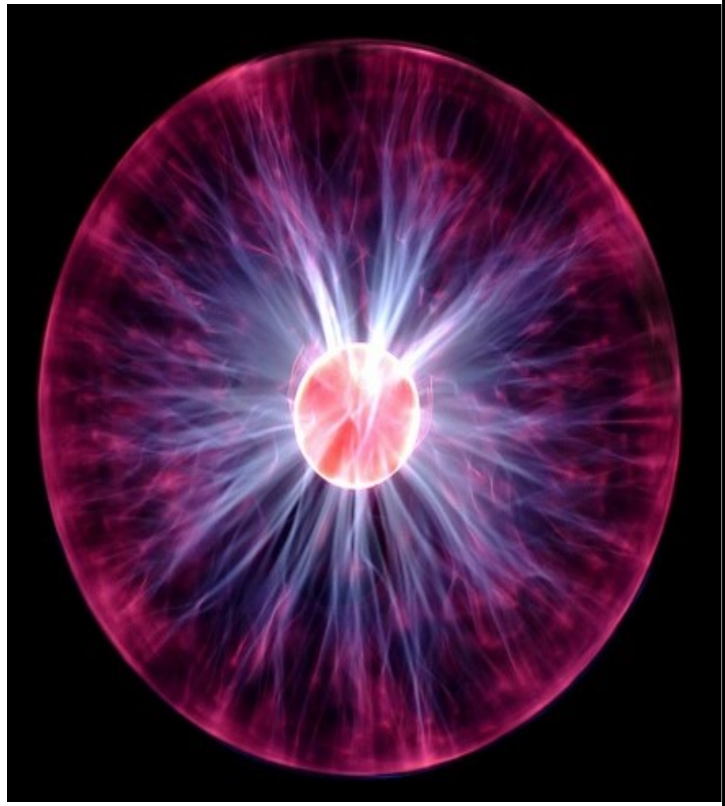
Academic Year :

2024 -2025



ELECTROSPHERE

---- A Technical Magazine

Department of Electrical Engineering
AISSMS's Institute of Information Technology, Pune.

Volume VIII

INDEX

About Department of Electrical Engineering

The Department of Electrical Engineering was established in 1999 at AISSMS, Institute of Information Technology, Pune. The department offers **B.E. in Electrical** and **M.E. in Power Electronics and Drives**. The department currently has 13 professional faculties, including 02 IEEE, 11 IE(I) and 13 ISTE members. In the department, near about 30 courses are offered, encompassing all areas of electrical engineering. Faculty and students are engaged in courses and research in the fields viz, power systems, control systems, power electronics, electrical machines, renewable systems and power quality. The department focuses on developing its strengths and aligning with the institutional priorities of IOIT.

The vision of the department is to contribute to the society by imparting quality education in the field of electrical engineering and prepares students to succeed in their professional career by inculcating in them high human values.

The department's mission is to develop innovative and socially responsible engineering professionals by delivering in-depth knowledge of electrical engineering.

Several small, medium and large projects have been sanctioned to department faculty in the last five years. This has led to the development of center of excellence in power quality.

Department faculty has been traditionally contributing to administrative activities both within and outside the Institute. Currently, 10 faculties are serving as chairman/paper setter/examiner at University. Several faculties from the department are currently serving as coordinators within the Institute.

The department endeavors to produce confident professionals tuned to real time working environment. Department Alumni have made excellent contributions in various fields like entrepreneurship, industry, and academics. A few illustrious who have distinguished themselves are Kalyani Abhyankar (Sr. Operations Engineer, Sacramento, California Area), Ruchi Muku Das (Infrastructure and Network Procurement, Unilever Asia Pvt. Ltd), Amol Manal (Controls Specialist at Lorik Tool & Automation Kitchener, Ontario, Canada) , Vishakha Chandhere (Founder, OrjaBox Pune, Maharashtra) , Lalit Ghatpande (Relay Setting Engineer, Synchro Grid Limited LLC).

The infrastructure and lab facilities are upgraded from time to time and provide a good practical learning and innovative environment for the students and researchers. There are about 07 laboratories just for the exclusive benefit of students of department of EE.
The department strives to provide a conductive environment for the students to develop analytical and practical skills and apply them to real world problems. To motivate the students, the department organizes regular training workshop.

A competitive environment is fostered, and development of leadership skills and team skills are also encouraged by means of the department professional body societies such as IEI, IEEE, ISTE, ISLE, REC, EESA which holds various co-curricular and extracurricular events, contests from time to time to bring out hidden talents.

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Mr. S. D. Raste	Mr. R. R. Waghulde	Mrs. D. D. Changan	Mr. A. A. Joshi

Electrical Department Faculty Members

Technical Articles

Advancements in Electrical Engineering in India: A 2025 Overview

Mrs. S. M. Shaikh

As of April 2025, India is experiencing a transformative phase in electrical engineering, driven by innovations in renewable energy, smart grids, quantum technologies, and educational reforms. This article delves into the latest developments shaping the sector and their implications for the nation's infrastructure and economy.

1. Smart Grids and Digital Power Infrastructure

India's power sector is undergoing significant modernization through the integration of smart grids. These systems employ advanced metering infrastructure (AMI), artificial intelligence (AI), and machine learning (ML) to enable real-time monitoring, predictive maintenance, and enhanced cyber security. Such upgrades are essential for accommodating the increasing share of renewable energy sources and ensuring grid stability. (Ref: Renewables, EVs, and smart grids to reshape sector by 2025)

2. Renewable Energy and Green Hydrogen Initiatives

The Indian government is intensifying efforts to boost renewable energy capacity, with a focus on solar, wind, and green hydrogen. Pilot projects targeting hard-to-decarbonize industries like steel, cement, and heavy transport are underway, aiming to position India as a leader in green hydrogen production. Domestic manufacturing of electrolyzers is also being promoted to reduce costs and enhance production capabilities. (Ref: Renewables, EVs, and smart grids to reshape sector by 2025)

3. Quantum Technologies: National Quantum Mission

Launched in 2023, the National Quantum Mission (NQM) is a significant initiative by the Government of India to advance research and development in quantum technologies. With an investment of ₹6,003.65 crore, the mission focuses on four key areas: quantum computing, quantum communication, quantum sensing and metrology, and quantum materials and devices. Notably, India has developed a 6-qubit quantum processor, marking a milestone in the nation's quantum computing capabilities. (Ref: National Quantum Mission India, India's quantum computer)

