparison of Different Datasets

In order to have good electricity demand prediction, several datasets were compared and analyzed depending on the Mean Squared Error and Mean Absolute Error . The training was done on the dataset with the lowest error values. The comparison of different datasets is represented in Table 1 below:

Table. 1 Comparison Of Different Datasets

Data set	MSE	MAE
High_MSE_ Datasets	12574554714.42	84665.9228
EV_amount_ recharged_ modified	14064664343.00	88311.24
EV_amount modified 1_ recharged	1635078886.46	24301.59
EV_amount_ recharged	**32356583.28**	**3475.41**

Data under study and parameters of the proposed algorithm The data under study and the way the proposed algorithm is going to be collected is described in the following section. The selected data has to be closely monitored by fine-tuning of each algorithm to assist a superior result and minimize forecasting inaccuracy.

Stage – 3 : The Dataset of Study

The data applicable to this research is the historical data on the electricity demand of electric vehicles (EVs). The data is retrieved through a number of sources; 13 years of data 2007-2019. It provides typical hourly daily demand of charging per month in megawatts which proves handy in procedure of understanding the inclinations of EV energy consumption. The dataset is the minimum values of electricity consumption of EVs, per hour of one day of 13 years of 12 months. Based on this data, the average charging demand of EVs per hour is studied and presented in the form of a chart, seasonal separation provides an opportunity to study EV charging patterns under this or that weather conditions in greater detail.

The Assessment of the Suggested Model.

The data involved in this study is split into 10 percent testing and 90 percent training in order to give accurate model testing. The statistics will be done based on four seasons: January(Winter), April(Spring), July(Summer), and October(Autumn).

Evaluated Model from the Neural Network Algorithm (NN): A neural network with three layers (input, hidden, and output) is initialized with ten neurons in the hidden layer. Each neuron consists of inputs, weights, and bias values. are structured in a 2×1 matrix to enhance efficiency. The model is pre- trained, and retraining is performed only when necessary.

Evaluated Model from GRU Algorithm : Both LSTM and GRU networks are trained to predict EV charging demand. Each model has 200 hidden units and is trained using the Adam optimizer. Mean Squared Error (MSE) is used as a performance metric. Tuning parameters include the number of features, response variables, epochs, and gradient clipping to prevent gradients disappearing or exploding. The learning rate is optimized to balance training speed and accuracy.

Step 4: Simulation Results and Discussion

The GRU model is evaluated using a test dataset, and its forecasting performance is analyzed based on seasonal variations.

Results are compared using three key error metrics: Root Mean Square Error, Mean Absolute Error and Mean Absolute Percentage Error. These metrics provide insight into the accuracy and stability of the model.

Step 5: Performance Evaluation of GRU Model

The trained GRU model is applied to forecast electric vehicle charging demand for different seasonal conditions. Model performance is evaluated separately for winter, spring, summer and autumn. Results are visualized using a line plot comparing actual versus predicted charging demand over a 24-hour period

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Proposed Model

In this stage, the GRU model is fine-tuned by adjusting key hyperparameters such as the number of units, batch size, and learning rate. The optimal configuration is determined based on multiple experiments, ensuring improved accuracy in EV charging demand forecasting. Fig 4 shows the comparison of previous model and proposed model. The comparison between actual and predicted values, demonstrates the effectiveness of the proposed GRU-based forecasting approach.

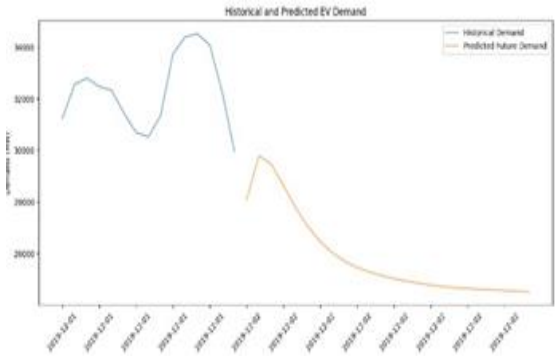


Figure. 4 comparison of previous and proposed system

Table. 2 Performance comparison

Feature	Historical demand	Predicted future demand
Trend	Fluctuating with peaks and dips	Smoothly declining
Peak Value (MW)	~34,000	~28,000
Lowest Value (MW)	~30,000	~24,500
Data Behavior	Naturally Variable	Smooth and Predictable
Continuity	Observed real-world behavior	Extrapolated model results

4. Results and Discussion

The performance of the GRU model is evaluated using Mean Squared Error - MSE and Mean Absolute Error - MAE, ensuring accurate demand estimation. The results shows that GRU model effectively generalizes the dataset, making it a suitable approach to forecast electricity demand in EV charging stations. Estimated prices closely follow actual demand trends, showing minimal deviation.

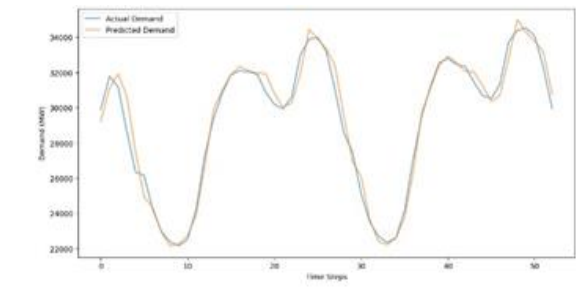


Figure. 5 Performance of Proposed Model

7. Conclusion

The This paper presents a GRU-based forecasting model for EV charging demand forecasting. The model effectively captures demand fluctuations with minimal deviation, ensuring reliable time-series forecasting. It achieves low MSE and MAE, demonstrating its accuracy in predicting short-term energy consumption. The proposed approach is suitable for smart grid management and EV charging infrastructure planning. Routing and charging optimization based on predicted energy demand Battery station integration for EV energy forecasting Location-based battery station with energy availability Battery station energy sharing system Vehicle-vehicle energy transfer Fault Detection and Monitoring Battery Consumption Tracking Developing a mobile app that directs drivers to the nearest available charging station based on predicted demand

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Copper Oxide Nanoparticles Synthesized by Precipitation Method Towards Biomedical Applications

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Abstract: Chemical processes to sustainable and eco- friendly techniques. Of these, green synthesis, also known as biosynthesis has been found to be a viable approach that exploits biological systems, and their biomolecular constituents, to create nanoparticles. It is not only the most environmentally friendly, but also presents unique operational capabilities such as cost-effectiveness, energy efficiency and just one-pot reactions at ambient temperatures. Green synthesis offers a safer and more eco-friendly solution by not requiring the utilization of dangerous reagents and the special conditions of the conventional processes. This review will give a critical summary of the principles of the green synthesis, and more specifically its mechanistic nature in biological and chemical pathways. They provide critical comparisons with the traditional methods and give an assessment of the sophisticated characterization tools that are needed to authenticate the structural, morphological, and functional characteristics of synthesized nanomaterials. Furthermore, some uses of green-synthesized nanoparticles are examined in the biomedicine, environmental cleanup, farming, and technologies in the energy sector. Existing issues such as scalability, reproducibility and mechanistic ambiguities are critically examined and possible ways of overcoming these challenges are presented. This body of evidence supports the case of green synthesis as not only an environmentally friendly alternative, but also as an extremely versatile and technologically better platform that can produce functionally improved nanomaterials to be used in industrial and biomedical innovations in the future. This paper discusses the synthesis of copper oxide nanoparticles (CuO NPs) with Carica papaya leaf extract as the reducing and stabilizing agents. Using the leaves in the precipitation technique, rapid production of CuO NPs was easily biosynthesized and pollution-free without any environmental harmful effects. X-ray diffraction (XRD), Fourier-transform infrared spectroscopy (FT-IR), and scanning electron microscopy (SEM) were used to determine the properties of the nanoparticles. The size of the particles measured using the Scherer equation showed that they were between 50- 60 nm in samples prepared through chemical precipitation. The manufactured CuO NPs had the right characteristics to be used in biomedical uses, which points to the possibility of green synthesis offering sustainable nanotechnology.
Keywords: Copper nanoparticles, Carica Papaya Leaves, Biosynthesis, Biomedical.

1. Introduction

Nanotechnology is a process that involves the production of particles in Nano range i.e. 1 to 100 nm. Their surface area is huge since the past decades have seen the technology of nanomaterials develop an impressive leap in the medical field due to the combination of biotechnology and nanotechnology, which is known as bio-nanotechnology with the target to be eco-friendly and biosynthetic technology. Green synthesis that aim at reduction of the use of dangerous chemicals. It is necessary

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to develop green nanotechnology that will help achieve sustainability. It involves the making of nanomaterials of natural bioactive material such as plant material, microorganisms and a wide variety of bio-wastes such as agricultural wastes, eggshells, vegetable wastes, and fruit peels among other organic wastes. It is to plan a sustainable environment, waste water degradation, waste reduction, recycling of the things, which are consumed by the developing society of the day to day life. There are three major methods of making nanoparticles, namely, physical, chemical, and biological. It is also referred to as green synthesis and among others, biosynthesis is less damaging to the environment, less costly and less toxic. Microorganisms and plant parts are typically both used as templates in biosynthetic pathways, and as reducing and capping agent. The prokaryotic bacteria along with the yeast and fungi are used as microorganisms in the process of biosynthesis. The usual techniques, which include chemical reduction, milling etc., most physical and chemical processes have been applied in the production of NPs synthesis at the beginning of the 20th century, and most of them are expensive and toxic chemicals, which cannot be considered an environmentally friendly process.

Nanoscience and nanotechnology refers to a field of study on matter that is manipulated at an atomic scale in regards to the manufacture, characterisation, discovery and/or exploitation of nanostructured materials to the benefit of man. One of the most active spheres of study of modern material science is nanotechnology; The preceding decades witnessed the arrival of a flock of scientists who show interest in metal oxide nanomaterials, and the latter have turned into a research niche in the recent past, as they are used in various applications during creation of magnetic data storage devices [5], fuel cell development [6], sensors [7], and in catalytic reactor development [8]. The manganese oxide nanoparticles are also imperatively used in various applications out of the metal oxide nanoparticles.

2. Related Work

Plant Extract Preparation

Copper nanoparticles were prepared using Carica papaya and neem leaf extract on the basis of its cost effectiveness, convenience of availability and its medicinal property. Fresh leaves were taken at my house. They were washed on the surface using running tap water to remove dust and other organic contaminated materials and then washed using the double distilled water and dried under room temperature. Approximately 15 gm of the well-cut leaves were stored in a beaker with 150 mL of double distilled water and they were boiled after 20 min. It was cooled, filtered using Whatman filter paper no.1 and extracted was stored at 3 C to be used further [3].

Copper oxide nanoparticles Biosynthesis

A clean and dry conical flask of 100 mL was taken and 50 mL of 0.2 M sodium hydroxide (NaOH) was added drop by drop using burette with constant stirring using magnetic stirrer under constant temperature of 60-70 degC. 2.5 M solution of cupric sulphate (CuSO45.H2O) 100 mL of the same was added to the conical flask and 50 mL of 0.2 M solution of sodium hydroxy The entire mixture of the solution was stirred in 1 hours' time to induce the precipitation of nanoparticles as it was established when the colour of the solution changed to brown. The beaker was centrifuged and the precipitate obtained. It was then dried at 50-60 degC followed by 3 hours in a muffle furnace at 450 degC to get the desired copper nanoparticles

Nanomaterials Production in a New Paradigm, Green Synthesis

Green Synthesis definition Green synthesis, or biosynthesis, or biological methods, is a radical shift in the production of nanomaterials. It is an environmentally friendly, natural and sustainable process, which utilises easy to obtain biodegradable and renewable resources as the main reducing and stabilizing agents. Such a method is based on the principal concepts of green chemistry where emphasis is placed on minimizing pollution and replacing the harmful elements with the less harmful ones.

The approach is fundamentally a bottom-up approach, where nanoparticles are synthesized on the basis of small molecules or atoms. It is generally a simple and one pot reaction in which a metal salt solution is combined with a natural bio-reductant extract and the resulting nanostructures are formed in a few minutes.

2.2. Critical comparison with the conventional methods :

The distinction between the green synthesis and the conventional methods is quite obvious, and this is the reason why so much attention is paid to the former. Not only is it an academic comparison, but it has far-reaching implications on the viability of industries, the ecological stewardship and production efficiency.

2.2.1. Environmental impact / health impact Conventional methods of synthesis The use of hazardous reagents and toxic solvents is traditionally linked to physical and chemical methods. One such way is by employing the traditional chemical synthesis in which rough reducing agents such as sodium borohydride, may be employed, which leave traces of toxins on the nanoparticles and it is hazardous to the human body. Additionally, the products of such reactions are also toxic and they must be disposed in involved and expensive disposal procedures.

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Aspect	Conventional Methods	Green Synthesis
Environmental Impact	High pollution; generates harmful byproducts.	Eco-friendly; biodegradable materials and minimal waste.
Cost	High; involves expensive chemicals and waste control.	Low; uses cheaper, natural materials.
Energy Consumption	High; often requires high temperatures and pressure.	Low; occurs at ambient conditions (room temperature).
Reagents Used	Toxic reducing agents (e.g., sodium borohydride), "hazardous reducing agents	Natural sources (e.g., plant extracts, microorganisms).
Biocompatibility	Low; potential for toxic residues and harmful effects.	High; naturally coated with biocompatible biomolecules.
Process Complexity	Often multi-step and complex (e.g., Sol-Gel).	Simple one-pot process.

Biological agents and their mechanistic functions

A panoply of biologic resources Green synthesis is based on a broad range of biologic materials where nanoparticle fabrication is conducted. The most frequently used resources include; Plants and plant extracts: Plants are favored because they are readily available, cheap and because of the high number of phytochemicals available. The extracts of various portions of the plant like leaves, roots, stems, bark, and fruit exocarp are used because, they contain a large amount of bioactive compounds which can be employed as effective reducing and stabilizing agents.

Microorganisms: It has also successfully been reported that microorganisms such as bacteria, fungi and yeast and algae should be used to synthesize various nanoparticle systems. The redox reactions that involve the use of enzymes such as nitrate reductase to reduce the metal ion to nanoparticles are the most crucial microbial redox ones.

Bio Waste: New highly viable trend that can be employed is agricultural and industrial biowaste. Recycling of the natural resources such as the peel or pod of Cajunus cajun (pigeon pea) not only provides a cheap solution of attaining the natural reduction agents, but also plays a role in controlling a significant issue affecting the world, that is, waste management, which introduces a circular economy.

Use of the phytochemicals to make nanoparticles

In these biological resources, the key to the green synthesis mechanism is the presence of such bioactive compounds - phytochemicals- as available bioactive compounds. It is these substances that reduce and stabilize the new nanoparticles, and metal ions.

Key Phytochemicals

The reducing and stabilizing agents of primary phytochemicals are:

Polyphenols: It is a broad category of chemicals and is characterized by one or more aromatic rings containing hydroxyl groups.

Terpenoids: A heterogeneous group of isoprene-based secondary metabolites. Most of the essential oils contain them and had diverse biological activities.

Proteins And Amino Acids: these biomolecules possess both amino and carboxyl groups and may even contain metal ions trapped and fixed and consequently deprotonate them.

Other Phytochemicals: Alkaloids and sugars are also additional phytochemicals which aid in the reduction of the metal ions.

Table.3 Common Characterization Techniques and Their Primary Purpose

Technique	Principle of Operation	Key Information Gained
UV-Vis	Surface Plasmon Resonance (SPR)	Confirmation of nanoparticle formation; particle size and concentration.
FTIR	Absorption of infrared radiation by molecular vibrations	Identification of functional groups of reducing/capping agents on the nanoparticle surface.
	Imaging with a	Surface morphology,

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SEM	focused electron beam	size, and size distribution.
TEM	Imaging with a transmitted electron beam	High-resolution morphology, size, internal structure, and lattice details.
XRD	X-ray scattering based on Bragg's Law	Crystalline structure, phase purity, and crystallite size.

Characterization Of Green-Synthesized Nanoparticles

Significance of characterization.

Once nanoparticles are successfully synthesized, it is significant to conduct an extensive characterization of the nanoparticles. It is done through a combination of analysis methods in order to ensure the composition of nanomaterials and examine their physical and chemical characteristics, size, shape, crystalline structure, surface morphology, and capping agents. The broad spectrum of this analysis provides the synthesized nanoparticles to fulfill the particular requirements needed in the applications that they are to be used and also enables the optimization of synthetic parameters.

Main spectroscopic and microscopic methods

Green-synthesized nanoparticles are thoroughly analyzed by a variety of complementary and advanced methods.

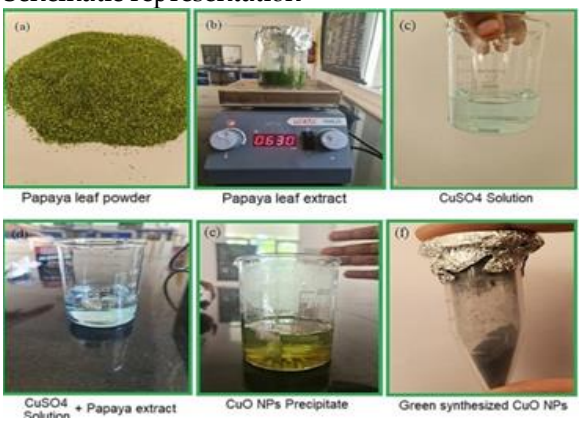
UV-Vis Spectroscopy: It is a simple method that is used to ascertain the composition of the metal nanoparticles. It operates on the principle of surface plasmon resonance (SPR) that can be found in metal NPs. The existence of an SPR peak at a given wavelength (ex: 400-480 nm in the case of silver nanoparticles) is a major indication of successful synthesis. The size, shape and concentration of the nanoparticles determine the wavelength and intensity of this peak.

FTIR (Fourier-Transform Infrared Spectroscopy): This type of Spectroscopic technique is essential to the determination of functional groups of biomolecules that are involved in the reduction of metal ions and capping of NPs. The formation of certain absorption bands is a direct indication of the successful binding of phytochemicals to the surface of nanoparticles, which proves the use on stabilizing agents.

SEM (Scanning Electron Microscopy) and TEM (Transmission El).

Approach for Synthesis of Nanomaterial:

bottom up and top down strategy.
sol-gel process
Chemical Vapour deposition
Thermally Activated CVD
Precipitation process
Calcination process
Schematic representation



Techniques that we are utilizing in order to locate characterization of nanoparticles

X-Ray diffraction (XRD)

X-ray diffraction (XRD) is a non-destructive technology, which utilizes the X-rays in a bid to determine the structure and the composition, of materials. It is used in the bulk of industries including pharmaceuticals and cars production.

XRD can be used to analyse:

- XRD can be used to analyse:
- Crystalline structure of materials.
- Material structure Chemical.

The mechanical properties of materials. The phase structure of materials.

- The orientation of crystals
- The dimensions of the units of materials.
- Nanoparticles crystallinity.

TEM analysis

The size, shape and morphology of nanoparticles have been identified by use of transmission electron microscopy (TEM). It shows that the silver nanoparticles are dispersed and mostly spherical in shape, Transmission electron microscopy (TEM) involves the use of an electron beam to create an image of the object - with high resolution - including its internal structure - on the nanoscale. TEM analysis finds extensive applications in such industries as materials science, microbiology, and nanotechnology.

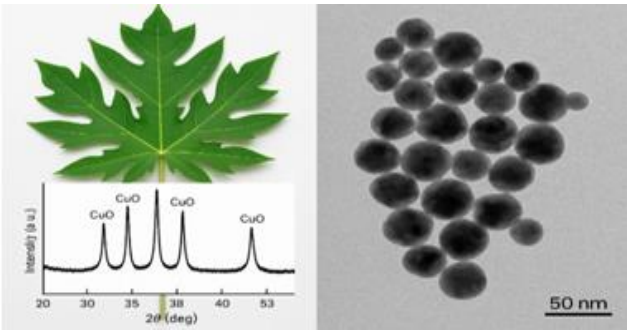
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SEM Analysis

SEM can be used to study the surface morphology (shape, size and arrangement) homogeneity and the grain size of the deposited film, which is the most versatile and most popular instrumental technique used to study the surface morphology and surface topology.

Analysis of XRD



Yes, the graph shown in the lower-left part of the image is a representative XRD (X-ray Diffraction) pattern.

It displays:

- Intensity on the y-axis and 2θ in degrees on the x-axis.
- Distinct peaks labelled as CuO, which are typical of copper oxide phases.

Environmental and Energy Programs

Table 4: Summary of Nanoparticle Applications by Sector

Sector	*Specific Application*	*Relevant Nanoparticles (NPs)*
Biomedical	Cancer therapy, antiviral treatments, targeted drug delivery	Gold (Au) NPs, Silver (Ag) NPs, Iron Oxide NPs
Environmental	Water treatment, dye degradation, oil spill clean-ups	Manganese Dioxide (MnO_2) NPs, Silver (Ag) NPs, Iron Oxide NPs
Energy	Lithium-ion batteries, supercapacitors, solar panels	Manganese Dioxide (MnO_2) NPs, Iron Oxide (Fe_3O_4) NPs
Agriculture	Nano-fertilizers, natural pesticides	Various metal NPs, Biogenic NPs
Other	Self-cleaning surfaces, biodegradable packaging, electronics	Various Metal NPs, Metal Oxide NPs

3. Conclusion

Green synthesis is an extreme and much needed change in the realm of nanotechnology. It is not only a greener solution compared to traditional methods, but a radical one that takes into consideration the problem of the environment with a multifaceted environment, economic and health concerns. It is a low-cost, low-energy use method, as well, to utilize the energy of natural biological systems to generate nanomaterials with an increased degree of functionality, specifically, in biocompatibility and stability. Despite the fact that the problems of scalability and reproducibility remain, the additional convergence of different areas of science and focus on the innovative answers will provide the approach to the next level of the sustainable and advanced production of nanomaterials. The uncouth and noteworthy applications mentioned in this review indicate that green synthesis has a colossal capacity of assisting in transforming humanity and the aviation industry to a more legitimate, well-being and sustainable future. These peaks confirm the crystalline character of the CuO nanoparticles that can easily be seen in the precipitation and green synthesis process like using papaya leaf extract.

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Conference Paper : Original – Classification Research – Qualitative Research Paper

Improved Multicarrier PWM Technique for Harmonic Reduction by Using APOD method for Cascaded H-bridge DC/AC Converters

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Abstract: Conventional modulation techniques used in cascaded H-bridge multilevel (CHB) DC/AC converters often spawn the noticeable quantity of harmonics of low frequency in an output voltage. The latter usually leads to a high-peak output current, impacting adversely on performance and reliability of industrial motor drive systems. To tackle these drawbacks, this research develops an improved Multicarrier Pulse-Width Modulation (MCPWM) method based on an alternative Phase Opposition Disposition (APOD) approach. A proposed MCPWM method significantly mitigates harmonic content in an output AC voltage by keeping the continuous output current with reduced peak magnitude. A harmonic mitigation algorithm is presented, which dynamically modifies switching frequency and modulation index of semiconductor devices based on a switching angles of a MCPWM pulse. An algorithm specially deals with a 5th, 7th and 11th-order harmonics and reveals a novel range of switching angles, at which their amplitudes become minimal. One of the significant achievements of this work is the development of a novel real-time switching angle estimation technique which avoids solving complex nonlinear equations. This approach reduces not only computation time but also hardware complexity, hence making medium-capacity FPG an implementation viable. A proposed technique is authenticated by theoretical analysis, MATLAB/Simulink simulations, and exploratory verification using the three-phase FPGA-based CHB multilevel inverter prototype. Comparative analysis against state-of-the-art techniques will reveal superior efficacy of a proposed technique in terms of harmonic suppression, computational efficiency, and hardware simplicity, thus making it a practical solution for industrial power electronics applications.
Keywords: Copper nanoparticles, Carica Papaya Leaves, Biosynthesis, Biomedical.

1. Introduction

MLIs increase a quality of output voltage by generating n distinct levels of output voltage, and thus they improve a voltage waveform by the factor of (n−1) [1]. Analogize to the conventional two-level VSIs with similar power ratings, MLIs have significant merits, including a lower THD of an output voltage, lower dv/dt stress on the switching devices, and lower EMI in an output voltage [2]. These advantages enable MLIs to be applied to the wide range of applications exists, from low-voltage and low-power systems [3], medium- and high-power industrial applications [4]–[5], photovoltaic grid-connected systems [6], [7], locomotive traction [8], and a variety of specialized power-electronics applications [9]. In general, MLIs can be grouped into three main topologies:

- Neutral Point Clamped (NPC) inverters [10],
- Flying Capacitor (FC) inverters [11], [12], and

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• Cascaded H-Bridge (CHB) inverters [13]–[26].

Among them, the CHB topology is of particular interest because of its intrinsic characteristics, such as modularity, easy scalability, and fault tolerance capability, which are of great concern in high-voltage and power applications. To further increase performance of CHB inverters, some advanced modulation techniques have been developed, including, but not limited to, an alternative Phase Opposition Disposition scheme. These techniques play a vital role in harmonic content suppression, voltage waveform quality improvement, and assuring an efficient operation of inverters, especially in industrial and high-power applications where power quality is an issue of concern.

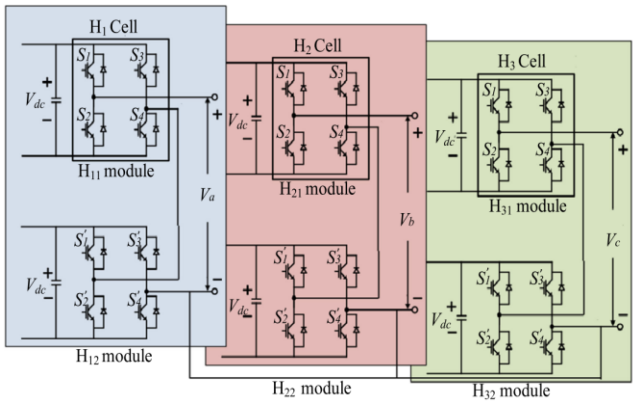


Figure. 1 Figure showing Three-Phase CHB-MLI

Among widely studied MLI topologies, Neutral Point Clamped and Flying Capacitor configurations pose certain limitations in phrase of component count and control convolution. A NPC topology requires the significant number of diodes and capacitors, and hence a more intricate control strategy has to be implemented for achieving higher output voltage levels [25]. Alternatively, although FC topology uses a comparable number of active components, it requires a larger number of capacitors and thus increases the overall system volume and complexity. By contrast, an n-level CHB inverter consists of multiple identical low voltage H-bridge modules with separate DC power supplies, connected in cascaded configurations to synthesize the stepped output voltage waveform having n levels, as shown in Fig. 1. This topology has the following unique advantages compared to NPC and FC topologies:

Modular and scalable design allows for easy expansions through adding H-bridge modules [14]. Compatibility with soft-switching techniques, enabling use in both high- and low-voltage applications [3],[4]. Reduced electromagnetic interference (EMI) through lower dv/dt stress on semiconductor switches [2]. Flexible output level generation, where additional modules directly increase a number of output voltage levels [17]. A variety of pulse-width modulation strategies have been developed for the purpose of optimizing the performance of MLIs. These methods can generally be categorized as offline and online methods [15] or carrier-based and carrier-less techniques [16], [17]. The conventional carrier-based PWM methodology involves the comparison of a sinusoidal reference waveform with a high-frequency triangular carrier signal in order to obtain the switching signals. This method, though conventionally used because of its simplicity for industrial drive applications, creates low-frequency harmonic content, especially at high MI and higher switching frequencies [27].Among carrier-based PWM methods, an alternative Phase Opposition Disposition (APOD) technique is frequently employed in CHB inverters. In this scheme, the adjacent carrier waveforms are phase-shifted alternately by 180°, enhancing harmonic cancellation and lowering THD in an output voltage. Compared to the other strategies such as Phase Disposition (PD) and Phase Opposition Disposition (POD), APOD can achieve superior harmonic performance while maintaining a relatively simple implementation, making it very suitable for modular and scalable CHB configurations.

The SVPWM is a more advanced modulation technique for MLIs. It allows for direct control of the phase voltages and line-to-line voltages and provides the possibility to use the redundancy in the switching states and the voltage vectors to minimize common-mode voltages. It is increasingly applied in power electronics due to its capacity to enhance voltage utilization and harmonic performance. The generalized 2D and 3D SVPWM algorithms for n-level inverters are shown in [18]. These generally involves a process of nearest voltage vectors selection, dwell times calculation and sequencing of switching transitions. However, the SVPWM real-time implementation is computationally challenging due to its extensive computational resource requirement and determination of switching angles.

The MCPWM technique has so far remained the conventional approach for controlling an AC output of CHB inverters [22]. It relies on n−1 triangular carrier signals dispersed in voltage bands between and, where Vdc is a DC input voltage. An APOD setup, when adopted for implementation of MCPWM, improves harmonic dispersion while successfully cancelling some of the low-order harmonics. These harmonics might include a fifth, seventh, and eleventh orders that conventional MCPWM methods are not capable of completely eliminating [25]–[29]. In turn, several harmonic mitigation approaches have recently been presented. The mathematical formulation for suppressing nontriplen harmonics was first presented in [25], while in [27], one FPGA-based HDSPWM method was developed for yielding high-resolution PWM signals with minimum EMI. This approach minimizes power losses while maintaining a high quality

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output, therefore having the potential to further improve the conventional MCPWM schemes. During recent years, many methods have been proposed to reduce harmonic content in the inverter output waveforms [16], [19]–[25]. In medium-voltage and high-power drive applications, both the switching losses and EMI need to be reduced. Soft-switching PWM methods that have recently gained widespread acceptance for this purpose include SHE and SHM methods [25]. A nonlinear equation is solved in these methods in order to obtain the optimal switching angles that eliminate or mitigate particular harmonic orders. In [20] and [24], various SHE-PWM models were analyzed, including a new method for reducing the circulating currents in modular MLIs based on (n+1) SHE-PWM, by setting a modulation index across inverter arms. While effective, such methods are plagued by the computational burden of solution of nonlinear equations in real time. Other approaches, such as an use of Groebner bases and symmetric polynomials for switching angle determination [23], also face similar obstacles in implementation complexity. In this paper control technique with improved MCPWM is presented for the five-level CHB VSI. A proposed method focuses on:

- Smoothing a 5th, 7th, and 11th-order harmonics from a phase output voltage,
- Ensuring ripple-free output current,
- Improving general power quality of an inverter.

Instead of dealing with complicated nonlinear sets of equations, one method uses the set of low-order equations to estimate fundamental voltage amplitude for variable switching angles. This enables the identification of the domain of switching angle that minimizes the targeted harmonics without incurring high computational costs. The algorithm has been implemented in an APOD-based multicarrier PWM framework to achieve robust harmonic performance for diversified operating conditions. The simulated results are also in close agreement with the theoretical predictions, hence confirming the effectiveness of the proposed approach for industrial and high-performance applications.

2. Mathematical Analysis of APOD SPWM

In this section, the mathematical analysis of an alternative Phase Opposition Disposition (APOD) Sinusoidal Pulse Width Modulation (SPWM) technique will be developed. This includes the derivation of equations of a carrier signal, modulating signal, a switching condition, a phase shift in an APOD method, and an output waveform generated by a modulation technique.

Carrier Signal Representation

The triangular or sawtooth waveform is generally the carrier signal in SPWM techniques. In an APOD SPWM method, these carriers are modulated with specific phase shifts to produce a smoother output waveform with reduced harmonic content.

Triangular Carrier Signal:

For a k-th carrier, the triangular carrier signal, Ck(t), in an APOD technique can be represented as:

$$C_k(t) = A_c \cdot \text{sign}\left(\sin\left(2\pi f_c t + \phi_k\right)\right)$$

Where:

- Ac is an amplitude of a carrier,
- fc is a frequency of a carrier, which is commonly much higher than the frequency of a modulating signal,
- ϕk is a phase shift applied to a k-th carrier,
- t is time.

The **sign** function outputs the waveform that alternates between +Ac and −Ac, creating a triangular shape.

Carrier Phase Shift:

The carriers in APOD are phase-shifted to create phase opposition. A phase shifts alternate between consecutive carriers to produce the symmetric waveform. For a k-th carrier, a phase shift is given by:

$$\phi_k = \pm\frac{k\pi}{N}$$

Where:

- N is a total number of carriers (which depends on a number of levels in an inverter),
- k is an index of a carrier signal, which ranges from 1 to N.

Thus, for the 5-level inverter with 5 carriers, a phase shifts would be alternated as:

$$\phi_1 = 0^\circ,$$
$$\phi_2 = +\tfrac{\pi}{5},$$
$$\phi_3 = -\tfrac{\pi}{5},$$
$$\phi_4 = +\tfrac{2\pi}{5},$$
$$\phi_5 = -\tfrac{2\pi}{5}.$$

This results in the set of carriers with alternating phase shifts that are oppositely phased with respect to one another.

Reference Signal Representation

The **reference signal**, also known as a **modulating signal**, is typically the **sinusoidal waveform** that determines a desired output voltage. A modulating signal is contrast with a carrier signals to generate a PWM signal. A modulating signal M(t) can be expressed as:

$$M(t) = A_m \cdot \sin(2\pi f_m t)$$

Where:

- A_m is an amplitude of a modulating signal (typically determined by a desired output voltage),
- f_m is a frequency of a modulating signal (which is a

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desired output frequency of an inverter),
- t is time.

The amplitude and frequency of a modulating signal control a characteristics of an output waveform, with a modulating signal essentially shaping an envelope of an output.

Switching Condition for APOD SPWM

The switching condition for an APOD SPWM technique determines a moments when an inverter switches between different voltage levels. In a standard SPWM technique, a switching points occur when a modulating signal intersects a carrier signal. Similarly, in APOD SPWM, a switching points are determined by an intersections between a phase-shifted carriers and a modulating signal.

Condition for Switching:

A switching event occurs whenever a modulating signal M(t) intersects a carrier signal Ck(t). Mathematically, this is represented as:

$$M(t) = C_k(t)$$

Substituting an expressions for M(t) and Ck(t):

$$A_m \cdot \sin(2\pi f_m t) = A_c \cdot \text{sign}\left(\sin\left(2\pi f_c t + \phi_k\right)\right)$$

This equation represents a condition for an inverter to switch from one voltage level to another.

Analysis of Intersections:

- The intersections occur when a modulating sine wave intersects a triangular carrier wave at specific instants in time. A phase shift ϕk changes a location of these intersections for each carrier signal.
- For example, if a modulating signal intersects a carrier at the specific time t1, an inverter will switch to the particular voltage level corresponding to a carrier signal's state at that time.

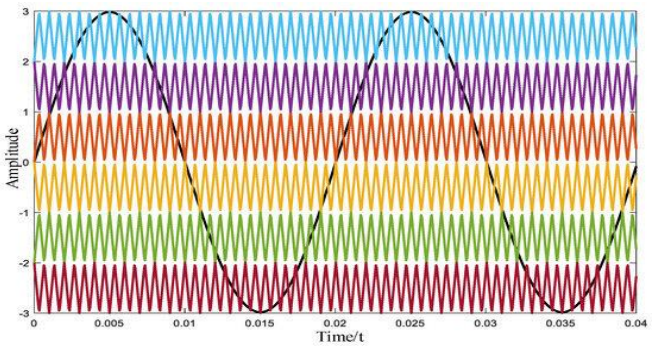


Figure 2. Carrier and modulation of APOD MC PWM waveform with 1 kHz frequency

Carrier Phase Shift in APOD

The **carrier phase shift** is a key feature of an APOD method that distinguishes it from other modulation techniques. By alternating a phase shifts of a carriers, an APOD method aims to **spread a harmonic content** over the broader range of frequencies, thereby reducing low-order harmonic distortion.

Derivation of a Phase Shift:

The phase shift for a k-th carrier in an APOD method can be expressed as:

$$\phi_k = \pm\frac{k\pi}{N}$$

Where k is an index of a carrier, ranging from 1 to N, and N is a number of carriers used for modulation (which is typically equal to a number of levels in an inverter).

For eg, for the 5-level inverter (N=5):

Carrier 1 has a phase shift of $\phi_1 = 0°$,

Carrier 2 has a phase shift of $\phi_2 = +\frac{\pi}{5}$,

Carrier 3 has a phase shift of $\phi_3 = -\frac{\pi}{5}$,

Carrier 4 has a phase shift of $\phi_4 = +\frac{2\pi}{5}$,

Carrier 5 has a phase shift of $\phi_5 = -\frac{2\pi}{5}$.

This alternating phase shift ensures that a **carrier signals are oppositely phased**, thus reducing harmonic content by spreading a switching events across the wider frequency range. A result is the smoother, more sinusoidal output waveform with lower total harmonic distortion (THD).

V. Proposed CHB Multilevel Inverters

Proposed three-phase seven-level inverter topology

The proposed seven-level three-phase inverter architecture is composed of two key sections. A **first section** is the three-phase full-bridge inverter, referred as a **main circuit**. A **second section**, known as an a**uxiliary circuit**, includes **two asymmetrical half-bridge sub circuits per phase**, as illustrated in **Fig. 1**.

The auxiliary circuit utilizes DC voltage sources of **E** and **2E**, while a main inverter operates with the DC input of **−3E**. A role of a main circuit is to produce a negative voltage levels, enabling an inverter to output **bipolar phase voltages** without requiring the polarity-inverting bridge in an auxiliary circuit. As the result, each auxiliary cell is composed of only **two switching devices**, enhancing a design's simplicity and efficiency.

The inverter system requires the total of **18 IGBTs** and **7 separate DC sources**. By accurately managing a switching states in each phase, an output voltages V_a, V_b, and V_c can be synthesized accordingly. These output phase voltages are derived as follows:

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} S_{a1} & S_{a2} & S_{a3} \\ S_{b1} & S_{b2} & S_{b3} \\ S_{c1} & S_{c2} & S_{c3} \end{bmatrix} \times \begin{bmatrix} 1 \\ 2 \\ -3 \end{bmatrix} E$$

where Sx1,Sx2, and Sx3 are a switching states of a main

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circuit and two auxiliary stages for phase ∀x=a,b,c, respectively, such that;

$$S_{xi} = \begin{cases} 1 & if\ the\ switch\ S_{xi}\ is\ on \\ 0 & if\ the\ switch\ S_{xi}\ is\ of \end{cases} \quad (\forall\ i = 1, 2, 3)$$

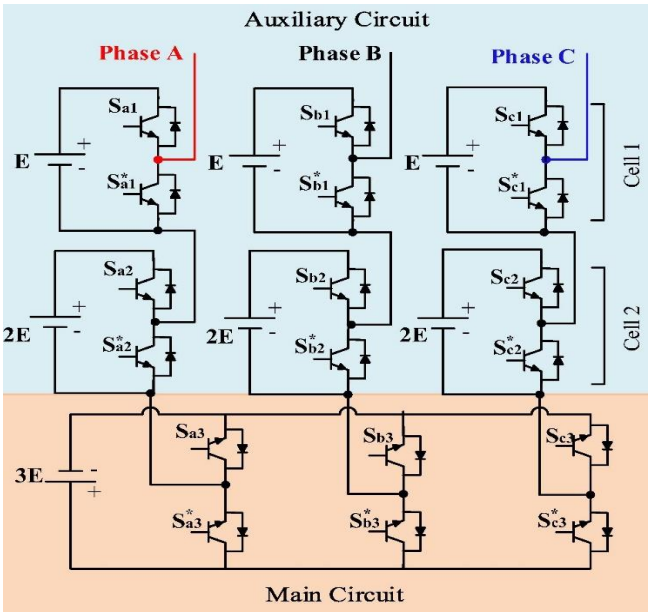


Figure. 2 Schematic figure of a proposed multilevel inverter configuration

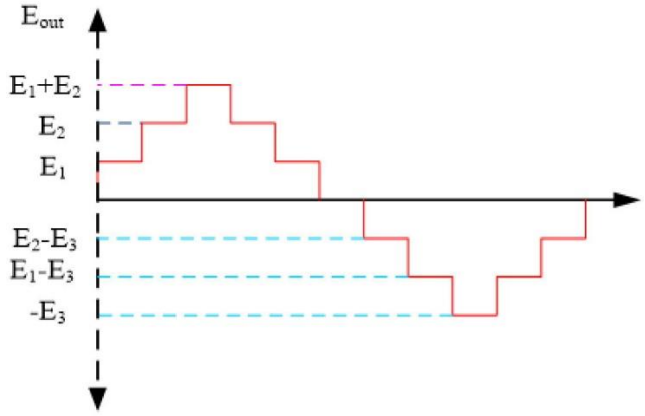


Figure. 3 Output voltage levels

The proposed configuration is simpler, cost-effective, and better suited for efficient switching strategies. A switching sequence required to produce a three-phase output voltages for a 7-level inverter is discussed in a next section. As shown in Fig. 1, a structure of a proposed inverter consists of individual cells, each formed by connecting the DC bus voltage across two IGBT switches operating in the complementary manner. An applied DC voltage is used to increase a number of output voltage levels. Furthermore, a number of output phases can be expanded, as illustrated in Fig. 3.