4. Electric Vehicles (EVs) and Vehicle-to-Grid (V2G) Integration

The adoption of electric vehicles in India is accelerating, particularly in the two- and three-wheeler segments, driven by government incentives and expanding charging infrastructure. Vehicle-to-Grid (V2G) technology is being explored to allow EVs to supply power back to the grid, thereby enhancing grid stability and supporting renewable energy integration. (Ref: Renewables, EVs, and smart grids to reshape sector by 2025)

5. Educational Reforms: AICTE's New Curriculum

The All India Council for Technical Education (AICTE) has introduced a new model curriculum for undergraduate Electrical Engineering courses, emphasizing industry relevance and innovation. The curriculum incorporates practical training, industry exposure, and emerging technologies such as artificial intelligence and renewable energy, aiming to equip students with the skills necessary to meet the evolving demands of the electrical engineering sector. (Ref: New AICTE Electrical Engineering Curriculum Focuses on Industry Relevance and Innovation - Times of India)

6. Electronics Manufacturing Boost

In March 2025, the Indian Cabinet approved a ₹22,919 crore ($2.7 billion) plan to enhance the manufacturing of electronic components, including those for telecommunications, automobiles, and energy sectors. This initiative is expected to generate approximately 92,000 direct jobs and is part of India's broader strategy to strengthen its electronics manufacturing capabilities. (Ref: Indian cabinet approves $2.7 billion plan to boost electronic components manufacturing)

Conclusion

India's electrical engineering landscape in 2025 is characterized by significant advancements in smart grid technology, renewable energy adoption, quantum computing, and educational reforms. These developments not only aim to modernize the nation's infrastructure but also position India as a global leader in sustainable and innovative electrical engineering solutions.

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The role of AI in lighting

Mr. Atul A. Joshi

The lighting industry commonly employs novel techniques in lighting design and control. Significant transformative changes within the sector include the evolution of the light bulb and the introduction of inter-networked lighting components that implement protocols such as DALI. In the context of lighting control systems, the scope for applying AI is intriguingly broad, impacting the various stages involved in the lighting life-cycle such as design, installation, commissioning, and configuration.

For example, a self-learning network of lighting components can communicate and set-up itself without requiring human intervention, similar to auto-commissioning systems used in the IT industry. Such a network will decrease the time needed to commission new lighting installations. By observing and measuring the indoor environment, an AI-based lighting system can optimise and tune light parameters accordingly to impact user experience and wellbeing.

AI lighting Benefits-

The utility of an AI-based lighting system is not limited to end-users or tenants but extends to other stakeholders such as building owners and facility managers as well. A data-driven network of lighting components continuously generates data which is collected and stored at a centralized server. AI algorithms can run at the source component, such as a sensor, for decentralized, real-time decisions, or at a server for making centralized decisions. Furthermore, the data collected applies to other Building Management Systems (BMS) such as Heating, Ventilation and Air Conditioning (HVAC), or access management.

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Smart Electric Vehicle Charging Station with Automated Payment System

Dr. V. S. Kamble
Ms. Srushti Kadam, **Student, SY M. Tech (PE&D)**

***Abstract*- The rapid rise of electric vehicles (EVs) has sparked a global transformation in the transportation sector, driving the need for a robust and accessible charging infrastructure. Electric vehicle charging stations (EVCSs) play a pivotal role in facilitating the widespread adoption of electric mobility and addressing the challenges associated with limited driving range and charging availability. This abstract highlight the significance of EVCSs in supporting the transition to sustainable transportation. Furthermore, we delve into the different types of EVCSs, ranging from residential charging stations to public and commercial charging networks. Each category is analysed, considering their unique features, charging capabilities, and scalability. The abstract emphasizes the significance of establishing a diverse and interconnected charging network to ensure seamless and convenient access to charging infrastructure for EV owners. Finally, the abstract discusses the challenges and prospects of EVCS deployment. Topics such as charging infrastructure planning, demand management, and the role of government policies and incentives are addressed. The potential for innovation and collaboration between public and private entities is also explored, underscoring the need for a holistic approach to foster the growth of EVCSs.**

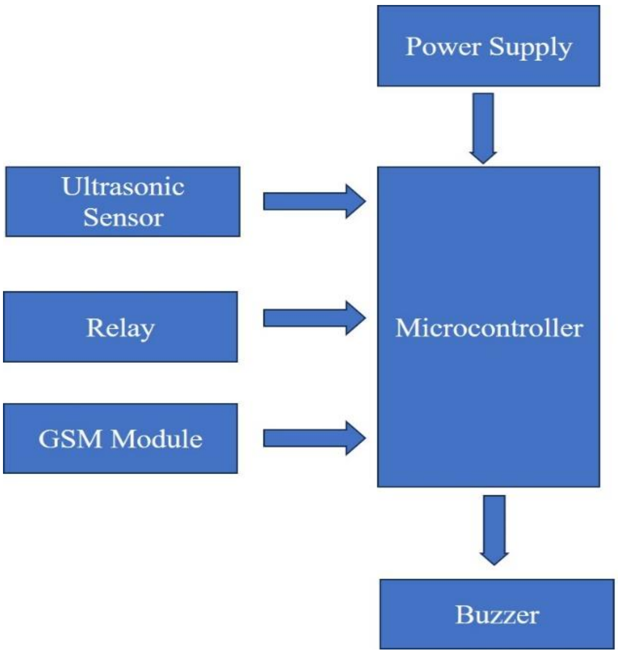
Keywords- Smart EV charging station, Automated payment system for EV, electric vehicle charging infrastructure, Automated billing system, Wireless EV charging payment, EV charging payment.

I. INTRODUCTION

The global transportation sector is undergoing a transformative shift from traditional fossil-fuel vehicles to electric vehicles (EVs) to address environmental concerns and combat climate change. EVs offer a cleaner, more efficient alternative and are increasingly embraced due to advancements in battery technology, government incentives, and rising environmental awareness. As the popularity of EVs grows, so does the need for a robust and accessible charging infrastructure to support the increasing number of EVs on the road. In the current landscape, many EV charging stations still rely on manual or semi-automated payment methods, which can be time-consuming and inconvenient for users. Additionally, these traditional systems can introduce errors and inefficiencies that impact both user satisfaction and operational effectiveness. By automating the billing process, this project aims to develop a scalable, user-friendly solution that simplifies payment and enhances the overall charging experience, ultimately promoting the wider adoption of EVs. The purpose of this project is to design and implement an automatic billing system that improves the usability and management of EV charging stations.

Automating the billing and payment processes reduces operational costs and eases administrative tasks for charging station operators, while also providing EV users with a smoother, faster charging experience.This project contributes to larger goals, such as fostering EV adoption, reducing greenhouse gas emissions, and supporting sustainable development by ensuring greater access to EV charging. The increasing demand for convenient and efficient charging experiences presents several challenges. Firstly, current EV charging systems often involve manual payments or complex interfaces that can frustrate users and create unnecessary delays. Secondly, a lack of real-time monitoring means users may struggle to locate available charging stations, especially in high traffic areas. Additionally, station operators face obstacles in managing payments, tracking usage patterns, and ensuring efficient operation, all of which can lead to under-utilization of resources and revenue loss. The current systems also lack the flexibility to adapt to the growing needs of EV users, as they are not easily scalable or adaptable to new technologies. This project aims to address these challenges through the development of an automated billing solution. The proposed system provides user authentication, tracks charging sessions, calculates billing based on real-time usage, and offers flexible payment options. It integrates features such as digital wallet compatibility, credit card processing, and real-time availability updates, allowing users to receive up-to-date information on station occupancy. For station operators, this system provides critical insights into usage patterns and revenue, empowering them to optimize their operations and maximize resource utilization. The scope of the project encompasses the design, implementation, and testing of the billing system, ensuring that it meets the functional needs of both users and operators. The system will be scalable, allowing it to adapt to increasing EV demands and integrate additional payment technologies as they emerge. It is designed to accommodate various EV types and charging speeds, with a user-friendly interface accessible through a mobile application.

II. Methodologies



1. **Microcontroller (Raspberry Pi Pico)**

- The Raspberry Pi Pico is the central controller of the entire system. It handles the coordination between various input devices, processes the information and control the output devices accordingly.

Role:

- It processes sensor data (from the input devices like Ultrasonic, Relay, GSM, etc.).
- It manages the charging process and controls communication with external components (like the Charging Coil, LCD, and Buzzer).
- It monitors and detects irregularities in the system.
- It communicates with the GSM Module to send notifications for charging completion or any faults.
- It operates the Relay to control the connection between the power source and the wireless charging module.

2. **Charging Coil RX/TX (Wireless Charging Module):**

- Role: The charging coil consists of the transmitter coil (TX) on the charging station and the receiver coil (RX) on the electric vehicle (EV). The transmitter coil (TX) sends energy wirelessly to the receiver coil (RX) in the vehicle for charging.
- Connection: The Raspberry Pi Pico controls communication with the wireless charging module and ensures that the charging process begins once the vehicle is correctly aligned, and the necessary conditions (like power availability) are met

III. Conclusion

The wireless EV Charging Station system is a comprehensive and efficient solution that aims to address the growing demand for electric vehicle (EV) infrastructure. The system combines advanced technologies such as ultrasonic sensors, wireless charging, battery management, and automated payment processing to deliver a user-friendly and secure charging experience for EV owners.

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Small signal stability analysis of stand alone microgrid with composite load

Mrs. D.D. Changan

Abstract:

Microgrid concept provides suitable context for installing distributed generation resources and providing reliability and power quality for loads. During grid connected mode of microgrid, all stability issues are getting handled by main grid due to its sufficient inertia. But when islanding occurs, microgrid faces stability-related problems. This paper presents the state space model of isolated microgrid along with load dynamics. This paper investigates the effect of static load, induction motor type of dynamic load and composite load on the stability of the island microgrid. The paper also studies the effect of damping and inertia on the stability of the microgrid. The performance of the test system is evaluated using MATLAB simulation software. The present studies show that during the planning of the microgrid, effect of types of loads and load changes should be considered for stable operation of the system. Keywords: Island, Microgrid, Eigenvalues, Small signal stability, Load modelling, Composite load.

Introduction: The integration of distributed generation with the main grid is called microgrid. Microgrid is the combination of small sources, like renewable energy sources, network and the loads. The inverter is the main interfacing part of the microgrid, and it can be considered as a source. Microgrid enhances the overall power generation and reliability of the power system. Due to the use of power electronics devices, microgrid has a lot of issues related to power quality, stability and neutral current. Therefore, it is necessary to consider the effect of source location, location of load, type of load and load parameter before the installation of microgrid. the loads can be classified as static load, dynamic load and composite load. Static loads are the algebraic function of voltage and frequency, and it is composed of constant impedance characteristics, constant current characteristics and constant power characteristics. Generally, static loads do not effect on the stability of the system because it considers only present values of the system data. One main disadvantage of the static model is that in addition to ignoring the dynamics of the dynamic load, it does not take into consideration the effect of the load inertia constant. The dynamic loads affect the stability of the microgrid because it considers the present as well as historical data during performance. The load modelling of dynamic load like induction machine is to be carried out accurately for voltage stability analysis. Composite load modelling consists of a combination of static load and dynamic load. The superiority has increased due to aggregated dynamic load representation in both small and large disturbance studies. Composite load modelling is important for accurate modelling because the dynamic model can only express the dynamic response of load model. When the influence of distribution generation is not negligible, the induction motor load model cannot effectively describe the actual load characteristic. While planning of microgrid, it is most important to consider the composite loads. During the planning of microgrid, it is most important to study the impacts of load dynamics on stability.

Considerable attention has been given in the literature to consider the effects of constant power load (CPL) on the small signal stability of the island microgrid. However, the analysis of an islanded microgrid system based on a state space model of the CPL does not essentially guarantee the stability of the system. Amelian et al suggested a state space model of a constant power load model of islanded microgrid to investigate the small signal stability. In their study, authors do not present the effect of loading and damping. The study also limited up to three bus systems with 2 generators and one load. The small signal stability framework is carried out for studying the islanded microgrid system for constant load under the different uncertainty conditions. The simulation was carried on the 9 bus DC microgrid system. Authors were not considered the effects of dynamic load conditions. So, this model would not be perfect for stability analysis of islanded microgrid. Amelian et al. have discussed the comprehensive effect of dynamic load and static load on microgrid stability. But this paper has not discussed the effect of damping and inertia on stability. In [10], dynamic load model is considered for stability analysis of microgrid. The author has considered medium voltage microgrid for analysis. Guzman et al. [11] presented the dynamics of inverter-based islanded microgrid. the bifurcation theory was used to present the oscillation and load margin of the composite load. Kallamadi et al. [12] have discussed small signal stability analysis of microgrid for static and dynamic load, but authors do not discuss the composite load. Pogaku et al. discussed [13] the effect of inverter parameters on the stability of microgrid. A sensitivity analysis was presented to analyze stability. Hossain et al. [8] discussed stability microgrid for constant power loads only with pole zero location for the different cases. The effect of PID controller is also presented in the paper, and simulation model was developed on the MATLAB software. In [14] state space model of isolated microgrid with wind energy source and two types of loads, heating and induction machines and their effect on stability have been discussed. The microgrid stability is getting disturbed while the transition of AC microgrid from grid connected mode to stand-alone mode. The effect of energy storage systems on the stand-alone microgrid is presented. To fulfill the power generation and load demand in the stand-alone microgrid system, energy storage system and energy management system can be integrated. As microgrid is working in stand-alone mode, the energy storage system can be used for fulfilling the load demand. The effect of constant power loads and constant current loads on the DC microgrid and their effect on stability have been witnessed in [22]. A Lyapunov stability theory was presented to analyze dynamic stability, which revealed that the eigenvalues of constant power loads affect more as compared to the constant current loads. In [23], the effect of constant power loads, droop gain and line impedance on the small signal stability of dc microgrid is investigated. The analysis reveals that as the droop gain is increased the system becomes more unstable. When microgrid connects to main grid, the load dynamics does not affect the stability because of its sufficient inertia (Because main grid has more inertia as compared to microgrid). After islanding, microgrid faces stability-related problems because of its low inertia. Hence, in this paper stability analysis of islanded microgrid is studied in detail.