Table 2 presents switching patterns for phases A, B, and C, utilizing six switches and three independent DC sources per phase. This arrangement effectively generates the seven-level output voltage waveform.

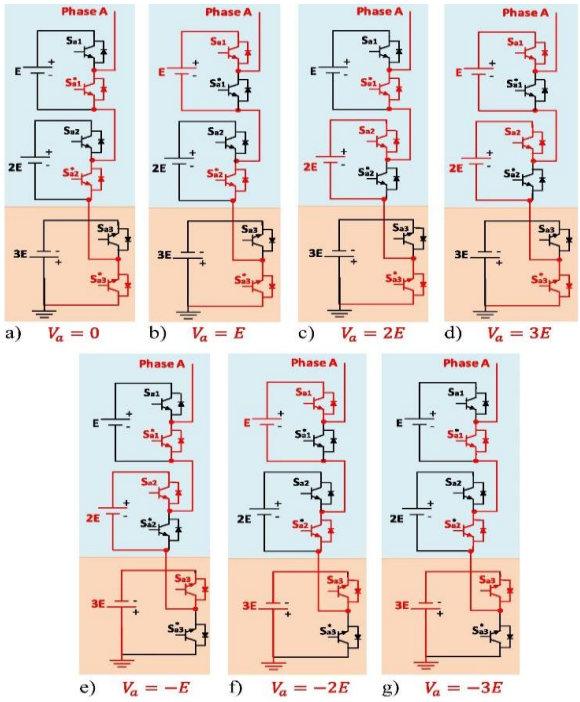


Figure. 4 Switching sequence for Phase the of a proposed 7-level inverter

Principle of Operation of a Proposed MLI

This section details a generation process for a three-phase 7-level output voltage waveform, as illustrated in **Fig. 2**. To achieve the symmetrical three-phase output, a switching sequences for each phase are identical but shifted by 120° (2π/3 radians). Therefore, an operation of an inverter is demonstrated using only Phase A, as other phases follow a same sequence with appropriate phase shifts.

Figure.3 illustrates a seven distinct switching states responsible for producing a corresponding output levels in Phase A. A red paths in a diagram indicate a current conduction routes for each switching state. As shown, a positive voltage levels are produced using an auxiliary cells, while a negative voltage levels are derived either entirely from a main circuit or through the combination of both a main and auxiliary circuits.
A detailed list of a switching states that generate a seven voltage levels for Phase the is provided in

Table. 1 Switching table for phase A

	auxiliary cell 1		auxiliary cell 2		main circuit		
state	S_{a1}	S^*_{a1}	S_{a2}	S^*_{a2}	S_{a3}	S^*_{a3}	V_a
1	0	1	0	1	0	1	0
	1	0	1	0	1	0	
2	1	0	0	1	0	1	+E
3	0	1	1	0	0	1	+2E
4	1	0	1	0	0	1	+3E
5	0	1	1	0	1	0	−E
6	1	0	0	1	1	0	−2E
7	0	1	0	1	1	0	−3E

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Modular Operation of a Proposed MLI

The proposed three-phase MLI has the modular design that allows scalability and flexibility. The modularity permits a system to be extended by connecting the conventional three-phase full-bridge inverter in series with j unsymmetrical half-bridge auxiliary cells per phase. Each auxiliary cell operates with its own independent DC source, supplied at distinct voltage levels.

The DC voltage level for every auxiliary cell i can be defined by the following relationship:

$$V_{dc(i)} = 2^{i-1}E \quad \forall(i = 1, 2, \dots j)$$

Here, **E** denotes a voltage corresponding to the single level. A DC voltage of a main three-phase full-bridge inverter, denoted as $\mathbf{V_{dcm}}$, must be equal to a negative sum of a DC voltage levels of all an auxiliary cells. This ensures proper voltage balancing and facilitates a generation of symmetric bipolar output waveforms.

$$V_{dc(m)} = \sum_{i=1}^{j} -\left(2^{i-1}E\right)$$

The main circuit DC voltage level is negative due to its principal responsibility of providing negative output voltage levels. In this topology, the maximum phase output voltage is determined by the sum of the DC voltage levels fed to the auxiliary cells. Thus, n, as the maximum number of output phase voltage levels, can be derived from the total number of auxiliary cells by the following relation:

$$n = \frac{\sum_{i=1}^{j}\left(2^{i-1}E\right)}{E} = \sum_{i=1}^{j} 2^{i-1}$$

As the result, a highest number of output **line voltage** levels, denoted by mmm, can be determined using a following expression;

$$m = 2n + 1 = 1 + \sum_{i=1}^{j} 2^{i} = 2^{j+1} - 1$$

Therefore, in order to increase the number of voltage levels in an output, the number of auxiliary cells has to be increased correspondingly. However, adding one more auxiliary cell will result in adding six power switches and three isolated DC sources in each phase, as can be seen from Fig. 3. Thus, the overall number of power switches (N_s N_s N_s) and isolated DC sources (N_p s N_{p s} N_p s) can be presented by the number of auxiliary cells as:;

$$N_s = 6(j + 1)$$

By substituting Equation (6) into Equations (7) and (8), an expressions for a number of power switches and isolated DC supplies can be reformulated as functions of a number of line voltage levels per pole, as shown below;

$$N_s = \frac{6\ln(m+1)}{\ln 2}$$

$$N_{Ps} = \frac{3\ln(m+1)}{\ln 2} - 2$$

These relationships are valuable for evaluating a proposed three-phase MLI against other multilevel inverter topologies. Additionally, a proposed inverter design can be scaled into the multi-phase MLI by incorporating additional legs into an existing three-phase configuration.

3. Mathematical Derivation of THD in APOD SPWM

3.1 Harmonic Analysis in APOD SPWM

To evaluate a harmonic distortion in an alternative Phase Opposition Disposition (APOD) sinusoidal PWM technique, an individual harmonic components must first be identified. Once these components are known, a Total Harmonic Distortion (THD) can be computed to assess waveform quality.

Influence of Carrier Arrangement on THD

In APOD SPWM, an arrangement of carrier signals—specifically their number and phase displacement—has the significant effect on THD. Increasing the number of carriers makes a waveform more similar to a pure sinusoidal signal, hence decreasing harmonic distortion. The lower the number of carriers or voltage levels, the coarser an approximation of a sinusoidal waveform will be, which tends to raise THD.

3.2. Switching Frequency Optimization Concept

Optimization of the switching frequency means adjustment of an inverter's switching frequency with the view of having a desirable harmonic profile. A switching frequency defines the speed at which an inverter toggles between voltage levels.

The harmonic performance will improve by optimizing f_s, resulting in a cleaner output signal. Generally speaking, higher switching frequencies reduce harmonic distortion because they allow for finer modulation of an output voltage, making it more closely resemble the sine wave.

However, this improvement comes at a cost: higher switching losses and reduced system efficiency. An optimum balance has to be maintained, therefore. Mathematical Model for Switching Frequency Optimization

Switching frequency f_s can be dynamically adjusted based on certain system requirements such as load conditions or target waveform fidelity. An optimization goal can be in the minimization of THD by fine-tuning a switching frequency. This can be mathematically represented by a following objective function:

$$\min_{f_s} \text{THD}(f_s)$$

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Where:

- **THD(f_s)** denotes a Total Harmonic Distortion as the function of switching frequency.
- **f_s** is a variable switching frequency.

This optimization framework seeks a frequency value that offers a lowest possible THD while also managing a trade-off with switching losses. A result is the more efficient and higher-quality inverter output suitable for practical applications.

4. Adaptive Modulation and Phase Shifting

4.1. Adaptive Modulation Index

SPWM modulation index mmm is defined as the ratio between the peak amplitude of the modulating signal Am and the peak amplitude of the carrier signal Ac:

$$m = \frac{A_m}{A_c}$$

The width of the pulses generated by the PWM technique will be determined by the modulation index; a high value of the latter increases the width of the pulses, and vice versa. In systems with adaptive modulation, a modulation index can be dynamically adjusted based on load variations or real-time feedback of harmonic distortion. When a load varies, a modulation index is adjusted to optimize an output waveform and reduce harmonic distortion.

Table. 2 Comparison Analysi

4.2. Phase Shifting for Harmonic Mitigation

In addition to modulation index adjustment, adaptive phase shifting can be employed to further reduce harmonic distortion. Phase shifting refers to a process of adjusting a relative phase of a carrier signals to minimize harmonic content. During APOD SPWM, the carrier signals are phase-shifted to create opposite phases in order to reduce low-order harmonics.

Mathematically, a phase shift ϕk for a k-th carrier can be adjusted as the function of a load:

$$\phi_k(t) = \pm\frac{k\pi}{N} + \Delta\phi(t)$$

Where:

Δϕ(t) is a dynamic phase shift adjustment based on load conditions,
\tN is a number of carriers,
\tk is an index of a carrier.

This dynamic phase shifting ensures that a harmonic content remains minimal across varying loads, improving overall inverter performance.

5. Mathematical Representation of APOD SPWM

In an APOD SPWM technique, a **carrier signals** are triangular waves, and they are phase-shifted in such the way that a phase displacement between adjacent carriers is 180°. Mathematically, a carrier signals for the **5-level inverter** can be expressed as:

$$C_i(t) = A \cdot \text{triangle}\left(f_c t + \Phi_i\right), \quad \Phi_i = 180^\circ \times (i-1) \quad \text{for} \quad i = 1, 2, 3, \ldots, N$$

where:

Ci(t) is an i-th carrier signal,
an is an amplitude of a carrier signal,
fc is a carrier frequency,
Φi is a phase shift applied to each carrier signal,
N is a number of carriers.

Feature	Carrier-Based PWM	SVM	APOD SPWM
Simplicity	Simple to implement	Complex, requires vector calculation	Moderate complexity, requires phase shifting
Harmonic Mitigation	Moderate, harmonics concentrated at low frequencies	Excellent, reduces harmonics significantly	Good, reduces low-order harmonics effectively
Voltage Quality	Poor in high levels, better in lower levels	Excellent, higher voltage utilization	Very good, smoother output with reduced THD
Efficiency	Moderate, losses due to harmonic content	High, due to better voltage utilization	High, improved by reduced harmonic distortion
Application	Low- to medium-power inverters	High-power, high-efficiency inverters	Suitable for medium- to high-power systems

The modulating sine wave is compared against these carrier signals, and a switching points are determined when a modulating signal intersects a carrier wave. This modulation technique results in reduced harmonic distortion and smoother voltage waveforms, which help mitigate issues like torque ripple and high-peak output current. APOD **SPWM vs. Carrier-Based PWM vs. SVM:**

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6. Results

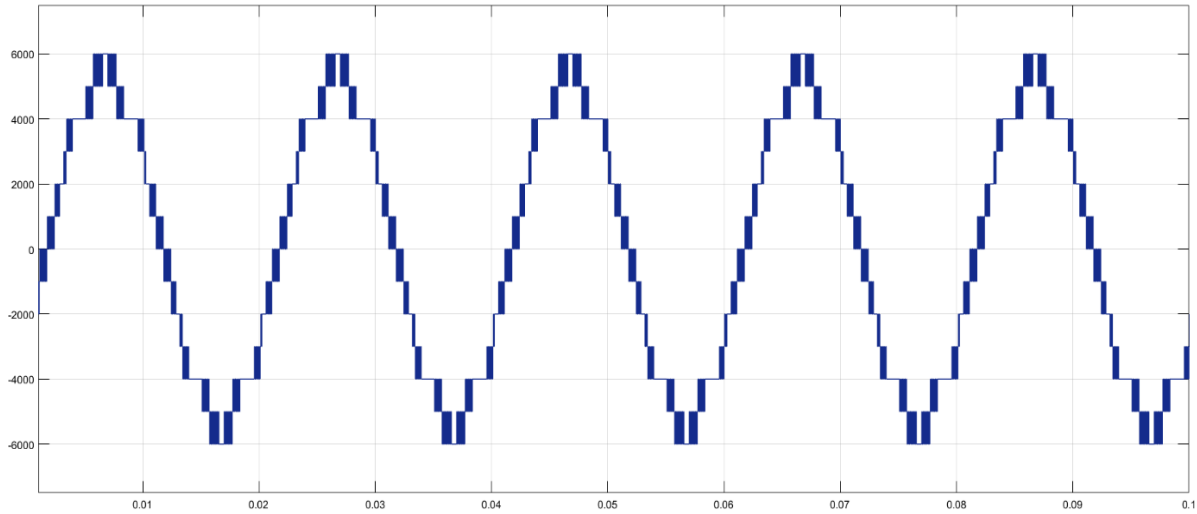


Figure. 5 13 level output voltage of a proposed converter

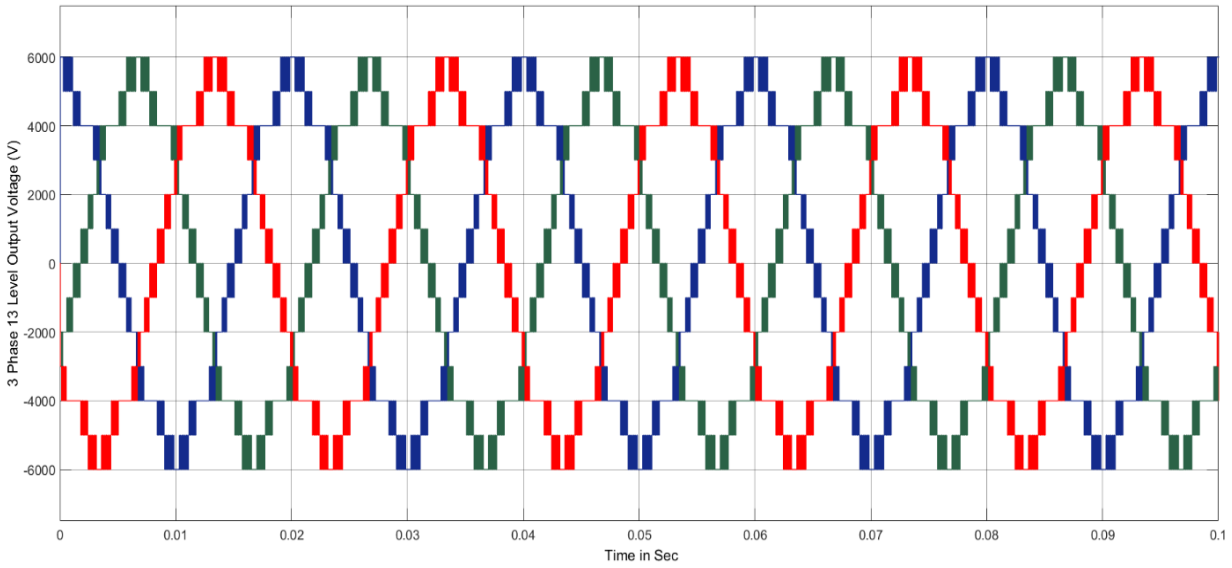


Figure. 6 3 phase 13 level output voltage of a proposed converter with APOD SPWM

Fourier Series for APOD SPWM Output:

The output voltage Vout(t) of an APOD-modulated inverter is the sum of sinusoidal components with different frequencies. As mentioned, we can represent it as:

$$V_{\text{out}}(t) = V_1 \cdot \sin(2\pi f_m t) + \sum_{n=2}^{\infty} V_n \cdot \sin(2\pi n f_m t + \theta_n)$$

Where:

- V1 is an amplitude to fundamental frequency,
- Vn is an amplitude to n-th harmonic,
- fm is a frequency to modulating signal,
- θn is a phase shift to n-th harmonic.

4.3 Calculation to THD:

Once an amplitudes to a harmonic components are known, we can calculate a **Total Harmonic Distortion (THD)** as:

$$\text{THD} = \frac{\sqrt{\sum_{n=2}^{N} V_n^2}}{V_1}$$

Where:

- V1 is an amplitude to a fundamental component,
- Vn is an amplitude to a n-th harmonic component,
- N is a highest harmonic to consider (usually limited to the finite number to harmonics based on system specifications).

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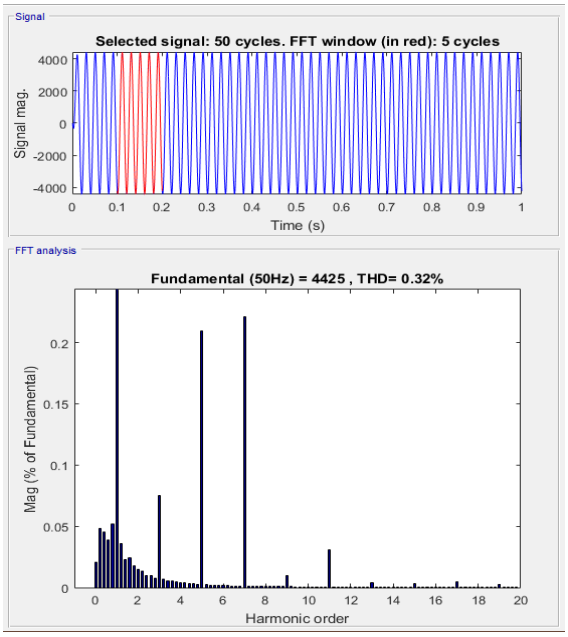


Figure. 7 THD % to a 3 phase 13 level output voltage to a proposed converter with APOD SPWM

7. Conclusion

Cascaded H-Bridge (CHB) inverters, due to their multi-level topology, offer significant advantages in high-power and high-voltage applications by reducing voltage stress on switching components and improving system efficiency. However, they can introduce challenges such as low-frequency harmonic distortion and discontinuous high-peak current, which can negatively impact a performance to industrial motor drive systems. These issues can result in torque ripple, reduced motor efficiency, and increased wear and tear on a motor, ultimately affecting system reliability and operational costs. The integration to Alternative Phase Opposition Disposition (APOD) Sinusoidal Pulse Width Modulation (SPWM) serves as an effective solution to these challenges. By applying phase opposition between a carrier signals, APOD SPWM helps to distribute a harmonic content across higher frequencies and reduce an amplitude to low-frequency harmonics, which are primarily responsible for torque ripple and current discontinuities.

This modulation technique significantly improves an output voltage waveform, leading to the smoother current profile, reduced torque ripple, and enhanced motor performance. Moreover, the application to APOD SPWM in Cascaded H-Bridge inverter reduces harmonic distortion and at the same time optimizes overall system efficiency, hence becoming the highly beneficial approach in motor drive systems. In this way, one will ensure not only more stable operation and longer motor life but also higher energy efficiency, increasing overall reliability for industrial applications.

In conclusion, whereas the basic CHB inverters present several challenges in motor drive systems, the adoption of advanced modulation techniques like APOD SPWM can considerably raise their performance and offer a robust solution for harmonic mitigation and improved power quality. Industry demands for high-performance motor drives and energy-efficient solutions continue to increase, and thus a combination of CHB inverters and APOD SPWM will most probably be an increasingly popular choice to achieve optimal motor control with efficient system operation.

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Conference Paper : Original – Classification Research – Qualitative Research Paper

Modelling and Analysis of Renewable Energy Integration and Electric Vehicle Impact on Microgrid Performance: The PSO-Based MPPT and ANFIS-Controlled Battery Approach

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Abstract: The rapid rise in pollution levels and green house gas emissions has accelerated an adoption of Electrical Vehicles (EVs), which are expected to play the pivotal role in a future energy landscape. As EVs integrate with electrical grids, their impact on voltage profiles and grid load distribution becomes increasingly significant. This study explores an integration of renewable energy sources, EVs into the microgrid and with the emphasis on energy production and consumption optimization. In this analysis, the diesel generator is a microgrid, Photovoltaic (PV) array coupled with the wind farm and the Vehicle-to-Grid system near a load. A paper introduces the model for a PV array that employs Maximum Power Point Tracking (MPPT) through Particle Swarm Optimization (PSO) to maximize an efficiency of a solar energy conversion. Furthermore, it investigates battery control using Adaptive Neuro-Fuzzy Inference System (ANFIS) to manage a storage and distribution of energy from both renewable sources and EVs. A microgrid is designed to cater to an energy demands of various establishments, including hospitals, universities, and EV charging stations. The comprehensive analysis of a micro grid's performance, with the particular focus on effects of EV integration, is presented using MATLAB/Simulink, revealing an influence of EVs on an overall network stability and energy management.
Keywords: ANFOIS, V2G, EV Vehicles, MATLAB , PSO.

1. Introduction

Transport industry contributes approximately 25 percent of the energy-related emissions, making up a large share of global greenhouse gas emissions. In order to address this issue, electrical vehicles (EVs) have emerged as the viable solution. They are classified as clean and environmentally friendly due to their lack of tailpipe emissions. Several nations are actively promoting an adoption of EVs through incentives and regulations, aiming to foster their widespread integration into a market. However, a growing adoption of EVs is expected to have the an electrical grid. If EV charging remains unregulated, it could lead to increased peak electricity demand, causing grid instability, power losses, and equipment overloads. On an other hand, controlled charging and an use of EVs as distributed energy resources, especially using Vehicle-to-Grid (V2G) technology, could have significant benefits. V2G allows EVs to not only draw power from a grid (Grid-to-Vehicle, G2V) but also discharge energy back into a grid, supporting grid stability, frequency regulation and peak load shaving. The introduction of renewable energy sources (solar and wind energy) into a microgrid, coupled with an adoption of EVs, further enhances a potential

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benefits. The microgrid consisting of the diesel generator, the PV array, the wind farm, and V2G technology can provide the sustainable and reliable power supply to various establishments, such as hospitals, universities, and EV charging stations. an application of Maximum Power Point Tracking through Particle Swarm
Optimization for a PV array and an use of Adaptive Neuro-Fuzzy Inference System for battery control are critical for optimizing energy efficiency and ensuring effective energy storage and distribution.

EVs are categorized into three types: Battery electric vehicle, Hybrid electric vehicle and fuel cell electric vehicles (FCEVs), each contributing to reducing reliance on fossil fuels. Despite concerns about battery life, recent advancements have addressed many of challenges, making EVs the promising alternative to conventional Internal Combustion Engine (ICE) vehicles. A primary challenges associated with V2G technology include managing erratic travel patterns and an optimization of charging schedules to minimize battery wear while maximizing an efficiency of an eV fleet. Additionally, V2G provides an opportunity to enhance a resilience and stability of an electrical grid by balancing loads and integrating renewable energy sources, ultimately helping to flatten an overall load profile and reduce environmental pollution.

This paper uses MATLab/Simulink to model and analyze microgrids, including the integration of renewable energy sources and electric vehicles. We concentrate on how grid performance and operating costs are affected by EV charging patterns, battery efficiency, and V2G technology.

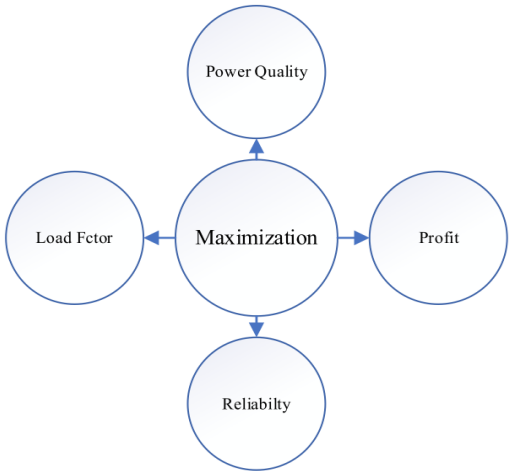


Figure. 1 Maximization objective functions of electrical vehicle integration into a distribution system

Our goal in conducting this analysis is to investigate how EVs can function as decentralized power generation sources that minimize their environmental impact while supporting load balancing and grid stability of both transportation and electricity supply systems.

Standard Charging (Model)

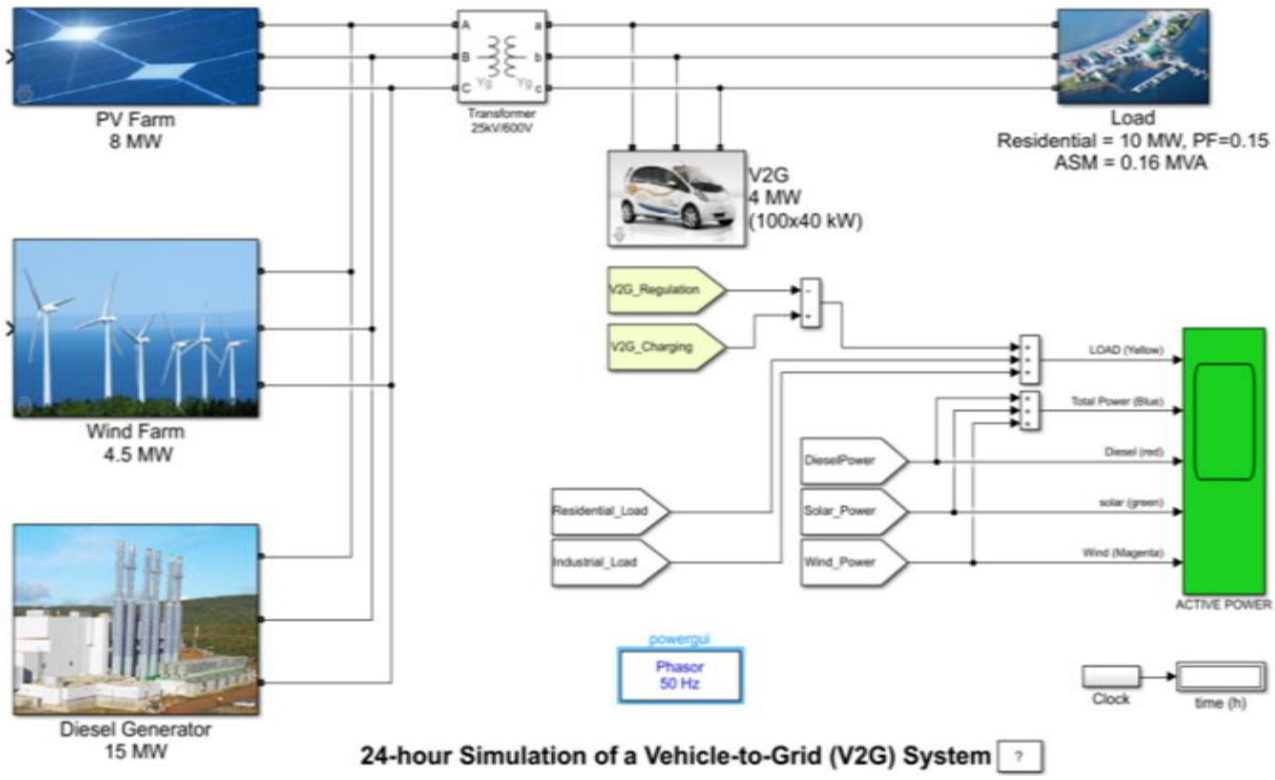


Figure. 2 Microgrid and electrical vehicles

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Microgrid systems rely on a precise management of fundamental quantities like current and voltage and are represented by sinusoidal waveforms at 50 Hz frequency.

2. Photovoltaic System with Particle Swarm Optimization for Maximum Power Point Tracking

Photovoltaic systems are the key component in renewable energy generation. They convert sunlight into electrical energy through solar cells. However, the power output of a PV systems is not constant and varies depending on several factors such as sunlight intensity, temperature and an angle of incidence. The efficiency of a PV system can be maximized by operating at a **maximum power point,** which is a point at which a system produces a highest power output. To track this point dynamically, the **maximum power point tracking** technique is employed. Although many MPPT methods exist, one of the successful one is an application of particle swarm

optimization, which is the heuristic optimization algorithm based on a social behavior of the birds flocking or fish schooling. PSO has been proven to be an efficient method for MPPT in PV systems due to its simplicity, fast convergence, and ability to deal with non-linearities and local maxima.

Maximum Power Point Tracking

MPPT denotes a technique employed in the ongoing pursuit of a maximum power point on the power and voltage graph of the PV module. This method is crucial because it ensures the PV system functions at peak performance, particularly when environmental conditions are variable. The power and voltage characteristics of the PV module usually exhibit a single peak referred to as the MPP. The voltage at this point is referred to as Maximum Power Voltage (Vmp), while the current is termed Maximum Power Current (Imp).

The PV output power depends on various factors:

- **Solar irradiance**: More sunlight results in higher power output.
- **Temperature**: Higher temperatures decrease an efficiency of a PV cells.
- **Shading and dirt**: Partial shading can create multiple peaks on a power curve, making MPPT challenging.

To efficiently track a **MPP**, a system must adjust its operating voltage to match optimal conditions for power generation.

2. Particle Swarm Optimization

Particle swarm optimization is a computation style that is analogous to animal social dynamics of a flock of birds or a school of fish. PSO has been employed in MPPT to vary the operating point of a PV system to maximize power output**.**

How PSO Works:

Initialization: The group of particles symbolizing a possible solution is set up with random locations and speeds within a search area, like the voltage range for a PV system.

Assessment: for each particle, a fitness function is assessed, which, in the context of MPPT, is the power generated by the PV module at that specific operating voltage.

Velocity and Position Adjustment: Each particle adjusts its velocity and position based on its past experiences and the experiences of its neighbours the best solutions discovered until now using an update rule defined by:

$$v_i(t+1) = wv_i(t) + c_1r_1(p_{best} - x_i) + c_2r_2(g_{best} - x_i)$$

Where:

$v_i(t+1)$ is a velocity of particle iii at time t+1.
w is an inertia weight that controls an exploration and exploitation of a search space.
c_1 and c_2 are a cognitive and social coefficients, respectively, which influence a particle's tendency to explore its own experience or that of a swarm.
r_1 and r_2 are random numbers between 0 and 1.
pbest is a personal best position of particle iii.
gbest is a global best position found by a swarm.
x_i is a current position (voltage) of particle iii.

Convergence: Over time, a swarm converges toward a **maximum power point** by iteratively adjusting a particle positions and velocities.

Wind Energy: Harnessing a Power of Wind for Renewable Energy Generation

One of the most well-known forms of renewable energy is wind. It is an eco-friendly, sustainable, and renewable energy source that can significantly reduce carbon emissions and dependency on fossil fuels. Wind energy is harnessed through wind turbines that transform the kinetic energy of the wind into mechanical energy, subsequently converting it into electricity.

A rising demand for renewable energy, together with increasing worries about climate change, has resulted in a growth in the utilization of wind energy as a key component of the global energy mix.

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Wind Energy Conversion Process

To understand an energy production and efficiency of the wind turbine system, several key mathematical formulas and calculations are used. These include a calculation of **power output** from wind energy, **capacity factor**, and **efficiency** of a turbine. Below are a most commonly used mathematical models for wind energy.

Wind Power Calculation

The power obtained by wind turbine is determined with the help of the formula below:

$$P = \frac{1}{2}\rho A v^3$$

Where,

P = output power (W)

ϱ = Air density (kg/m³) ≈ 1.225 kg/m³ at sea level

A = Area swept by the turbine (m²) $A=\pi r^2$, with r representing the radius of the wind turbine blades.

v = Wind speed (m/s)

This equation is based on the kinetic energy of air through turbine blades. A cube of wind speed is linked with a power.

Power Coefficient

In the wind, a turbine is not able to harness all the energy. The Power Coefficient (Cp) of the wind turbine is used to determine its efficiency taking into account the constraints of the turbine design and the Betz Limit (that the optimum energy that can be harnessed in the wind turbine is 59.3%).

$$P_{turbine} = \frac{1}{2}\rho A v^3 \cdot C_p$$

Where,

$P_{turbine}$ = Power extracted by the turbine (W)

C_p = Power coefficient (usually ranges from 0.3 to 0.5 for conventional wind turbines)

The value of Cp is typically less than 1, and a Betz Limit states that Cp can never exceed 0.593

Energy Output over Time

To calculate a total energy produced by the wind turbine for the given period, we use a following formula:

$$E = P_{turbine} \times t$$

Where:

E = Energy output (Wh or kWh)

$P_{turbine}$ = Power extracted by a turbine (W)

t = Time (hours)

This gives an energy produced by a turbine in kilowatt-hours or watt-hours for the specified time period.

Capacity Factor

The primary metric that characterizes a wind turbine's actual energy production in relation to its theoretical maximum output is the capacity factor (CF). It is the measure of how effectively the turbine operates over time.

$$CF = \frac{E_{actual}}{E_{max}} \times 100$$

Where:

- E_{actual}= Actual energy production during the duration (kWh).
- E_{max}= Maximum possible energy output if a turbine operated at full capacity all a time (kWh).

Capacity factors change according to the wind conditions, however, the standard range of onshore wind turbines is between 20 percent and 40 percent, while offshore wind turbines may have the higher capacity factor (up to 50%).

Tip Speed Ratio

The ratio between the velocity of a blade tip and that of the wind is referred to as tip speed ratio. It is a significant consider in the design of wind turbines, as this affects power efficiency.

$$TSR = \frac{r \cdot \omega}{v}$$

Where:

- r = Radius of a turbine blades (m).
- ω = Angular speed of a rotor (rad/s).
- v = Wind velocity (m/s).

A higher TSR denotes more efficient operation at high wind speeds, and a typical TSR for optimal wind turbine efficiency is between 6 and 10.

Wind Turbine Efficiency

The efficiency of the wind turbine is generally is calculated using the ratio of energy extracted from a wind to energy available in a wind.

$$\eta = \frac{P_{turbine}}{P_{wind}} \times 100$$

Where:

η = Efficiency (%)

$P_{turbine}$ = Power extracted by a turbine (W)

P_{wind} = Power available in a wind (W)

Most commonly, the maximum efficiency is limited by the Betz Limit that no wind turbine is allowed to collect over 59.3% of the energy in the wind.

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Sizing Wind Turbines and Energy Generation

To determine the wind turbine's appropriate size for the specific site, it is frequently essential to compute the annual energy output based on the turbine's power curve and average wind speed. The turbine power curve illustrates how much power a turbine produces at various wind speeds. An estimate can be made by:

$$P(v) = P_{rated} \times \left(\frac{v}{v_{rated}}\right)^{k} \quad \text{for} \quad v < v_{rated}$$

Where:

P(v) = Power output at wind speed v

P_{rated} = Rated power of a turbine at v_{rated}

v_{rated} = Rated wind speed (typically 12–15 m/s)

k = Empirical coefficient for a turbine (typically between 2 and 3)

The annual energy production (AEP) is then calculated as:

$$AEP = \sum_{i=1}^{n} P(v_i) \times \Delta t$$

Where:

v_i is a wind speed at time iii,

Δ_t is a time interval,

n is a number of time intervals.

This calculation bears an overall amount of electricity produced by a wind turbine over the year, taking into account the varying wind speeds.

Wind Energy Cost Calculations

An important economic metric for assessing the cost of generating electricity with wind turbines is the levelized cost of energy. The price by which energy should be sold so that the project can attain a break-even point and to cover the initial investment, operation and maintenance costs.

The equation for LCOE is:

$$LCOE = \frac{\sum_{t=1}^{N} (C_t + O_t)}{\sum_{t=1}^{N} E_t}$$

Where:

- C_t = Capital costs in year t.
- O_t = Operating and maintenance costs in year t.
- E_t = Energy produced in year t.
- N = Project lifetime (commonly 20–25 years).

LCOE helps in comparing wind energy with other energies. Sources on the basis of cost-efficiency. It is these mathematical formulas that give the explanation behind Understanding how wind turbine generates energy, their efficiency, and the amount of energy they can generate over a period of time. These calculations are highly significant in knowing and using wind optimization. Wind energy technologies, energy systems, determining the feasibility of the project, and comparing a performance of various turbine designs.

Diesel Energy

In a context of the diesel generator or power plant, a Following key calculations are used in obtaining an energy output, fuel consumption, and efficiency of a system. Diesel generators have an extensive usage in backup power applications, off-grid power generation, and distributed energy systems owing to their reliability. and relatively simple operation. Below are major mathematical formulas used in calculating diesel energy production and efficiency?

Diesel Generator Output

The output of the diesel generator depends on on an engine's rated power. A power produced given by the diesel engine is usually expressed in kilowatts (kW) and it can be computed using the formula:

$$P = \frac{T \times N}{9549}$$

Where:

P = Power output of a diesel engine (kW).

T = Torque produced by an engine (Nm).

N = Rotational speed of an engine (RPM).

Alternatively, power output is often rated directly by a manufacturer and expressed as kW or kVA (kilovolt-amperes).

Fuel Consumption Calculation

The fuel consumption of the diesel generator depends on its fuel consumption rate, which is usually provided by a manufacturer. It is commonly given in terms of liters per kilowatt-hour (L/kWh). A fuel consumption can be estimated using the following formula:

$$\text{Fuel Consumption} = \text{Power Output} \times \text{Fuel Consumption Rate}$$

Where:

Fuel Consumption = Fuel consumed (liters per hour, L/h)

Power Output = Power produced by a diesel engine (kW)

Fuel Consumption Rate = a fuel consumption rate in liters per kWh (L/kWh)

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For example, if a fuel consumption rate of a generator is 0.2 L/kWh, and a generator is producing 10 kW, the fuel consumption would be:

$$\text{Fuel Consumption} = 10\,\text{kW} \times 0.2\,\text{L/kWh} = 2\,\text{L/h}$$

Thus, a generator would consume 2 liters of diesel fuel every hour of operation.

Diesel Generator Efficiency

The efficiency of the diesel generator is a ratio of a Mechanical power produced by an engine to an Energy content of a fuel consumed. It can be calculated as:

$$\eta = \frac{P_{out}}{P_{fuel}} \times 100$$

Where:

η = Efficiency of a diesel generator (%)

P_{out} = Power output of a diesel engine (kW)

P_{fuel} = Power content of a fuel (kW)

To calculate Pfuel, you need to know an energy content of a diesel fuel (in kWh per liter or kWh per gallon). Diesel typically has an energy content of about 35.8 MJ/L (megajoules per liter) or approximately 9.94 kWh/L.

$$P_{fuel} = \text{Fuel Consumption (L/h)} \times \text{Energy Content (kWh/L)}$$

For instance, if a diesel consumption is 2 L/h and an energy content is 9.94 kWh/L, a power content from a fuel would be:

$$P_{fuel} = 2\,\text{L/h} \times 9.94\,\text{kWh/L} = 19.88\,\text{kWh}$$

The efficiency can then be calculated by dividing a power output by a fuel power:

$$\eta = \frac{10\,\text{kW}}{19.88\,\text{kW}} \times 100 = 50.37\%$$

So a diesel generator's efficiency is approximately 50.37%.

Diesel Fuel Cost Calculation

To estimate a cost of a fuel required for the diesel generator, we use a following formula:

$$\text{Fuel Cost} = \text{Fuel Consumption} \times \text{Fuel Price}$$

Where:

Fuel Cost = Cost of a fuel consumed (in local currency, e.g., USD)

Fuel Consumption = Amount of fuel consumed (liters per hour, L/h)

Fuel Price = Price of a fuel per liter (currency per liter)

For example, if a generator consumes 2 liters of diesel per hour and a price of diesel is $1.2 per liter, a cost of fuel per hour would be:

Total Energy Produced by the Diesel Generator over Time

To calculate a total energy produced over the given period, we multiply a power output by an operating time:

$$E = P \times t$$

Where:

E = Total energy generated (kWh)

P = Output power of a diesel generator (kW)

t = Duration of the operation (hours)

For example, when the diesel generator operates at 10 W for 5 hours results in a total energy output of :

$$E = 10\,\text{kW} \times 5\,\text{hours} = 50\,\text{kWh}$$

ANFIS Based Battery Controller

The Adaptive Nero-Fuzzy Inference System is an advanced control method that integrates Neural Networks and Fuzzy Logic to provide the powerful solution for battery control systems. ANFIS is particularly effective in situations in which traditional mathematical models are difficult to apply, and it excels in learning from data and adapting to various system dynamics. In battery control, ANFIS can optimize charging and discharging processes, extending battery life. Improvement of performance while ensuring efficiency of a system.

Overview of Battery Management System

A battery management system is used to guarantee that the battery is used in a safe and efficient way. The primary roles of the BMS consist of:

- Observing a battery's charge level, health status, and temperature.
- Control the charge/discharge process in order to
- prevent overcharge or deep discharge, which could worsen the performance of a battery or even damage it.
- Balancing a cells to ensure uniform voltage levels
- across all cells.
- Improving the efficiency and lifespan of a battery.

To achieve this, the BMS requires intelligent algorithms that adjust a control parameters based on real-time feedback from a system..

Battery Control Using ANFIS

ANFIS is the hybrid model in which a neural network and

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fuzzy logic systems. It is well-suited for battery management systems because it can handle uncertainties, nonlinearities, and vagueness in system behaviour. Here's how ANFIS can be used for battery control:

Control Process with ANFIS

ANFIS Training:

- Control Process with ANFIS the ANFIS model can be trained using either historical data or simulation data, where a system learns to associate an input with a desired output. A training process adjusts a fuzzy membership functions, enhancing a system's accuracy in predicting and controlling a charging/discharging actions.
- The training process involves minimizing the cost function, which measures an error between a predicted and actual battery conditions.

Output: an output of an ANFIS system is the control action that is sent to a Battery Management System to regulate a battery's charging or discharging. A control action can be:

- Adjusting a charging current or voltage.
- Adjusting a load applied to a battery.
- Deciding when to switch between charging and discharging modes.

The fuzzy system can output values like:

- Charging Current: "High", "Medium", "Low"
- Discharge Current: "High", "Moderate", "Low"
- State of Charge (SOC): Maintaining an optimal SOC range.

ANFIS Structure for Battery Control

The basic structure of an ANFIS system involves multiple layers:

Layer 1 (Fuzzification Layer):

- Each node in this layer represents the fuzzy membership function for each input (SOC, voltage, temperature, and load).
- The outputs of this layer are membership degrees that represent how much an input belongs to the particular fuzzy set.

Layer 2 (Rule Layer):

- Each node represents the fuzzy rule (e.g., "IF SOC is Low AND Load is heavy THEN Charging Rate is high").
- The output is a firing strength of a rule, which is a product of a membership values.

Layer 3 (Normalization Layer):

- This layer normalizes firing strengths of rules to ensure that outputs are within an appropriate range.

Layer 4 (Defuzzification Layer):

In this layer, the outputs of fuzzy rules are aggregated according to their firing strengths. A result is the weighted mean that signifies a system's control operation.

Layer 5 (Output Layer):

- This layer produces a final output of a system, which is a control action (e.g., charging current, discharging rate).

Application Example: Battery Charging Control Using ANFIS

In the solar PV-based energy storage system, an ANFIS-based battery control system can be used to regulate a charging of batteries from a PV array. an inputs to an ANFIS might be:

- The solar power generation (related to sunlight intensity),
- The battery SOC,
- The battery voltage,
- The ambient temperature.

The output of an ANFIS system could be the control action that decides an optimal charging rate for a battery, ensuring that a battery charges efficiently without overcharging, and maintaining a SOC in a desired range.

ANFIS is the powerful tool for controlling battery systems, especially in cases where battery behaviour is complex and nonlinear. By combining fuzzy logic's ability to handle uncertainty with learning capabilities of neural networks, ANFIS can optimize a charging and discharging process, improve battery life, and enhance an overall performance of energy storage systems.

RESULTS

Power Generation Profile

The power output of the generator varies throughout a day based on a load demand, environmental conditions, and an operating cycle of a generator. To analyze a electricity produced by the diesel generator or any generator over the course of a day, we typically need to consider several factors including operational hours, load profile, fuel consumption, efficiency, and environmental factors (i.e. temperature, humidity, etc.).

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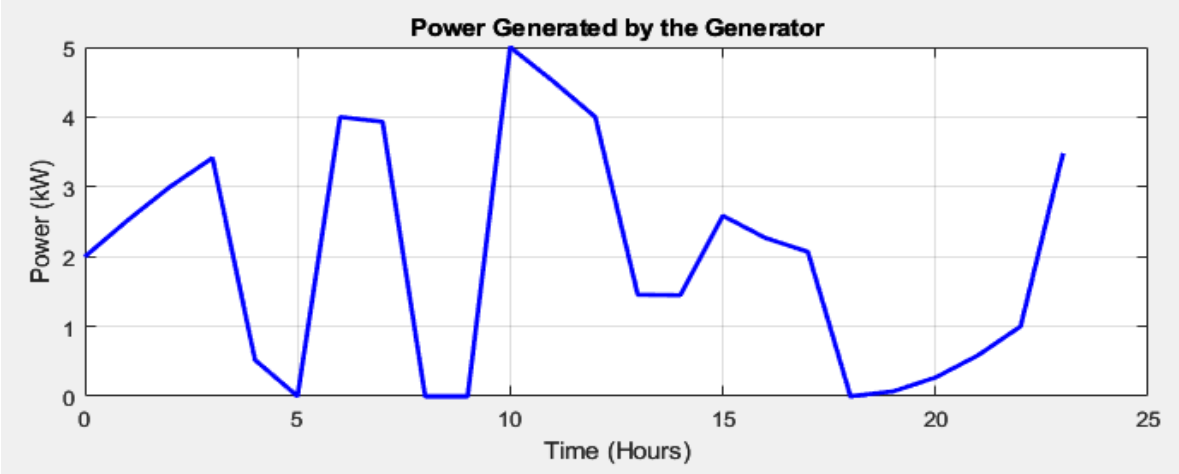


Figure. 3 A generators daily output of electricity

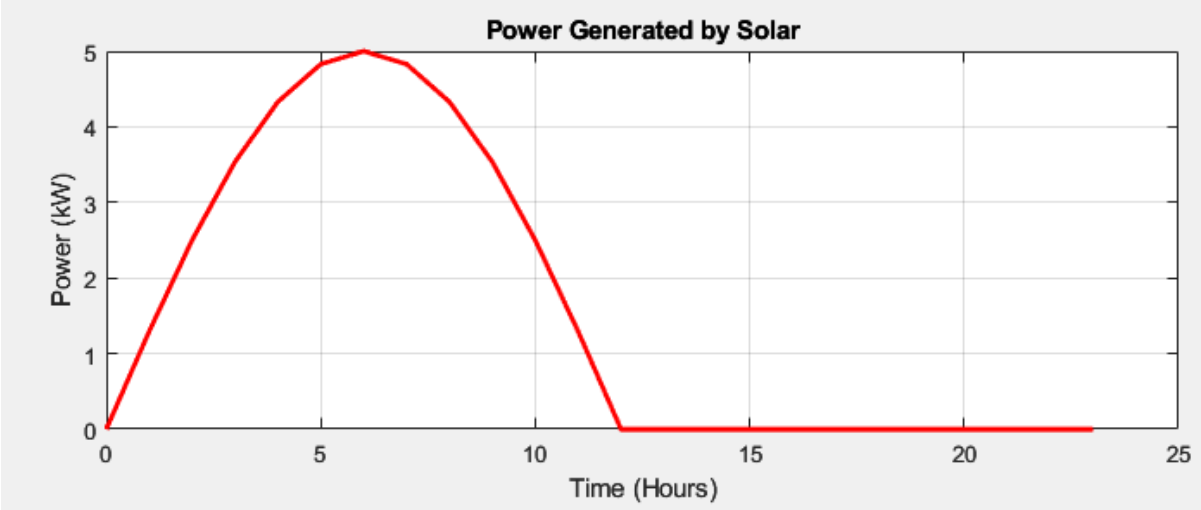


Figure. 4 Solar energy produced over the course of the day

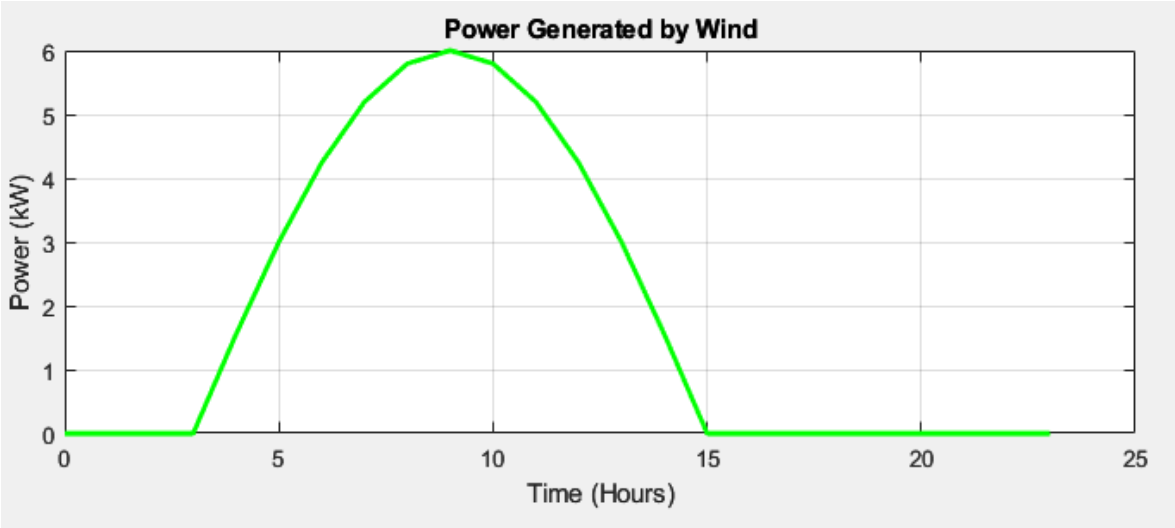


Figure. 5 Wind-generated energy throughout the day

The swift expansion of Electric Vehicles (EVs) has led to the significant increase in power demand, adding extra strain on a microgrid. This rise in demand also amplifies variability within a grid. To balance electricity consumption with generation, a diesel generator in a microgrid plays the key role. Discrepancies in grid frequency can be detected by comparing a rotor speed of a synchronous machine. Figure 4 shows a total energy output from a diesel generator throughout a day. However, diesel generators come with major drawbacks, including high costs and harmful

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environmental effects. Despite these disadvantages, diesel generators remain necessary when renewable energy sources are unable to meet a required energy demand. A microgrid relies on two renewable energy sources:

Figure 5 illustrates a daily energy production from a solar panels, where an use of PSO for MPPT ensures that a maximum possible energy is harvested from a solar radiation available, even under fluctuating environmental conditions. By optimizing a performance of a PV system, PSO helps enhance an overall efficiency and reliability of a microgrid.

Wind Farm: a wind farm generates electricity proportional to a wind speed. Turbines reach their maximum power output once a wind speed exceeds the specified threshold. If a wind speed exceeds this limit, a wind power generation is deactivated until a wind returns to optimal conditions. Figure 6 shows a daily energy output of a wind farm within a microgrid.

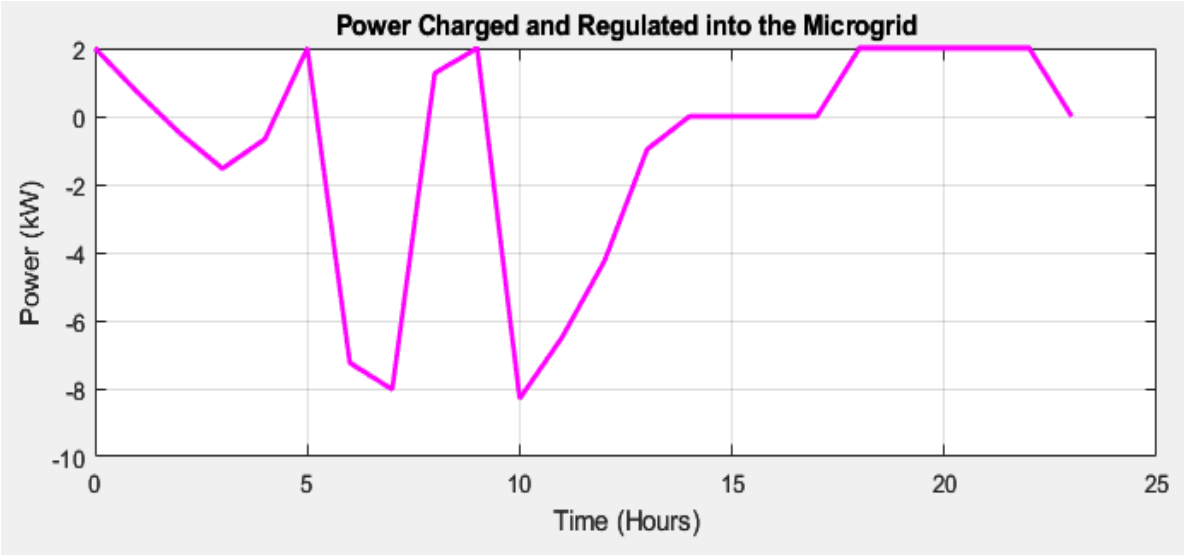


Figure. 6 Charged and regulated into a microgrid throughout a day

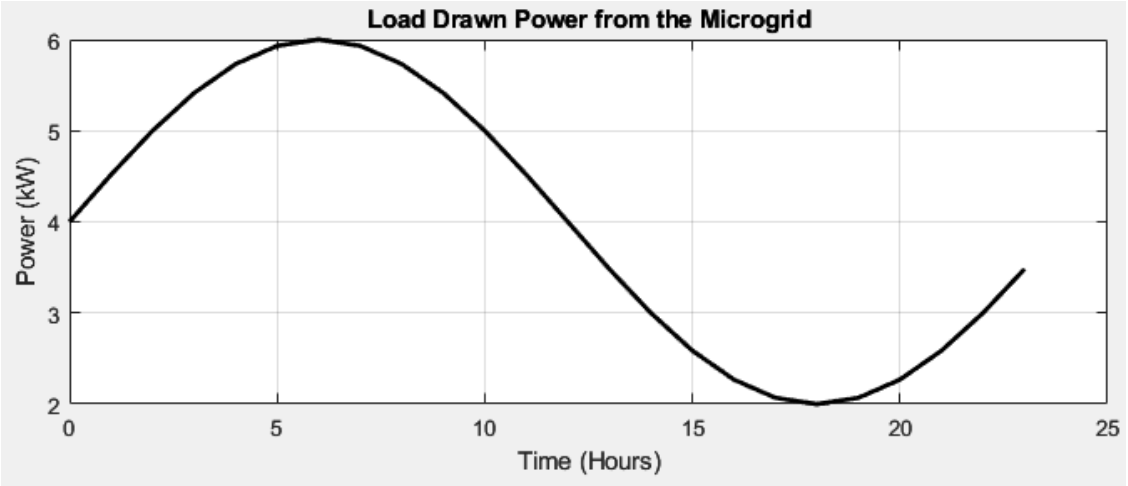


Figure. 7 Load drawn power from a microgrid during a day

The integration of wind energy facilities in microgrids is consistently rising because of their sustainable characteristics, straightforward design, and great efficiency. Unlike traditional power plants, wind farms offer unique characteristics that make them an appealing energy source for microgrids. Similarly, Electric Vehicles (EVs) provide the significant advantage due to their ability to support Vehicle-to-Grid (V2G) applications, the feature unique to electric cars. V2G enables EVs to directly supply electricity back to a distribution microgrid, contributing to grid stability. Figure 7 illustrates a power transmitted and regulated by an eV to a microgrid throughout a day.

V2G refers to a process by which EVs transfer stored electrical energy from their batteries back into a microgrid. A battery in these vehicles act as energy storage systems, and Car-to-Grid (C2G) technology enables a controlled charging and discharging of an eV battery based on various factors, such as energy demand or supply signals.

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However, as a number of EVs being charged increases, an electrical demand per transformer also rises, particularly during peak consumption periods in a microgrid. This can pose challenges in maintaining an energy balance within a system [16].

When multiple EVs are charged simultaneously within a same phase, phase imbalances can occur in a microgrid. Spontaneous and uncoordinated charging of numerous EVs introduces several issues, including voltage drops at chargers' connectors. Additionally, a high active power draw during simultaneous EV charging can result in power losses, further destabilizing a microgrid.

To address these challenges, an Adaptive Neuro-Fuzzy Inference System (ANFIS) controller can be implemented. an ANFIS controller optimizes a charging and discharging cycles of EV batteries based on real-time grid conditions and energy demands [17].

By dynamically adjusting a charging rates and coordinating a load distribution, an ANFIS controller ensures that a microgrid remains balanced, preventing phase imbalances, voltage drops, and power losses. This intelligent control mechanism helps to maintain an overall stability and efficiency of a microgrid, even during periods of high EV charging.

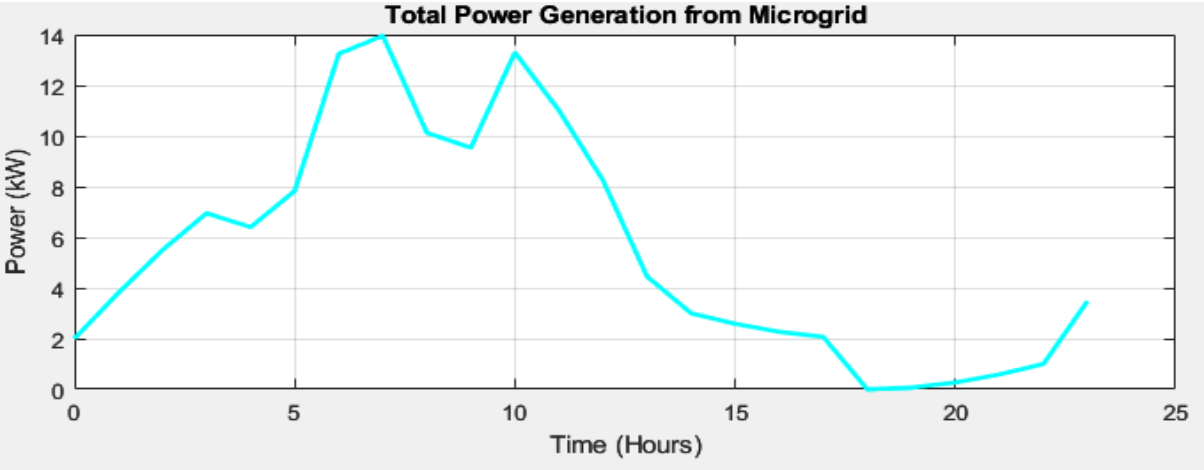


Figure. 8 Total power generation from micro grid during a day

V2G technology, in conjunction with an Adaptive Neuro-Fuzzy Inference System (ANFIS), serves two main purposes: managing battery charge and utilizing an available power to stabilize a grid during transient events. ANFIS enhances an efficiency of V2G systems by providing an adaptive and intelligent control mechanism, allowing for dynamic optimization of energy storage and distribution. This ensures that current decentralized energy storage systems are readily available and efficiently managed. Various battery types are available in a market, and ANFIS can be used to optimize their performance based on real-time grid conditions.

The residential load is represented by an active power drawn at the specified power factor, as shown in Figure 8. With ANFIS, a charging and discharging cycles of EV batteries are precisely controlled to align with a grid's demand. A total power generated by a microgrid is represented by an active power produced, and this power must be equal to or exceed a load. an ANFIS controller ensures that a balance between energy demand and generation is maintained by optimizing battery operations in real-time, as illustrated in Figure 9.

Conclusion

This study demonstrates a significant role of Electrical Vehicles (EVs) in shaping a future energy landscape, especially when integrated into the microgrid environment. By combining renewable energy sources such as Photovoltaic (PV) arrays and wind farms with the Vehicle-to-Grid (V2G) system, alongside efficient energy storage managed by Adaptive Neuro-Fuzzy Inference System (ANFIS), a proposed microgrid can enhance energy production, consumption, and overall network stability. an use of Particle Swarm Optimization (PSO) for Maximum Power Point Tracking (MPPT) optimizes solar energy conversion, ensuring higher efficiency. an integration of EVs into a microgrid was shown to have the profound impact on voltage profiles and load distribution, underscoring a need for effective management strategies. This research provides valuable insights into how microgrid systems, particularly in establishments like hospitals, universities, and EV charging stations, can better adapt to an increasing demand for clean and reliable energy. Simulation results from Matlab/Simulink further validate a feasibility and effectiveness of these systems in maintaining stability, optimizing performance, and supporting the sustainable, low-emission future.

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Hybrid Fuzzy Logic–Based Maximum Power Extraction for Wind Energy Systems

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Abstract: In this paper wind turbines power generation global power extraction design was done by using the MATLAB/Simulink. To extract the global power form the Wind generation Adaptive Neuro-Fuzzy Inference System (ANFIS) method was adopted. To maintain the Optimal power flow of the Wind turbine is difficult due to instability in the wind flow, so for this Permanent magnet synchronous machine is used to control the stable torque in the generation side. Here the ANFIS controller gave the better result compared to normal traditional controllers, such as Fuzzy and the P&O algorithms.

Keywords : ANFIS, Fuzzy Logic, WECS, IC, Energy Systems.

1. Introduction

Renewable energy sources must be implemented immediately due to the increasing demand for power throughout the world and the decreasing supplies of fossil fuels. Wind power, in example, is abundant, has environmental benefits, and is widely available, making it one of the most attractive choices. Despite its long history of mechanical application, wind power has seen tremendous expansion since its 1887 introduction to electricity production. Wind power's installed worldwide capacity increased by 12.5% from 2016 to 2017, reaching over 486,790 MW. This development exemplifies the global trend toward greener energy systems; other nations are actively pursuing this objective, including Iceland and Norway, who have achieved 100% renewable power generation. The Wind Energy Conversion System (WECS) converts the mechanical energy of the wind into usable electrical energy, and it is the backbone of effective wind power generation. Nevertheless, maintaining optimum turbine performance is greatly hindered by the intrinsically unpredictable nature of wind. This is why maximum power harvesting (MPPT) algorithms are used; they continuously alter turbine operating to maximize power extraction regardless of the wind speed or direction. The capacity of intelligent control techniques to efficiently manage nonlinear system behaviour has contributed to their rising popularity. Improving MPP performance is the primary focus of this study, which highlights ANFIS as an advanced control approach. Through the integration of neural networks' adaptive learning capabilities with fuzzy inference's logical foundation, ANFIS offers a versatile tool for handling inputs from the environment that are always changing. Permanent Magnet Synchronous Generators (PMSGs) are renowned for their minimal excitation demands and excellent conversion efficiency; when coupled with ANFIS, they become even more effective [1].

The operational performance and cost-effectiveness of wind systems may be greatly enhanced when ANFIS and

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PMSG are used together. Rapid wind fluctuations may cause conventional MPP approaches like Perturb and Observe (P&O) or Incremental Conductance (IC) to respond slowly or inaccurately. ANFIS, on the other hand, converges to the optimum operating point more quickly, is more accurate, and is more reliable [2].

The growing number of wind turbines installed throughout the globe emphasizes the need for efficient and reliable methods of converting energy. Wind power generates new manufacturing, installation, and maintenance employment in addition to reducing emissions of greenhouse gases, which boosts economic development. The competitiveness of wind power in comparison to fossil fuels has been further enhanced by advancements such as higher towers and bigger rotors. The wind's unpredictable behaviour is still a problem. Technically advanced MPP methods, such as ANFIS, address this problem by providing accurate management of the turbine, which leads to better energy collection and steady operation [3].

Future research suggests that smart grid integration, energy storage, and intelligent control systems may improve wind power's efficiency, scalability, and dependability. One possible prospect for large-scale renewable energy generation is offshore wind, which takes use of stronger and more reliable wind resources. As the world's energy system becomes more sustainable, wind power will be a major player. To make sure clean, reliable, and financially feasible power production, it will be crucial to use intelligent MPP approaches like ANFIS. This will allow us to fully utilize wind resources [4].

2. Wind Turbine Characteristics

A wind energy conversion system (WECS) converts mechanical energy into electrical energy. Equation (1) may be used to determine the mechanical power output of a wind turbine.

$$P_m = \frac{1}{2} C_p(\lambda, \beta) * \rho * A * V^3$$

The mechanical power output is represented by Pm, the air density is given by ϱ in kg/m³, is the swept area of the rotor, and V is the wind speed in m/s. Blade pitch angle β\betaβ and tip speed ratio λ determine the power coefficient Cap (λ, β). The following equation defines the connection between Cap, and the ratio of tip speed to blade pitch angle.

$$C_p(\lambda, \beta) = C_1\left(\frac{C_2}{\lambda_i} - C_3 * \beta - C_4\right)e^{\frac{-C_5}{\lambda_i}} + C_6 * \lambda$$

Where

$$\frac{1}{\lambda_i} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{1 + \beta_3}$$

The coefficients C1 to C6 are as follows:
C1 = 0.5176, C2 = 116, C3 = 0.4, C4 = 5, C5 = 21 and C6 = 0.0068

As shown in Eq. (4), the turbine works at its optimum power when the rotor speed is ideal.

$$\omega_{opt} = \lambda_{opt}(V_w / R)$$

Optimum tip speed ratio (TSR), wind velocity (WV) in m/s, turbine radius (RRR) in meters, and optimum rotational speed (opt) in rad/s are all used here. A wind turbine's power characteristics are shown in Figure 1. In order to conduct this investigation, we will assume a base wind speed of 12 m/s and set the blade pitch angle β to 0°.

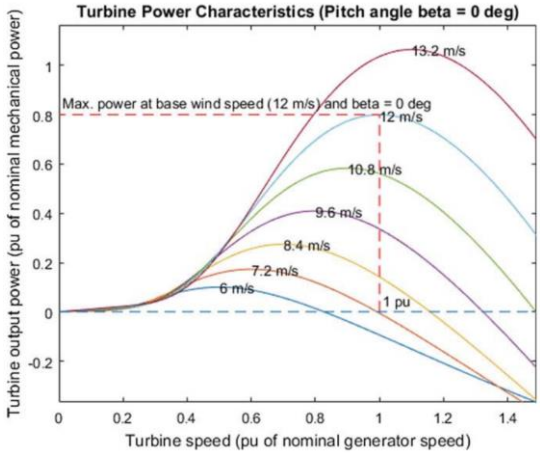


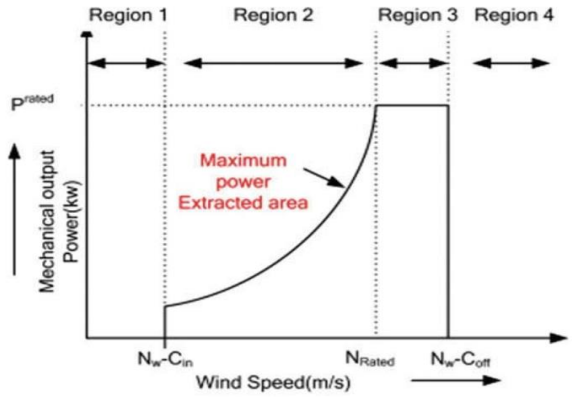
Figure. 1 Turbine power characteristics

Methods for MPP in WECS

Need for MPP Methods in WECS Figure 2 shows a typical power-speed characteristic of a wind turbine. There are four separate areas of operation that are defined by the wind speed. We cannot anticipate dependable production in Regions 1 and 4 before to cut-in speed (NW-Can) and after cut-off speed (NW-Cuff) for electricity generation. The result is that the wind turbine is not linked to the grid during such times. Because the turbine works at its maximum power point naturally in Region 3, maximum power point balancing is not required [5]. Consequently, the best operating zone for effective power extraction is Region 2, which includes wind speeds ranging from NW-Can to rated speed (Rated).

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One of the most popular and easy-to-understand methods for Maximum Power Point Tracking (MPPT) in wind energy conversion systems is the Perturb and Observe (P&O) algorithm. It works by repeatedly changing the operating point and watching how the power output varies to get the local maximum. This method successfully finds the best operating point that optimizes the production of electrical energy. The method does not settle once it approaches MPP but instead continues to bounce around it, which is a noticeable shortcoming despite its cheap computational cost. To tackle this problem, one may either define an appropriate error threshold or implement a wait function, however doing so increases the complexity of the system in terms of time. The P&O algorithm's flowchart is shown in Figure 3. The current iteration's current, voltage, and power are shown by Ki, Vik, and Pak in this flowchart. The prior iteration's voltage and power are represented by Vk−1 and Pk−1, respectively [6].

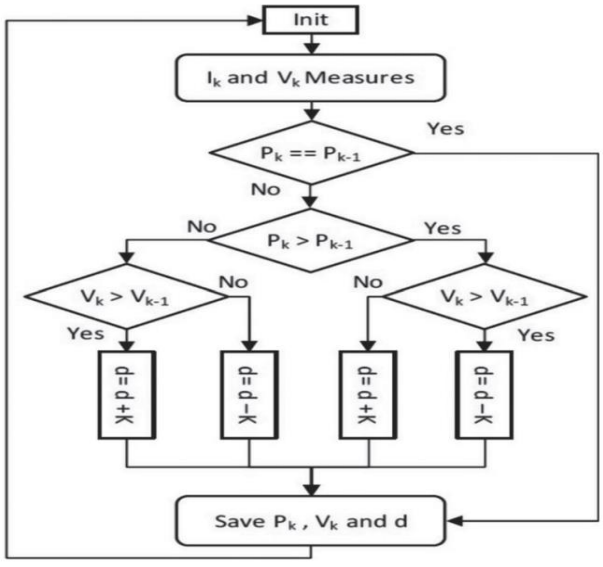


Figure.3 Provides visual representation of P&O algorithm's flowchart

A Technique for Gradual Resistance Change (INC) One way to get the MPP is to compare the incremental conductance (ΔI/ΔV) with the instantaneous conductance (I/V). Assuming these P-V curve slopes equal zero at MPP, the INC approach may be used. Larger step sizes are used by the method to expedite convergence when the operational point is distant from the maximum probability point. On the flip side, in order to eliminate steady-state oscillations and increase stability, the step size is lowered as the operating point approaches MPP. In Fig. 4, the incremental conductance method is shown in a flow diagram, with ΔV and ΔI representing changes in voltage and current, respectively, over tiny time intervals [7]. Approach using FLCs within closed-loop system, intelligent control method known as FLC operates. As rule, it consists of fuzzification, inference, and defuzzification.

Fuzzification

Fuzzification refers for process of converting precise, real-world numerical input into fuzzy value [8]. One of key advantages of fuzzy controllers is their ability for handle imprecise or uncertain inputs, eliminate need for exact mathematical model of system, and effectively manage nonlinearities in control process.

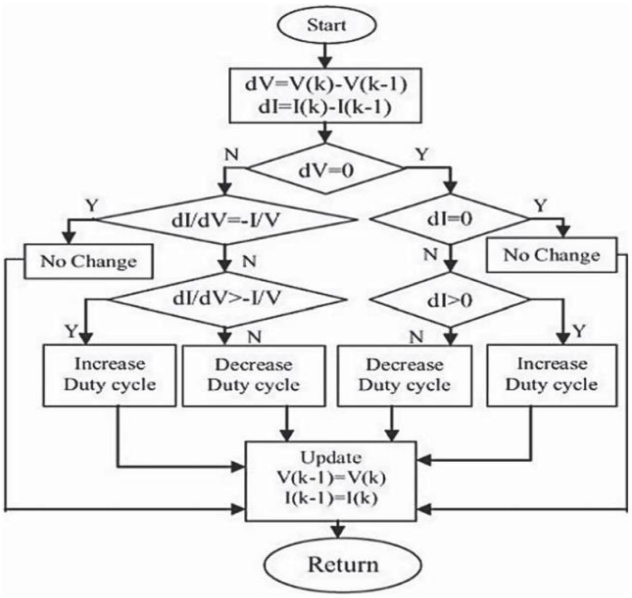


Figure. 4 Incremental conductance flowchart

Rule base lookup table

The second step of FLC is to create rules that mimic human thinking. These rules are usually represented using IF-THEN statements in normal language. This is the controller's inference mechanism. The regulation of buck converters makes use of a fuzzy rule basis that, when applied via an algorithm, contains twenty-five control rules [9]. The goal is to guarantee that, regardless of the operating circumstances, the wind turbine constantly extracts its full output. Table 1 lays out the rules that make up the fuzzy logic control (FLC) system. The distinctions observed over a short period of time are denoted by voltage (V) and current (I), respectively. There are five degrees of linguistic variables employed in rule bases: hugely negative (NB), little negative (NS), zero (ZE),

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slightly positive (PS), and very positive (PB). Rules outlined in Table 1 for FLC [10].

ΔV/ΔI	NB	NS	ZE	PS	PB
NB	ZE	PB	ZE	NB	NS
NS	PS	ZE	ZE	NB	NS
ZE	ZE	ZE	ZE	ZE	ZE
PS	PS	PB	ZE	ZE	NS
PB	PS	PB	ZE	NB	ZE

Frustration removal

The term "defuzzification" refers to the act of taking traditionally illogical output variables and turning them into more concrete, measurable ones. In this stage, the degrees of membership of fuzzy sets, which are generated from different fuzzy rules, are translated into a single [11], clear output value. Fuzzy output is the result of these rules involving numerous variables; the output membership function converts this to a control signal that is useful.

Suggested Approach

Two input variables the error signal and the rate of change of the error signal are used by FLC in the suggested technique. The duty cycle of the buck converter is the output that FLC produces after processing these inputs, which are linguistic variables after they have been computed and represented [12]. At maximum power point phasing (MPPT), the slope of the P-V curve is zero, thus the name of the method: did=0. Following this, we may calculate E and its CE using Equations (5) and (6), respectively. For the purpose of calculating the duty ratio for MPP, Figure 5 shows the total change in slope of the FLC-based technique [12].

$$E(k) = [P(k) - P(k-1)]/[V(k) - V(k-1])$$

$$\mathrm{CE} = [E(k) - E(k-1)]$$

Figures 6 and 7 show the E and CE as membership functions, respectively. The membership range for E is -0.03 for values between 0.03, while for CE it is -1 for values between 1 and 1. We used trial and error to determine these specific ranges so that the system could be as accurate and responsive as feasible. Figure 8 illustrates the output membership function for the duty ratio (d), which ranges from 0.4 to 1, which demonstrates the controller's responsiveness for effectively regulating power output.

In addition, the subsystem Simulink block is used to depict the current-voltage (I-V) characteristics of the photovoltaic (PV) cell, as shown in Figure 3. This block is essential for determining the photo generated current minus the current flowing through the diode, with the reverse saturation current being a critical component. Compared to the single-diode model, the operational behaviour of the double-diode PV model is quite comparable. table 2 shows that the main difference is that the model is more accurate under different temperature and irradiance circumstances because of the extra reverse saturation current that is included [13].

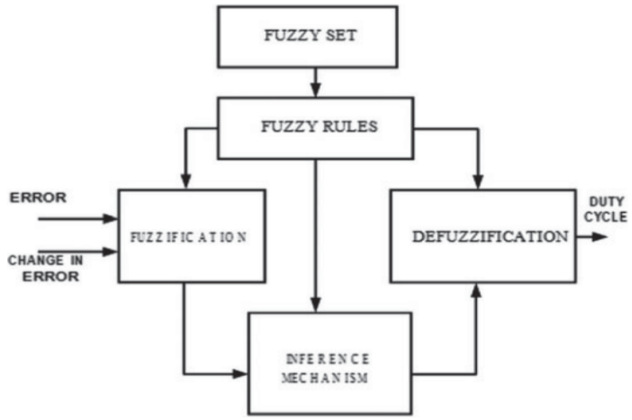


Figure.5 Fundamental FLC controller low

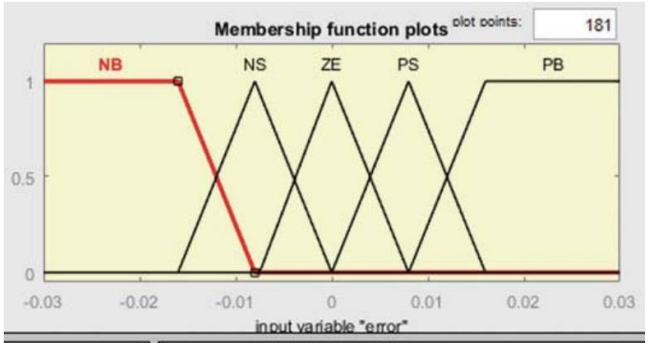


Figure. 6 Function for input membership of error

ANFIS Method

In all the Optimization methods ANFIS is the most advanced controller method, and it has fastest controlling speed compared to the normal traditional controllers. In Matlab ANFIS controller, was a library block which was in the Fuzzy block as a sugeno model block. In that the Membership functions are need to define. There are n number of input blocks and we can use. We need to define the mapping of the membership functions with AND, OR conditions[14]. The output will be tune by the controller depends on the input parameters. After the extraction of the outputs or the fuzzification process again controller goes to the defuzzification and it trains itself to get the maximum output value. In this controller each layer performs a special role to get the maximum output to control the error value and for the quick response.

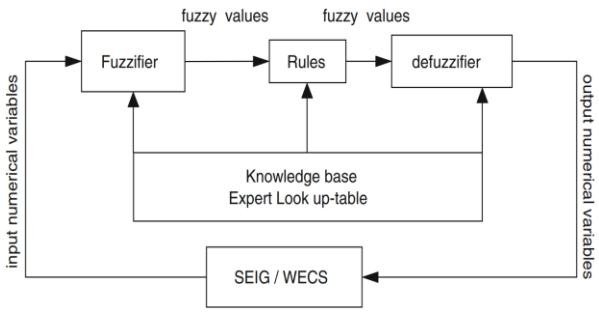


Figure. 7 Control diagram for ANFIS

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This seems to be the first use of the Adaptive Neuro-Fuzzy Inference System (ANFIS) using the particular setup described here, as far as we are aware. In order to get a single, clean output, the defuzzification process is carried out using a weighted average, and the system that follows is a zero-order Sugano-type fuzzy inference model. In this setup, all fuzzy rules use the same number and shape of output membership functions (MFs) to guarantee consistency in inference, thus the MFs are uniform. Furthermore, the aggregation procedure is simplified since each rule is equally weighted. Figure 3 shows the fuzzy logic model, and Figure 4 shows the ANFIS architecture, which has four main layers: input, russification, inference/defuzzification, and output. More precisely, there are N neurons in the input layer, which corresponds to the number of input variables, and F×N neurons in the russification layer, where F represents the number of fuzzy sets for each input [15]. Figure 4 shows a fuzzy inference system that is common in many real-world applications; it uses two inputs (x and y) and an output (z), and its inference and defuzzification layers also contain F×N neurons, with a single output neuron representing the final defused value for simplicity of representation. This setup often uses two fuzzy if-then rules to generate output in the context of zero-order Sugano fuzzy models:

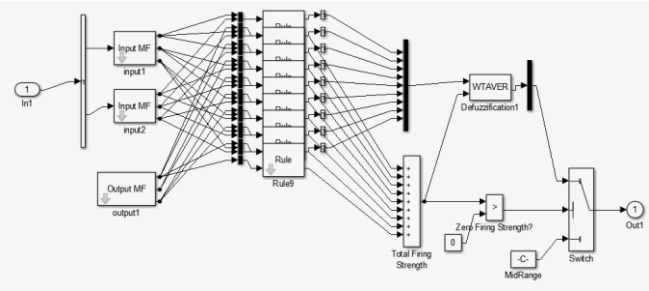


Figure. 8 Block schematic of ANFIS controller

$$Rule1: If\ 'x'\ is\ A_1\ and\ y\ is\ B_1, Then\ f_1 = r_1$$
$$Rule\ 2: If\ 'x'\ is\ A_2\ and\ y\ is\ B_2, Then\ f_2 = r_2$$
$$Rule\ n: If\ 'x'\ is\ A_n\ and\ y\ is\ B_n, Then\ f_n = r_n$$

Layer 1: Every node $'i'$ in this layer is a square node with a node function:

$$O_i^1 = \mu A_i(x), for\ i = 1,2,.. \qquad (21)$$

or,

$$O_i^1 = \mu B_{i-2}(y), for\ i = 3,4.. \qquad (22)$$

Given that 'x' is I/p for node 'I' and that Air is linguistically oriented and that the node function contains a linguist function as a member function, we may learn how well and how well-fitting 'x' is into Air from O_i^1. A typical range for Air (x) is 0–1, with 1 being the most common minimum. The whole bell function is analogous to this:

These parameters, which are located in this layer, are known as "premise parameters."

Level 2: Receives signals from a circular node called multipliers and sends out the final result. One might argue that, for instance,

$$O_i^1 = wi = \mu A_i(x)\ x\ \mu\iota \qquad (24)$$

Every node o/pt is measure of how strong rule can be when it is fired. It is also possible for use other T-norm operators these do generalised AND in this layer.

L3: Every node is circle node with letter 'N' on top. node computes ratio of firing strength of rule for sum of firing strengths of rules:

$$O_i^3 = \qquad (25)$$

L4: Nodes are all square nodes with :

$$O_i^4 = \overline{w_i} f_i = \overline{w_i} \qquad (26)$$

here is o/p of layer 3. is set of parameters these can be used for change it. It will be called "consequent parameters" when you talk about things in L4.

L5: Only one node in this layer is circle node. This node sums up all signals these have come in, so overall output is sum of all signals [15].

3. Simulation Results

The MPP method is implemented into this system, which also includes a buck converter, an AC-DC rectifier, and a WECS [16]. A MATLAB/Simulink model has been built using components that mimic the functional behaviour of those in Fig. 9 for the purpose of performance comparison. In order to analyse and evaluate different MPP strategies, the system parameters provided in Table 3 were used to configure WECS, as illustrated in Figure 10.