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The Importance of Renewable Energy Sources for Sustainable Development

Dr. K. S. Gadgil

In the face of escalating climate change, dwindling natural resources, and growing energy demands, renewable energy has emerged as a cornerstone of sustainable development. Unlike fossil fuels, renewable sources such as solar, wind, hydro, biomass, and geothermal are naturally replenished, making them vital for long-term ecological and economic stability. One of the primary advantages of renewable energy is its minimal environmental impact.

Traditional energy sources like coal and oil release significant amounts of greenhouse gases, contributing to global warming, air pollution, and ecosystem degradation. In contrast, renewables generate energy with little or no emissions, reducing the carbon footprint and helping nations meet international climate commitments like the Paris Agreement. Renewable energy also promotes energy security and economic growth. By reducing dependence on imported fuels, countries can stabilize their energy prices and improve resilience against geopolitical shocks. Furthermore, the renewable energy sector creates millions of jobs globally—from solar panel manufacturing to wind turbine maintenance—thus supporting inclusive economic development.

Access to clean energy is also critical for improving quality of life, especially in remote and underserved communities. Decentralized renewable systems can bring electricity to areas where grid extension is unfeasible, empowering education, healthcare, and small businesses. However, the transition to a renewable-based energy system requires supportive policies, investment in infrastructure, and advances in energy storage and grid integration. Governments, industries, and individuals must work collaboratively to accelerate this shift.

In conclusion, renewable energy sources are not just an alternative, they are essential for a sustainable, equitable, and resilient future. Embracing them is a vital step toward safeguarding our planet and ensuring prosperity for generations to come.

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The Future of Microcontrollers: Smarter, Safer, Smaller

Mr. P. P. Mahajan

Microcontrollers (MCUs) are evolving rapidly, driven by trends in AI, security, and miniaturizetion.

AI Integration:

Next-gen MCUs are embedding AI capabilities directly on-chip, enabling real-time decision-making without cloud reliance. This is key for applications like voice recognition, gesture control, and predictive maintenance. Examples include ARM Cortex-M55 with NPU and STM32H7 running TensorFlow Lite.

Security Enhancements:

As devices become more connected, security is critical. Modern MCUs now include secure boots, hardware encryption, ARM Trust Zone, and even physical unclonable functions (PUFs) to guard against cyber threats.

Miniaturization:

The smallest MCUs, like Microchip's ATtiny and Ambiq's Apollo4, offer high performance in tiny packages. Advances in chip design and packaging are enabling ultra-compact, energy-efficient systems for wearables, sensors, and implants.

Conclusion:

Future MCUs will be intelligent, secure, and ultra-compact paving the way for smarter and more autonomous embedded systems.

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Journal Paper

Harmonic Measurement and Analysis in Manufacturing Industry: Case Study

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Abstract— **Power Quality (PQ) has gained significant importance in recent years and is one of the critical aspects of modern manufacturing plants. Harmonics is one of the important Power Quality disturbances and many failures of critical components in industry are observed due to it. This paper presents the case study of harmonic measurement in a manufacturing industry which was facing the issues of stoppage of critical processes due to harmonics. Extensive PQ measurements using Class A & Class S power quality loggers were performed in March and May 2024 in the industrial plant located in Chakan, Pune (India). It was observed that the HVAC load was causing harmonics distortion of 29.1% with dominant 2nd, 4th, 5th and 7th order harmonics and was injecting 46 A harmonic current. Shifting of the HVAC feeder load on the raw power resulted in an 81% reduction in the total harmonic current and a reduction of voltage THD from 2% to 0.66%. Detailed analysis of PQ measurements of UPS Output with and without HVAC load with the help of waveforms and harmonic spectrums is presented. Active harmonic filter sizing to improve the power quality of the industry is presented.**

Keywords— Harmonic analysis, Power system harmonics, Harmonic filter, Harmonic distortion, Power quality, THD.

I. Introduction

The new-age industries are adopting equipment like Uninterruptible Power Supply (UPS), thyristor-controlled heaters, LED lighting, variable frequency drives (VFDs) etc. which use power electronics devices. These non-linear devices improve the efficiency of the process but at the cost of the quality of the power [1]. One of the main PQ disturbances introduced by the power electronic devices is harmonics which cause system voltage distortion, power loss, additional heating and finally equipment failures [2]. The power converter devices which are widely used in industrial systems generate characteristic harmonics as well as non-characteristic harmonics and sometimes even order harmonics [3]. IEEE 1159 categorizes PQ variations (disturbances) [4] into seven categories viz. Transients (Impulsive and Oscillatory), Short-duration root-mean-square (rms) variations – (Sag, Swell, Interruption, and Voltage Imbalance), Long duration rms variations (Sustained interruption, Undervoltages, Overvoltages, and Current overload), Imbalance (Voltage, Current), Waveform distortion (DC offset, Harmonics, Interharmonics, Notching, and Noise), Voltage fluctuations and Power frequency variations. Harmonics are one of the most common PQ disturbances, and they cause an increase in losses in transformers and cables, overheating of equipment, voltage distortion, and interference with sensitive electronic equipment. IEEE 519 [5] recommends harmonics limits however they are applicable at PCC and sometimes they may be within the limits at PCC but still there can be failures observed inside the plants due to harmonic distortions caused by non-linear devices as well as due to the wrong configuration of distribution systems. It is recommended to separate non-linear loads from the critical loads to avoid the nuisance tripping of equipment, heating as well as mal-operation and stoppage of the critical process[6].

In this case study, exhaustive harmonic measurements conducted in a manufacturing industry covering the input and output of UPS as well as load feeders are presented. The impact of connecting a non-linear load feeder to UPS supplying the critical load is analysed.