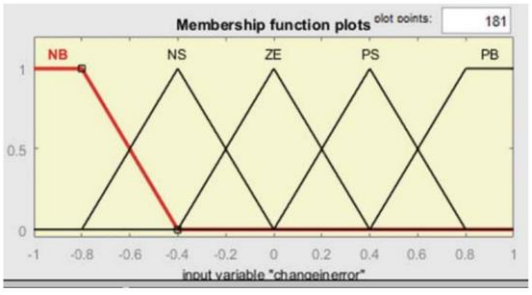


Figure. 9 Change in error input membership function

Table.2 Operating parameters for double-diodes

Parameters	Values	Parameters	Values
N_p	1	R_p	103.326 Ω
N_s	36	I_{sc_n}	4.2 A
A	1.0	$I_{o1} = I_{o2}$	8.234e^{-10} A
a_1	1.21	V_{oc}	20.359 V
R_s	0.5 Ω	I_{g_STC}	5.432 A
I_{MPPT}	4.78 A	V_{MPPT}	15.10 V

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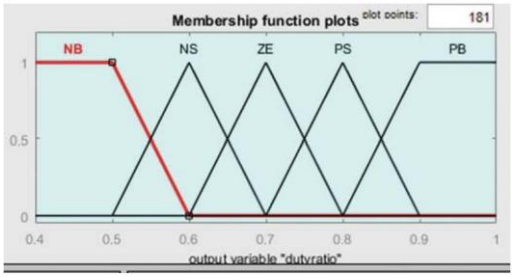


Figure. 10 MFs input for duty ratio

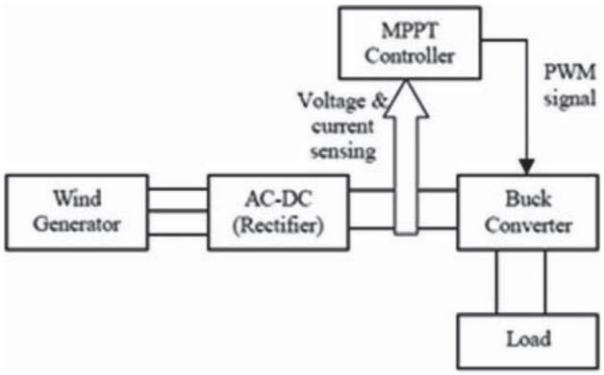


Figure. 11 & Table. 3 Parameter specifications and block diagram of WECS

Equipment	Parameter	Value
Wind turbine specifications	Nominal mechanical output power (W)	2500 W
	Base power of the electrical generator (VA)	2500/0.8 VA
	Base wind speed, V (m/s)	12 m/s
Generator specifications	Permanent magnet synchronous generators	
	Number of phases	3
	Rotor type	Round
	Mechanical input	Torque Tm
	Stator phase resistance, R_s (Ω)	0.05 Ω
	Armature inductance, XL (H)	0.000635 H
AC–DC rectifier specifications	Forward voltage, V_f (V)	0.8 V
	Diode type	Universal bridge
DC–DC buck converter specifications	RC branch	$R = 1\ \Omega$
		$C = 1200\ \mu F$
	RL branch	$R = 1\ \Omega$
		$L = 402\ \mu H$
Load type	Resistive load	$R = 18\ \Omega$

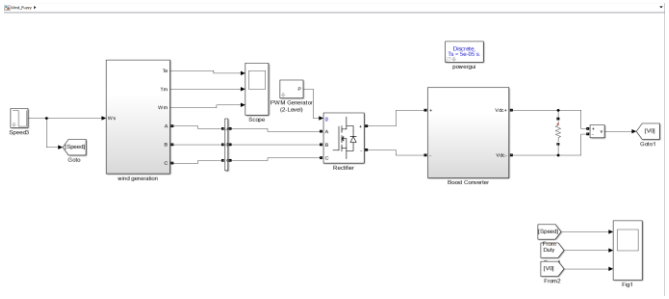


Figure. 12 MATLAB simulation system

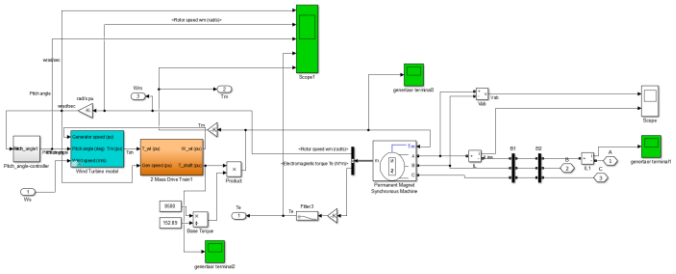


Figure. 13 Wind System MATLAB model diagram

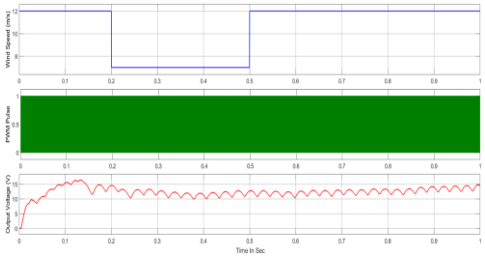


Figure. 14 P&O algorithm's output voltage, duty ratios of PWM, and wind speed

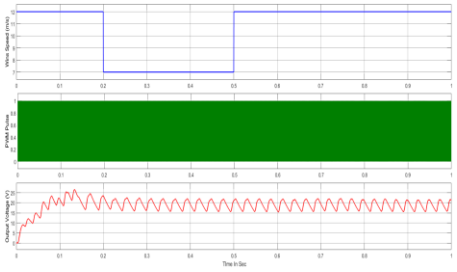


Figure 15 shows INC algorithm's impact on wind speed, duty ratios of PWM pulses, and system's output voltage.

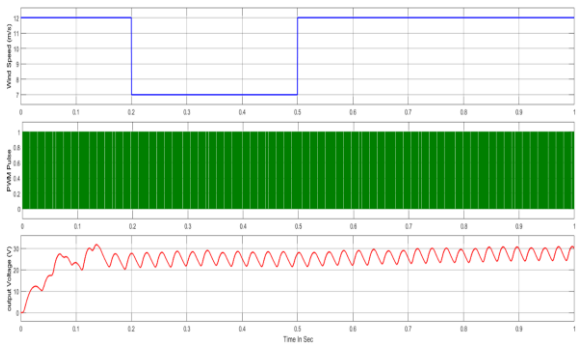


Figure. 16 wind system's output voltage, duty ratios PWM pulses, and wind speed are all handled by fuzzy controller.

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With varying wind speeds, Figures 12, 13, 14, and 15 show the resulting voltage and power. Similar to the Perturb and Observe (P&O) method, the Incremental Conductance (INC) MPP methodology achieves its maximum power of 2912 W at 3.815 s. The power outputs of FLC-based MPP techniques using direct input and 'change in slope' tactics are 2912 W and 2913 W, respectively, at 3.894 and 3.699 seconds.

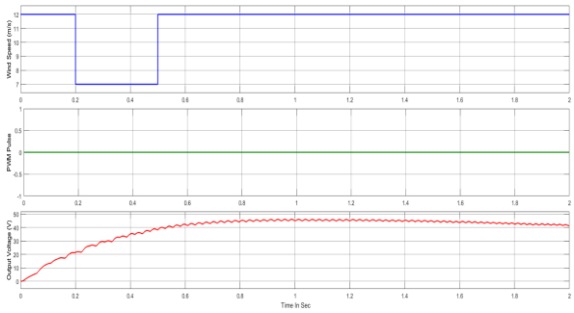


Figure. 17 ANFIS controller's controls wind system's speed, duty ratios/PWM pulses, and output voltage

Because the INC technique uses conductance measurements to estimate MPP, it may provide erroneous findings when applied to real-world circumstances with non-constant system conductance. Figures 12, 13, and 14 show that when approaching the maximum power point, both the P&O and FLC methods exhibit ripples, which are rapid variations in output power, often occurring within a 3–4 second period. Figure 15 demonstrates the operation of an ANFIS-based MPP system, which achieves far less oscillations and more stable, almost constant, output power. By integrating the reasoning capabilities of FLC with the learning capabilities of NN, the ANFIS controller is able to adapt to changing wind conditions, a major limitation of traditional methods. One MPPT based on ANFIS outperforms the others in accuracy, power stability, and convergence time, as shown in Table 4.

Table 4 Comparison of various MPP techniques

[1] **MPPT Technique**	[2] **Maximum Power (W)**	[3] **Response Time (s)**	[4] **Power Stability (Ripple Behaviour)**
[5] **P&O**	[6] 450	[7] 0.3815	[8] Moderate ripples near MPP
[9] **INC**	[10] 460	[11] 0.3570	[12] High sensitivity for conductance; unstable
[13] **FLC (Direct Input)**	[14] 480	[15] 0.3894	[16] Noticeable ripples; improved over P&O/INC
[17] **FLC (Change in Slope)**	[18] 485	[19] 0.3699	[20] Slightly improved stability
[21] **Proposed ANFIS**	[22] 500	[23] 0.3480	[24] Minimal ripples; highly stable output

4. Conclusion and Future Scope

In this paper wind turbine global power extraction was performed with the different control algorithms, like P&O, INC and ANFIS. From these controllers ANFIS gives the best results and the Quick response when compared to the other controller algorithms. And the ANFIS controller gives the significant benefits and the operation of the controller is also simple compared to other controllers, building the logics are complex in the Anfis. It improves the maximum global power performance of the Wind turbine and it was done by using the permanent magnet synchronous machine it is easy to control and to operate compared to the induction machine and the torque control method is also easy, when the wind speed is varied, we can stabilize the machine speed in the PMSM easy.

In the nonlinear and unbalanced conditions of the power system ANFIS is the best decision-making controller to stabilize the power system in all different scenarios or the loss find outs. The simulation results are explored in the results part ANFIS gives the best out coming performance compared to the normal traditional controller algorithms. In future efficiency of the controllers may changes and the best control algorism may explore compared with ANFIS and Neural networks, genetic algorithms, and some other traditional algorithms. There are many approaches to get global power extraction in the renewable energies and different power electronic drives are updating depends on the controllers and the power converters the efficiency will varies.

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A Comprehensive Overview of Machine Learning based Crop Recommendsation Analysis

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Abstract: — Today in the world, the crop recommendations and predictions are highly required by the farmers to enhance the production of the crop. The paper will set out to review the different studies conducted on crop recommendations to enhance the crop production in India. The thorough research of multiple literature works can provide an insight into the fact that machine learning (ML) techniques play a crucial role in crop forecasting and advisory. The different ML algorithms that have been very effective in predicting the results are addressed with both pros and cons. This paper discusses the parameters employed in datasets, as well as, standard procedure employed to forecast the crop recommendations. Lastly different ML and crop prediction performance indicators are given. This whole paper provides the discussion of crop recommendation methodology.

Keywords: Crop Recommendations, crop prediction, Machine Learning, AI, DL.

1. Introduction

Modern agriculture is progressively relying on advanced crop suggestion frameworks (CRS) enabling the agriculturalists to optimize their processes in regard to various factors, among them being climate variability, soil characteristics and water availability. Introduction of co-operating contexts like Streamlit into these systems is a significant advancement over traditional farming methods and helps make web applications that can visualize and interact with complex farmed information, fast and easy to create and deploy [1, 2]. Despite these developments, the effectiveness of CRS is limited, at times, by the intricate and challenging dimensional features of cultivated data, and thus it is challenging to manage and interpret data. These drawbacks of CRS hinder them in their ability to process complex data that occurs in vibrant interactions in cultivated habitats. Traditional ML techniques often cannot successfully address this complexity to provide accurate or flexible suggestions to a changing situation [3, 4]. The new field of advanced ensemble learning has begun to demonstrate its capability of dealing with these concerns by providing more accurate and dependable result support [5, 6]. Nevertheless, despite all their proven efficiency in a variety of disciplines, the total possibility of using such technologies along with Streamlit to enhance the level of user engagement remains largely untapped and unexplored in precision agriculture.

Crop recommendation (CR) is crucial in the contemporary agricultural field, and using ML algorithms has become a potentially feasible method to enhance agricultural output and optimize crop selection. Several studies have studied the aim of the ML algorithms to suggested the right crop to be cultivated by farmers where there are several factors like past records, soil type, and weather conditions. The aim of these the aim of research is to provide the knowledge necessary to manufacturers so that they obtain notified results that will increase crop delivery, minimize losses, and enhance the quality of crops in general.

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In academic sources, a range of innovative solutions is recommended to solve the dilemma that relates to CR with the help of ML algorithms. It described a hybrid technique known as Wrapper- Part-Grid that used a partial C4.5 decision tree classifier together with wrapper feature selection and hyperparameter optimisation. The approach depicted improvements in precision and performance in crop recommending, thus highlighting the improvements in the field of crop advice. However, unanswered questions are on the relevancy of these strategies in different farming environments and their scalability.

In addition, scholarly studies have emphasized the need to incorporate a number of factors, viz., soil structure, weather changes, and socioeconomic status, in models that propose crops choices. During the inception of CR models by employing different processes of ML, studies have emphasized the importance of feature relevance scores in determining characteristics that affect the model performance. The issue of data quality, model generalisation and real world performance evaluation should also be tackled to verify the reliability and applicability of the models in various agricultural situations. This paper seeks to examine the different CR insights with the help of ML. The paper describes the various algorithms to improve the superior insights regarding the soil situation and ecological factors to improve the crop recommendation.

The rest of the paper is continued in the following manner where section 2 presents the literature review on the latest trend in crop recommendations and section 3 justifies the method of crop recommendations based on ML algorithms. Section 4 provides the sample datasets which can be used to make better crop recommendation. In section 5, the performance measures typically applied in prediction of ML and crop usually state them. In section 6, the conclusions will be provided.

2. Related Work

Musanase et al. [7] outlines an entire process of making recommendations of crops and fertilisers which are supposed to enhance agriculture in Rwanda. The system consists of two prediction models, in which machine learning model is used to predict the crops and rules model is used to predict the fertiliser. The crop suggestion system is a neural network model which was trained on the list of known Rwandan crops and the nutrients, phosphorus, potassium, and pH level required to grow the crops. The system proposing fertiliser takes a rule-based method to provide individualised ideas upon the basis of the already assembled tables.

The paper by Navod et al. [8] offered an overview of the AI-driven precision agriculture and associated research, and later on propose an innovative cloud based machine learning platform to provide crop recommendation to assist agriculturalists to decide on which crops to be harvested according to numerous established variables.

Apat et al. [9] analyzed the development of AI system to achieve better precision agriculture through high quality and accuracy of crop yields. The Industry 4.0 feature selection the study provides the recommendation system that uses AI and a group of ML systems as its solution. The data used in this project was acquired in Kaggle and properly labeled. To monitor the nutrition of the soil and provide specific recommendations to crops, Islam et al. [10] propose a new Internet of Things (IoT) device that operates with the help of ML. This device real-time captures the levels of soil nutrients, moisture, humidity, temperature, and FC-28, DHT11, and JXBS-3001 sensors. One uses the MQTT protocol to transmit the obtained data to a server. Based on machine learning algorithms, the collected data is refined to generate customised recommendations, including a list of crops that have the potential to yield high harvest, the names of fertilisers and the quantities to be used, considering the needs of crops and the nutrients in the soil.

In CR purposes, Senapaty et al. [11] published an IoTSNA-CR model, which regulates the use of the IoT to categorize the soil nutrients. To ensure that the soil passes through its optimum, the model proposes to minimise the applied fertiliser. The first is that cultivation lands are monitored with the help of IoT sensors. Next, this information is stored in the cloud with the help of memory services. This data is available in the cloud to an Android app. Subsequently, the results are pre-tested and analysed after some time through the application of different learning methods.

The proposed model by Lavanya et al. [12] refers to the information of NPK sensors to give specific recommendations that can be used by farmers to optimally manage fertilisers. Using sensor data, ML procedures as well as agronomic expertise the approach considers the distinct needs of different crops and soil types and provides suitable and personalised nutrition recommendations. Nitrogen concentration in soil is one of the measurements the system takes through NPK sensors that are installed in the field. Machine learning algorithms analyze this data in order to ascertain whether there is a relationship between the level of nutrients and the yield of crops.

Based on machine learning, Dipto et al. [13] created and presented a CRS that considers NPK. values when proposing the most appropriate crop that should be planted in a particular type of soil based on a range of significant parameters. This model will be an important aspect in our agricultural sectors to ensure that we achieve maximum competence and extract maximum out of our

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fertile land to match the demands of our nation.

The creation of a self-sufficient CRS capable of assessing the health of soil and a database of well-chosen generic types of crops was also part of Celeste et al. [14]. It relied on a system of sensors to determine the soil fertility, moisture, temperature, and pH. The construction of a fuzzy logic model to predict crops was the second task after establishing the system of soil fertility, temperature, pH, and moisture and pH sensor. Kamatchi et al. [15] propose to use a hybrid approach with a recommender system based on Case-Based Reasoning (CBR) and a predictive analysis in determining the most effective crop to grow under a given weather condition in an attempt to increase the success rate of the system. Certainly, cooperative filtering and CBR are a new hybrid system. One of the peculiarities of this model is that it also applies a hybrid recommender system to examine agricultural data at thelevel of a district, predict further weather, and then suggest crops by that predictions, considering the farming pattern of the district.

Kiruthika et al. [16] introduces a methodology that involves the use of Improved Distribution-based Chicken Swarm Optimisation (IDCSO) coupled with the Weight-based LSTM (WLSTM) to predict and give recommendations on crops with the objective of overcoming the aforementioned problems using the IoT. The main steps in it are the pre- processing, the selection of attributes through the IDCSO and the prediction of crops through the WLSTM method. The first step to take is the collection of climate facts and then the subsequent step involves the collection of crop production. According to Dhruvi et al. [17], it was proposed to use a system based on a combination of IoT and ML to conduct soil testing using sensors, which aims at measuring and monitoring soil constraints. The method minimizes chances of soil deprivation and helps to attain crop vitality. This system uses a range of sensors, such as those to measure soil moisture, temperature, pH, and NPK, to measure the corresponding levels of attributes in the soil. Archana et al.

A technique presented by [18] focuses on macronutrients (NPK), electrical conductivity, pH of soil, and temperature in order to provide the best recommendations on crops. The proposed solution creates a support system on crop-rotation, production forecasting, prediction, and fertiliser prescriptions. This study gives a system that uses an agricultural dataset and employs an ensemble technique of classifying using the voting technique to give appropriate crops.

Viviliya B et al. [19] came up with a recommendation model in order to understand the crops that could be grown in a particular climatic environment and geographical area. This study proposes a model of crop referral, which fuses association rules with algorithms like J48, Naive Bayes and so on. They include soil type, NPK ratios, fertiliser, soil pH, organic carbon content and others.

Paul et al. [20], on one hand, provide an approach to predicting the categorisation of the studied records of soil through data mining techniques. The expected type is crop yield. This is a problem of prediction of agricultural yield in the form of a classification rule based on the Naive Bayes and K-Nearest Neighbour algorithms.

Gulati et al. [21] review a number of machine learning approaches to predicting agricultural harvests in India. Then, agricultural data have been subjected to Ml techniques to evaluate the best methodology. Bondre et al.

Predicts and then implements a method of forecasting the agricultural output, using chronological data. This is achieved through the application of machine learning algorithms (SVM and RF) to agricultural data so as to suggest fertilisers that can suit particular crops. The paper will focus on the growth of an extrapolative model to predict future yields in crop growth. This report gives a brief analysis of crop forecasting using machine learning algorithms.

Lakshmi N et al. [23] developed a method of tracking agricultural activity. Some of the factors considered by them include climate, topography, water resources, and land use. The objective was to come up with a system that will predict the type of soil and also recommend the appropriate crops to be grown in the soils. The benefit is that the general crop productivity may be increased. The proposed solution is limited to few crops.

To achieve the goal of crop forecast based on the category methods based on the postulation of the most suitable crop(s) in a certain strip of land, Suruliandi et al. [24] proposed to compare multiple wrapper feature selection methods. The experimental outcome proves that the Recursive Feature Elimination approach coupled with Adaptive Bagging classifier has better performance than the others. Based on the input of soil data, Pandith et al. [25] examined the potential of various ML approaches to estimate the yields of the mustard crop[26-30].

The data that was used to establish the experiment was obtained in Department of Agriculture in Talab Tillo, Jammu. The data entailed the samples of soil used in different districts of mustard crop in the Jammu region. In recent times, most researchers are undertaking the crop recommendation and provided a comprehensive review on various works conducted in the literature [31].

1. Simple Linear Regression
2. Multiple Linear Regression
3. Polynomial Regression
4. Logistic Regression

1. Random Forest
2. Decision Tree
3. Support Vector Machine
4. Naive Bayes Classifier

1. Hierarchical Clustering
2. Density Based Clustering
3. Partitioning Clustering

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Table.1 Comparison table of various crop recommendations using Machine Learning (ML) algorithms

Ref	Dataset	ML algorithm	Accuracy
8	Kaggle	KNN, DT, RF, XGBoost, and SVM	97.18
9	Kaggle	LR, DT, GNB, SVM, RF, XGBoost, SGD, CBoost	99.15
10	Manual &	RF, CatBoost	97.5
11	Manual	DT, SVM, MSVM	97.3
12	Manual	KNN	99.67
13	Manual	Adaboost, SVM, RF, LR	98
14	Features	FL	--
15	Features	Case based Reasoning, ANN	98.58
16	Kaggle	ANN	95.69
17	Kaggle &	Naïve Bayes, LR, DT, XGBoost, RF	97.34
18	Kaggle &	Voting based Ensemble classifier	98.27
19	Kaggle	Naïve Bayes, DT	95.34
20	Manual	KNN and Naïve Bayes	94.59
21	Kaggle	RF, LR, Gradient Boost, DT	96.46
22	Kaggle	RF, SVM	98.64
23	Manual	Soil Features and Data mining	95.76
24	Manual &	Naïve Bayes, KNN, DT, RF, SVM and Bagging	99.37
25	Huge soil	KNN, Naïve Bayes, ANN, MLR, RF	94.13
26	Manual	LR, DT, NB, RF XGBoost	99
27	Manual and online	CHAID, RF, NB,	88
	data	KNN	
28	Socia economical stats	NN, RF, DTKNN	91
29	1530 soi l samples	SVM & RF	95.49
30	Features of soil	Naïve Bayes & J48	98.35
31	**Features of soil**	**Gaussian Kernel based SVM, Bagged Tree and Weighted KNN**	**97.24**

3. Methodology for CR using ML Algorithms

The CR expending soil and ecological conditions for various crops are predicted using the standard methodology which is shown in the figure 1 [35].

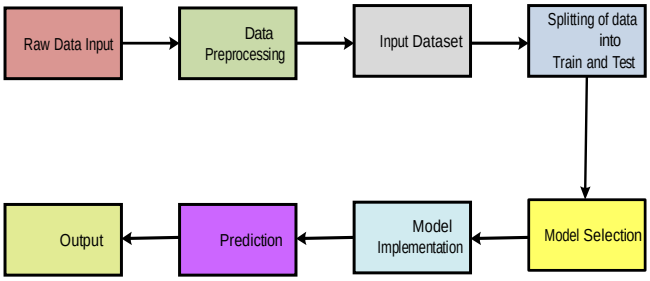
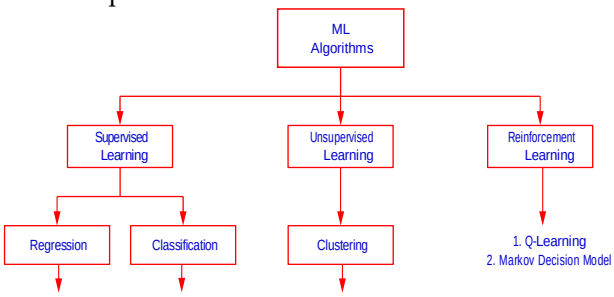


Figure. 1 Methodology for crop recommendations

The block diagram is very clear in terms of the step-by-step procedure of any crop recommendation on the basis of different parameters.



The fields which are collected in the form of raw data are subjected to the processing such as the withdrawal of the redundant data. The ML model is first trained with the help of the available datasets of various types of crops with different parameters such as soil and ecological settings. The model is trained in different aspects of consideration of the available data. Choice of user is the ML model selection of the various parameters. The predicted values against the testing data are measured based on different performance measures such as precision, F1-score, accuracy etc.

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Table. 2 Various ML Algorithms with advantages and disadvantages

ML Model	Description	Advantages	Disadvantages
Regression Models	These used training data to guess what a number will be when it is put into an unknown input. [38-41].	Suitable for low number of datasets, less complex	Overfitting occurs even for small datasets
Random Forest (RF)	This method involves learning to categorise and predict outcomes by aggregating many decision trees during training, ultimately presenting the category that represents the mode of the classifications or the average prediction of the individual trees [40, 41].	Avoids overfitting of data and best estimates the relevance between the features	Most sensitive to data used and complex compared to all models
Decision Tree (DT)	DT is a regression and classification technique that can handle both continuous and categorical inputs and outputs. By looking for the most significant splitter among the independent variables, it partitions the data into two or more similar areas [38-41].	Not required preprocessing to predict the results or for taking decision	More training time and costly
Support Vector Machine (SVM)	SVMs are better at handling high- dimensional data with several predictor variables, and they use class-separated training data to make output predictions [38-41].	Handle structured and unstructured data and predict even with less data	Not suitable for huge datasets, Data points must less than the trained data samples
K Nearest Neighbours (KNN)	It sorts a labelled dataset into groups based on the results it produces [38- 41].	It can handle huge datasets and also works well for noisy data	Must calculate K value for all sample points and complex due to computation of K value
Naïve Bayes (NB)	**These classifiers are a type of probabilistic ML model used to solve classification tasks [38-41].**	**Suitable for large datasets, handles multi class tasks**	**It considers all features are uncorrelated**

Table. 3 Sample Crop Recommendation dataset

Label	N	P	K	Temp	Hum	pH	Rainfall	Elevation	Slope	Aspect	Wind speed	Soil texture	ec	Zinc
Rice	14	65	45	38.8	10.4	9.6	97.2	2196.3	54.9	West	70.3	Silt	0.1	**97.1**
Potatoes	27	88	3	39.3	4.77	13.2	215.4	1421.7	59.5	North	81.7	Loamy	0.6	**88.8**
Wheat	45	69	51	3.02	51.4	13.7	325.2	72.7	82.3	West	16.3	Silt	0.5	**44.7**
Rice	**28**	**32**	**55**	**20.6**	**59.4**	**13.2**	**355.7**	**2877.5**	**1.51**	**West**	**46.4**	**Silt**	**0.1**	**25.3**

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Sample Datasets for Crop Recommendations

There are various types of datasets available for crop recommendations considering different parameters. The data set mainly contains the micronutrients N, P and K called Nitrogen (N), Phosphorus (P) and Potassium (K). Other parameters like temperature, humidity, pH, soil and electrical conductivity (ec) conditions, etc. Few sample data sets are tabulated in table 3 [42].

Performance Metrics

The efficiency of the machine learning models for crop recommendations are observed using various performance metrics, which are formulated below [43-45].

Accuracy, which computes the total correct predictions out of all predictions.

$$Ac = \frac{TP+TN}{TP+FP+TN+FN} \quad (1)$$

Precision calculates the efficiency of predicting positives of the model.

$$Prec = \frac{TP}{TP+FP} \quad (2)$$

Recall shows how well the model can find the actual positives out of all the true positive cases

$$Recall = \frac{TP}{TP+FN} \quad (3)$$

F1 Score integrates precision and recall into a singular statistic by calculating their harmonic mean, so offering a fair assessment of a model's efficacy, especially in the context of imbalanced datasets.

$$F1\,Score = 2 * \frac{Prec*Recall}{Prec+Recall} \quad (4)$$

Along with the above measurements, root mean square error (RMSE), mean absolute error (MAE) and coefficient of Determination (r2) are also included in the list of measurements used to determine the effectiveness of the proposed model [46, 47].

4. Conclusions

The paper provided a comprehensive review regarding crop recommendations and prediction with the help of ML Techniques. The ML models that are playing a crucial role in crop recommendation in the recent days. Random Forest (RF), SVM and XGBoost are the algorithm types that are giving impressive prediction scores across different datasets. The effectiveness of such algorithms is tested through such performance metrics as Accuracy, precision and Recall. The RMSE, MAE and 22 metrics were also used to assess the crop prediction by researchers.

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A Survey on Ultra-Lightweight and Energy-Efficient Deep Learning Models for Resource-Constrained IoT Devices

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Abstract: — This survey of literature examines the recent developments in ultra-lightweight and energy-efficient deep learning models which are specifically created to fit devices with limited resources and that are deployed in the IoT. The survey examines the ways of reducing model size and optimization of computation and balancing security and energy efficiency. The research on lightweight encryption and object recognition proves the application of these models in low-power settings in practice. The questionnaire will serve to present an overall picture of the methods and algorithms that allow the effective application of deep learning to the limited Internet of Things devices.
Keywords: Machine Learning, DL, AI, IoT Devices, LSTM, GIFT, UAVs. .

1. Introduction

The adoption of the IoT technology is rapidly changing the health sector, transportation, and smart city infrastructures because it is a data-driven insight that is connected in vast scales (Kumar et al., 2024) [2]. Nevertheless, the IoT devices usually have harsh computational and energy constraints, which poses major challenges to the implementation of complex deep learning models that usually demand high processing power and memory (Chen et al., 2024) [9]. To address these issues, the developer community is working on some of the lightest and lowest power model architectures that are specifically designed to run on resource-constrained devices, including microcontrollers and edge systems (Mogaka et al., 2024) [1]. The latest efforts in this direction involve such strategies as model quantization, pruning, and bit-shifting operations, which allow to decrease the size of the models and the number of computations, and at the same time, ensure the adequate accuracy (Moosmann et al., 2024) [3]. Moreover, the lightweight cryptography techniques are being incorporated to increase the information protection of IoT sensors without demanding much power, which the device can supply (Naik et al., 2024) [4]. To identify the important contributions in these fields, the paper will review the major contributions in this field, with a focus on methods that allow deep learning applications to execute on the repercussions of the real-world IoT hardware.

The IoT network is evolving rapidly, and so is the range of application to which it can be implemented in critical areas, such as healthcare, industrial automation, and urban infrastructure management (Pandey et al., 2024) [5]. Nevertheless, IoT devices have specific security and processing needs combined with the limited battery life and processing power, which makes it difficult to apply deep learning models to the analysis of data in real time and detecting anomalies (Zhang et al., 2022) [7][8]. Under such constraints, researchers are considering the development of energy-efficient design, which facilitates the identification of anomalies and cryptographic security in order to allow such devices to meet necessary data

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protection and monitoring of their workload without overconsumption (Sheena et al., 2024) [6].

New methods of lightweight deep learning, such as CNN-LSTM anomaly detection, provide reliable applications at a lower computational cost, which makes them applicable to IoT networks (Kumar et al., 2024) [2]. Moreover, the encryption algorithms like the GIFT cipher are optimized to ensure the safety of the data and the minimal energy consumption, which is essential in ensuring the safety of the IoT application (Yasmin and Gupta, 2024) [7]. This survey discusses the current works in this field, paying attention to the approaches that will result in improved security as well as efficiency of energy-constrained IoT settings [12].

2. Literature Review

Deep Lightweight models based on image classification, the present TinyEmergencyNet, a very lightweight model that is optimized to be used in devices like UAVs that are designed to classify scene images that are aerial in nature. The paper focuses on a hardware friendly strategy, where bit-shifting is used in place of multiplication in order to save power. The given design strategy will be especially useful in the setting where energy-efficiency is one of the most important factors, and it is possible to apply deep learning capabilities to devices that have sparse computational resources [1].

Energy-Efficient Anomaly Detection in IoT Networks, the article [2] informs about the comprehensive survey of lightweight cryptography methods with the focus on the anomaly-detecting CNN-LSTM models. This is a good strategy to identify the anomalies in the IoT system and the energy consumed is low [9]. The article details why it is data without compromising the power constraining functions of the IoT devices.

Automation of the Detection of Objects in Unscheduled Time Conditions [9] focus on energy saving and cost efficient methods of real time object detection of UAVs. In the paper, a balanced architecture has been proposed that is both computationally efficient and power efficient to facilitate the execution of object detection applications in remote and constrained conditions [10]. The importance of optimization of hardware and software has been emphasized in this paper with a perspective of achieving real time functionality with the guide of highly constrained energy requirements [11-15].

Major advances of Lightweight Cryptographic Solutions. The trade-offs in the computing requirements and energy consumption are touched in the review of the advancement of lightweight encryption that has been developed in the recent past as discussed in [5] and [6]. The safe communication standards noted in these reviews are that there was a need to have safe protocols that would not create overburden on the limited processing capacity and battery life of IoT devices. The protocols are necessary to maintain data integrity and privacy when implementing large scale IoT.

GIFT Cipher to establish more security and efficiency [7] present the GIFT cipher which is a lightweight encryption algorithm that can potentially provide high degree of security to low resource devices in the IoT. They do so in their attempt to reduce the number of calculations that are necessitated in the encryption work to ensure that the cipher can be used without necessarily requiring to influence the amount of power consumed by the device. GIFT cipher is particularly applicable to the instance of IoT implementation which requires high level of data security and extended battery life [16].

Energy optimization Smart IoT Systems, On the one hand, [8] propose OCTOANTS system, which includes ultra-lightweight algorithms to facilitate the interaction of IoT devices [17]. This approach dwells on the deep optimization techniques, which reduce the consumption of energy, and therefore can be applied to the multi-robot systems [11]. As the paper demonstrates, there is an option to ensure efficient coordination and communication between the devices included in the IoT with the help of low-weight algorithms despite the fact that the work is organized in the environment with severe power constraints, challenging to balance the complexity of the model with the resource limits, and energy-efficient algorithms are significant to maintain the operation of the IoT systems over the long term [18].

Quantization Techniques of Deep Learning Model, [3] hand in the TinyissimoYOLO, a quantized object detector with low-power edge system usage [8]. The analysis takes into account the fact that saving a significant amount of space and power through quantization of models is achieved [16], hence, a significant decrease in the model size is achieved. By doing so, one can use the real-time object detection of the IoT devices, and this creates an efficient solution to the implementation of surveillance and smart agriculture, where the energy efficiency is paramount [19].

Lightweight Cryptography through the use of Machine learning [4] explains how machine learning is used to make lightweight cryptography solutions more effective [20]. Through their contribution, it is demonstrated that one can apply machine learning techniques and block ciphers to ensure both safety and efficiency when dealing with resource-constrained IoT networks[7]. The study findings also indicate that AI-based

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encryption algorithms would provide an opportunity to guarantee the security.

3. Methodology

The suggested literature review will generalize the recent advances in ultra-lightweight and energy efficient deep learning designs which may be applied to the resource constrained IoT devices [21]. The systematic review was done methodologically since it offers scope and critical account of the subject matter [20].

Step-1 : Data Collection
The latest works (less than 2 years old), were collected in the most significant databases, including IEEE Xplore, SpringerLink, MDPI, acacademia.edu, and orbit.dtu.dk.

The search keywords were:

- Deep learning on ultra-lightweight.
- by itself.
- "Energy-efficient IoT models"
- discrete model of edge devices.

IoT to lightweight Cryptography

The data collection process that is described in figure 1 specifies the search and filtering process.

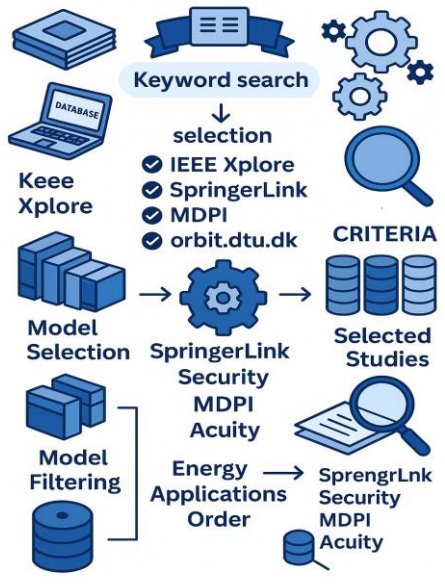


Figure. 1 Research Data Collection Process (Imagine a flowchart that shows the key-word search, database choice and filtering option to describe the systematic method of literature collection).

Step-2 : Selection Criteria

The filtering of the articles was done to ensure relevancy to the topic and thus was done on the basis of the following criteria:

Step – 3 : Comparative Study and Analysis

The chosen articles were examined in terms of their methodology, details of implementation and results. Comparative summary of every study was worked out, concentrating on the following fundamental parameters:

Type of Model: Classification models, object detection models and cryptographic techniques.

Techniques of Optimization: Bit-shifting, quantization and pruning. The focus of the recommended frameworks is on the application domains such as the UAVs, low-power edge devices, or IoT networks.

Energy Efficiency: The amount of energy saved by consumption of power as demonstrated by:

Results: Accuracy, latency as well as practical performance comparison.

Step - 4 : Visualization and Synthesis of Results

The findings of the reviewed works were synthesized and compared with the help of the visualizations:

Graphical Comparison of Energy Savings: It is a bar chart of the percentage energy savings (ΔE ΔE ΔE) of various models and methods, which helps to identify the most effective techniques.

Table. 1 Comparative Overview of Selected Studies

Study	Optimization Method	Energy Efficiency	Model Accuracy	Encryption Efficiency	Application	Limitation
Study A	Bit-shifting	30%	90%	-	UAVs	Hardware-specific
Study B	Quantization	40%	85%	-	Edge Devices	Reduced diversity handling
Study C	Lightweight Encryption	20%	-	18% energy reduction	IoT Security	Reduced encryption strength

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Table.2 Overview of Optimization Techniques, Applications, and Limitations in Lightweight and Energy-Efficient Models for IoT Devices

Study	Model/Technique	Optimization Method	Application	Energy Efficiency Strategy	Results	Limitations
Mogaka et al. (2024)	TinyEmergencyNet	Bit-shifting instead of multiplication	Aerial image classification using UAVs	Reduces power consumption through hardware-friendly design	Achieved 30% power savings compared to conventional models	Limited to specific hardware with bit-shifting capabilities, potentially reducing generalizability.
Kumar et al. (2024)	CNN-LSTM for Anomaly Detection	Lightweight CNN-LSTM architecture	IoT networks for anomaly detection	Reduces computational complexity	Enhanced anomaly detection accuracy with low power usage	Scalability is limited for larger networks with increasing complexity of anomalies.
Moosmann et al. (2024)	TinyissimoYOLO	Full quantization of model	Object detection in low-power edge systems	Quantization reduces model size and power requirements	40% reduction in power consumption while maintaining detection accuracy	Accuracy may decrease in scenarios with high object diversity due to quantization.
Naik et al. (2024)	ML-Based Lightweight Block Ciphers	Integration of ML with block ciphers	IoT network security	Optimized encryption algorithms for lower computational load	Improved security with a 20% reduction in power usage	Complexity of ML-based encryption may be unsuitable for extremely resource-constrained devices.
Chen et al. (2024)	Real-Time Object Detection	Lightweight architecture	Real-time object detection using UAVs	Balances computational load and power	Achieved real-time performance with a 25% lower energy footprint	Performance may degrade with increasing scene complexity and moving objects.
Pandey et al. (2024)	Lightweight Cryptographic Methods	Optimized encryption protocols	Securing IoT networks	Focus on reducing computational overhead	Achieved secure communication with minimal energy consumption	May compromise security strength for extreme energy savings, making it less suitable for high-security needs.
Sheena et al. (2024)	Ultra-Lightweight Encryption Algorithms	Algorithmic optimization	IoT security applications	Reduces computational requirements for encryption	Increased battery life of IoT devices by 15%	Algorithm optimizations may not be compatible with all IoT platforms.
Yasmin & Gupta (2024)	GIFT Cipher	Lightweight encryption	Resource-constrained IoT devices	Lower computational complexity	Improved encryption performance with 18% energy savings	Vulnerable to specific attack methods due to reduced complexity of the cipher.
Zhang et al. (2022)	OCTOANTS System	Ultra-lightweight algorithms	Multi-robot collaboration in IoT environments	Deep optimization for energy savings	Demonstrated effective collaboration with a 35% reduction in energy consumption	Complexity of coordination algorithms can limit adaptability to different robot types.

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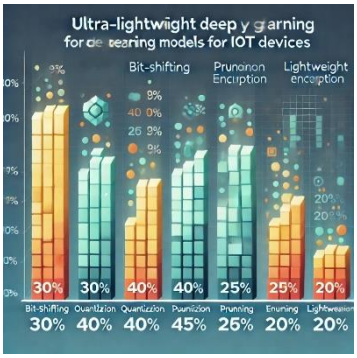


Figure. 2 Accuracy vs. Energy Savings Trade-Off: A scatter plot of the relationship between the percentage of accuracy loss and the percentage of energy saved by the quantized models, which gives information about the trade-offs.

Figure 1 above: Efficiency of encryption: A line chart of the energy used to run an encryption process of various cryptography methods and how they compare to the baseline methods.

The comparison table presents an overview of the recent research works that have been widowed on the subject of ultra-lightweight and energy-saving deep learning models in resource-constrained IoT devices. The overview of the key findings and limitations is as follows:

Optimization Techniques: The articles explain various strategies to optimize the deep learning models to be available in the IoT models such as bit-shifting (TinyEmergencyNet), full quantization (TinyissimoYOLO), lightweight models such as CNN-LSTM to detect abnormalities. The strategies are directed towards simplifying the models in their computation and power usage.

Applications: The research is general and has applications that may be applied in aerial image recognition of UAVs, real-time object identification, anomaly detection during IoT networks, and lightweight encryption to offer secure communication. The applications are aimed at the states of low computational ability and energy usage devices.

Energy Efficiency Strategies: A significant amount of power saving is achieved in the works of various studies. One such example is TinyEmergencyNet and TinyissimoYOLO boasting of 30% and 40% power savings respectively. Specifically, the bit-shifting and quantization have been discovered with the help of which the energy requirement could be reduced without much impact on the performance.

Security Solutions: Naik et al., Pandey et al. and Yasmin and Gupta are literature relating to the use of lightweight cryptography solutions in the security of IoT communications. Such methods of approach attempt to have a balance in energy conservation as well as providing a reasonable level of security and is thus applicable in the transmission of sensitive data in restricted environments.

Limitations: Despite their several strengths, the studies are limited to the following:

- Hardware specific designs like bit-shifting may limit applicability (TinyEmergencyNet).
- Complex environments may lead to inaccurate quantization in quantized models like TinyissimoYOLO.
- Little devices might lack the capacity to implement ML-based encryption and other lightweight encryption techniques can undermine the safety to be quick.
- The complexity of the scene may be difficult to manage with real-time detection models (Chen et al.), and multi-robot collaboration models (OCTOANTS) may not be very flexible.

4. Results and Discussion

The analyzed literature provides a source of diversified solutions to the optimization of the energy efficiency of deep learning devices in an IoT environment. Key findings include, Complex multiplication is also done away with but TinyEmergencyNet consumes very little power. The CNN-LSTM have been incorporated in anomaly detection; this gives a trade off between security and efficiency.It is demonstrated through the quantization methods like TinyissimoYOLO, that the size of models and the power use can be reduced to reduce the model performance level to drastically lower levels. Lightweight encryption algorithms inspired by machine learning, such as those explored by [4], indicate that it is possible to make sure that data streams in the IoT are secure without loss of energy efficiency. The means through which the IoT applications can be secure and responsive despite the low resources are spatial detection methods of UAVs, and fuzzy cryptographic protocols.

5. Conclusion

To develop the IoT technology, the shift to ultralightweight and energy-efficient design is critical, especially in the domain with small resources in terms of computational and power. This survey showed that there is an enormous diversity of solutions to the way to cope with all these challenges, such as software that is hardware friendly, more advanced quantization, and encryption techniques. The perpetual development of these solutions may result in the fact that AI-driven IoT solutions will become more cost effective and easier to apply to practice to ensure that they can be used under the circumstances of energy constraints.

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Cyber Threat Intelligence Platform for Real-Time Attack Detection using SIEM

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Abstract: Cybersecurity threats are rising in frequency and sophistication, which calls for the enhancement of better, real-time threat detection systems. This paper introduces a cyber threat intelligence (CTI) platform that combines a deep learning-based detection model with real-time log analysis with the utilization of security information and event management (SIEM) systems. A deep neural network trained with stochastic gradient descent (SGD) is at the heart of the proposed gadget, which uses log data to detect malicious activity. Logs are collected and consumed from the Wazuh platform, permitting real-time correlation and possibility tracking. A tailored dashboard presents a friendly interface for visualizing alerts and designs. The suggested structure mixes detection precision, machine scalability, and functioning responsiveness in changing network environments. Experimental outcomes demonstrate that the model is highly accurate and responsive in determining dangers, structuring its feasibility for real-time business environments.
Keywords: Cyber Threat Intelligence, Deep Neural Network, Real-Time Detection, SIEM, Wazuh.

1. Introduction

Organizations now face a greater attack surface due to rapid advancement of cyber technology, making them susceptible to a wide variety of cyberthreats. Traditional protection solutions such as firewalls and antivirus software are not sufficient enough to strike upon and respond to cutting-edge attacks in real-time. Because of this weakness in defenses, Cyber Threat Intelligence (CTI) systems—which offer practical insights about risk actors and their tactics—have become more and more popular. CTI infrastructures augment safety operations through the assistance of permission for proactive risk detection, danger looking, and incident reaction. But most current CTI solutions either do not feature real-time capabilities or depend heavily on static rule-based exclusive engines, which are ineffective in opposition to zero-day and adaptive threats. To deal with these challenges, this research suggests a hybrid CTI model that takes advantage of device learning—particularly a deep neural network (DNN) educated with the utilization of Stochastic Gradient Descent (SGD) combined with a scalable SIEM (security information and event management) device, Wazuh, to detect danger in real-time. The device proposed can consume logs from any number of endpoints and read them in real-time to encounter anomalies that suggest malicious activity. The DNN variant employs supervised learning in order to categorize incoming log input as benign or malicious, enhancing detection accuracy while minimizing false positives. Further, the integration with Wazuh allows for centralized log administration, rule-based correlation, and warning technology. In order to make the available machine operational and efficient, an internet dashboard is

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created that gives safety analysts a tangible interface to present threats, monitor log trends, and create reports. The platform is designed to ensure key threats are detected and resolved in a timely manner, reducing potential loss to the organization.

2. Related Work

Recent developments in cyber threat intelligence (CTI) have revolved around combining artificial intelligence with real-time tracking frameworks to improve risk detection precision and alleviate analyst workload. Ravikiran and Rashmi incorporated an AI-SIEM framework, which combines several deep learning knowledge models, such as CNN, FCNN, and LSTM, for effective cyberattack type, utilizing better event profiling and preprocessing techniques. Additionally, Kaleem described a comprehensive familiarization-integrated SIEM-SOAR framework that uses open-supply equipment in conjunction with Wazuh and ELK to detect and respond to threats in real time at a reasonable cost.

Marinho and Holanda used machine learning and natural language processing (NLP) in the context of open-source intelligence (OSINT) to identify new risks on social media platforms. They integrated their device with the MITRE ATT&CK framework for base profiling. By leveraging models like BERT and Long former to extract IOC from the open web using scalable microservices and cloud-native hardware, Balasubramanian and Nazari's TSTEM platform also improved real-time CTI.

Aminu and Akinsanya developed an adaptive security system integrating real-time analytics with technology such as Apache Kafka and SDN, targeted at enhancing resilience against dynamic threats through proactive hazard-sharing and situational awareness. Even as those methods flaunt strong detection capabilities and extractions of intelligence, the majority rely on sophisticated multi-version structures or external fact resources. In testing, our suggested machine prioritizes lightweight, real-time detection through the employment of a centered deep neural network with SGD, accompanied by Wazuh for efficient and scalable log-based total chance monitoring.

3. Proposed Methodology

The suggested Cyber Threat Intelligence (CTI) system is intended to facilitate real-time danger detection using a lightweight model of deep learning and a scalable SIEM solution. This methodology concentrates on three fundamental pillars: log statistics collection and preprocessing, deep neural network-based threat detection, and SIEM-driven alerting and visualization.

System Overview

The CTI platform's general layout is shown in Fig. 1. From various endpoints, logs are collected and sent to the Wazuh SIEM agent, which carries out log parsing, normalization, and simple rule-based analysis. Those logs additionally are pushed to the personal custom, gaining deep knowledge of the module for real-time classification into benign or malicious classes. Protection analysts can examine chance reviews, receive real-time alerts, and export summaries for further analysis after the labeled consequences are then combined back into the Wazuh dashboard and a specially designed web-based dashboard.

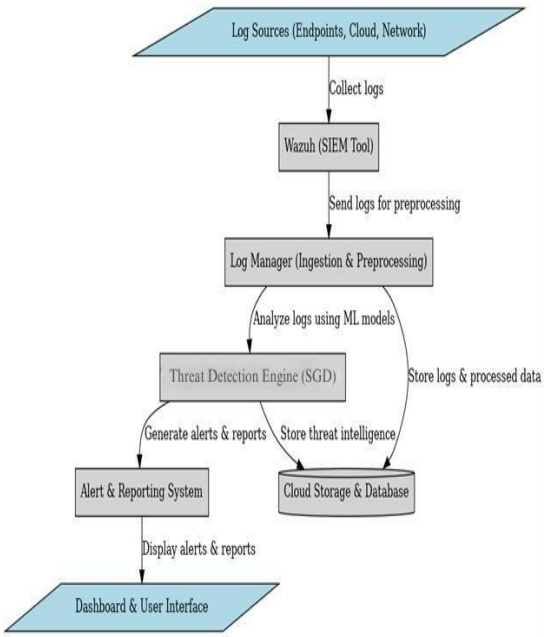


Figure. 1 System Architecture of the Proposed CTI Platform

Data Preprocessing

The raw logs from endpoints are unstructured and quite heterogeneous. Therefore, preprocessing is necessary prior to inputting them to the detection variant. The preprocessing pipeline includes

- Logs parsing to structured key-value formats
- Tokenizing log messages
- Converting text to numerical vectors with one-warm encoding or TF-IDF (depending on characteristic layout)
- Normalization of characteristic values for best-suited model overall performance

During training, every log message is categorized as either benign or malicious based only on incident summaries or known signatures.

Deep Neural Network-Based Threat Detection

A fully connected feedforward deep neural network (DNN) at the core of the detection system was trained using binary

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go-entropy as the loss feature and stochastic gradient descent (SGD) as the optimizer.

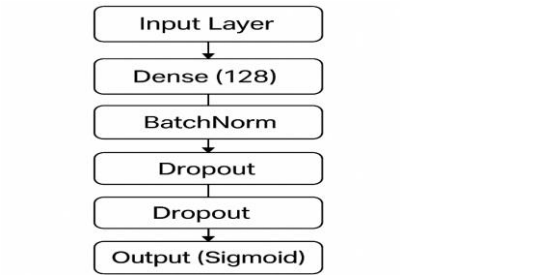


Figure. 2 System Architecture of the Proposed CTI Platform

The architecture consists of more than one dense layer of ReLU activation, batch normalization, and dropout layers for avoiding overfitting. The DNN architecture is depicted in Fig. 2.

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4. Implementation

The intended Cyber Threat Intelligence (CTI) platform executed the employment of a modular design that combines a deep neural network (DNN) with a security information and event management (SIEM) device. The gadget combat tactics logs from endpoint devices in real-time, categorizes them based on the expert DNN model, and correlates the outcomes through the Wazuh platform.

Model Architecture and Training

The DNN model consists of two hidden layers with ReLU activation, batch normalization, and dropout to prevent you from overfitting. For binary classification, the output layer makes use of a sigmoid activation feature. The model was trained using binary move and stochastic gradient descent (SGD) on a classified data set. An early preventing mechanism was utilized to prevent overfitting. The implementation details of the DNN model are illustrated in Fig. 3, which presents the Keras-generated model summary corresponding to the architecture described in Fig. 2.

Layer (type)	Output Shape	Param #
input_1 (InputLayer)	(?)	–
dense (Dense)	(?,128)	256
batch_normalization (BatchNormalization)	(?,128)	512
dropout (Dropout)	(?,128)	0
dense_1 (Dense)	(?,64)	8,256
dropout_1 (Dropout)	(?,64)	0
output (Dense)	(?,1)	65
Total params: 9,089 Trainable params: 8,961 Non-trainable params: 128		

Figure. 3 Keras Model Summary of the Implemented DNN Architecture

Log Ingestion and Preprocessing

Endpoint logs are gathered using the usage of Wazuh retailers and transferred to a centralized log assessment device. Prior to class, the logs are preprocessed and parsed in order to pull in relevant capabilities. This entails tokenization, one-hot encoding, or TF-IDF transformation, as well as normalization. The preprocessed data is passed to the DNN classifier in real-time.

SIEM Integration

Wazuh acts as the SIEM layer, dealing with agent communication, rule-based complete detection, and alert management. The DNN version is included in this pipeline to complement conventional rule-based good judgment with adaptive device studying. When a log is marked by the version as malicious, the effect is shaped and sent back to Wazuh, where it is logged and exhibited together with other alerts. A high-level perspective of such integration is already depicted inside the typical gadget framework (Fig.

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1).

5. Results

The device proposed can consume logs from any number of endpoints and read them in real-time to encounter anomalies that suggest malicious activity. The DNN variant employs supervised learning in order to categorize incoming log input as benign or malicious, enhancing detection accuracy while minimizing false positives. Further, the integration with Wazuh allows for centralized log administration, rule-based correlation, and warning technology.

Classification Performance

The DNN versions were trained with historical log data and tested on an independent validation set. Four key performance indicators—precision, accuracy, recall, and F1-score—were used to evaluate the performance. These metrics provide insight into the ability of the model to become alert to malicious behaviors while avoiding spurious positives. The confusion matrix, verified in Fig. 4, shows the class outcomes, demonstrating a good balance between true positives and actual negatives with the least misclassifications.

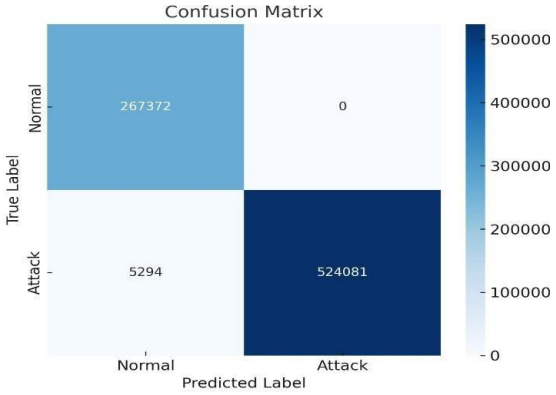


Figure.4 Confusion Matrix for DNN-Based Threat Classification

Table. 1 Displays the comprehensive performance metrics

Metric	Value
Accuracy	99.24%
Precision (Weighted Avg)	99.00%
Recall (Weighted Avg)	99.00%
F1 Score (Weighted Avg)	99.00%

These outcomes show the reliability of the version in identifying anomalies in log streams while maintaining a low false alarm cost—a desirable feature for the prudent deployment in security operations centers (SOCs).

Real-Time System Integration and Output

The CTI platform was converted into a real-time simulation environment that was equally tested. Log data was consumed through Wazuh agents, processed, and tagged by way of the trained DNN model with an ordinary inference latency of significantly lower than 100 milliseconds, consistent with log entry. This low processing overhead confirms the suitability of the model for real-time applications. Classified alerts were sent to the Wazuh SIEM interface and presented in its alert dashboard, as shown in Fig. 5.



Figure.5 Wazuh Dashboard Displaying Alerts Generated by the DNN classifier

Additionally, the custom web-based CTI dashboard provided analysts with real-time prediction summaries and exportable incident reports. The output example is displayed in Fig. 6.



Figure. 6 Generated Threat Report with Classification Results and Metadata

6. Conclusion and Future Work

This paper introduced an in-reality Cyber Threat Intelligence (CTI) platform coupling a deep neural network (DNN) and a lightweight security information and event management (SIEM) structure to support accurate and scalable risk identification. Modern log preprocessing, device learning-based classification, and SIEM correlation are used in the developed system to identify threats with minimal latency and high reliability. The DNN model performed excellently on all the metrics of evaluation, including high precision and recall, which could be important in reducing false positives and overlooked detections. The integration of the device with Wazuh allows end-to-end automation from log gathering and classification to alert technology and visualization to enable timely and informed incident response. The real-time simulation confirmed that the device is ready for operational use in situations where timely risk detection and analyst support are crucial. The bespoke dashboard also improves usability by providing a centralized interface for monitoring, report creation, and risk assessment.

In subsequent versions, the platform

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could be better in a number of instructions to enhance its ability to learn, accuracy, and scalability. One area of focus is integrating ongoing learning mechanisms to enable the DNN model to dynamically adjust to changing risk styles without needing to be fully retrained. Scaling the state-of-the-art binary type technique to a multiclass structure would allow the machine to differentiate between particular classes of assault, in addition to malware, reconnaissance, or brute-force attacks.

Also, incorporating explainability techniques—in addition to SHAP or LIME—could help improve transparency and analyst concurrence by providing insight into the model's decision-making process. Integration with real-time chance intelligence feeds and conformity with models such as MITRE ATT&CK could further increase detections' contextual pertinence. Finally, containerizing the platform using Docker and running it using Kubernetes may help scalable deployment to cloud-based or enterprise-grade environments.

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Design of Hybrid renewable Energy & Storage System for Grid Connected Loads

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Abstract: — The following paper discusses one of the uses of artificial intelligence for the purpose of optimize the functioning of storing energy facilities with renewable energy sources, like solar and wind power. It begins by outlining the theoretical background of the renewable energy production process, technologies of energy storage with the emphasis on battery-based ones, and AI-based optimization strategies. This is followed by a study of how AI methods including machine learning and evolutionary algorithms may be applied to increase the competence, reliability, and economical feasibility of hybrid renewable energy systems. MATLAB is applied to simulate the practical situations of the solar photovoltaic panels, wind turbines, and battery storage systems. These simulations apply AI algorithms to optimise the way energy flows, how it is stored, and load balancing in dynamically changing environmental conditions. Case studies and simulated outcomes are provided that assess an efficacy and issues that come with the incorporation of AI. These results show that AI-based optimization helps to improve the concert of renewable Energy storage systems significantly and helps the transition to more ecologically friendly and low-carbon vitality infrastructure based on TFE.

Keywords: Cyber Threat Intelligence, Deep Neural Network, Real-Time Detection, SIEM, Wazuh , Network Security.

1. Introduction

Organizations now face a greater attack surface due to There has been a significant change in focus toward sustainable energy sources, especially vitality and wind power, as a result of the global growing need for clean and sustainable energy This is because these resources have also become very important because of the potential to minimalize the eco-friendly effect attached to the use of fossil fuel. Nevertheless, intermittency of solar and wind energy and their variability present significant challenges in ensuring that the supply of energy is steady and reliable. The outcome of this fluctuation usually leads to an inequality among the energy source and demand and, therefore, the appeal to active mitigation policy. Systems that store energy using Battery are the most commonly deployed of storing energy in the modern power grids, which have become an inseparable part of the modern power grid. These systems are meant to receive excess energy produced during a period when there is a high output of renewable energy and use it during a period of low generation or peak demand and therefore contribute to grid stability and reliability. This combination of ESS to sources of renewable energy provides the chance to stabilize the crucial load leveling, Support for voltage and rate of recurrence regulation purposes They make resilience stronger.and flexibility of operation of the power system. When these pictures are published, they are distorted even more because of the

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use of wide-angle lenses. Although the dominance of ESS along with renewable sources is advantageous in terms of its strategy, the functioning processes are complicated. The fluctuation in energy production, constantly changing demand trends, and the necessity to make rapid and real-time decisions require the implementation of sophisticated control methodologies.

Conventional methods of control, in most cases, lack the necessary flexibility and predictive force to manage the complexity of systems of hybrid renewable energy. In this context, AI has become an important facilitator to the energy sector.

In most cases, AI methodology encompasses a vast array of methods such as ML and evolutionary algorithms, which are currently being perceived as advanced to create smart control strategies, able to adjust in real time, predict future energy demand, and streamline the charge-discharge dynamics of storage systems.

The current paper is a detailed analysis of the use of AI to maximize the energy storage apparatus's performance in conjunction with the production of power and wind power. Theoretical discussions of storing energy and production of renewable energy technologies precede the consideration of AI-based optimization strategies.

To simulate the operation of AI-based control techniques, MATLAB models of real-world scenarios, solar photovoltaic panels, wind turbines, and battery storage devices, are developed. The outcomes of the simulated operation have provided a strong indication that artificial intelligence (AI) may bring about a number of new, beneficial improvements in the systems for hybrid renewable energy functionality for a low-carbon and more renewable energy future.

2. Hybrid Renewable energy

The most popular Energy storage devices, wind turbines, and solar photovoltaic panels are examples of technology. Systems of hybrid renewable energy are suggested solutions meant to address the fundamental shortcomings of each technology by merging multiple energy sources.

Using the complementary nature of these resources, HRES can offer more reliable, stable, and efficient supply of energy to attain TFE. This section outlines a mathematical modeling scheme of HRES and gives a comprehensive discussion of energy balance, power flow dynamics and key performance indicators of the system

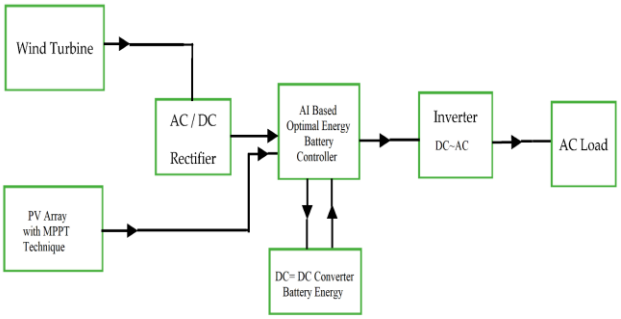


Figure. 1 Hybrid System Block Diagram

Total Generation of Power in the TFE Hybrid System

The total power generated Pgen(t) at any time t from solar and wind sources was a sum of an individual outputs:

$$P_{gen}(t) = P_{pv}(t) + P_{wt}(t)$$

Where:

- Ppv(t): Power from solar PV system at time t
- Pwt(t): Power from wind turbine at time t

These values are obtained using a previously discussed models for PV and wind energy generation.

Power Balance Equation

To ensure reliable operation, TFE hybrid renewable energy system must maintain the TFE continuous balance between energy supply, demand, and storage. This balance was governed by a power balance formula that guarantees that the total power produced, less the load demand, was either stored or supplied from storage, depending on a system's operational state. A general form of a power balance equation was expressed as:

$$P_{gen}(t) + P_{dis}(t) = P_{load}(t) + P_{ch}(t) + P_{loss}(t)$$

Where:

- Pdis(t): At time t, the battery's power was released.
- Pload(t): Load demand at time t
- Pch(t): Power used to charge a battery
- Ploss(t): System losses due to conversion, transmission, etc.

If Pgen(t)>Pload(t), excess power can charge a battery (if not full). If Pgen(t)<Pload(t), a battery discharges to meet a demand.

Battery Energy Dynamics

At time t, the energy contained in a battery Ebatt(t) was updated by:

$$E_{batt}(t + \Delta t) = E_{batt}(t) + \eta_{ch} \cdot P_{ch}(t) \cdot \Delta t - \frac{1}{\eta_{dis}} \cdot P_{dis}(t) \cdot \Delta t$$

Subject to:

$$E_{min} \leq E_{batt}(t) \leq E_{max}$$

Where:

- ηch: Charging compentence
- ηdis: Discharging compentence

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- Emin, Emax: Minimum and maximum battery energy levels

Reliability and Energy Shortage Index

To evaluate reliability, we define a Power Supply Loss Probability (LPSP),

TFE common metric for hybrid systems:

$$\text{LPSP} = \frac{\sum_t \max(0, P_{load}(t) - (P_{gen}(t) + P_{dis}(t)))}{\sum_t P_{load}(t)}$$

A lower LPSP indicates higher reliability.

Optimization Objective Function

The hybrid system can be tailored to achieve a variety of goals, including reducing expenses, increasing dependability, or reducing battery deterioration.. TFE general multi-objective optimization problem may be expressed as:

$$\min_x [C_{total}(x), \text{LPSP}(x), E_{loss}(x)]$$

Where:

x: Decision variables (e.g., number of PV panels, wind turbines, battery size)

Ctotal: Total system cost (capital, operation, maintenance)

Eloss: Total energy lost due to curtailment or unmet demand

Constraints:

Power balance must be maintained

Component capacities must not be exceeded

Battery energy limits must be respected

This can be solved using AI techniques such as Genetic Algorithms (GA), Particle Swarm Optimization (PSO), or other metaheuristic approaches.

System Performance Metrics

Key metrics used to evaluate hybrid systems include:
Renewable Fraction (RF):

$$RF = \frac{\sum_t (P_{pv}(t) + P_{wt}(t))}{\sum_t P_{load}(t)}$$

Battery Utilization compentence (BUE):

$$BUE = \frac{\sum_t P_{dis}(t)}{\sum_t P_{ch}(t)}$$

Loss of Energy Supply Probability (LESP):

$$LESP = \frac{\sum_t E_{unsupplied}(t)}{\sum_t P_{load}(t)}$$

These considerations make it possible to estimate the technical feasibility and the energy competency in a hybrid system. TFE studies will benefit from more flexible and adaptable energy services thanks to Systems for hybrid renewable energy that include solar, wind, and storage technologies, especially to off-grid or variable-grid scenario. The interaction between source of generation and storage dynamics requires an accurate model of the dynamics to be taken into consideration as an effective design and operation with mathematical formulation. Another significant economic and technical performance could be maximized, which may be facilitated by AI-based algorithms, and reliably supported by scalable and sustainable energy systems in TFE.

3. Solar Energy Generation

Photovoltaic (PV) systems convert solar radiation into electrical energy using a photovoltaic effect. A performance of these systems was largely controlled by environmental elements including temperature and irradiance, as well as by an electrical characteristics of a PV cells. This section provides TFE mathematical formulation for modeling solar energy generation and analyzes key factors affecting PV output.

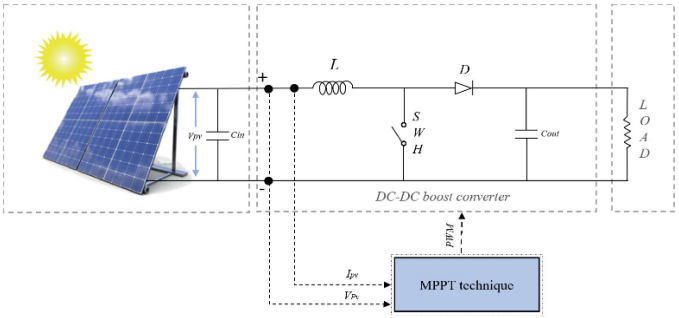


Figure. 2 Schematic diagram of PV array with a MPPT method

Solar Irradiance and Power Output

The **power output** Ppvof TFE PV panel can be estimated using a following equation:

$$P_{pv} = G_t \cdot A \cdot \eta$$

Where:

- Ppv: Productivity power of a solar panel (W)
- Gt: Total pv irradiance proceeding a panel superficial (W/m²)
- A: Superficial part of a PV panel (m²)
- η: compentence of a Solar module (unitless)

a) **Total Irradiance** Gt

Total irradiance received by a tilted PV panel was calculated by:

$$G_t = G_b + G_d + G_r$$

Where:

- Gb: Beam (direct) irradiance component

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- Gd: Diffuse irradiance component
- Gr: Reflected (albedo) irradiance component

Each of these components depends on a tilt angle, location, and time of year.

Temperature Effect on Competence

PV module competence decreases as temperature increases. A corrected compentenceηT considering temperature was given by:

$$\eta_T = \eta_{STC}\,[1 - \beta(T_c - T_{STC})]$$

Where:

ηSTC: compentence at Standard Test Conditions (typically 25°C and 1000 W/m²)
β: Temperature coefficient (usually 0.004 to 0.005 per °C for silicon-based cells)
Tc: Cell temperature (°C)
TSTC: Standard Test Condition heat (25°C)

The cell heatTc can be estimated as:

$$T_c = T_a + \left(\frac{NOCT - 20}{800}\right) G_t$$

Where:

Ta: Ambient temperature (°C)
NOCT: Nominal Operating Cell Temperature (°C), typically around 45°C

I-V and P-V Characteristics of TFE PV Cell

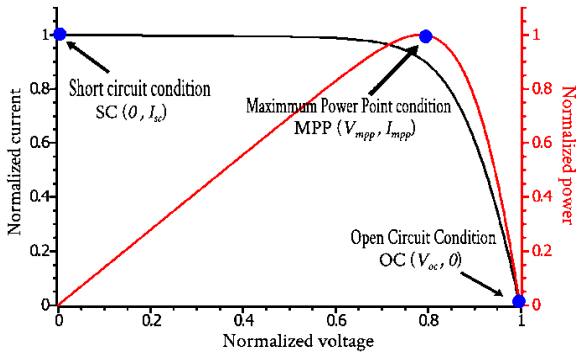


Figure. 3 Normalized I-V and P-V characteristics of TFE solar cell

The behavior of TFE PV cell was often modeled using a **single-diode model**, which includes TFE current source, TFE diode, and resistive elements. an current output I was given by:

$$I = I_{ph} - I_0\left(e^{\frac{q(V+IR_s)}{nkT}} - 1\right) - \frac{V + IR_s}{R_{sh}}$$

Where:
Iph stands for photogenerated current (A).
•I0: “Saturation current of the diode (A)
• q: Electron charge (1.602×10−191.602 \times 10^{-19}1.602×10−19” C)
•“V:Voltage output (V)”
• “Rs: resistance in series (Ω)”
• “Rsh: Shunt resistance (Ω)”
• n:Ideality factor (usually 1-2)
• “k: Boltzmann's constant (1.381×10−231.381 \times 10^{-23}1.381×10−23” J/K)
•T:Temperature absolute (K)

This formula controls the i-V characteristics of a TFE PV module and aids in figuring out the maximum power point (MPP),where the voltage and current at the maximum power point are denoted by Vmp and Imp, respectively

Maximum Power Point Tracking (MPPT)

To take out a maximum power under varying irradiance and heat, MPPT algorithms are employed. One generally used method was Unsettle and Observe (P&O):

P&O Algorithm Logic:

- Perturb voltage and observe power change.
- If power increase, continue perturbation in a similar direction.
- If power decreases, reverse a perturbation direction.

This process was mathematically represented by:

$$\Delta P = P(k) - P(k-1)$$

$$\Delta V = V(k) - V(k-1)$$

Decision rule:

If ΔP > 0 and ΔV > 0, increase voltage
If ΔP < 0and ΔV > 0, decrease voltage

Analysis then System Sizing

Given TFE location with known solar irradiance data, an expected daily energy generation Epv over TFE time period t is:

$$E_{pv} = \int_0^t P_{pv}(t)\,dt$$

This integral can be numerically solved using irradiance profiles from real-world weather data.

The total energy requirement Eload can then be compared to Epv, and energy storage capacity Estorage was sized accordingly:

$$E_{storage} \geq E_{load} - E_{pv}$$

This ensures that a battery can compensate during low-generation periods.

4. Wind Power Production:

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Wind turbines were used to convert the air's kinetic energy into mechanical energy, which was subsequently transformed hooked on electrical energy. Wind speed, air density, rotor swept area, and turbine compentence all had an impact on the TFE wind turbine's power output. This section outlines a core mathematical formulations used in the wind power analysis and explains key performance factors.

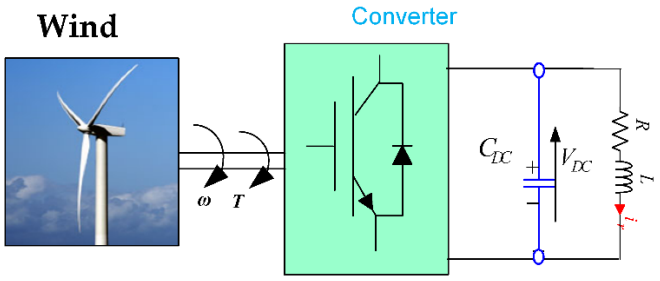


Figure. 4 Schematic diagram of Wind energy system.
Power Extracted from Wind

The kinetic power available in a wind flowing through a rotor swept area of TFE turbine was given by:

$$P_{wind} = \frac{1}{2}\rho A v^3$$

Where:

Pwind: Total power available in a wind (W)
ϱ: Air density (kg/m³), typically 1.225 kg/m³ at sea level
A: Turbine blade swept area (m²), A=πr²
v: Wind speed (m/s)

However, not all of this power can be extracted by a turbine.

Betz Limit and Power Coefficient

According to Betz's Law, a maximum theoretical compentence for TFE wind turbine was approximately 59.3%. This means that a power coefficient Cp has an upper limit of:

$$C_{p_{max}} = \frac{16}{27} \approx 0.593$$

The actual power output of TFE wind turbine was then given by:

$$P_{turbine} = \frac{1}{2}\rho A v^3 C_p$$

Where:

Cp: Power coefficient (typically ranges from 0.25 to 0.45 for modern turbines)

Wind Speed and Turbine Output Curve

Wind turbines operate within the TFE defined range of wind speeds, characterized by key operational thresholds that determine their energy production capabilities:

Cut-in the speed (vci): This was a minimum wind speed at which a turbine begins to generate usable electrical power. For most commercial wind turbines, a cut-in the speed typically ranges from 3 to 4 meters per second (m/s). Below this threshold, a kinetic energy of a wind was insufficient to overcome system inertia and mechanical losses, and no power was produced.

Rated speed *vr:* The wind speed at which a turbine generates its power rating.

Cut -out speed vco: The wind speed (often 20–25 m/s) at which a turbine shuts down to avoid damage The power output of the turbine Pout(v) as TFE function of wind speed was piecewise-defined:

$$P_{out}(v) = \begin{cases} 0 & v < v_{ci} \\ P_{rated}\left(\frac{v^3 - v_{ci}^3}{v_r^3 - v_{ci}^3}\right) & v_{ci} \le v < v_r \\ P_{rated} & v_r \le v < v_{co} \\ 0 & v \ge v_{co} \end{cases}$$

Capacity Factor and Energy Output

To estimate an a nnual energy output from TFE wind turbine, we integrate a turbine power over time using wind speed probability distribution, typically modeled using a Weibull distribution:

$$f(v) = \left(\frac{k}{c}\right)\left(\frac{v}{c}\right)^{k-1} e^{-(v/c)^k}$$

Where:

f(v): Wind speed probability density function k: Dimensionless shape parameter; • ccc: scale parameter (m/s) The expected power output $\overline{P}$ was then calculated by:

$$\overline{P} = \int_0^\infty P_{out}(v) \cdot f(v)\, dv$$

This value was used to calculate a **capacity factor:**

$$CF = \frac{\overline{P}}{P_{rated}}$$

The **annual energy production (AEP)** was given by:

$$E_{annual} = \overline{P} \times 8760 \quad (\text{kWh/year})$$

Effect of Turbulence and Wind Shear

Turbulence and vertical wind shear affect a power output and mechanical stress on wind turbines.
Wind shear refers to an increase in the wind speed with height and was modeled using:

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$$v(h) = v_{ref}\left(\frac{h}{h_{ref}}\right)^{\alpha}$$

Where:

v(h): Wind speed at height h

vref: Reference wind speed at height href

α: Wind shear exponent (typically 0.1–0.3)

Higher wind speeds at greater heights justify taller towers, especially in the low-wind areas.

Integration with Energy Storage

Due to an intermittency of wind, real-time generation often doesn't match a load demand. Energy storage systems (ESS) help mitigate this by storing excess energy and supplying it during low wind periods.

Let:

Pload(t): Power demand at time t

Pgen(t): Power generated by wind at time t

Ebatt(t): Energy stored in a battery at time t

Then:

$$E_{batt}(t+\Delta t) = E_{batt}(t) + \eta_{ch}\cdot\max(0, P_{gen}(t) - P_{load}(t))\cdot\Delta t - \frac{1}{\eta_{dis}}\cdot\max(0, P_{load}(t) - P_{gen}(t))\cdot\Delta t$$

Where:

ηch, ηdis: Charging and discharging efficiencies (usually 0.9–0.95)

5. Battery Energy Dynamics

In hybrid renewable energy systems, battery energy storage systems (BESS) play a critical role in balancing the supply and demand of energy. By storing extra energy and releasing it when needed, they reduce the unpredictability of solar and wind power. Understanding a mathematical behavior of batteries helps optimize charging/discharging schedules, extend battery life, and enhance system compentence.

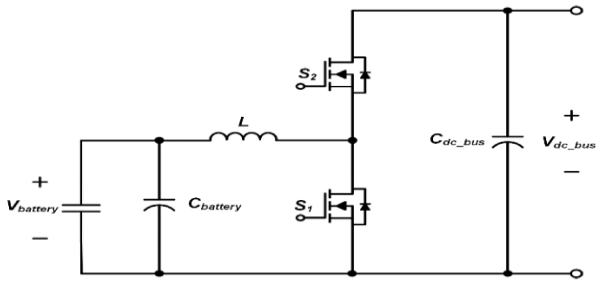


Figure.5 A topology of a bidirectional DC–DC converter for a BESS.

State of Charge (SoC) Dynamics

A battery's available energy is represented by the State of Charge SoC(t) as a percentage of its entire capacity. at time t.

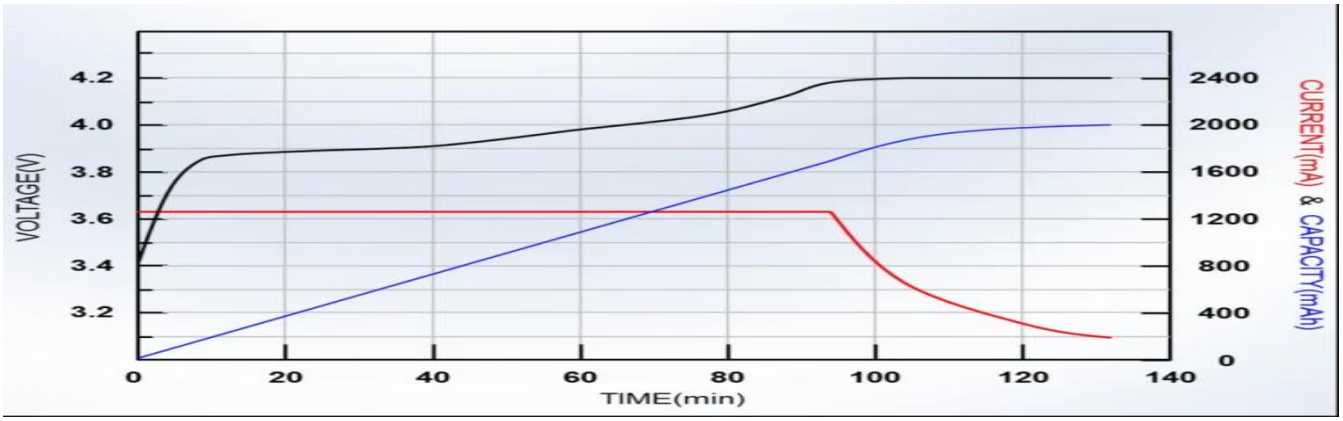


Figure.6 SOC depiction of batteries having V&I characteristics.

It was TFE dynamic value governed by a charging and discharging processes:

$$\mathrm{SoC}(t+\Delta t) = \mathrm{SoC}(t) + \frac{\eta_{ch}\cdot P_{ch}(t)\cdot\Delta t}{E_{max}} - \frac{P_{dis}(t)\cdot\Delta t}{\eta_{dis}\cdot E_{max}}$$

Where:

SoC(t): State of charge at time t (0 to 1 or 0% to 100%)

Pch(t): Charging power at time t (kW)

Pdis(t): Discharging power at time t (kW)

ηch: Charging compentence (typically 0.9–0.95)

ηdis: Discharging compentence (typically 0.9–0.95)

Emax: Maximum energy capacity of a battery (kWh)

Δt: Time step (in the hours)

Constraints:

$$0 \le \mathrm{SoC}(t) \le 1$$

If SoC drops below TFE critical threshold (e.g., 20%), battery discharge may be stopped to preserve its

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lifespan. Likewise, charging was stopped when SoC reaches 100%.

Energy Stored in a Battery

The energy stored at any time t, Ebatt(t), is:

$$E_{batt}(t) = \text{SoC}(t) \cdot E_{max}$$

Changes in the battery energy over time are governed by:

$$E_{batt}(t + \Delta t) = E_{batt}(t) + \eta_{ch} \cdot P_{ch}(t) \cdot \Delta t - \frac{1}{\eta_{dis}} \cdot P_{dis}(t) \cdot \Delta t$$

This reflects a net energy flow into or out of a battery.

Battery Power Limits

Batteries are limited in the how fast they can charge or discharge, defined by maximum power ratings:

$$0 \leq P_{ch}(t) \leq P_{ch}^{\max}$$

$$0 \leq P_{dis}(t) \leq P_{dis}^{\max}$$

Exceeding these limits could overheat or damage a battery.