The paper is organized as follows. Section II of this paper describes the industry details. Section III describes the measurements in detail. Section IV presents the results and analysis including, the presence of even harmonics in UPS output, and the impact of the separation of non-linear load on harmonic distortion. Finally, section IV gives a summary of the major findings as conclusions.

II. Industry Details

The industry is a small-scale plant (800 kVA Transformer) located in the industrial hub of Chakan in Pune (India). The plant was recently established and is working in the test phase before starting full-scale production. The industry manufactures the product having a manufacturing cycle of 4 days (non-stop 96 hours) and a packaging cycle of 2 days (48 hours). Out of this, no interruption is allowed in the manufacturing cycle as it damages the product, which needs to be discarded.

The plant receives power at 22 kV from Maharashtra State Electricity Distribution Company (MSEDCL) using non-express feeder. The incoming voltage is stepped down to 0.433 kV using an 800 kVA transformer. A standby Diesel Generator set of 750 kVA is provided which is backed by 400 kVA UPS (only for sensitive loads). An additional 400 kVA UPS is planned in phase 2 of the plant. A 300 kVAR thyristor-controlled APFC (Automatic Power Factor Correction) panel is provided for reactive power support. The output of 400 kVA UPS is supplied to the critical loads through the isolation transformer.

The manufacturing process of the hi-tech patented product involves heaters (thyristor controlled), spooling machines, stranding machines and strength testing equipment. VFDs are used in the main processing machines. The manufacturing area needs a fully controlled environment with a set temperature and humidity for which a separate HVAC section (multiple VRF air conditioners) is provided. The temperature being one of the critical parameters in the production process, the HVAC section is supplied through UPS.

A simplified schematic diagram of the network is shown in Fig. 1.

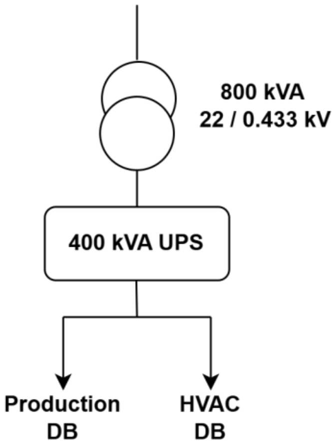


Figure 1. Simplified schematic diagram of the system

During the 96-hour manufacturing cycle testing phase, the industry was facing an issue of tripping of the UPS resulting in the stoppage of the critical production process. Also being a new facility by an international group, the technical team wanted to perform power quality benchmarking before starting the full production. The technical team was interested in power quality indicators like voltage quality (sag, swell, unbalance), harmonics (voltage and current), flicker, waveform distortion. After detail discussion with the technical team of the industry, a comprehensive PQ measurement plan was chalked out for the power quality benchmarking of the UPS as well as sensitive load feeders.

III. MEASUREMENTS

Measurements at different locations (UPS input, UPS Output, Production feeder, HVAC feeder etc.) were carried out using Fluke 1748 (Class-A) [7] & Fluke 1738 (Class-S) [8] Power quality loggers - complying with IEC 61000-4-30 Edition 3. Rogowski coils of 3000 A [9] & 1500 A [10] were used for the current measurement. A total of six 24-hour and two 1-week measurements were carried out in February - March 2024 (before UPS failure) and three 1-week measurements in May 2024 (with new UPS).

Three phase electrical parameters - voltage, current, active power, reactive power etc. were logged with 1-second intervals (for 24-hour measurements) and with 3-second intervals (for 1-week measurements). Voltage harmonics and current harmonic up to 50^{th} harmonic order were logged for each phase with a 3-second interval complying with IEEE 519 [5].

The measurements were carried out at UPS input, UPS output, production DB feeder and HVAC DB feeder. Fig. 2 shows the typical setup of Power Quality loggers during 1-week measurement. Fluke 1738 – Class S power quality logger is connected to the input of the 400 kVA UPS while Fluke 1748 – Class A power quality logger is connected to the output of the UPS. The Power Quality analysis of logged parameters was performed using Fluke Energy Analyse Plus software [11].

Shortly after the PQ measurements in February-March 2024 there was failure of the UPS. A new UPS was installed and also the HVAC feeder was shifted to raw power and PQ measurements were repeated in May 2024.

(a) (b)

Figure 2. PQ Logger setup (a) UPS input (b) UPS output

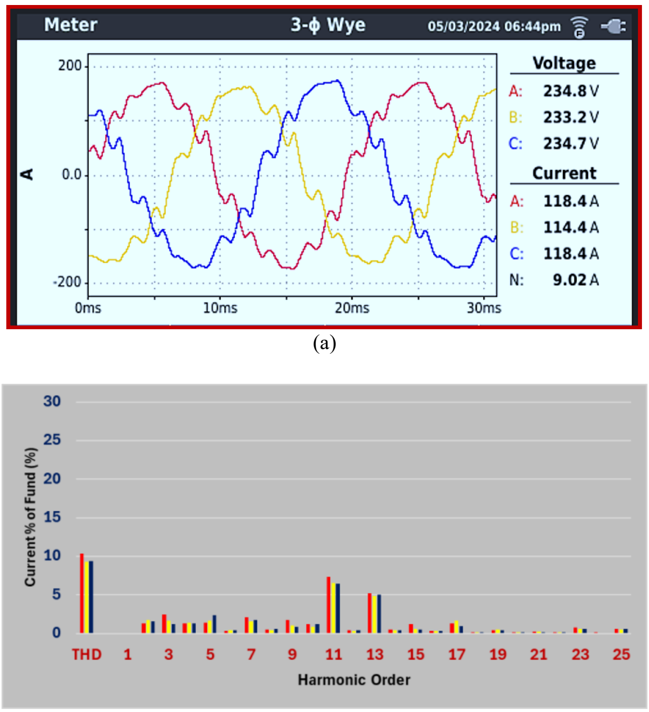
IV. RESULTS AND DISCUSSIONS

A. *Before UPS replacement (with HVAC Load)*

UPS was feeding the production load as well as the HVAC load. The power quality logging was done for 1-week at UPS input and UPS output. Table I lists the harmonic distortion values.