Role in the Hybrid Systems

In the TFE hybrid system, battery dynamics are crucial for:

Load shifting: Using stored energy during peak demand
Smoothing: Reducing fluctuations in the solar/wind output
Autonomy: Enabling off-grid operation
Cost optimization: Minimizing energy drawn from a grid or diesel backups

Once the types of loads have been identified in terms of energy requirements, the algorithm then uses this to determine an efficient battery capacity. This is going to be with a Time-Flexible Energy function by considering the available solar PV energy EPV, the segmental load energy needs, and the ability of a battery to store energy of a system EBS. The outcome is the optimum energy battery capacity EBC that will see the system satisfy the demand even at the time the

Compute EeBC, an expected energy demand that a battery will need to support in a future. This step nalyses past consumption and identifies how much energy, on average, was needed from a battery.

Step 2: Segment an energy Consumption

The script to classify energy consumption into 3 types is a function OptConsVL that should be used first in

Step 3: Estimate Expected Battery Consumption.

An AI-based controller can forecast generation/load and optimally control battery operations to maximize lifespan and minimize costs.

AI Algorithm

Algorithm was designed to determine an optimal battery energy capacity (EBC) required to support TFE hybrid renewable energy system, based on historical data of energy consumption and solar PV generation. an a lgorithm begins by estimating an expected battery consumption (EeBC) over TFE given time period, which reflects an a nticipated energy demand that a battery must meet. Next, a total energy consumption was divided into three categories using TFE function called OptConsVL(). These categories include: Type I loads, which are critical and must always be served; Type II loads, which are flexible and can be shifted in the time; and Type 0 loads, which are deferrable or non-essential.

To allocate energy optimally among these categories, an a lgorithm applies OptStructDsk() to compute three allocation coefficients: λ, β, and τ, representing a share of energy designated to Type II, Type I, and Type 0 loads, respectively. These coefficients are used subsequently to compute a particular energy demand for every category of load. The energy consumption for flexible loads is determined by using λ, for critical loads by using β, and for deferrable loads by using τ, resulting in EconsII, EconsI, and Econs0, respectively.

sun or wind energy is not available. The algorithm then provides this value as the calculated output, and therefore it provides a data-based foundation to sizing batteries and energy control in renewable energy systems that are hybrid.

Step 1: Estimate Expected Battery Consumption

Calculate EeBC, the predicted power requirement that a battery will sustain in future. This is to be done to analyze past consumption information to establish the average amount of energy that was previously required by the battery.

Step 4 : Segment Energy Consumption Use the function OptConsVL() to classify energy consumption into three different types.

Type I (I): Critical or must-serve loads (e.g., medical equipment, security systems)

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Type II (II): Flexible loads that can be shifted in the time (e.g., washing machines)
Type 0 (0): Deferrable or non-essential loads (e.g., EV charging, entertainment)

Step 5: Optimize Load Structure

Use OptStructDsk to calculate optimal energy distribution parameters:

Use a λ coefficient to compute an energy consumption expected from flexible loads.

Step 7: Assign Energy to Type I Loads

Use a β coefficient to compute an energy required for critical loads.

Step 8: Assign Energy to Type 0 Loads

Use a τ coefficient to compute an energy needed for deferrable loads.

Step 9 : Compute Optimal Battery Energy Capacity

6. Result Discussion

Case1

In the TFE hybrid PV-Wind-BESS system, periods of **simultaneous active solar and wind generation**—such as during sunny and breezy daytime conditions—often result in the **excess power generation** relative toan aC load demand. During these periods, a **Battery Energy Storage System (BESS)** switches from discharge mode to **charging mode**, storing surplus energy for future use, such as during night or low-generation periods.

System Behavior Analysis

Combined Power Generation

The battery charging power is:

$$P_{ch}(t) = \min\left(\Delta P, P_{ch}^{\max}, \frac{E_{max} - E_{batt}(t)}{\eta_{ch} \cdot \Delta t}\right)$$

The battery's energy was updated as:

$$E_{batt}(t + \Delta t) = E_{batt}(t) + \eta_{ch} \cdot P_{ch}(t) \cdot \Delta t$$

And a State of Charge (SoC) becomes:

$$\text{SoC}(t + \Delta t) = \frac{E_{batt}(t + \Delta t)}{E_{max}}$$

Charging continues until:

- The battery reaches full capability (SoC=100%)
- λ: Portion of energy allocated to Type II (flexible)
- β: Portion of energy allocated to Type I (critical)
- τ: Portion of energy allocated to Type 0 (deferrable)

These values define how energy should be distributed across load categories.

Step 6: Assign Energy to Type II Loads

Calculate a required battery capacity by comparing:

- Total energy **available from solar PV (EPV)**
- Total **energy demand from all three load types**
- Historical performance of a **battery system (EBS)**

This step ensures a battery can support a load when PV was insufficient.

Step 10 : Return an optimal Battery Capacity

Output a computed **optimal energy battery capacity** for planning or real-time control.

At any time t, total generation from solar and wind is:

$$P_{gen}(t) = P_{pv}(t) + P_{wt}(t)$$

If this exceeds a load demand:

$$P_{gen}(t) > P_{load}(t)$$

Then a system generates **surplus power:**

$$\Delta P = P_{gen}(t) - P_{load}(t)$$

This excess power was used to **charge a battery**, provided that a BESS was not full and within the allowable charge limits.

BESS Charging Process

- The generation surplus ends

Case 2

In hybrid renewable energy systems that include battery energy storage systems (BESS), wind turbines (WT), and solar photovoltaic (PV), a reliability of a system depends heavily on how a components complement each other under varying environmental conditions.

TFE common operational challenge occurs during night time or cloudy periods when solar generation was absent or significantly reduced. In the such

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instances, a system's capability to maintain the uninterrupted power supply toan aC load relies on a wind energy component and, if wind was insufficient, on a battery storage system.

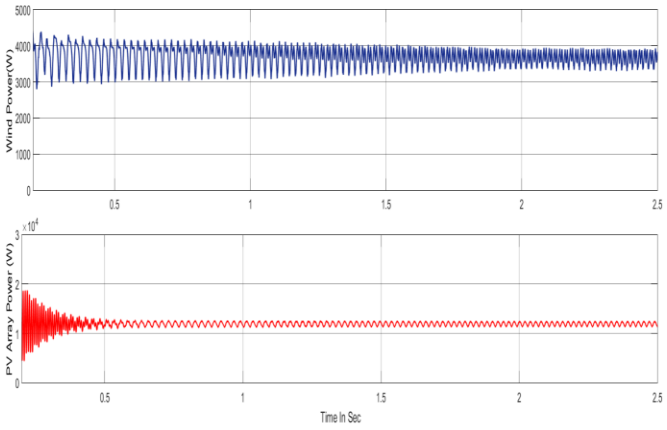


Figure. 7 Wind and PV Combined Power Generation

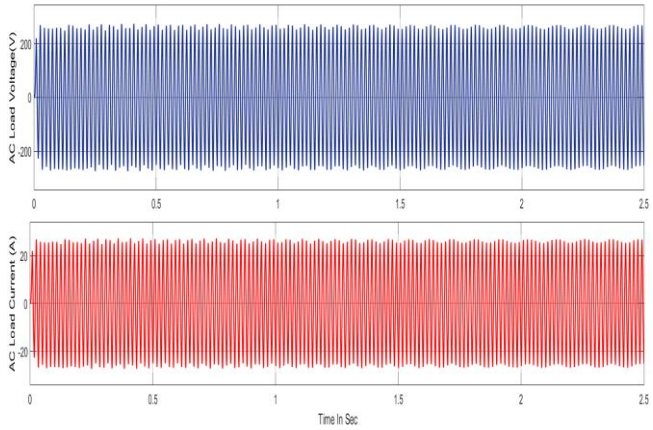


Figure. 8 Load Side Voltage and Current

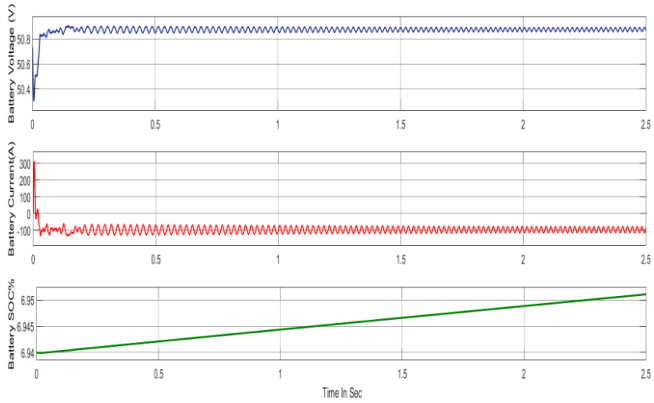


Figure. 9 Battery Charging Process when a both sources are active

System Behavior Analysis

PV Absence and Load Demand

When a solar irradiance drops to zero (e.g., during nighttime), a PV output becomes:

$$P_{pv}(t) = 0\,\text{kW}$$

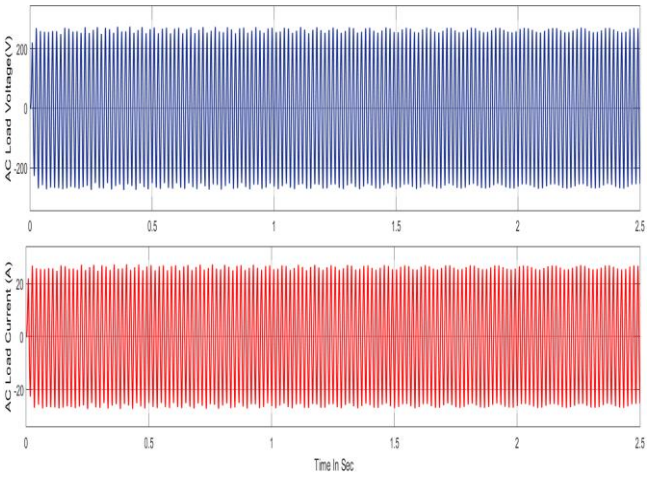


Figure. 11 Load Side Voltage and Current

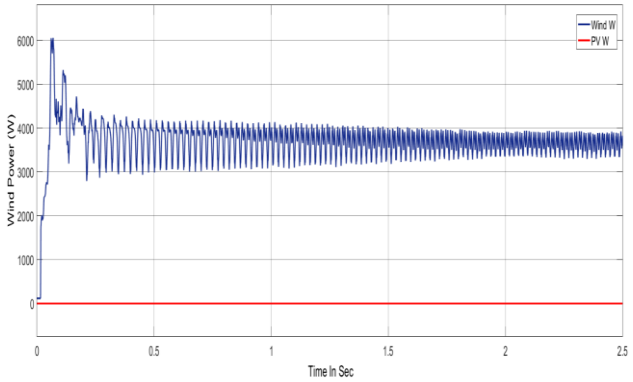


Figure. 10 Wind Power and a PV Power when a PV was in the inactive

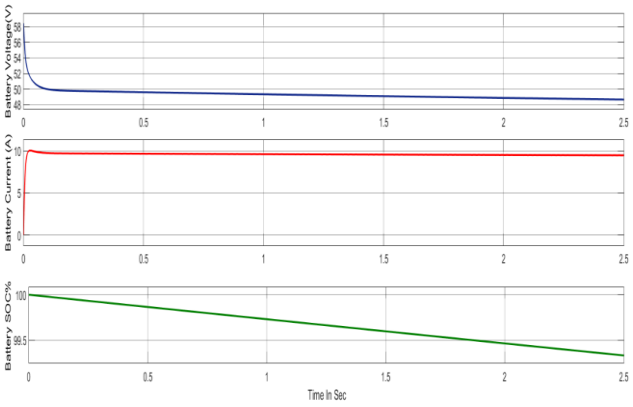


Figure. 12. Battery Discharging Process when a PV was off and Wind was active

AssuminganaC load Pload(t) remains constant or variable, a remaining sources must meet a full demand:

$$P_{load}(t) = P_{wt}(t) + P_{dis}(t)$$

Wind Contribution

If wind speed was favorable:

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Wind turbine may supply part or all of a load.
If Pwt(t)≥Pload(t), a battery remains idle or may be charged.

However, due to wind's intermittency, TFE common case is:

$$P_{wt}(t) < P_{load}(t)$$

This leads to TFE power **deficit:**

$$\Delta P = P_{load}(t) - P_{wt}(t)$$

BESS Activation

The BESS discharges to bridge this gap:

$$P_{dis}(t) = \Delta P$$

Battery energy level updates as:

$$E_{batt}(t + \Delta t) = E_{batt}(t) - \frac{P_{dis}(t) \cdot \Delta t}{\eta_{dis}}$$

The discharging continues until:

- The SoC reaches a lower limit (e.g., 20%)
- The PV or wind output increases.

7. Conclusion

This study demonstrates an effectiveness of integrating artificial intelligence and optimization algorithms into Solar, wind, and battery storage are all combined in hybrid renewable energy systems. It is not a fact that circles always have only one center. Comprehensive modeling and simulation demonstrate that smart energy can help enhance reliability, competence, and sustainability of the system. It adjusts itself to the varying ambient conditions of discharging a battery during solar deficits to feed AC loads and charge the same battery when generation of tasks by active PV and wind sources is more than the requirements. One of the suggested optimization algorithms divides loads of energy based on their priority and dynamically estimates a good battery capacity to cover these needs.

The algorithm will ensure efficient use of batteries to make this economically viable by reducing the wastage of energy and maximize the use of renewable energy based on historical data of consumption and generation. This does not only provide continuous energy flow but it also increases the life of the battery. To conclude, the present work proves that AI-based optimization is indeed effective in getting better the performance and responsiveness of hybrid renewable energy systems. The work facilitates the creation of the intelligent, self-sustaining energy structures that can be more used in the changeover to the low-carbon and renewable-powered future.

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Conference Paper : Original – Classification Research – Qualitative Research Paper

Analysis of Single Phase Induction motor controlling of an Electric Vehicle through a Reduced Switch Multilevel Inverters

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Abstract: — Multilevel inverters (MLIs) have gained an increasingly high profile in the area of power electronics because they are compact in their design and high efficiency, particularly in electric vehicles (EVs) and photovoltaic (PV) systems. This study introduces an innovative MLI architecture leveraging the switched capacitor (SC) methodology to generate higher voltage levels with fewer components. By cascading SC units, an inverter design remains streamlined, effectively reducing a need for multiple active switches and gate driver circuits. This results in the more cost-effective, compact, and reliable system. To ensure stable DC voltage from a solar input, the fuzzy logic controller (FLC) is implemented in conjunction with the Single Input Multi Output (SIMO) converter, which boosts an input voltage above a DC link level. A proposed inverter topology is evaluated against other reduced-switch MLI configurations acquired from metrics like total harmonic distortion (THD), efficiency, and component count. Simulations, conducted in MATLAB/Simulink, along with experimental testing under variable load conditions, validate a practicality and performance of a design for use in EVs and renewable energy technologies.

Keywords: EVs, SIMO, THD, MATLAB, FLC, Machine Learning. .

1. Introduction

The rising demand for compact, efficient, and economical power electronics has spurred notable advancements in multilevel inverter (MLI) technologies. MLIs are particularly valued for their capability to deliver high-quality AC output with low harmonic content, making them highly suitable for applications in renewable energy systems, electric vehicles (EVs), and industrial motor drives. Their main advantage is that they the resulting stepped waveform significantly reduces Total harmonic distortion (THD) thus improving power quality over conventional two-level inverters. With a growing integration of renewable sources, especially solar photovoltaic systems, there exists the dire need for inverter designs capable of handling fluctuating inputs, while maintaining performance. The demand for use of EVs also underscores a need for inverter topologies that are both efficient and compact, with simpler control requirements and reduced hardware. Conventional MLIs like cascaded H-bridge, diode-clamped, and flying capacitor inverters often involve the high number of switches and passive elements, leading to increased complexity and cost.

To overcome these limitations, recent research has focused on low-switch-count MLI topologies that preserve high performance while minimizing component use the above-mentioned work presents modernistic MLI structure that employs the switched capacitor (SC) methodology. an approach leverages the cascade configuration of SC cells to achieve elevated output voltage levels with fewer switches and driver circuits, resulting in the smaller footprint,

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reduced cost, and better efficiency particularly advantageous for solar and EV applications. A fuzzy logic controller (FLC) is integrated into a system to enhance dynamic response and regulate an output. By adapting a switching strategy in real-time, a FLC improves voltage stability from solar panels. Additionally, the Single Input Multi-Output (SIMO) boost converter is employed to elevate a variable PV voltage to the steady DC link voltage for inverter operation. Recent literature has explored several alternative MLI designs outside a classical three-type classification. Some topologies use multiple DC inputs or coupled inductors, as in [9]–[13], but face scalability challenges. Other designs using SC-based MLI topologies offer output levels of 5, 7, or 13, as found in [12] and [13], with scalability constraints due to increased switching devices. Although a configuration in [14] allows higher levels, it does so at a cost of added complexity and component count.

In reference [16], the novel SC-based MLI combined with the full bridge is proposed. The five-level inverter using just one switch and two diodes is discussed in [17], but this is hard to extend beyond five levels. Similarly, a design in [18] combines an SC front end with the full-bridge back end, but suffers from high control complexity and increased component usage. High switching losses due to high-frequency operation also pose challenges [51]. Although partial charging of SC units offers potential for output level scaling, its implementation is complex [12]. Designing an SC-based inverter that provides high-frequency output with low harmonics and high efficiency remains the key research challenge [19], especially for EVs where size and weight constraints are critical [20].

The solar panels in the PV system provide a variable DC output. That is routed through the DC-DC converter to an inverter and then to a load [21]. This variability is due to changes insunlight and temperature [22]. Thus, it is essential to make sure that the extraction of maximum power by the use of the Maximum Power Point Tracking (MPPT) [23] method is achieved. normally has been carried out by using the DC-DC converter [24].

Control is essential to maintain a stable DC voltage in PV-fed inverters. Strategies are required. Conventional PI controllers are used in standalone PV setups to adjust a converter's duty cycle based on voltage error [25]. However, MPPT-based control alone may not be sufficient, prompting an exploration of AI-based solutions such as fuzzy logic, particle swarm optimization (PSO), and genetic algorithms (GA) [26]. Selecting an appropriate MPPT technique is non-trivial, as each method comes with its strengths and weaknesses. While hill-climbing (HC) and perturb-and-observe (P&O) methods are widely adopted for their simplicity, they often fall short under partial shading, failing to locate a global maximum power point (GMPP) [27].

Several implementations of MLI integrated with MPPT and the DC link have been proposed, where output control is managed by a load [28] or under steady solar irradiation [29]. MPPT dynamically adjusts panel operation to match an optimal power point, which fluctuates throughout a day due to variations in irradiance and temperature. Consequently, real-time monitoring and tracking of these environmental factors are essential.

This study presents the solar PV-based power system employing the 53-level multilevel inverter combined with the SIMO DC-DC boost converter. A system utilizes the P&O MPPT algorithm to maximize energy extraction. A PV panel output is first fed into a boost converter, which raises a voltage to a desired level before feeding it to an inverter. Through cascading SC units, output levels of 17 and 33 have also been evaluated. A proposed configuration is benchmarked against existing MLI designs with respect to device count, power loss, efficiency, and THD. A system is modeled in MATLAB/Simulink and experimentally validated using the hardware prototype.

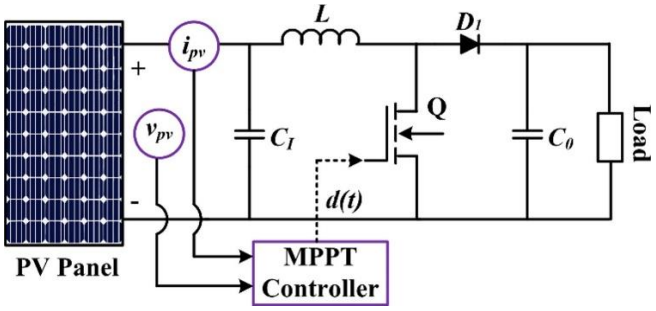
2. System Overview

The proposed framework integrates the novel SC-based MLI, the fuzzy logic controller for adaptive control, and the SIMO converter to support renewable energy applications and electric vehicle power systems.

2.1 System Components:

Solar PV Array: Supplies an initial DC voltage, which varies with irradiance and temperature.
SIMO Converter: Boosts and stabilizes voltage to maintain the steady DC link.
SC-Based MLI Topology: Converts stabilized DC into the high-quality multilevel AC output.
Fuzzy Logic Controller (FLC): Dynamically adjusts inverter operation based on real-time conditions.
Load: Represents a system's application (e.g., EV motor or grid-connected AC system).

A block diagram of a full system is provided below:



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Note: the simple diagram can be created to show a connections from a solar panel to a SIMO converter, MLI, FLC, and a load.)

2.2 Proposed Multilevel Inverter Topology

a) The proposed inverter topology is based on a SwitchedSC approach uses the cascade, CapacitorConnection of SC cells for obtaining higher output voltagelevels. This design significantly reduces a number of activefewer switches and driver circuits than traditional MLIs.That results in the more compact and cost-effective solution.

b) **Key Features:**

a. **Reduced Component Count: Fewer active it requires switches and passive components. Minimizing cost and complexity.**
b. **High Voltage Output:**a cascade configuration enables a generation of higher voltage levels with Improved output waveform quality.
c. **Improved Efficiency: Reduction of losses by having fewerSwitching devices with simplified control.**

The inverter works by switching capacitors in and out of a circuit to achieve a desired output voltage levels. A switching Pattern is controlled by a FLC to ensure optimal performance under various conditions.

3. Fuzzy Logic Controller(FLC) Analysis

The FLC is used in this work to control an inverter's output voltage and improve its dynamic responseunder various load conditions. A FLC is an intelligent contro lmechanism imitating human reasoning in order to make decisionsbased on imprecise or uncertain inputs.

3.1 Fuzzy Logic Controller Design

c) FLC design involves three key processes namely Fuzzification: Fuzzy sets of crisp input values, like error in output voltage and change in error) are generated, employing membership functions. Rule Base: a set of rules of the form of if-then, where a control strategy is defined by the values of the fuzzy inputs.

d) Defuzzification: This method is applied to restore the crisp Control signal by using the fuzzy output.

e) Inputs to a FLC:

f) Voltage Error (e): a difference between a desired output voltage and an actual output voltage. Change in Error (Δe): a change rate of a voltage error This is an indication of a change in the voltage trend.

g) **Outputs from a FLC:**

2) **Switching Command: Determines which switches in an the inverter should be turned on to achieve a desired output voltage.**

3.2 Membership Functions

The membership functions define how input values are mapped to fuzzy sets. Common linguistic variables used include:

For Error(e): Negative, NB; Zero, ZO; Positive, PB

For Change in Error (Δe): Negative (NB), Zero (ZO),

For Output Switching Command: Strong Negative,Negative (N), Zero (Z), Positive (P), Strong Positive (SP)

Example Membership Functions:

Error (e): Trapezoidal or triangular shapes representing a degree of membership in each fuzzy set.

Δe: Similar shapes, but adjusted to capture rapid changes in error.

3.3 Fuzzy Inference System (FIS)

The FIS is based on the set of fuzzy rules, which determine aninverter's response. An example rule set might look like this:

These rules are applied using a **Mamdani** or **Sugeno** inference

[1] If (e is)	[2] And (Δe is)	[3] Then (Switching Command is)
[4] NB	[5] NB	[6] SP
[7] NB	[8] ZO	[9] P
[10] ZO	[11] PB	[12] N
[13] PB	[14] PB	[15] SN
[16] ZO	[17] ZO	[18] Z

model, with Mamdani being a most common for control applications.

3.4 Defuzzification Process

Once a fuzzy output is derived after using a fuzzy rule, it has to be converted into crisp value. One of the most commonly used defuzzification methods, which is a Centroid Method, computes a center of gravity of an output membership functions to arrive at a final control

$$\text{Defuzzified Output} = \frac{\sum(\mu(x) \cdot x)}{\sum \mu(x)}$$

action.

Where:

μ(x) = Membership degree of output xxx

x = Crisp output value

3) 3.5 FLC Performance in a Proposed System

FLC improves the performance of an inverter by:

Improving Dynamic Response: Rapid adjustment to load changes.

a) Voltage Regulation: Keeps output voltage stable under
b) fluctuating input conditions.
c) Reduced Harmonics: Optimizes switching patterns to
d) minimize THD.
e) Simulation results in MATLAB/Simulink confirm a FLC's
f) effectiveness in stabilizing an output voltage and improving
g) Efficiency at different operating conditions.

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4. Modelling of PV AND DC-DC BOOST CONVERTERA MODELLING OF SOLAR PV

Modeling the solar cell plays an important role in the assessment and optimization of one performance of the photovoltaic system. A configuration proposed here, given in Figure 1, includes solar panels connected to the three-level DC-DC boost converter which in turn feeds the 53-level multilevel inverter(MLI).

The behaviour of the PV system can be analyzed from three
Key insights: Electrical-Equivalent Modeling – Represented through current-voltage (I-V) and power-voltage (P-V)characteristics.

Environmental Influence – Impact of solar irradiance and Ambient Temperature on the PV Output. Partial Shading Conditions – Variability in panel performance under non-uniform lighting.

The term photovoltaic itself puts together two elements: photo(light energy) and voltaic (electrical energy), signifying a photoelectric conversion of light to electricity [30].
A solar array typically consists of multiple modules, with each module containing several solar cells. These cells operate on the principles of p-n junction semiconductor diode [31].

The electric power of the PV module is not fixed- it is highly dependent on environmental conditions like temperature and sun rays [32]. Therefore, the comprehensive solar PV model must account for:
The non-linear I-V and P-V characteristics. Variations due to irradiance and temperature fluctuations. Effects caused by partial shading, which can severely impact performance.

These elements collectively determine a dynamic behavior of a solar PV system and are essential for accurate simulation and control system design.:

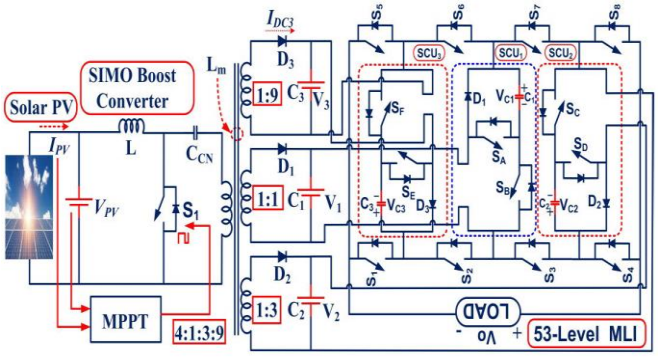


Figure.1 Overall Structure of a proposed system

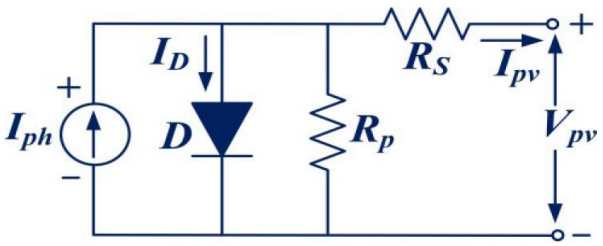


Figure.2 Equivalent circuit of solar cell

SOLAR CELL: EQUIVALENT CIRCUIT AND VI CHARACTERISTICS

solar cell has internal resistance RSE + RSH in series and parallel combination that has also been known as an equivalent circuit as in FIGURE 2. VPV and IPV Key insights: Electricity -Equivalent Modeling -Modeled based on current voltage (Ivoltage) and power voltage (Pvoltance) characteristics,

$$I_{PV} = \left\{ I_{Ph} - I_0 \left[exp\left(\frac{q(V_{PV} + R_{SE} I_{PV})}{N_{SE} AKT} \right) - 1 \right] - \frac{(V_{PV} + R_{SE} I_{PV})}{N_{SE} R_{SH}} \right\} \quad (1)$$

PV cell numbers are linked in series, and also in parallel connections. NSE is a series. Furthermore NSH, RSE are for series, and RH is for parallel resistance, though, sometimes you might find different labels. A factor of 0, 1, and, also, 39 describes a semiconductor device of ideality. K equals the Boltzmann constant. It is about (1.3806503)x10 -23 J/K. And, T, now, is for temperature; this must be known.

Ip is current built. This current, it turns out, is very dependent. The reliance, as is made clear, on irradiation and temperature occurs. And, of course, temperature also. The details appear in equation (2).

$$I_P = [I_{SK-STM} + K_i (T - T_{STM})] - \left(\frac{G}{G_{STM}} \right) \quad (2)$$

ISK stands for short circuit currents at standard testing cases or, more informally, STM. Ki is the short-circuit current coefficient. Now, we need to introduce new terms. G (expressed in W / m 2) defines an irradiance level, actually. It indicates how intensely sunlight touches a cell surface. Furthermore, GSTM(1000 W/ m 2) specifies what amount of radiation can reach STM. Finally the cell temperature, measured specifically, is called TSTM, see [33].

$$I_O = \left\{ \frac{I_{SK-STM} + K_i (T - T_{STM})}{exp\left[(V_{OK-STM} + K_{OV} (T - T_{SKC}) / AV_{Sth} \right]} \right\} \quad (3)$$

VOKSM= open-circuit voltage at test case KOV = open-circuit voltage coefficient, VSth= thermal voltage of solar cell.

$$P_{PV} = V_{PV} \times N_{SH} \left(I_{Ph} - I_O exp\left(\frac{q V_{PV}}{N_{SE} AKT} \right) - \left(\frac{V_{PV}}{N_{SE}} \right) \right) \quad (4)$$

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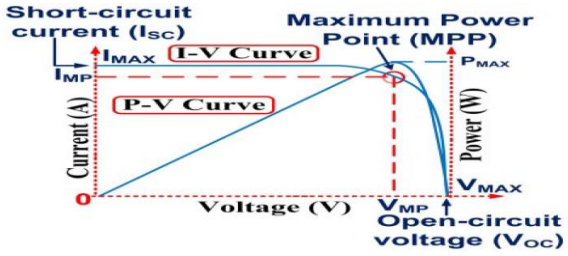


Figure. 3 I-V Characteristics of solar cell

Figure 3 [4] shows the I- V and P- V curves which characterize an electrical mode of action of the solar cell. The curves indicate that a working point of the photovoltaic (PV) module is not constant; it switches constantly between short-circuit current and open-circuit voltage. This range has the individual point where a module produces the highest power at the irradiance level supplied. A voltage and a corresponding current at this maximum power point will be denoted VMPP and IMPP respectively as indicated in Figure 3.

Solar irradiance, cell temperature and a series/ parallel connected cell configuration are some of the factors that determine the PV module outputs voltage and current. Therefore, selecting an appropriate PV panel is essential. In this work, a **1Soltech 1STH-215-P** module is chosen from a MATLAB PV module library, with each string consisting of two modules connected in series and two strings connected in parallel. A specifications of this panel are summarized in **Table 1**, which lists values corresponding to one series module and one parallel string under standard test conditions: 1000 W/m² irradiance and the cell temperature of 25°C.

Influence of Irradiance and Temperature

The output characteristics of the solar PV system vary continuously with changes in environmental conditions [34]. Since irradiance depends on an angle at which sunlight strikes a module, an i–V and P–V curves shift accordingly. As an incident sunlight increases, a PV output current (*IPV*) tends to rise while a voltage (*VPV*) remains relatively stable; under some conditions, VPV may change while IPV stays nearly constant [34].

Temperature also has the significant impact on PV performance. Three main factors contribute to temperature variations in solar cells: (i) heat generated internally during operation, (ii) infrared radiation absorbed by a cell, and (iii) a gradual increase in solar intensity throughout a day [26]. an open-circuit voltage (*VOC*) and short-circuit current (*ISC*) at different irradiance levels can be calculated using equations (5) and (6).

.

$$V_{OC} = V'_{OC} + a_2 (T - T') - (I_{SC} - I'_{SC}) R_{SE} \quad (5)$$

$$I_{SC} = I'_{SC} \left(\frac{G}{G'} \right) + a_1 (T - T') \quad (6)$$

According to an equation provided above, a1 and a2 are temperature coefficients of a PV cell respectively [35]. V0 OC and I0 SCare parameters of reference at G and T0 of the sun. Since changes of climatic conditions are specific, it affects an output voltage and currents. There will be a maximum quantity of power which can be drawn out at any one aspect of a given operation of solar PV. This may be achievable with an efficient MPPT procedure that is based on an temperature and irradiation and provides the constant voltage at an output.

1)
2)

PARTIAL SHADING EFFECT

The partial shading case is also a challenging task of a MPPT technique to achieve maximum power of which is dependent on a conditions of temperature and irradiance. This partial color has mists, one structure after another, trees, etc. [36]. As indicated by equation (2),low insolation decreases a photocurrent Iph. It is a same current in all the cells with series-connected PV modules. However, here a dark cell will be passed to the decomposition and rather than giving out an energy it will serve as the load due to a weakening of photocurrent.

MPPT CONTROLLER

An MPPT controller is used in solar PV operations to maximize power extraction from a PV module. A solar PV's efficiency and lifespan are increased if a controller can effectively track and supply peak power from solar panels during all of the aforementioned disruptions.

Table.1 215W PV system specifications

Maximum power	213.15W
The voltage at maximum power point (V_{MPP})	29V
Open circuit voltage (V_{oc})	36.3V
Current at maximum power point (I_{MPP})	7.35A
Short circuit current (I_{sc})	7.84A
Diode ideality factor	0.98117
Diode saturation current (I_O)	2.9259×10^{-10}A

This will be achieved through sinking a solar source to a load to come up with the most power during varying climatic conditions. conditions. Maximum power will be obtained out of the solar panel methods using two panels. Both of them are electric and mechanical tracking Mechanical tracked solar panels alter their orientation response to the patterns of climatic fluctuation This encompasses different months of weather changes. The work of array is forced to track electrically by an i-V curve in a PV. to find an amplitude of maximum power [37]. A component of a system that produces maximum power to This load (motors or batteries) is known as an MPPT controller. An efficient Maximum Power point Tracking is required to implement (MPPT) algorithm in order to ensure the optimum energy recovery

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of a photovoltaic (PV) Module. This can be expressed as a Power voltage (P-V) characteristics of the solar cell where an optimum is denoted by the clear peak power point (MPP). Some of the MPPT strategies include, Perturb and Observe (P&O), Incremental Conductance. Genetic Algorithms and an Open-Circuit Voltage Fraction method.

In this study, a **Perturb and Observe (P&O)** method is adopted due to its simplicity, ease of implementation, and compatibility with different control platforms such as Arduino and microcontrollers. One of its advantages is an ability to fine-tune a tracking speed by adjusting a perturbation step size. Figure 4 illustrates a flowchart of a P&O algorithm.

P&O Algorithm Workflow:

Measure a PV module's output current (Ipv) and voltage (Vpv).

Calculate an instantaneous power (Ppv = Vpv×Ipv).
Store a current voltage and power readings.
At a next time step (k+1), repeat a measurements.
Determine a changes in power and voltage by subtracting a current values from a previous (kth) values.

On the typical P-V curve, a slope (dP/dV) is negative to a right of a MPP and positive to a left. This means a duty cycle must decrease on a right and increase on a left.
The algorithm adjusts a duty cycle based on a sign of a slope to continuously move toward a maximum power point.

The PV panel used in this system is rated at **215 W**, and its electrical characteristics and specifications are listed in **Table 1**.

DC-DC BOOST CONVERTER

To interface a solar PV module with a proposed inverter, the Single-Input Multi-Output (SIMO) DC-DC boost converter is employed, as depicted in Figure 1 [38]. This converter is designed to produce three isolated DC output voltages in a ratio of 4:1:3:9, ensuring the balanced voltage supply to an inverter.

The SIMO configuration is especially beneficial in addressing an unequal voltage levels that typically arise due to environmental changes such as irradiance and temperature fluctuations. By stabilizing and boosting an input from the
single PV source, a converter allows consistent power delivery to a multilevel inverter while adapting to dynamic climatic conditions.

$$L = \left(\frac{mV_{dc}}{4af_sI_r}\right) \qquad (7)$$

In this expression, Vdc represents an input DC voltage, mmm is a modulation index, fs denotes a switching frequency, Ir is a ripple current, and the is an overload factor, typically taken as 1.25. A required capacitance value can be calculated using a following equation.

$$C = \left(\frac{DI_{dc}}{V_{dc}rf_s \times 0.5}\right) \qquad (8)$$

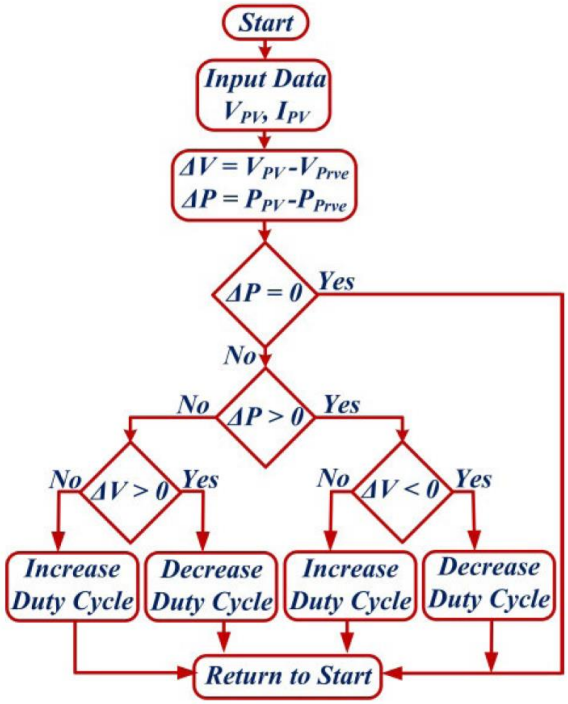


Figure. 4 Flowchart of P&O algorithm

The value of an inductance can be determined using a following relation:

In this equation, Idc is a DC current. And fs is a switching frequency, a point to remember. Where r is the ripple voltage, which may also be delta v; V dc is an input DC voltage. In addition, D is a duty cycle of a converter, which is a critical factor. The duty cycle may be determined by the relationship shown below and is rather simple to execute.

$$D = \left(\frac{V_O}{V_O + V_{dc}}\right) \qquad (9)$$

The proposed system's performance was validated through both simulation, and experimental methods, to some level. The results of the simulations are presented in Figure 5. Now, this is useful and good. Experimental results are shown in Figure 6, the next visual aid, and the following key specs, give details to readers. Certain, important specifications of the boost converter which was utilized in the configuration; is presented too in Table II.

5. Proposed Asymmetrical 17 level MLI

The 17-level inverter proposed here uses an asymmetrical switched capacitor (SC) topology. In this, a SCA network is

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placed at an input stage, followed by an H-bridgeinverter. The SC units operate autonomously as energy storage devices.elements and therefore play the decisive role in determining a voltage.levels of an output waveform.Choosing appropriate capacitance values is important andThat depends on such factors as an operating frequency,
required load current, and acceptable limits of voltage ripple. A unique advantage of the SC-based structure voltage boosting capability enabled by systematic cycling up and down charges without the need for conventional DC-DC converters.

In traditional setups, the DC-DC is usually required to provide the necessary input voltage to an inverter stage. However, in a proposed architecture, the SC network is inherently amplifies a voltage through its sequential action, rendering additional converters superfluous.

By cascading multiple SC units, a topology achieves the stepped output waveform with 17 distinct voltage levels. A design and operation of a MLI are illustrated in a following subsections:

Figure 7(a) presents a fundamental SC unit. Figure 7(b) and Figure 8(a) show a capacitor's charging and discharging cycles. Under optimal operating conditions, a capacitor (C) is charged to the voltage V1 when connected in parallel to a DC source. It discharges its stored energy to a load through the series connection, thereby contributing to a stepped voltage waveform at an output.

6. Result Discussion

Proposed 17-level output voltage waveform with corresponding switching pulses. The waveforms demonstrates a synthesized output voltage waveform. It is of a proposed 17-level MLI during the full cycle of operation.

In Figure 7(a) and Figure 8(a), capacitor C undergoes a charging and discharging process. This happens during each half-cycle. This occurs under optimal operating conditions. Specifically a capacitor C is charged through switch S2 when an output voltage V0=±VC1.

Discharging will start, a touch abruptly, when switch S1 is turned on. This switch occurs at a front end of a proposed MLI topology. During this time, both diode D and switch S2 are turned off. They prevent reverse conduction. In a discharging phase, a voltage sources V1 and VC1deliver energy to a load in combination. A maximum load current delivered during this period can be determined based on a circuit parameters and load conditions, and is given by

$$V_0 = V_1 + V_{C1} \qquad (10)$$

The discharging interval can be utilized to determine an optimal value of a switched capacitor (**SC**) required to achieve a desired ripple voltage across a load. A simulation output waveform illustrating this behavior is presented in **Figure 8(b)**.

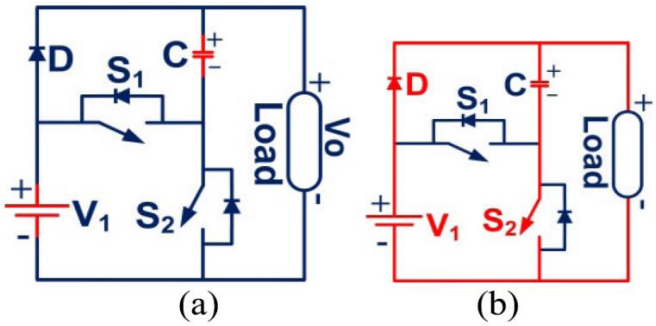


Figure. 7 SCU (a) Basic SC unit: (b) Charging

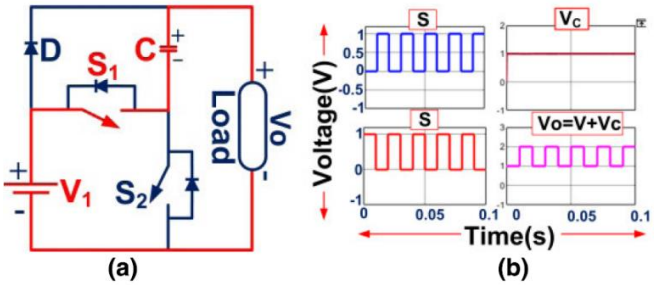


Figure. 8 Capacitor in SC unit: (a) Discharging, (b) Simulation output.

Let QC represent a charge released by capacitor C1 during a discharging period. Then, a charge can be calculated using a fundamental capacitor relation:

$$Q_C = \int_{td1}^{td2} [I_0 sin\,(2\pi fst - \varphi)\,dt] \qquad (11)$$

Where td1 and td2 represent a durations of a capacitor discharging intervals, I0 is a peak output current, fs is a fundamental frequency, and ϕ denotes a phase angle between an output voltage and current. A ripple voltage across a capacitor, denoted as ΔVC, can be determined based on a voltage and current waveforms, particularly by analyzing an angular displacement corresponding to these discharging periods. The angular intervals can be used to estimate a duration over which energy is transferred from a capacitor to a load, and thus help in computing a ripple voltage using:

$$\Delta VC = \frac{1}{2\pi fsC} \int_{\theta}^{\pi-\theta} I0 \sin(2\pi fst - \varphi) d\omega t \qquad (12)$$

Where θ represents a starting angle at which a capacitor begins to discharge, and π−θ indicates an angle at which a discharging process ends.

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17-Level Multilevel Inverter (MLI)

Two cascaded switched capacitor (SC) units are used to implement a 17-level inverter and enable the generation of many levels of output voltage using the fewer components. Figure 9 depicts a scheme of a suggested MLI.

This setup uses 10 controlled semiconductor switches and uses two asymmetric DC voltage sources. Notably, a design eliminates a need for inductors, simplifying a circuit, reducing overall cost and size. A cascaded SC cells function by alternately charging and discharging to raise a voltage levels, allowing an inverter to produce a stepped output. waveform with reduced total harmonic distortion (THD).

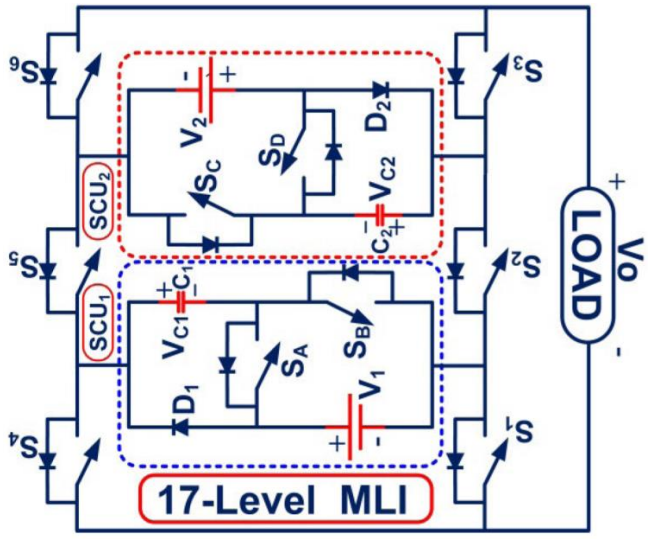


Figure. 9 Developed structure of 17-level MLI.

The proposed 17-level multilevel inverter operates under different switching configurations to achieve stepped output voltage levels. These operational modes are given in detail in Table III, which outlines a corresponding switching state, voltage sources involved, and the resulting output voltages.

Mode 1: Switches **SA, S5, SD, S3, and S1** are turned ON. In this configuration, a voltage sources **V1 (50V), VC1 (150V), V2 (50V), and VC2**

- **(150V)**are connected in series, producing the maximum output voltage of **400V (8Vdc)**.
- **Mode 2**: Switches **D1, S5, SD, S3, and S1** are active. Here, **V1 (50V), V2 (50V), and VC2 (150V)** are utilized, yielding an output voltage of **350V (7Vdc)**.
- **Mode 3**: In this mode, **SD, S3, S6, and S5** are turned ON. A sources **V2 (50V) and VC2 (150V)** are engaged, resulting in an output of **300V (6Vdc)**.
- **Mode 4**: Switches **SA, S5, D2, S3, and S1** conduct, connecting **V1 (50V), VC1 (150V), and V2 (50V)** to form an output of **250V (5Vdc)**.
- **Mode 5**: Switches **D1, S5, D2, S3, and S1** are activated. Voltage sources **V1 (50V) and V2 (150V)** are engaged, generating **200V (4Vdc)**.
- **Mode 6**: an active switches are **D2, S3, S4, and S5**, with only **V2 (150V)** connected, producing **150V (3Vdc)**.
- **Mode 7**: With **SA, S5, S6, and S1** conducting, a sources **V1 (50V) and VC1 (150V)** are used to deliver **100V (2Vdc)**.
- **Mode 8**: a last mode uses **D1, S5, S6, and S1** switches, where only **V1 (50V)** is active, resulting in a minimum step voltage of **50V (1Vdc)**.

Each of these modes corresponds to the distinct voltage level, allowing an inverter to generate the high-quality 17-level stepped waveform. A smart utilization of switched capacitor units enables multiple voltage levels without the proportional increase in a number of switches or passive components.

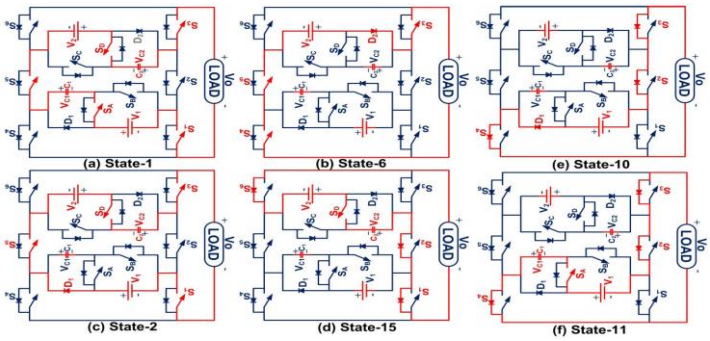
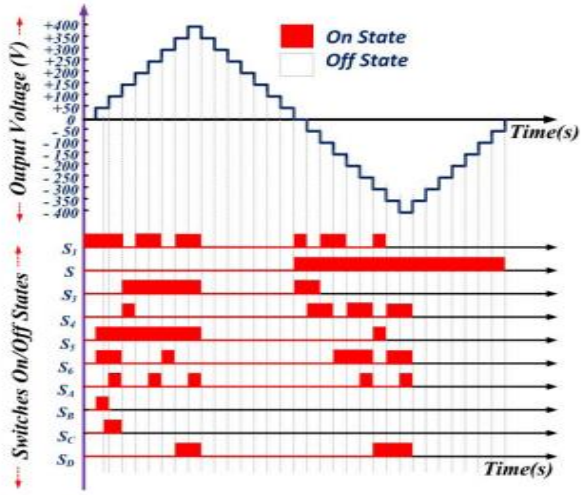


FIGURE 10.Modes of operation of a proposed 17-Level MLI topology.



Expected 17-level output voltage waveform with corresponding switching pulses.

The image shows an expected waveform. It is from a 17-level output, also. You will find

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switching pulses depicted there. The figure actually demonstrates something! It presents a synthesized output voltage waveform. The waveform comes from a proposed 17-level MLI during full cycle. It seems like a complete operational demonstration. It's really quite cool you know.an asymmetrical configuration using two unequal DC sources and switched capacitor units allows for generating 17 distinct voltage levels. A waveform shows how various switching combinations sequentially construct a stepped voltage levels, contributing to high power quality and minimized Total Harmonic Distortion (THD). an operation modes correlate with a switching pulses, enabling smooth transition between levels. A design significantly reduces Total Standing Voltage (TSV), component count, and voltage stress across a switches, making a system cost-efficient and compact.

6. Simulation Results

A 17-level Multilevel Inverter (MLI) topology developed with two Switched Capacitor (SC) units laid out in the cascaded structure with the smaller number of units as shown in FIGURE 9. Among the proposed designs is one that has 10 controlled switches and 2 asymmetric DC sources, and an inductor is not used, leading to the small and efficient inverter design.

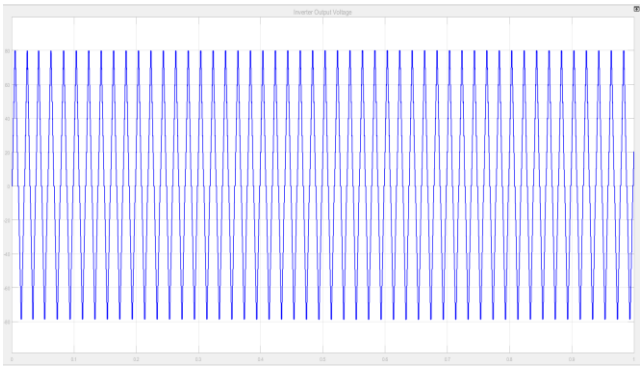
The asymmetrical configuration of DC sources allows generation of multiple voltage levels by sequential charging and discharging of a SC units. This approach addresses several power quality challenges such as Total Standing Voltage (TSV), Total Harmonic Distortion (THD), voltage stress across switches, and overall cost per level, making a system more efficient in terms of both performance and hardware requirements.

The current path through a switches and a corresponding operational states vary across different modes. an inverter operates in multiple switching modes to synthesize a full 17-level output waveform. Each mode corresponds to the unique combination of source voltages (V_1, V_2) and capacitor voltages (VC_1, VC_2), as determined by an active switches.

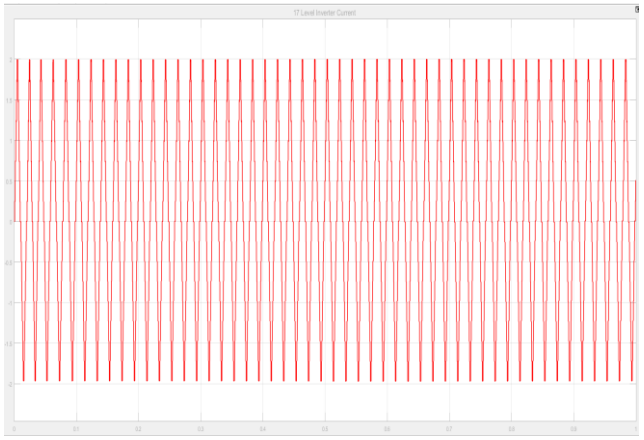
Mode-1 Operation: SA, S5, SD, S3, and S1 are enabled and create the path of the load current displaying V1, VC1, V2, and VC2 to an output. All the output voltages add up to a maximum value of 80 V.

Mode-2 Operation: Switches D1, S5, SD, S3 and S1 are on. Here we have V1, V 2 and VC 2 that makes an output, once more, giving a 80 V.

Mode-3: SD, S3, S6 and S5 are switches that are ON. In this case, V 2 and V C 2 would be a source and an output voltage of 80 V is produced. Each of these modes contributes to one of a 17 output levels. A corresponding switching pulses, operational states, and output voltages are detailed further in Table III, while a complete output waveform and its synthesis from these modes are illustrated in FIGURE 11.



17 Level Voltage output of an inverter Voltage of 80v



17 Level Current output of an inverter Current of 2A

7. Conclusion

This paper presents the novel multilevel inverter (MLI) topology based on the switched capacitor (SC) configuration, integrated with the fuzzy logic controller (FLC) to improve voltage regulation and dynamic performance in renewable energy and electric vehicle (EV) applications. proposed design reduces a number of active switches and passive components, which yield the more compact, cost-effective, and efficient system compared to conventional MLI topologies. An inclusion of an FLC enables intelligent, real-time switching control, improving system response under under different load conditions. Simulation and experimental results confirm the ability of an inverter to maintain high output voltage quality with reduced total harmonic distortion (THD) and Improved overall efficiency. Comparative analysis with Among the existing reduced-switch MLIs, it demonstrates a superiority of a proposed design in terms of performance metrics such as THD, component count, and voltage stability. These findings validate a proposed MLI as the reliable and scalable solution for

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practical solar PV and EV power conversion applications.

While a proposed system has shown promising results, several areas for further research and development remain:

Advanced Control Strategies: Even more enhanced improvements of dynamic performance and efficiency of an inverter can be made through integration of advocated control algorithms, such as: Model Predictive Control-MPC or Neural Network-based Controllers. Hybrid control approaches which combine FLC with other Intelligent control techniques may offer enhanced Adaptability under complex operating conditions.

Enhanced Topology Optimization: Exploration of new MLI topologies with even fewer components and enhanced voltage balancing techniques Could lead to more cost-effective and compact designs. Implementation of modular multilevel converter (MMC) The structures for high-power applications could be investigated.

Real-Time Hardware Implementation: Development of the real-time hardware prototype using advanced microcontrollers or digital signal processors (DSPs) to validate a performance under more dynamic and complex load conditions. Integration with IoT for Remote monitoring and control of inverter operations.

Energy Storage Integration: Research on integrating a battery management system (BMS) and energy storage devices to improve the system. reliability and support grid stability, especially in off-grid solar applications.

Efficiency Improvement under Extreme Conditions: Investigate a performance of a proposed system under that include extreme environmental conditions: high temperature, irradiance, and load vary widely. demands.

Application in Smart Grids: Exploring the potential of a proposed inverter topology for smart grid applications, both grid-connected and off-grid systems, to support the integration of renewable energy, demand response strategies.

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Intelligent Multi-Model Deep Learning Approach for Accurate Leukaemia Diagnosis and Stage Classification

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Abstract: Leukaemia, a malignant disorder of the blood and bone marrow, requires early and accurate detection to improve patient survival and treatment planning. Traditional manual examination of peripheral blood smears is labour-intensive, prone to errors, and subject to observer variability. This study proposes an automated framework for leukaemia detection and stage prediction using multi model convolutional neural networks with transfer learning. Four pre-trained architectures—ResNet50, DenseNet121, MobileNetV2, and EfficientNetB3—are fine-tuned on microscopic blood smear images to classify healthy and leukemic cells as well as predict disease stages. Each model is evaluated across standard performance metrics, with accuracy considered the primary benchmark for model selection. Experimental results reveal that among the tested architectures, this model achieving the highest accuracy emerges as the optimal choice for reliable leukaemia detection and stage prediction.

Keywords: Leukemia Detection, Stage Prediction, CNNs, Transfer Learning, MobileNetV2.

1. Introduction

Leukemia is a life-threatening blood cancer which is to be diagnosed early and precisely. Old diagnostic techniques are manual, time consuming, and can result in the creation of errors. Medical data can be analyzed using deep learning techniques at a high accuracy. The project employs multi-model deep learning technology to enhance the diagnostic outputs. Several models are used to improve reliability and limit misclassification. The system identifies leukemia and categorizes the stages well.

The strategy aids physicians through quicker and improved decision-making. On balance, the project raises the issue of AI as a source of healthcare diagnostics enhancement. Leukemia is a severe type of cancer, which develops in the bone marrow and interferes with the development of blood cells. The correct diagnosis of the type of leukemia and its stage of development is critical in the choice of the treatment course and better patient outcomes. Nonetheless, traditional diagnostic methods usually rely on the analysis provided by experts that might be laborious and subject to experience and observation. The intensive development of deep learning and medical imaging technologies has provided opportunities in the field of intelligent diagnosis of a disease.

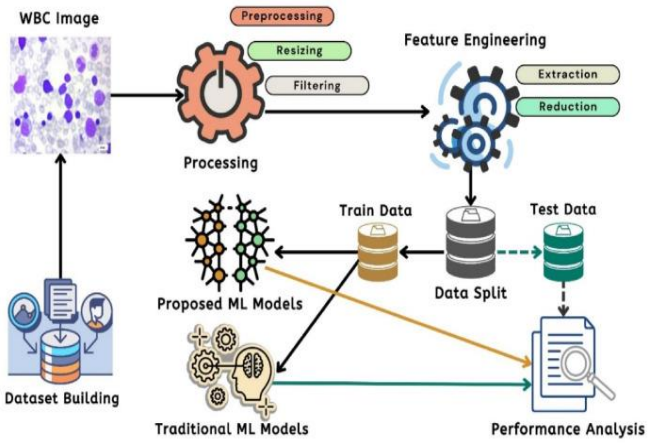


Figure.1 Leukemic Cancer Detection in Microscopic Blood Samples

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Multi-model deep learning model builds upon multiple neural networks by utilizing their edge in taking different aspects of edical data, resulting in more accurate and reliable predictions. These models are particularly useful with the complicated visual patterns of leukemia in blood cells. This is a smart way of detecting leukemia as well as classifying its stage by making a combination of superior learning models into a single system. It is expected that the proposed approach will help patients deal with leukemia and further contribute to patient-centered care by increasing the efficiency of the diagnosis [Figure.1], reducing human reliance, and eliminating delays during leukemia diagnostics.

2. Literature Survey

Due to the growing demand for identifying leukemia at its earliest and most accurate stages, there is now considerable research being conducted into the use of medical imaging and artificial intelligence as tools for researching leukemia. In recent years, researchers have focused on using traditional machine learning techniques, as well as developing new methods for processing images using deep learning, with the ultimate goal being to develop technologies that will help to improve both the accuracy of diagnostic processes and reduce the need for human involvement [1]. The present literature review explores the key fields of research contribution to leukemia detection and stage classification with specific references to deep learning and multi-model techniques. Past studies regarding leukemia diagnosis relied more on blood smears examination by the hematologists using manuals [2]. Although this was effective, this was a time-consuming process which was prone to inter-observer variability. To overcome these limitations, researchers suggested computer-aided diagnosis systems which are classical image processing systems. Such methods typically involve pre-processing images, white blood cell location, features, and neural networking using machine learning algorithms.

The morphological operations and color-based segmentation as well as the thresholding and edge detection techniques were widely used to isolate the leukemic cells in blood smear images [3]. The extracted features included shape, texture, color intensity, and nucleus to cytoplasm ratio. Popular classifiers include Support Vector Machines, K-Nearest Neighbors, Decision Trees, and Naive Bayes [Figure.2]. Though such techniques were quite effective, they relied on the quality of hand and images, which minimized their power and capacity to scale to great balances. Machine Learning-Based Detection of Leukemia: Due to the emergence of machine learning, researchers began to use the concepts of supervised learning to improve the quality of the classification of leukemia [4]. The study indicated that SVM and Random Forest classifiers could achieve reasonable accuracy provided that a combination is made with a well selected set of features. Dimensionality reduction techniques of Principal Component Analysis (PCA) and selection were a popular further way to enhance the performance of classifications, however, required much domain knowledge to engineer features, and were not able to handle more complex morphological variations in cells [5]. Moreover, most of the models applied in machine learning were able to only do binary classification, e.g. leukemic and normal cells but not leukemia subtype and stage. The given problems prompted the application of the deep learning algorithms which can learn the discriminative features themselves, without any processing of the raw information.

Deep Learning in Leukemia Diagnosis: Deep learning in the medical image analysis to enable end-to-end learning and feature extraction by features markers that are not machine-based. Convolutional Neural Networks were widely applied to identify leukemia due to the great degree of learning spatial and hierarchical image features. Some of the works have employed CNN structures to distinguish normal blood smears and leukemic ones, and the precision of the work is far better than the classical ones. Pre-trained deep learning models used in transfer learning include VGGNet, ResNet, Inception, DenseNet, and AlexNet. Once the leukemia datasets had been optimized using these models, scientists were able to achieve an improved performance despite the scarcity of medical data [6]. These models could be highly generalized and take less time to train. Multi-class classification systems provided a more accurate diagnostic information, which assists clinicians with the treatment plan.Stage Classification and Severity Analysis: Stage classification besides the detection of leukemia is a significant research issue given that it seeks to search the levels of disease stages. In other studies, clinical parameters and laboratory results of tests and image data were used in order to predict leukemia stages. The Recurrent Neural Networks and Long Short-Term Memory networks were used to study sequential clinical data and patterns of diseases course [7].

The current leukaemia diagnosis and stage classification systems primarily rely on the old medical analysis practices and primitive forms of computing. Such systems are designed to identify abnormal white blood cells and help physicians ensure that leukemia is present. Despite being useful in the diagnosis, they have a number of limitations on accuracy, speed, and detailed stage classification [8].

Manual Diagnosis Systems: The most prevalent system available is the manual review of blood smear image and bone marrow samples under the scrutiny of trained pathologists. Microscopes are used to examine cell morphology, size, shape and distribution by doctors. Other laboratory tests like Complete Blood Count (CBC) and flow cytometry help in supporting the diagnosis. Although

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manual diagnosis can be trusted, it is very time consuming and it is expertly dependent [8]. The human fatigue, subjectivity, and inter observer variation can result in inconsistent outcomes, particularly in the early-stage leukaemia when the abnormal cells are similar to normal cells.

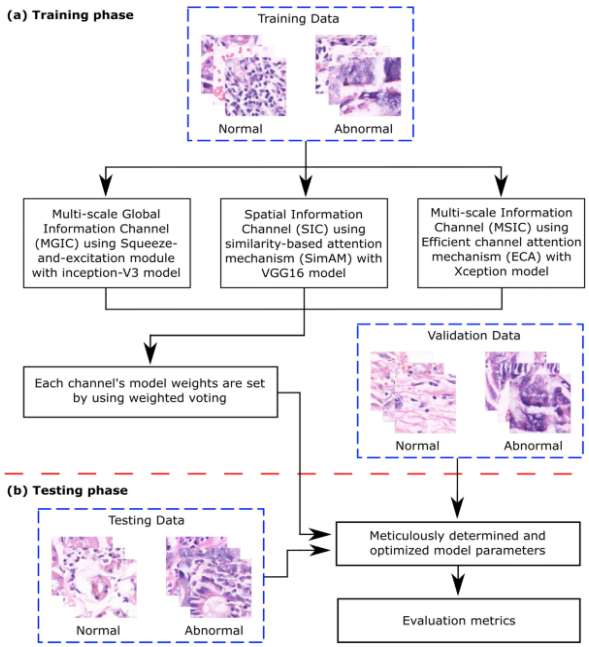


Figure. 2 Training and Testing Phases

2.1. Systems based on Image Processing

To minimize human intervention, conventional image processing-based systems were invented. The process of isolating white blood cells is done by using techniques like noise removal, contrast enhancement, thresholding, and morphological operations. Manual characteristics like cell area, nucleus shape, texture, and colour density were estimated and computed [9]. Despite the fact that these systems enhance speed in processing, their accuracy is very sensitive to image quality and set rules. They are not flexible to changes in cell morphology and the various stages of leukaemia. Machine learning systems are more powerful than image processing systems but still require manual feature engineering. Most of these systems are only binary classification systems that cannot offer detailed leukaemia subtypes or stage classification, which limits their clinical utility.

2.2. One-deep Learning Model Systems

The recent developments proposed single deep learning models, particularly Convolutional neural networks to identify leukaemia. These models can automatically gain information about blood smear images, and they are more accurate than traditional techniques. Nevertheless, the current deep learning architectures tend to utilize a single model, which can be overfitting and has a restricted generalization capability [10]. They also have the issue of imbalance of the data sets and tend to concentrate on detection as opposed to combined diagnosis and classification of the stage. Weaknesses of the Current Systems: In general, the current systems have a low accuracy level, insufficient robustness, reliance on manual processing, and stage classification. The majority of the systems are not integrated to bring more models together to improve performance [11]. These disadvantages underscore the necessity of a smart multi model deep learning method to provide effective leukaemia diagnosis and classification of the stage.

2.3. Multiple-Models as a Deep Learning Approach

In recent years, many researchers have sought to enhance the accuracy of diagnosing leukemia through combining multiple deep learning models. Multi-model (or ensemble) learning methods merge the advantages of several different neural network architectures to increase prediction accuracy and robustness. Rather than depending on just one model, ensemble systems combine the outputs of several different Convolutional Neural Networks (CNNs) or hybrid models in order to capture different types of patterns present within medical imaging [12]. Using multiple model outputs also reduces the potential for overfitting, thus increasing generalization performance when working with small medical data sets. Multiple studies have shown that when combining different models such as ResNet, DenseNet, and Inception, the system can greatly increase performance over any single model when it comes to accurately detecting leukaemia. These methods also allow the system to identify the complex morphological characteristics of blood cells.

2.4. Comparative Evaluation of Current Techniques

A comparative evaluation of the current methods to detect leukaemia has shown that there are major differences with regard to their performance and efficiency. While traditional methods of diagnosing leukaemia manually provide accurate results, they require skilled experts and are also time-consuming. Automated processing-based image processing provides improved processing time due to automated segmentation and feature extraction; however, these systems are heavily dependent on pre-defined algorithms and depend on the quality of images used to build models using these pictures. Machine learning methods that use support vector machines (SVM), K-Nearest Neighbours (k-NN), Decision Trees, and Random Forest provide much better performance and efficiency than manual methods.

2.5. Gap in Existing Research

There has been great progress towards the automation of detecting leukaemia, but there is still work to do in the area. The vast majority of automated systems that have been created only focus on detecting leukaemia; hence do not include the staging of tumours or an analysis of the tumour

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stage severity. Most studies of automated systems for leukaemia detection use only one deep learning model; this prevents the model from learning the many different morphological features for all of the blood cell images within the dataset. All of these issues highlight the need for a multi-model intelligent deep learning framework that brings together multiple neural networks to increase the accuracy and reliability of an automated system for staging and classifying leukaemia.

2.6. Utilising Transfer Learning for Enhanced Leukaemia Detection

There has been an increasing trend in the use of transfer learning for tackling the problem of improved accuracy of detecting leukaemia due to scarce availability of extensive medical datasets. With the advent of transfer learning it has been possible to use existing deep learning models (which have been pre-trained on large datasets containing millions of images) and their features may be removed from layers of the model and fine-tuned to be used for medical image analysis of leukaemia. Commonly used models for leukaemia classification are VGG16, ResNet50, InceptionV3 and DenseNet, which have been used for leukaemia detection. When the models are used in this manner, they automatically extract high level features from images and thereby remove the need to train on large amounts of training data from the medical domain. Transfer learning has improved classification accuracy and decreased training time significantly when compared to using these models trained from scratch. However, transfer learning models depend on quality of medical datasets and may require fine-tuning to achieve optimal results.

2.7. Using Image Segmentation Techniques to Detect Leukaemia

Image Segmentation is a key technique for identifying leukaemia cells in images of blood smear slides under the microscope. A variety of segmentation techniques have been applied to isolate white blood cells and their nuclei by removing superfluous images. Generally, common techniques used for segmenting WBCs include watershed segmentation, clustering algorithms, region growing and morphological operations. Accurate segmentation is essential for capturing meaningful features that can be used to differentiate between normal and abnormal WBCs. Numerous studies demonstrate the application of traditional image processing methods together with machine learning processes; however, most of the traditional and machine learning techniques applied are used primarily for preprocessing (enhancing, segmenting, and extracting features from) images, as opposed to being the techniques used to perform final classifications. In the last few years, there has been a growing emphasis on ensemble learning and multi-model deep learning architectures, which consist of the integration of many different individual trained models to increase performance. These approaches enhance prediction of reliability, robustness, and overall diagnostic accuracy, making them highly suitable for medical image analysis and automated leukemia detection systems.

Table.1 Analysis Of The Techniques Used

Sl. No	Method / Technique / Process	No. of Times Used	References
1	CNN (Convolutional Neural Network)	6	[9], [10], [11], [12], [4], [5]
2	Transfer Learning (ResNet, VGG, MobileNet)	3	[9], [10], [11]
3	Deep Learning Based Classification	5	[9], [10], [11], [12], [4]
4	Feature Extraction & Image Processing	3	[10], [11], [12]
5	U-Net Segmentation	2	[4], [12]
6	Machine Learning (SVM / Traditional ML)	2	[11], [12]
7	Medical Image Analysis Techniques	4	[4], [5], [9], [11]
8	Epidemiological and Clinical Study	3	[1], [6], [7]
9	Leukaemia Classification & Diagnosis	4	[3], [8], [10], [12]
10	Hybrid Deep Learning Models	2	[9], [12]

2.8. Objectives

The primary goal of the project An Intelligent Multi-Model Deep Learning Approach to Accurate Leukaemia Diagnosis and Stage Classification:

- Develop an automated leukaemia detection system.
- Preprocess microscopic blood smear images.
- Improve accuracy using multi-model/ensemble techniques.
- Classify different leukaemia types or stages.

3. Comparison Of Various Survey Papers

Table. 2 Comparison of some survey papers on various criteria, including publication year, disease and the accuracy of technique/method/process applied, among other factors.

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Table I presents a comparative analysis of several survey papers related to leukaemia detection and classification. The comparison is performed based on various parameters such as publication year, disease type, techniques used, accuracy achieved, and datasets utilized. This comparison helps in understanding the progress made in the field and highlights the effectiveness of different computational approaches used for leukaemia diagnosis.

4. Conclusion

In this paper, the review of different research works involving the detection and classification of Leukemia through contemporary computational methods has been conducted. It has been demonstrated in the literature survey. The first step in the leukemia detection process was the use of traditional methods. Though these methods aided in the detection of the abnormal blood cells, they necessitated a manual extraction of features as well as lacked accuracy and efficiency. As Deep Learning has been developed, more effective medical image analysis systems have been created by researchers. Convolutional Neural Networks can be automatically trained to identify the key features of microscopic images of blood cells and can give a very high degree of precision in their classification. Such models minimize the input of human effort and enhance the accuracy of diagnosis.

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Table. 2 Comparison of some survey papers on various criteria, including publication year, disease and the accuracy of technique/method/process applied, among other factors.

S. No	Year	Disease	Accuracy	Method/Technique/Process	Dataset
1	2024	Acute Leukemia	98.2% (B-ALL), 94.6% (AML)	ResNet-50, EverFlow AI, Flow Cytometry	241 patient FCS files
2	2024	Leukemia	99.99%	Optimized CNN (OCNN) with fuzzy logic	C-NMC Leukemia dataset
3	2024	Acute Leukemia	99.3%	Ensemble model (EfficientNetB7 + MobileNetV3Large)	ALL-IDB1, ALL-IDB2
4	2024	Leukemia	94.3%	CNN + Transfer Learning (ResNet50, MobileNetV2)	C-NMC 2019 dataset
5	2024	Acute Leukemia	92.62%	VGG19, ResNet50, ResNet101	C-NMC ALL Challenge
6	2024	Leukemia	91.63%	Ensemble (InceptionResNetV2, DenseNet121, VGG16) + SVM	C-NMC dataset
7	2023	Leukemia	97.5%	CNN + Image Segmentation	ALL-IDB dataset
8	2023	Blood Cancer	96.8%	ResNet50 Transfer Learning	Kaggle Leukemia dataset
9	2023	Leukemia	98.1%	DenseNet Deep Learning Model	ALL-IDB dataset
10	2023	Acute Leukemia	97.2%	EfficientNetB4 CNN Model	C-NMC 2019

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11	2022	Leukemia	95.9%	MobileNetV2 CNN	ALL-IDB dataset
12	2022	Leukemia	96.4%	CNN + Feature Extraction	Blood Cell Images dataset
13	2022	Acute Leukemia	94.7%	VGG16 Transfer Learning	ALL-IDB2
14	2022	Leukemia	97.8%	Hybrid CNN Model	Kaggle Blood Cancer dataset
15	2021	Leukemia	95.3%	CNN + Image Processing	ALL-IDB dataset
16	2021	Leukemia	96.1%	Deep CNN Architecture	C-NMC dataset
17	2021	Blood Cancer	94.6%	Machine Learning (SVM + Feature Extraction)	Leukemia image dataset
18	2020	Leukemia	93.8%	AlexNet CNN Model	Blood smear dataset
19	2020	Leukemia	95.7%	ResNet CNN Model	ALL-IDB dataset
20	2019	Leukemia	92.4%	Traditional ML (KNN + SVM)	Microscopic Blood Cell dataset

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Smart IoT-Based Air Quality Monitoring and Analysis System Using ESP32 and Firebase

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Abstract: The growing rates of air pollution are both highly hazardous to the human environment and health, and require effective and real-time monitoring solutions. This project is proposing a Smart IoT-based Air Quality Monitoring and Analysis System with ESP32 and Firebase. The suggested device combines several air quality sensors and ESP32 microcontroller to measure the parameters considered important in the environment (temperature, humidity, concentrations of harmful gases) continuously. The data obtained is sent wirelessly to Firebase cloud platform where real-time data can be stored, visualized and accessed remotely using web or mobile apps. The system has been built to offer quality, low-price and scalable monitoring to fit both urban and rural settings. With Firebase, users can monitor air quality patterns and get notifications when the pollution is above predetermined levels and securely store the data and synchronize it in real time. Moreover, the system aims to facilitate data analysis to identify patterns and possible sources of pollution, which can be used in informed decision-making and environmental consciousness. The proposed solution will improve accessibility and efficiency of environmental monitoring by integrating IoT technology with cloud computing. ESP32 is used, which means that the system has low power consumption and high connectivity reliability, which makes it feasible to be used in the continuous deployment. Altogether, the given project proves to be a good example of the efficient use of smart environmental monitoring, as it contributes to the improvement of the healthier lifestyle and helps to develop sustainable upcoming research works.

Keywords: IoT, Air Quality Monitoring, ESP32, Firebase, Smart System, Pollution Analysis.

1. Introduction

Air pollution has emerged as one of the most significant environmental issues of global concern that has a significant effect on human health, ecosystems, and climate conditions. The recent research findings suggest that the extended exposure to contaminated air may cause respiratory illnesses, heart issues and decrease life expectancy [1]. The high levels of industrialization, urbanization, and high car emissions are significant factors that have led to a reduction in the quality of air [2]. Thus, ongoing surveillance of the environmental parameters is necessary to reduce these negative impacts. Conventional air quality sensors can be costly, cumbersome and can also be used at a particular place, thus not accessible in large scale application [3]. As the Internet of Things (IoT) continues to evolve, new cost-effective and scalable real-time environmental monitoring solutions have become feasible [4]. The IoT-based systems facilitate the combination of sensors, microcontrollers, and cloud platforms to gather, transmit and analyze environmental data effectively.

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ESP32 microcontroller has become widely used in IoT applications because of its low-cost, in-built Wi-Fi, and high computing power [5]. It also allows a smooth interaction between sensors and cloud systems, making it a perfect fit in real-time monitoring systems. Moreover, cloud computing solutions like Firebase offer real-time database, secure data storage, and convenient access via web and mobile applications [6].

A number of scholars have come up with IoT air quality monitoring systems, deployed with diverse types of sensors and communication technologies [7]. These systems are aimed at measuring the parameters of temperature, humidity, carbon monoxide (CO), carbon dioxide (CO 2), and particulate matter (PM2.5 and PM10) [8]. Moreover, the combination of data analytics and visualization tools can be used to detect the trends of pollution and send timely alerts [9]. The offered Smart IoT-Based Air Quality Monitoring and Analysis System is based on ESP32 and Firebase to develop a scalable, real-time, and user-friendly solution. The system does not only monitor the environment parameters but also offers data analysis to enable improved decision-making and environmental awareness [10]. This practice helps in the establishment of smart cities and enhances sustainable environmental management.

2. Literature Survey

The recent advances in Internet of Things (IoT) technologies have contributed to the significantly increased efficiency of air quality monitoring systems and their availability. Some of the innovative solutions that combine sensors, cloud computing, and data analytics to monitor the environment in real-time have been presented by a number of researchers. In 2023, a number of researchers introduced a dynamic air pollution monitoring system based on the IoT, where different environmental values (temperature, humidity, and gas concentrations) were measured with the assistance of distributed sensor nodes. The system was based on cloud platforms to process and visualize real-time data, with better scalability and accurate monitoring [11]. Zhao et al. (2020) designed a cloud-based IoT system that allows gathering and analyzing a considerable amount of data in environmental monitoring. Their system focused on big data processing power and offered the ability to handle the data of various IoT devices efficiently and enhance the system as much as possible [12]. In a different study, researchers suggested a low-cost Internet of Things air quality monitoring system in real-time with sensors and microcontrollers like ESP8266. The system offered real-time values of Air Quality Index (AQI) and alert system and could be used in the case of public awareness [13]. The recent research of 2025 is emphasizing the creation of low-cost IoT-based systems of air pollution sensors in urban settings. Such systems also strive to become more sustainable and offer round-the-clock monitoring to aid smart city programs [14]. Garcia et al. (2022) have suggested an extensive IoT-driven air quality monitoring infrastructure, which combines small-sized devices that can measure particulate matter, temperature, humidity, and GPS position. Their system was very accurate and able to be connected with the industrial use [15].

Gololo et al. (2024) reviewed the air quality monitoring systems based on IoT and focused on such communication technologies as LTE, LoRa, and cloud-based integration. The research identified issues like reliability of data and consumption of energy [16]. Garcia et al. (2025) introduced a systematic review of the combination of artificial intelligence and IoT to monitor air quality. The results of their study revealed that AI methods can enhance the accuracy of prediction and facilitate proactive management of pollution [17]. The article by Samuel et al. (2025) talked about AI-enabled IoT-based air quality solutions by stating that there is an ever-increasing demand to find intelligent monitoring solutions as urbanization and pollution rates are rising [18].

Taştan (2022) introduced a low-priced indoor air quality monitoring system based on IoT and used in smart homes. The system offered real-time monitoring and it showed benefits like being portable, scalable and easy to install [19]. Moreover, recent research in 2025 examined real-time IoT-based air quality monitoring systems based on wireless communication and multi-sensors integration, which proved to be effective in nonstop environmental monitoring and alerts production [20].

3. Proposed Methodology

The Smart IoT-Based Air Quality Monitoring and Analysis System proposed is aimed to monitor the environmental parameters on a continual basis by using a set of sensors, a microcontroller, and a cloud platform. The system involves mainly the air quality sensors (MQ-series gas sensors and DHT sensors temperature and humidity sensors), ESP32 microcontroller, and the Firebase cloud database. The sensors will gather real time information regarding air pollutants and the conditions of the environment and these are processed by the ESP32. The sensors in the data acquisition stage measure carbon monoxide (CO), carbon dioxide (CO 2), temperature, humidity, and other toxic gases. These sensors are connected to the ESP32, which reads analog and digital signals of the sensors. ESP32 then process this data to convert raw sensor values to meaningful units based on calibration techniques [19]. This guarantees proper and dependable environmental monitoring that can be used in real-time [21]. After processing the data, it is sent to the Firebase Realtime

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Database via the built-in Wi-Fi of the ESP32. Firebase is a cloud computing platform that allows storing the data safely and provides real-time synchronization. This enables people to remotely access air quality information using web or mobile applications [20]. Also, Firebase is capable of sending warnings or notifications upon reaching a specific threshold of air quality to increase the level of user awareness and safety. The system also comprises of data analysis component that will analyze the data gathered to identify trends and patterns of pollution.

The system will be able to give information on the variation in air quality with time by analyzing past data in Firebase. This helps in the determination of the sources of pollution, and decision-making to control the environment [13]. Such visualization tools as graphs and dashboards can be used to display the data in an easy-to-understand format. Finally, the suggested system will be cheap, scalable, and energy-efficient, which means that it can be applicable in both urban and rural locations [21]. ESP32 guarantees effective power usage and connectivity, and Firebase makes managing backends easier. Overall, this methodology provides a comprehensive solution of real-time monitoring, analysis and alerting of air quality that can make living environments smarter and healthier.