TABLE I. VOLTAGE AND CURRENT DISTORTION VALUES OF UPS

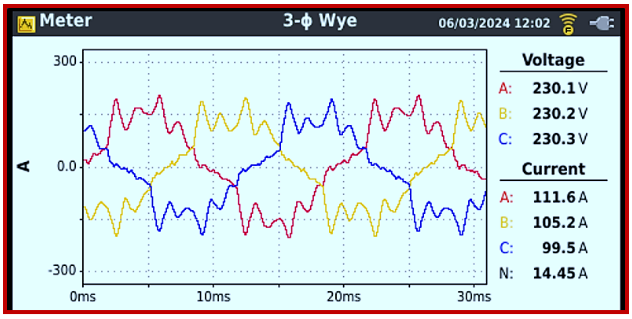
PQ Parameter	UPS Input	UPS Output
Voltage distortion (V_{THD})	1.7%	2.0%
Current distortion (I_{THD})	10.4%	28.1%
Dominant current harmonic	11,13	2,4,5,7,11,13
Total Harmonic Current (I_{THC})	16.1 A	41.9 A



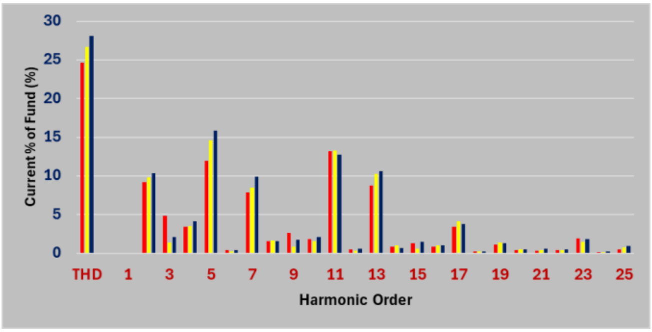
(b)

Figure 3. Current waveform (a) and harmonic spectrum (b) of UPS Input

Current waveform (Fig. 3(a)) at the input of UPS is quite distorted. Fig. 3(b) shows the current harmonic spectrum at the UPS input. Harmonic order from 0 to 25 is considered as the higher order harmonics (26 to 50) are small and can be neglected.



(a)



(b)

Figure 4. Current waveform (a) and harmonic spectrum (b) of UPS Output

Current waveform (Fig. 4(a)) at the output of UPS is highly distorted. Fig. 4(b) shows the current harmonic spectrum at the UPS output. It can be seen that current THD is low on the input side (Fig 3(b)) of UPS and 11^{th} and 13^{th} order harmonics are dominant while Fig. 4(b) shows an increase in current THD on the output side of UPS with the dominance of 2^{nd}, 4^{th}, 5^{th} and 7^{th} order harmonics followed by 11^{th} and 13^{th}

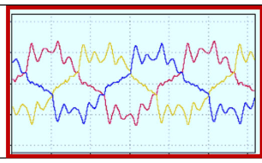
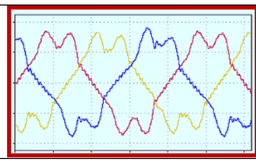
It was observed that the major source of harmonics was the HVAC feeder with an I_{THD} of 45.3% (Fig. 5(b)) while on the production feeder, I_{THD} was observed in the range of 8 to 9%. UPS failure occurred shortly after the above measurements. It was recommended to separate the HVAC feeder from the production feeder. The HVAC feeder was shifted to raw power and a dedicated new UPS was installed for the production feeder.

B. *After UPS replacement (without HVAC Load)*

To confirm the improvement of power quality by isolating sensitive load from the non-linear load (HVAC feeder), 1-week power quality measurements were carried out at the UPS input and UPS output in May 2024.

Table II compares the power quality parameters of UPS output with and without HVAC load.

TABLE II. COMPARISON OF PQ PARAMETERS (WITH AND WITHOUT HVAC LOAD)

PQ Parameter	UPS Output (With HVAC Load)	UPS (New) Output (Without HVAC Load)
Voltage distortion (V_{THD})	2.0%	0.66%
Total Harmonic Current (I_{THC})	41.9 A	7.95 A
Dominant current harmonic	2,4,5,7,11,13	5,7
Current Waveform		

From table II, it can be observed that total harmonic current (I_{THC}) was reduced by 81% after removing the HVAC feeder from the UPS output. Current waveform was improved considerably.

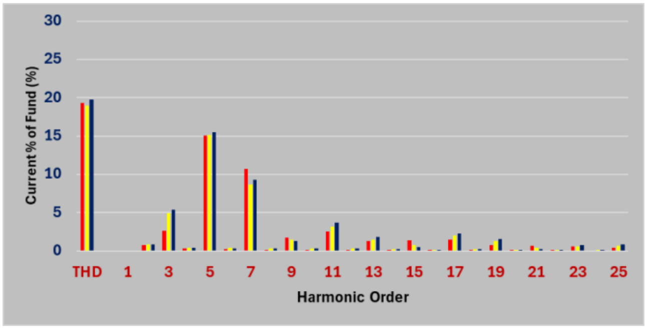


Figure 5. Current harmonic spectrum of UPS (New) Output

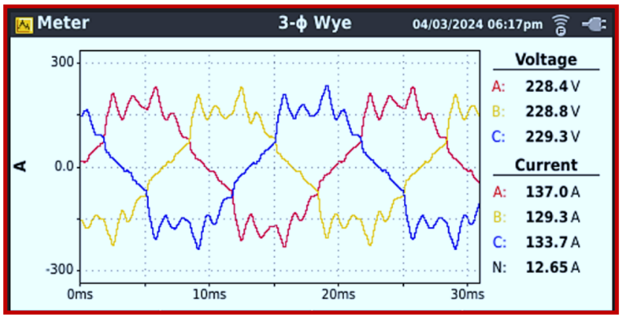
Fig. 5 shows the current harmonic spectrum of output of New UPS. When compared to Fig. 4 it can be seen that along with the reduction on the current THD, the 2^{nd}, 4^{th}, 11^{th} and 13^{th} order harmonics are reduced significantly.

After installation of new UPS with shifting of HVAC feeder to raw power, no interruption is observed in the production area.

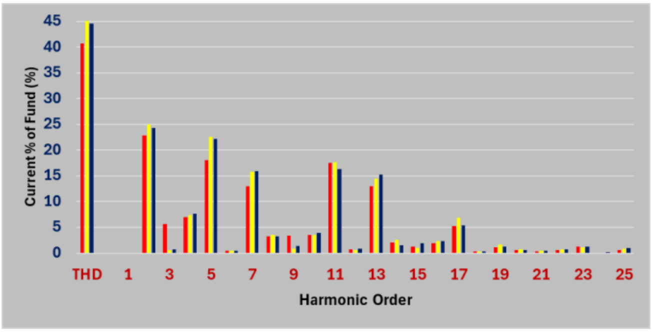
C. *HVAC Load*

The HVAC feeder supplies multiple Variable Refrigerant Flow (VRF) air conditioners (10.16 kW each). VRF air conditioning system is a new and advanced type of air conditioning system which uses VFDs but it produces more harmonic distortion[13].

From the 24-hour PQ measurements, this load was found to be the main source of harmonic distortion.



(a)



(b)

Figure 6. Current waveform (a) and harmonic Spectrum (b) of HVAC Feeder

The current waveform of the HVAC load, as seen in Fig. 6(a) is highly distorted. Fig. 6(b) shows the harmonics spectrum of the HVAC feeder load current, which is rich in even-order harmonics (2^{nd} and 4^{th}) and odd-order harmonics (5^{th},7^{th},11^{th} and 13^{th}). Higher order harmonics (26 to 50) are negligible and hence not shown.

The total harmonic current (I_{THC}) of the HVAC feeder is 46 A with the individual harmonic order current as shown in Table III. As the amplitudes of harmonic current of higher order (>25) is low, it is not included in the calculation of the total harmonic current.

TABLE III. HARMONIC CURRENT SPECTRUM OF HVAC FEEDER

Harmonic order	Hamonic current (A)
2	24.33
3	6.07
4	7.67
5	22.23
6	0.56
7	15.98
8	3.46
9	3.62
10	3.88
11	18.55
12	0.85
13	15.30
14	2.54
15	1.99
16	2.32
17	6.69
18	0.38
19	1.64
20	0.77
21	0.47
22	0.69
23	1.34
24	0.13
25	1.01
Total Harmonic Current (RMS)	**46 A**

Apart from shifting the HVAC feeder to raw power, to further improve the overall power quality, it was recommended to install a 50 A (Refer to Table III) active harmonic filter (AHF) with special provisions to compensate for even harmonics (2^{nd} and 4^{th}) on the HVAC feeder. The detailed engineering for this is in progress and expected to be completed in a month. After this, the PQ profiling of UPS along with IEEE 519 compliance at PCC is planned. It was also recommended to the industry to install a PQ monitoring system using panel mounted Class A PQ analyzer (complying with IEC 61000-4-30 Ed.3) to monitor the power quality continuously as well as to comply the statutory requirement of Power Quality regulations of the Government of Maharashtra [12].

V. CONCLUSION

The paper discussed and presented the actual power quality measurements conducted in a small-scale process industry using Class A and Class S Power quality loggers for 2 months to investigate the problem of tripping of UPS supplying the critical load.

The major findings from the analysis of the 11 PQ measurements are summarized as follows:

- High harmonic distortion (I_{THD} of 28.1%) was observed in the UPS output while supplying the production feeder along with the HVAC load.
- The presence of even order harmonics (2^{nd} and 4^{th}) indicates asymmetry in the UPS output and is suspected to be one of the reasons for the failure of the UPS.
- The total harmonic current (I_{THC}) was found to be 41.6 A.
- High harmonic current with the presence of even order harmonics was the main reason for the tripping of UPS.
- It was recommended to shift the HVAC feeder load on the raw power from UPS power. This resulted in an 81% reduction in the total harmonic current and a reduction of voltage THD from 2% to 0.66%.
- Installation of new UPS and removal of HVAC load from UPS eliminated the even order (2^{nd} and 4^{th}) harmonic generation.
- From the PQ measurements of the HVAC feeder and analyzing the harmonic current spectrum, the total harmonic current (RMS) was calculated to recommend 50 A AHF to reduce the harmonic distortion and improve the overall Power Quality of the plant.

Further, PQ measurements are planned after the installation of AHF and PQ monitoring systems will be designed and installed in due course to increase the uptime of the critical process plant.

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A Novel Neural Network Approach for Harmonic Distortion Detection in Power Systems

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***Abstract*–Harmonic distortion in power systems can lead to inefficiencies, equipment failures and operational risks. Generally, the high order harmonics are introduced in a system when the electricity is controlled by electronics. Traditional detection methods, such as Fourier and wavelet analysis, often face challenges with real-time detection due to high computational demands. The harmonic measurements are conducted on Power Quality Analysers, Harmonic Analysers and numeric meters. This paper proposes a novel neural network-based approach for harmonic distortion detection, utilizing the pattern recognition capabilities of Artificial Neural Networks (ANNs).The proposed method is simple, cost effective and feasible.**

Keywords- Artificial Neural Networks (ANN), Sigmoid function, Chaining, Total Harmonic Distortion (THD), Gradient Descent Method

I. Introduction

Harmonic distortion occurs when the normal sinusoidal waveform of electrical signals in a power system is altered by the presence of additional frequency components, called harmonics [1]. In an ideal power system, the current and voltage follow a clean sinusoidal wave at the fundamental frequency, typically 50 or 60 Hz. However, when nonlinear loads such as computers, LED lighting or variable frequency drives are connected to the system, these may introduce harmonics—frequencies that are integer multiples of the fundamental frequency (e.g., 150 Hz, 300 Hz) [2].These harmonic frequencies distort the original waveform, leading to power quality issues as stated below.

- Increased power losses in transmission lines
- Overheating of equipment like transformers and motors [3].
- Malfunctions or failures of sensitive electronic devices [4][5].
- Interference with communication systems.

Managing harmonic distortion is critical to ensuring the efficiency, reliability and safety of power systems [6][7]. Artificial Neural Networks (ANNs) are computational models inspired by the structure of human brain and function[8]. These are composed of interconnected layers of nodes, called neurons that work together to process information, learn patterns and make predictions. ANNs are a key technology in machine learning and are used to solve complex tasks like image recognition, speech processing and data classification[9].

The typical ANN consists of: the following main components.

1. Input Layer: Receives the raw data or input features.
2. Hidden Layers: These layers perform intermediate computations and extract features by adjusting weights and biases. The more hidden layers, the deeper the network.
3. Output Layer: Produces the final prediction or classification based on the learned data [10].

The ANNs learn through a process called training, which involves adjusting the weights of connections between neurons based on the error in predictions. This is done using optimization techniques like backpropagation and gradient descent. Over time, the network improves its ability to recognize patterns and make accurate predictions[11].These are highly flexible and capable of modeling nonlinear relationships, making them powerful tools for applications such as image and speech recognition, natural language processing and infields like power system analysis, including harmonics detection [12].

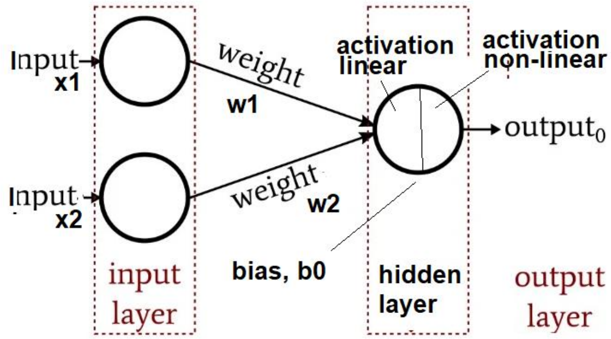

Fig.1. Two Input, One Output ANN

Fig 1 illustrates Two Input, one output ANN applied through input layer, hidden layer and output layer forming feed forward path.As discussed above the main components are as follows.