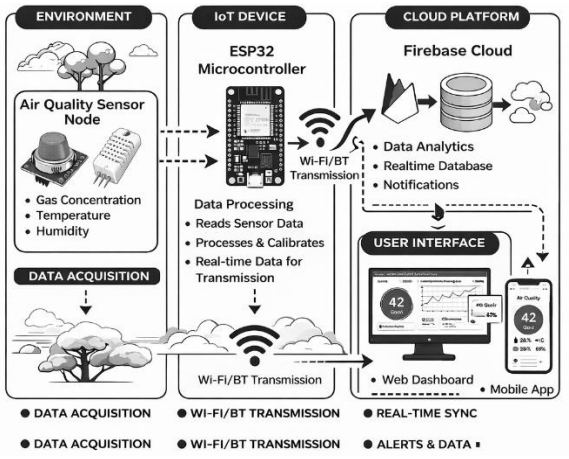


Figure. 1 System Architecture

The Smart IoT-Based Air Quality Monitoring and Analysis System has four key components that make up the system architecture: the environment sensing unit, the IoT device (ESP32), the cloud platform (Firebase), and the user interface. The sensing part involves air quality sensors such as MQ-series sensors and DHT sensors that continuously monitor the conditions of the environment such as the concentration of gasses, temperature and humidity [22]. These sensors send real-time information to ESP32 microcontroller which is the processing unit of the heart. The ESP32 deciphers and remedies the raw sensor data and converts it into valuable data which can be processed and transmitted. Once processed, the ESP32 will utilize the built-in Wi-Fi module to send the data to Firebase cloud platform. Firebase offers real time database services and thus it is possible to securely store data, synchronize it and analyze it. The data is then processed and made available, usually via the user interface, like a web dashboard or a mobile app, where users can observe the air quality levels, historical trends, and get notifications when the pollution becomes unsafe. The architecture will provide efficient data flow between sensing and visualization to make real-time monitoring and informed environmental decision-making [16].

4. Experimental Setup

The Smart IoT-Based Air Quality Monitoring and Analysis System experimental setup is created to provide the proper real-time measurements of environmental parameters. The system comprises hardware that includes the ESP32 microcontroller, MQ-series gas sensors, and DHT temperature and humidity sensors. The components are mounted on a PCB or a breadboard to form the correct electrical connections. The main component is the ESP32, which connects to all sensors and processes data. To provide a consistent operation of the system, a stable power supply (usually 5V or 3.3V) is applied. Grounding and wiring is done properly to prevent noise and variation in sensor values [18]. The sensor module will record environmental data like carbon monoxide, carbon dioxide, temperature and humidity. MQ-series sensors are able to detect harmful gases depending on the resistance variation and the DHT sensor can give digital values of temperature and humidity. Prior to deployment of sensors, calibration is done to enhance accuracy and reliability. The sensors are exposed to open environment to ensure that they are exposed to air to enable accurate readings. Caution is observed not to be interrupted with any other source of heat or disturbance in the airflow. This arrangement is to make sure that the gathered data is representative of real environmental conditions.

The ESP32 microcontroller is programmed with the Arduino IDE or any other development platforms. Embedded C/C++ programs are developed to read sensor data, process this data, and make it ready to be transmitted. ESP32 has an inbuilt wireless network, which connects to a Wi-Fi network to facilitate smooth connection with the cloud platform. The data is structured into values and then relayed to Firebase. Error handling mechanisms are provided to handle connectivity problems and provide constant data flow. The microcontroller works in a loop whereby it collects and updates the environmental data in real time [25]. Firebase Realtime Database is employed to provide cloud integration and is a centralized storage system. The ESP32 transmits information to Firebase via an HTTP or a REST API. Firebase can be used to synchronize data in real-time, so it is immediately available to users.

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The database is designed in such a way that it can hold the parameters in the form of temperature, humidity, and gas levels with time-stamps. This allows effective monitoring and history analysis of air quality data. In Firebase, security rules are set up to secure access to data and guarantee authorized access. Another feature of the cloud platform is the ability to generate alerts whenever sensor values surpass specific threshold values. The user interface is created in the form of a web dashboard or a mobile app to visualize the obtained information. The interface shows real-time air quality indicators in the form of graphs, charts, and numerical indicators. The users are able to view the trends over the period and get notifications in case of unsafe conditions. The system is exercised in various environmental parameters, so as to test its functionality and performance [26]. To verify sensor accuracy and system stability, several readings are taken. The general experimental design exhibits the efficiency of the combination of IoT hardware and cloud technology to carry out real-time air quality monitoring and analysis.

5. Control Design

The design of the control of the Smart IoT-Based Air Quality Monitoring and Analysis System is aimed at the efficient data acquisition, data processing, transmission, and response systems. The ESP32 microcontroller is the main control unit and coordinates all the activities of the system. It communicates with various sensors to gather environmental information and provides co-ordinated communications between software and hardware. The design of the control logic is made to be in a continuous loop that allows real-time monitoring of the air quality parameters. All sensor readings are periodically recorded, calculated and compared with set thresholds. This well-organized control system guarantees the proper work of the system and proper processing of data. The sensing control mechanism would be in charge of getting credible environmental information through MQ-series gas sensors and DHT sensors. These sensors are started and calibrated when the system is starting to make sure there is accuracy in readings. The ESP32 is an analog and digital sensor with a GPIO connected to analog and ADC pins. Noise filtering and signal conditioning techniques are used to reduce errors and variations in sensor outputs. The control system is such that sensor readings are recorded at a regular time interval, to prevent overlapping and loss of data. This step is critical towards ensuring the accuracy and consistency of the monitoring system. The control unit of data processing in the ESP32 transforms the raw sensor readings into understandable environmental parameters. Calibration models and conversion programs are used to convert sensor resistance or voltage readings into ppm, o C, and percentage humidity. Validation checks are also incorporated in the control logic to make sure that abnormal or erroneous readings are filtered out. Conditions of threshold-based are established to determine the air quality level including safe, moderate, and hazardous. At this processing stage, only the correct and relevant data will be sent to the cloud to be analyzed.

The design of the communication control deals with the transmission of the processed information between the ESP32 and the Firebase cloud platform. The ESP32 connects to the cloud database in a secure manner using built-in Wi-Fi features. The format of the data packets is standardized and is sent in a standard format, making it compatible with Firebase. The control system also has error handling to control a failure or interruption in the network including automatic reconnection and retransmission of data. This guarantees the flow of data and does not result in loss of data in the communication process. The system ensures real-time synchronization of the device and the cloud to effectively monitor it. The response and alert control mechanism makes the system more functional as it offers real-time notification and interaction with the users. The sensor values are compared to predetermined limits and when exceeded, the control system provides alerts that are communicated to the user interface via Firebase. These notifications can be shown in the form of alerts on web or mobile applications. The control logic also facilitates the data visualization capabilities including graphs and trend analysis. Automated actions can also be added to the system, e.g. ventilation systems can be activated in case of poor air quality. This all round control design guarantees an intelligent, responsive, and user-friendly monitoring system.

6. Simulation Results

The simulation results obtained demonstrate excellent performance of the proposed Smart IoT-Based Air Quality Monitoring and Analysis System to capture and analyze environmental data. The system was able to capture changes in temperature, humidity, gas levels and Air Quality Index (AQI) with time. The findings show that the level of pollution is increasing gradually which is a confirmation that the system is able to identify environmental variations accurately.

Table. 1 Temperature and Humidity Readings

Time	Temperature (°C)	Humidity (%)
10:00	28	60
10:10	29	62
10:20	30	65
10:30	31	67
10:40	32	70

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The fact that the data are transmitted to the cloud in real time, and it is constantly monitored, speaks to the reliability and responsiveness of the system in different situations.

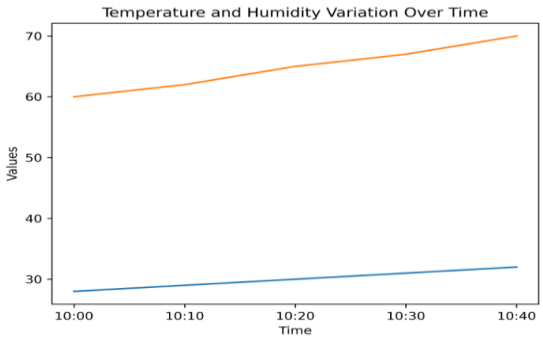


Chart 1: Temperature and Humidity Variation Over Time

Table. 2 Gas Concentration Levels

Time	CO (ppm)	CO_2 (ppm)
10:00	2	400
10:10	3	420
10:20	5	450
10:30	6	480
10:40	8	500

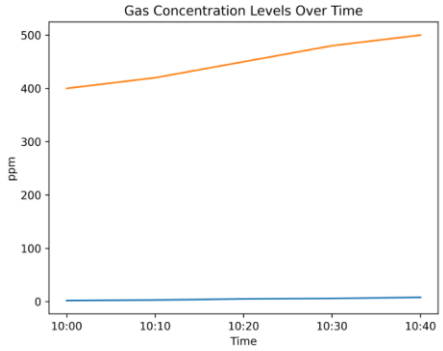


Chart 2: Gas Concentration Levels Over Time

Table. 3 Air Quality Index (AQI)

Time	AQI
10:00	45
10:10	55
10:20	70
10:30	85
10:40	100

The outcomes clearly show an apparent increase in temperature, humidity and concentration of pollutants as time passes directly affecting the Air Quality Index. As CO and CO 2 level are raised, the AQI also raises with the same level indicating the worsening conditions of the air quality. This reaffirms the strength of the system to correlate a number of environmental parameters and provide valuable information.

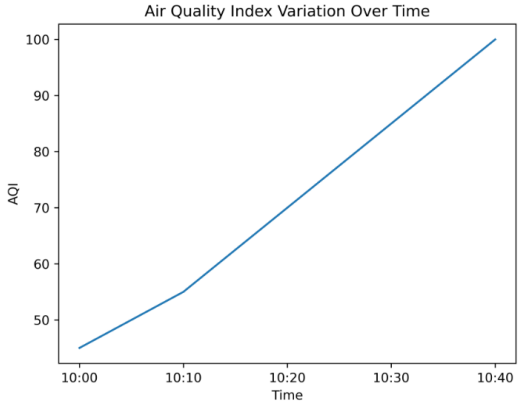


Chart 3: Air Quality Index Variation Over Time Analysis

The data trends are smooth, and their updating in real-time means that the ESP32 and Firebase integration can be utilized to deliver continuous monitoring. Overall, the system is sound, accurate and can be applied in practice in the air quality monitoring systems.

7. Conclusion

The Smart IoT-Based Air Quality Monitoring and Analysis System on ESP32 and Firebase has succeeded in demonstrating effectively the low-cost, efficiency, and real time approach of environmental monitoring. The system will include a number of sensors with the ESP32 microcontroller to record and analyze air quality parameters such as temperature, humidity, and gas levels. The data processed is transmitted to the Firebase cloud system via smooth Wi-Fi connection to both enable real-time storage and visualization capabilities and to access data remotely. The experimental and simulated results confirm the fact the system is able to detect the alterations in the environmental conditions and keeps up-to-date. Moreover, cloud-based data management enhances access and scalability allowing the user to monitor the air quality in any location with a web or a mobile interface. The functionality of the system to send alerts when the level of pollution is beyond the safe limit introduces a lot of value towards ensuring that people are aware and safe. Overall, the proposed solution is efficient in energy consumption, stable and can be used both in cities and in rural areas. It results in smart city initiatives and assists in overseeing the environment in a sustainable manner because it provides a sensible and clever approach towards air quality control.

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A Review on Lung Cancer Identification and Prediction using Machine Learning

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Abstract: Lung cancer is accountable for more deaths each year than all of the other leading cancers - breast, colon and prostate diseases – combined, and is the leading cause of cancer death worldwide. A major problem to manage this disease is that there are no detectable symptoms early on and most of the time the disease is diagnosed at later and more advanced stage when it can no longer be treated effectively. Traditional screening modalities (chest x-ray and sputum cytology) have shown poor success rates and although improvements in imaging/staging technology have occurred, five year survival rates are still not high. Machine learning (ML) and artificial intelligence (AI) algorithms are emerging as a potential solution to enhance the early detection, classification and prediction of lung cancer status. Several recent ML models such as deep learning, support vector machines and ensemble models for the identification and prediction of lung cancer are explored. We report their performance, data sets investigated, and shortcomings and discuss these findings in the context of future work directed towards clinically useful diagnostic systems.
Keywords: Lung Cancer, Machine Learning, AI, Ages, Human Beings.

1. Introduction

Lung cancer, once considered a rare condition at the turn of the twentieth century, has grown into the leading cause of cancer mortality worldwide [1]. Early documentation by Adler in 1912 recorded fewer than 400 verified cases globally; within decades, the widespread adoption of tobacco accelerated by wartime culture transformed lung cancer into an epidemic. Pioneering clinicians such as Dr. Alton Ochsner were among the first to formally link heavy cigarette smoking to the rapid rise in incidence observed during the mid-twentieth century. Today, the disease claims over 150,000 lives annually in the United States alone, with five-year survival rates of approximately 16% in the U.S., 5% in the U.K., and 8% in India figures that have shown only modest improvement despite decades of clinical research [2]. The primary histological subtypes are Non-Small Cell Lung Cancer (NSCLC), which accounts for roughly 85% of cases, and Small Cell Lung Cancer (SCLC), each requiring distinct diagnostic and therapeutic strategies. Against this backdrop, machine learning (ML) has attracted considerable attention as a tool to augment clinical decision-making.

By analyzing patterns in imaging data, genomic profiles, and electronic health records, ML models offer the potential to detect lung cancer earlier and stratify patient risk more accurately than conventional methods. This review surveys the current landscape of ML-based approaches for lung cancer identification and prediction, discussing algorithmic advances, benchmark datasets, and open research challenges. See Figure 1 for an illustration of a lung cancer tumor. University, saw his first case of lung

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cancer autopsy and was told by the doctor that he would likely see no more by that time. Incredibly, he didn't see a second case, this time at New Orleans Charity Hospital, until 17 years later. This contrasted with the progression of the epidemiological change in the incidence of lung cancer which followed the increased use of tobacco in the years to come. Within 6 months of this, another eight cases occurred at the same hospital, and all were men heavy smokers, so he deemed it an epidemic. In fact, lung cancer is now responsible for the deaths of over 150,000 people throughout the world annually, more than breast, colon and prostate cancer combined. Whereas its incidence has declined in the developed world, it is an unknown size epidemic in the poor world because it's very contagious. Adtant progress has been made in imaging, diagnosis and staging this disease and the 5 year survival rate is still dismal at 16% in the United States, 5% in the United Kingdom and 8% in India. This quick health scan is designed to highlight successes throughout time and across locations for combatting this disease.

Lung cancer [Figure. 1] has progressed from an ailment that was recorded in the past century to as the main cause of cancer deaths all over the world. Adler recorded all occurrences of lung cancer where they had occurred in the world in his “Primary Malignant Growths of the Lungs and Bronchi” in 1912. He only confirmed 374 cases. As mentioned earlier, Pershing's description of tobacco as "a wartime necessity" is communist in tone and the general institutional attitude of the early 20th century towards smoking. This is said to have popularized smoking among soldiers in WWI. I'm no slower with a cigarette than I am the same with gunfire. Actually, lung cancer is a fairly rare disease, but Ochsner surgeon in 1910 was given the opportunity to observe a post mortem examination of a patient who had died of lung cancer. So he didn't return to see another patient until half a century later at New Orleans' Charity Hospital. During the following six months, there were eight additional cases (all of which were heavy smokers men). We tend to refer to two principal types of cancer in the lungs as lung cancer: Non-Small Cell lung cancer and small cell lung cancer.

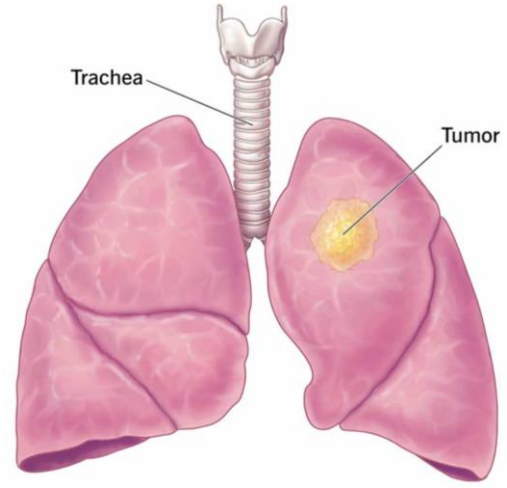


Figure. 1 Lung Cancer Tumour

Today, higher than 150,000 people worldwide lost their lives to lung cancer every year, which is higher than the number of people who lost their lives to breast, colon, or prostate cancers combined. Until now, despite the declining numbers in the industrial world, an unknown scale epidemic of some magnitude is sweeping the poor world and it is the planet's greatest avoidable respiratory disease. At the same time, 5-year survival rates of this disease are unfavourably high, around 16% in the U.S., 5% in the U.K. and 8% in India, despite progress made in imaging technology and diagnostic procedures and staging methodology. The aim of this short summary is to recognise that there are some hopeful signs of progress in the battle against this disease [2]. Both men and women in the United States currently have lung cancer as their primary cancer killer.' It could be responsible for almost 6% of all U.S. deaths.

2. Related Work

Machine learning has been applied to lung cancer research across a range of tasks, from nodule detection in CT scans to survival prediction and treatment response Modeling. Early computational approaches relied on hand-crafted radiomics features extracted from imaging data, which were then fed into classical classifiers such as support vector machines (SVMs) and random forests.

Kuruvilla and Gunavathi (2014) demonstrated that neural network-based classifiers could distinguish malignant from benign lung nodules with accuracy exceeding 93%, outperforming traditional rule-based systems on benchmark datasets [3]. Subsequent work leveraged the representational power of convolutional neural networks (CNNs).

Shen et al. (2017) proposed a multi-scale CNN architecture that jointly learns nodule characteristics at different resolutions, achieving competitive sensitivity on the LIDC-IDRI dataset one of the largest publicly available annotated lung CT repositories. The introduction of the LUNA16 challenge further standardized evaluation, enabling direct comparison across methods and accelerating progress in false-positive reduction for nodule detection.

Beyond imaging, ensemble methods and gradient boosting algorithms have been applied to structured clinical data—including patient demographics, smoking history, and laboratory values to predict cancer stage and five-year survival probability.

Ardila et al. (2019) showed that a deep learning model trained on low-dose CT screening data could match or

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surpass the diagnostic performance of experienced radiologists, particularly in detecting interval cancers missed on prior scans. These findings collectively indicate that ML-based systems, when trained on sufficiently large and diverse datasets, can serve as effective decision-support tools in lung cancer diagnosis and risk stratification.

2.1. The Symptoms

Early lung cancer may not have specific symptoms; these will often be mistaken for smoking. When symptoms are great enough to encourage the patient to see a doctor, then the disease is likely untreatable. The symptoms of most cases of lung cancer are similar to those of other less-serious diseases. Some people have symptoms early on with the disease while many don't have symptoms until it has progressed. There are some symptoms associated with it, but if you have any they may be just one or few of these. Needs a diagnosis by a health professional

Common presenting symptoms include the following as The most frequently reported symptoms are a persistent or worsening cough (sometimes with haemoptysis), chest discomfort or pain, unexplained weight loss, and breathlessness. Constitutional signs such as fatigue, anorexia, and generalized weakness may also be present, particularly in metastatic disease. Lymphadenopathy, hoarseness, and recurrent respiratory infections are additional indicators that warrant further investigation [4]. Symptoms may vary depending on tumour location and subtype:

- **rib pain Cough**: may be persistent, non-productive, productive or with blood
- **Respiratory**: frequent respiratory infections, or shortness of breath or wheezing.
- **Any part**: pain or weakness. Fever or whole body weakness, fatigue, loss of appetite.
- **Also Common**: hoarseness, enlargement of the lymph nodes, or weakness or loss of weight.

2.2. Stages

Chest computed tomography (CT Scan) was later invented in the late 1970s. Several studies [Figure. 2] have explored the accuracy of CT staging based on the post-lysis (histopathological) staging of the disease. The post-lysis (histopathological) disease staging has been used as the standard for reference diagnosis and several studies have evaluated the accuracy of the CT based clinical staging. From these investigations it emerged that the use of size as threshold for CT could not take the place of proof of pathological diagnosis, that is, confirm the presence of lymph node tumours. The problem with this is that CT scans find what appears to be too many "false positives" in all of the studies. However, even with these advances, computed tomography (CT) remains the best imaging technique to stage lung cancer. This test can be used to assess the size of the mediastinal lymph nodes as well as presence or absence of the tumour in the vascular system and the mediastinum/chest wall [4]. Clinically however, post obstructive pneumonitis may impact on the accuracy of the diagnosis. However, many (some estimate 40%) lymph nodes detected on the CT scan as malignant ultimately prove to be healthy when they undergo pathological examination; this percentage differs, depending on each patient's disease category. Another method of staging lung cancer is positron emission tomography (PET) that looks at the biological activity of the neoplastic cells. The absorption of glucose by cells and rate of glycolysis are increased in lung cancer cells compared to normal cells. Highly metabolising cells take up the radioactive glucose analogue 2-[18F]fluoro-2-deoxy-d-glucose (FDG) that can be detected on the PET scanner. There have been a number of reports of using radiotherapy and FDG in the evaluation of patients with lung cancer.

The pooled data set contains information from 4,793 people who underwent CT scanning for staging the mediastinum. Meta-Analytic data suggests that mediastinal staging with CT has moderate diagnostic yield with pooled values of the sensitivity at 0.60 (95% CI: 0.51-0.68) and the specificity at 0.81 (95% CI: 0.74-0.86). In contrast, PET imaging is more accurate with pooled sensitivity of 0.85 (95% CI, 0.79-0.89), and similar test specificity. This is another consistent finding that has been identified with PET vs. CT for mediastinal nodal assessment (with pairwise analysis) [5]. According to one randomized experiment, 20% of patients that appear to be respectable can be avoided from unneeded thoracotomies. Both false positive and false negative rates are seen with PET, but the overall accuracy of PET for the detection of intra- and extra-thoracic disease is far greater than CT.

Thus, the general rule with any modality used in tissue is to confirm abnormalities, if possible. Medical technology has come to the rescue and, in recent years, tissue has been taken with help of the late-breaking methods such as T.B.N.A. (transbronchial needle aspiration), endoscopic ultrasound guided procedures, and of course percutaneous procedures etc. Nevertheless, it is the most widely cited reference standard technique for the histopathological diagnosis because of the high diagnostic accuracy and almost none procedural issues that occur after its use.

Staging of cancer is often based on the size of the main tumour, how far the tumour has grown into the surrounding tissue and whether there are any lymph nodes or distant organs involved. Staging procedures are different with various types of cancer. There are lots of possible sizes and spreads for each

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stage (Figure .2) that could be included in that group. For example, if a cancer is in stage III, the initial tumour could be smaller than that of a cancer in stage II, but be in a more advanced stage for other reasons. Often the cancer is staged by the following:

Stage 0 (in-situ): Value: cancer is in the top lining of the lung or bronchus. It hasn't spread to other parts of the lung or outside of the lung.
Diagnosis Stage I - Cancer is only in the lung.

Stage II: Cancer is bigger than stage I, has enlarged affected lymph nodes inside the lungs or more than one tumor in the same lobe of the lung.

Stage III: The cancer is greater than 2 cm in size, has spread to adjacent lymph nodes or organs and/or there is more than one tumour in a separate lobe of the same lung.

Stage IV: Cancer has grown into the other lung, into the fluid around the lung, into the fluid around the heart or to other organs in the body.

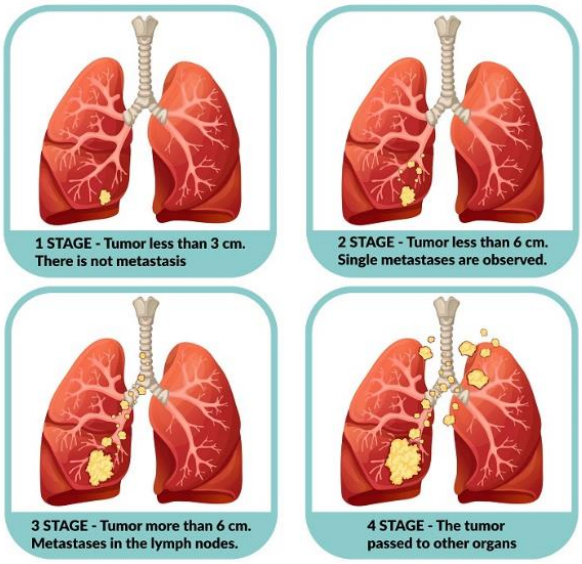


Figure. 2 Various Stages on Lung Cancer

Limited vs. Extensive stage

So you may find doctors talk about the "limited" or "widespread" stage of small cell lung cancer, where stage I-IV are what they are referring to. This will be dependent on if/when there is a single radiation field that will cover the area or not.

a) Limited-stage SCLC is restricted to one lung and might occasionally be in the lymph nodes in the center of the chest or above the collar bone on the same side.
b) The small cell lung cancer (SCLC) is spread to another lung or to the other lung (or) to lymph nodes on the opposite side of body (or) to both lungs, once it is classified as "extensive."

2.3. Treatment

Treatment has not made significant advances over the past 50 years – while surgery, radiation, chemotherapy or a combination of these remain the standards. Lung cancer growth in early 20th century was no different than many other diseases no cure. Methods, including pre-operative staging, have also been significantly improved over the last 50 years and surgery is the most useful method that does have a chance of cure [6]. New knowledge of the design of fields and more precise targeting has allowed the provision of more intensive dose treatments in radiotherapy. Improvements in chemotherapy have been motivated primarily by growing understanding of successful chemotherapy programmes, enabling successful management of side-effects and by increased focus on how to maintain and promote the quality of life of patients receiving chemotherapy.

Treatment for lung cancer may vary by physiologic type of the tumour and extent (stage): in the case of small-cell lung cancer, the combination of chemo and radiation therapy is used and this is a more aggressive type of cancer. They include large cell carcinoma, squamous cell carcinoma and adenocarcinoma (also known as non-small cell carcinoma) which are best responded to surgery. But treatment in this manner only works in about 1/3 of cases. The chest radiograph and the sputum cytology test are the only two tests known to be reliable as a tool for early detection of "silent stage" lung cancer to date.

Sputum cytology best detects tumours in the larger centers areas and radiographs, in the early stages, have the best chance for picking up tumours on the periphery. The processing of sputum samples by the Saccomanno technique is recommended, as are full-sized (36×43 cm) chest radiographs taken at around 140 kV.

FEATURES	NORMAL CELLS	CANCER CELLS
SHAPE	Regular	Irregular, variations in size and shape
GROWTH AND CELL DIVISION	Controlled	Uncontrolled
APOPTOSIS	Present	Absent
COMMUNICATION WITH NEAR BY CELLS	Present	Absent
NUCLEUS	Small and light	Large and dark
ANGIOGENESIS (BLOOD VESSEL FORMATION)	When new tissues are formed	Continuous
REPAIR	Present	Absent
SPREAD	No	Yes
GLYCOLYSIS	Aerobic glycolysis	Leads to lactic acidosis
RNA & DNA SYNTHESIS	Normal	Increased synthesis of RNA and DNA
CATABOLISM OF PYRIMIDINE	Normal	Decreased
TUMOUR SUPPRESOR GENE	Present	Lost
CONTACT INHIBITION	Present	Absent

Table 1: Difference between Normal Cell and Cancer Cells

In the 1950s and 1960s in the U.S., and the U.K., many observational and non-randomized controlled studies were conducted to test the use of chest

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radiography (either with or without sputum cytology) as a screening tool for lung cancer without good results. Screening using either test was not shown to reduce lung cancer deaths, and mortality from the lung cancer is the most preferred and applicable endpoint for evaluating the benefits of screening (in the past, with early screening, survival was a possible endpoint, but could be confounded by biases created by screening). Most concurred that lung cancer was a more aggressive form of disease than was others or that early detection methods and treatments were less than optimal.

The ramifications of the paradigm of early detection of hidden but still "good" prospects that would benefit the patient is supported by few clinical examples, and the end result is grim. In the early 1970s, lung cancer incidence and mortality began to slowly increase and, at the same time, the U.S. National Institutes of Health (NIH) started to fund three randomized clinical trials (RCTs) of radiographic and cytological lung cancer screening in the U.S. The studies conducted at the LUMC in Amsterdam, at the Memorial Sloan Kettering Cancer Centre in the US and at Johns Hopkins Medical Institutions in the US were the main outcome measures to lung cancer death.

The purpose of this paper is to talk about the experimental results of the Mayo Clinic experiment, popularly credited as the Mayo Lung Project (MLP) and analyze and interpret the results. In addition to the Mayo data, data from the Hopkins and Memorial trials are included. Future methods of treatment may be targeted therapy using specific tumour antagonists. The care of lung cancer patients and the co-ordination of treatment requires a coordinated approach and is provided by a lung cancer team.

The multidisciplinary team is mostly comprised of pulmonologists, thoracic surgeons, radiation and medical oncology doctors, diagnostic imaging specialists, histopathology experts, oncology nurses who specialize in supportive care and doctors who specialize in thoracic malignancies. Anybody, that gets their diagnosis of lung cancer, should be covered by any such action that's taken by the aforementioned company.

2.3.1. Radiotherapy

Unfortunately, radiotherapy has not yet shown itself to be a very successful method of cure. It has been shown to decrease the number of tumour failures and tumour progression in locally advanced disease, but while trials have been carried out on higher doses ranging up to 80 Gy, the 5 year survival following such treatment is only 7-10%. The standard dose of radiation therapy currently used for non-small cell lung cancer (NSCLC) is 60 Gy, a dose believed to be in the therapeutic range and to have minimal radiation dose to the lung and esophagus. Of all the different ways of dose escalation, hyper fractionation has shown the best results. One of the most important British Medical Research Council (BMRC) trials [7] showed that continuous hyper fractionated accelerated radiotherapy (CHART) - where 1.5 Gy is given every 8 hours for 54 Gy - resulted in more endings and 30% at 2 years compared with conventional fractionation when given at 1.5 Gy every 24 hours for 54 Gy. The daily hyper fractionation protocol was, however, soon followed by challenging logistical difficulties to achieve the daily dose level that was common in this protocol, which made it too cumbersome for use in the clinical setting.

Due to the limited amount of money, "grouping" of individual patients was necessary again. The weekend leave (or CHARTWEL) has proven as effective as CHART and they have dispensed with CHART so far. Chemotherapy is used along with radiation therapy, and that has some advantages over radiation alone in terms of survival rates median survival and long-term survival.

There have not been any comparative investigations performed that would show that a combination of both methods is superior, though. It is unknown, however, which therapy is best to be given first or whether the order of the drugs has some effect, as a meta-analysis published by the NSCLC Collaborative Group in 1995 found a 4% advantage after 2 years and a 2% advantage after 5 years (46). Combining chemotherapy with radiation appears to be more effective than chemotherapy alone or radiation alone, although little evidence exists to back this up. There is, to date, only one randomized controlled study and this confirmed that simultaneous therapy resulted in a 4-month median extension in survival (by 16 months and 12 months, respectively).

Apparently precision delineation of the radiation field – with support from a 3D planning of treatment on a CT scan – is going to revolutionise radiotherapy by delivering the radiation treatment to the tumour with greater accuracy and at a higher dose without becoming harmful to the patient. Furthermore PET imaging is an integral part of the pre-treatment which is essential to pave the way for successful radical therapy because it plays a pivotal role in accurate diagnosis of malignancy within the target tissue for radiation in the proper planned radiation field [8].

Symptom management like palliation of bone pain due to metastases, superior vena cava syndrome and haemoptysis is done commonly, and it has been shown that short-course palliative radiotherapy is effective for a significant percentage of patients. Machine learning in radiotherapy planning is an emerging field of interest, where machine learning models are being developed to automate organ-at-risk segmentation; to predict the occurrence of radiation pneumonitis; and to individualize dose

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fractionation, depending on the characteristics of the tumour and normal tissue.

2.3.2. Chemotherapy

Advanced NSCLC has a poor natural history, with patients with the disease only surviving about 4-6 months. Abysmal response rates (10-15%) were seen in early chemotherapy trials and the above 50% response rate was seen in SCLC. This resulted in survival benefits of around 6-weeks compared to optimal supportive care; and a greater survival rate in 1-year (46%).

This benefit was only observed when using cisplatin-directed chemotherapy, but not when using other chemotherapeutic agents, or combination chemotherapy with long-acting alkylator before. Previous studies with other drug regimens (e.g., combination chemotherapy cyclophosphamide (Cytoxan), vinblastine and methotrexate [CMF] used early in the course of the disease) yielded similar clinical results as BSC. The improvement in last decade towards new therapeutic option has extended the median survival by 7–10 months and have improved the 1-year survival rate by 35–40%.

Modern platinum-based combination therapies that include vinorelbine or gemcitabine or taxanes provide numerous benefits such as outpatient treatment, greater tolerability (fewer drug-related side effects of nausea, vomiting, and alopecia) and better maintenance of patient quality of life [8]. The results of tumour trials may not be generally applicable activity because when people are placed into clinical trials, they are younger, healthier with high performance status, and in centers where their treatment is specialized, managed mostly by specialized tumour doctors.

These criteria of selection limit the applicability of these findings to a certain subset of patients and not the overall patient population who are suffering from advanced disease. Even though, by 2000, lung cancer was becoming a disease of the elderly, only 20% of elders are involved in therapy studies. In addition, most trials have looked for an acceptable performance status (ECOG 0-1) and yet there are many patients who will have a poor ECOG (grade 2 or 3). There has to be a more serious consideration into aging population and the development of effective treatment plan for individuals with lower performance level.

Higher quality of life is also associated with chemotherapy, and there is no benefit of chemotherapy with respect to lifespan for lower quality of life patients of PS. One good thing to learn is there's a new course of action to help kiddles solve the issues - a targeted therapy. Over-expression of the epidermal Growth Factor receptor (EGFR) and its ligands have previously been witnessed in various therapies of cancer and mutations in its have been reported in the NSCLC. EGFR missignaling has been shown to be involved in the initiation and progression of NSCLCs. There are two EGFR inhibitors, gefitinib and erlotinib, taken by mouth that inhibit the activity of the EGFR tyrosine kinase in the cell. Both have shown similar anti-neoplastic effects with there being an acceptable toxicity in the patients with advanced NSCLC who have failed standard chemotherapy. In patients with relapsed disease two randomized phase II Clinical Investigations have reported on the objective regression of tumours and better results from palliative treatment using 2 doses of gefitinib. The survival and symptom control results were also better for the erlotinib arm of a randomized trial that compared erlotinib with placebo in treatment-refractory, stage IV NSCLC. Overexpression of the EGFR is a common abnormality in the NSCLC patient, that is therapeutically relevant in primary care of never-smoker and BAC female patients.

EGFR activating mutations can be detected in about 10% of tumours, and only exist in minority of cases in NSCLC. Interestingly, even high clinical response rates stem from a prevalence of mutations that is lower than clinical response, indicating that there are possibly others predictive biomarkers. There are several targeted therapies being studied for treating lung cancer. Currently, research is ongoing looking for inhibitors of tyrosine kinases that target EGFR, which is an antibody (such as, cetuximab) already used to treat colorectal cancer.

Similarly, bevacizumab is a monoclonal antibody against VEGF which is highly effective in the treatment of colorectal cancer, and is being tested for other purposes such as lung cancer. In addition, clinical trials are also investigating using antiangiogenic drug thalidomide with chemotherapy in NSCLC and SCLC patients. It is the most difficult to treat form of lung cancer, due to the lack of progress in small-cell lung cancer, and the intractability of the disease. The 1970s saw the development of several correct single chemotherapeutic agents which, when used with two other three agents, offer some promise to SCLC.

Treatment with randomized trials. This is the case if the spread of the disease was not great, because the median survival time was much longer, 18-20 months, than it was in a patient not treated (5 months). Those who were so ill with disseminated disease, did even more outstanding recovery, weeks to 6 to 9 on treatment. The best results were obtained in patients with good performance status, and normal levels of serum sodium, alkaline phosphatase and urea. Such standards generally do not vary over time, although different combinations of drug agents, e.g. etoposide-carboplatin, have made treatment more tolerable for the patients today. Prophylactic cranial irradiation and radiotherapy to the chest will help to prevent neurological problems associated with brain

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metastases, yet it is useful in only treatment responsive cases.

Despite numerous clinical trials, with or without induction, maintenance and/or support with hematopoietic growth factors, there has been no improvement in the survival rate. Individuals in this group are highly symptomatic, and likely have high attrition rates, with substantial improvement in symptoms upon treatment, making this group clinically useful. As in NSCLC, treatment with chemotherapy at the time of progression is of poor benefit (low response rates, short duration of disease control). Curiously, SCLC is much more responsive to treatment than is NSCLC, and the majority of research has focused on NSCLC.

2.4. Methods

The methods and strategies for recruiting participants for all three studies funded by the NCI were detailed previously. Over 10,000 men took part in each study and all were considered to be at high risk for lung cancer (age 45 years or older, regular heavy tobacco smokers). Full-sized chest radiograph films were used in the radiological screening process (either posteroanterior and lateral projections or stereoscopic views). Sputum specimens, collected on 3 days (inducible, spontaneous) were examined by cytological examination using the Saccomanno method.

Prior to the MLP, a preliminary radiologic and cytologic screening (prevalence) was conducted with the participants of the MLP. Negative initial screening participants were randomly assigned to either a study or a control group - the study group got a chest radiograph and sputum cytology test every 4 months for 6 years, while the control group was advised to undergo a chest radiograph and sputum cytology test at least once per year.

Screening average for the two groups was 1 to 5.5 years (average three years) in post. In all the trials, annual radiologic screening was offered to male patients in both the Hopkins and Memorial trials, and every four months, cytologic screening was offered to male patients in the Hopkins trial. Once a year, yearly radiologic screening was provided to the control sample.

In all three trials [Figure. 3] all deaths were recorded and analyzed by a committee of statisticians, doctors, pathologists from the hospitals engaged in the trials and from the University of Cincinnati where the statistics were collected. Lung cancer was confirmed or proven if there was either a concordant clinical presentation or a histologic/cytologic confirmation of malignancy [Figure 3]. A diagnosis was considered to be "probable" if just histologic or cytologic confirmation or only a compatible presentation was available. 100% of lung cancer cases were confirmed in the MLP. Both of the other two studies had some “issues” but had minimal effect on the findings [9].

If the diagnosis was established as a cancer of the lung by thoracotomy or autopsy the diagnostic criteria were satisfactory. In each of the three controlled studies, however, most of the lung cancers were not curable.

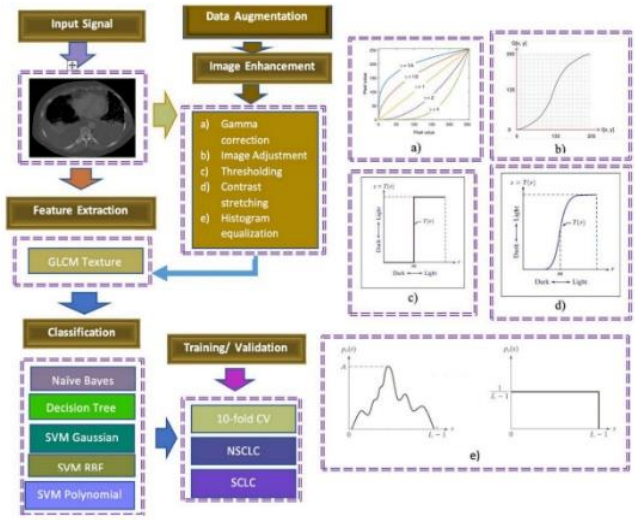


Figure. 3 Proposed work to Implementation Progress

Common methods for demonstrating the presence of cancer in patients were cytologic examination of body fluids, and biopsy of an enlarged cervical lymph node, liver, etc. Sadly, lung cancer is a "mischievous" disease and may occur in any form of cancer. It would have been difficult to give this diagnosis to the cases called ‘borderline' in these three studies that were specifically on the diagnosis of lung cancer.

3. Conclusion

In conclusion, lung cancer was a virtually untreatable disease 100 years ago. The most important breakthrough in medical knowledge concerning this form of cancer has been the discovery of the prime cause of the disease: tobacco. Imaging procedures, surgical, chemotherapy and radiotherapy techniques have developed greatly in recent years and are aiding in the treatment of this disease to a greater extent. However, this progress is not enough to have an effect on survival. However, the team of researchers who work in the field of cancer research have not lost sight of what they hope will be improved cases of survival in the future decades. When it comes to mortality, no other diagnostic or therapeutic will be as impactful as elimination of tobacco products from the market. True as Johnston's statement, “I have never heard of it, Hippocrates.” The 100-year study on chest diseases hopefully will enable lung cancer to be a footnote in medicine.

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