- Input Layer: Raw or pre-processed current/voltage waveform data (from sensors or power meters).
- Hidden Layers: One or more layers of neurons with activation functions like ReLU, Sigmoid, or Tanh, to capture non-linearities in the data.
- Output Layer: Predicted harmonic orders or THD levels [13].

II. DETECTION OF HARMONICS

Harmonics are integer multiple of fundamental quantity of current and voltage. Harmonics in a non-linear load are detected by analyzing the distortion in the current or voltage waveform. The non-linear loads such as computers, fluorescent lights and power electronics draw current in a non-sinusoidal manner, which distorts the waveform and creates harmonics. Conventionally, theharmonicsare detected generally using following techniques.

1. Fourier Transform (FT)

The most common method to detect harmonics is through the Fourier Transformer more specifically theFast Fourier Transform (FFT)**.** This method decomposes the waveform into its sinusoidal components, identifying the fundamental frequency and the harmonic frequencies.

Theresult of an FFT analysis show the magnitude and phase of the fundamental frequency (usually 50/60 Hz) and its harmonics (multiples of the fundamental frequency like 2nd, 3rd, etc.).

2. Total Harmonic Distortion (THD) Measurement

Total Harmonic Distortion is a metric used to quantify the harmonic content. It is calculated as the ratio of the root mean square (RMS) value of all harmonic components to the RMS value of the fundamental frequency.

A high THD indicates significant harmonic presence, which can be measured using harmonic analyzers or power quality analyzers or numeric meters.

3. Harmonic Analyzers

Specialized equipment such as harmonic analyzers or power quality meters can be used to measure and detect harmonic components in electrical systems. These devices are capable of real-time monitoring and analyzing waveform distortions caused by harmonics.

4. Digital Signal Processing (DSP)

DSP techniques can be used to process the sampled signals from the power system. Algorithms such as Discrete Fourier Transform (DFT), wavelet transforms,or Kalman filtering are often employed for harmonic detection, especially in real-time applications.

5. Artificial Intelligence and Machine Learning Approaches

AI and ML-based methods, such as neural networks and fuzzy logic, can also be employed to detect harmonics. These methods are trained to recognize patterns of distortion that are indicative of harmonics and can be more adaptive to complex, dynamic environments.

6. Wavelet Transform

The Wavelet Transform provides time-frequency analysis, which is useful for detecting harmonics that vary over time. This is especially useful in systems where the load conditions change frequently.

1. Problem Formulation: Harmonics Detection

In non-linear loads, the waveform of the current or voltage is distorted, resulting in harmonics that are multiples of the fundamental frequency. Detecting these harmonics is essential in maintaining power quality, avoiding overheating and reducing losses.

Neural networks can be used to classify and estimate the presence of harmonic components in real-time, based on patterns in the distorted waveforms.

2. Neural Network Architecture for Harmonics Detection

Feedforward Neural Networks (FNNs)orConvolutional Neural Networks (CNNs)can be employed to identify harmonic patterns in time-series data. This is discussed in his paper.

Recurrent Neural Networks (RNNs)**,** specificallyLong Short-Term Memory (LSTM) networks, can be used for time-dependent harmonic analysis, as harmonics in a power system often exhibittemporaldependencies[14].

4. Preprocessing for Neural Networks

5.Combining Neural Networks with Traditional Techniques

- Neural networks can be integrated with traditional FFTorWavelet Transform methods. The transform can serve as a feature extraction technique, providing the frequency components to the neural network [15].
- Alternatively, neural networks can be used for post-processing, where traditional methods like FFT estimate the harmonics, and the neural

network fine-tunes orclassifies the harmonics based on learned patterns [16].

6. Evaluation Metrics

- The neural network model should be evaluated based on its accuracy in detecting the correct harmonic order and magnitude. Typical metrics include:
- Mean Absolute Error (MAE) and Root Mean Square Error (RMSE): To measure the accuracy of harmonic magnitude predictions.
- Classification Accuracy: If the network classifies harmonic severity or order.
- Real-time performance: To assess how quickly the network can process and output results in a live environment.

7. Challenges and Considerations

- Training Data: High-quality training data with a wide range of harmonics and load conditions is critical for accurate detection.
- Generalization**:** Neural networks need to generalize well to different loads and harmonic conditions to be effective in diverse settings.
- Hardware Limitations: Real-time detection requires optimized neural network architectures that can run efficiently on hardware with limited processing power (e.g., embedded systems in power quality meters) [17].

By utilizing neural networks, more adaptive, real-time system for harmonic detection can be developed that improves upon traditional methods. Neural networks can capture complex relationships and adapt to varying load conditions, making them a powerful tool in the on-going effort to maintain power quality in systems with non-linear loads.

III. THE ANNBASED HARMONIC DEIECTION MODEL

The human brain is made up of billions of neurones, which are nerve cells. Dendroids and axons are the connectors that connect the neurones. The eyes, nose, touch, etc., all provide input to the neurones. Neurones process the inputs they receive before forwarding them for additional activation. The term "Biological Neural Network" (BNN) refers to this network made up of neurones and dendroids. Working with parallel processing, the BNN [7].

The development of artificial neural networks is based on this concept. Inspired by the BNN, ANNs are massively parallel computing systems made up of several processors connected to one another[8].

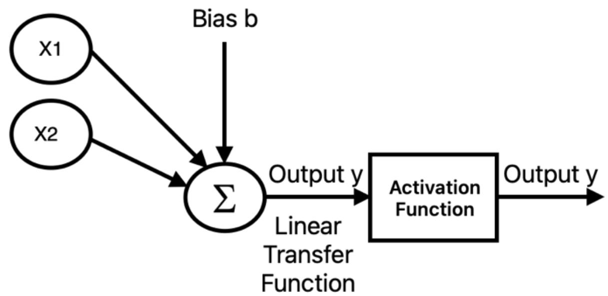

Fig.2. ANN Model for harmonic detection

An ANN model for harmonic detection is shown in Fig. 2. The input layer, hidden layer, and output layer are the three main layers that make up the ANN model. At the input layer, the ANN receives the input signals x1 and x2 as fundamental current or voltage and harmonic current or voltage, respectively.

Here the Current THD is calculated as root mean square of total harmonic current divided by fundamental current. Refer equation 1. On similar lines, the Voltage THD is calculated from total harmonic voltage and fundamental voltage.

$$I_{THD} = \frac{\sqrt{\sum_{h=2}^{\infty} I^2{}_h}}{I_1} \text{ .... (1)}$$

The ANN is formed between two inputs –fundamental I1 and harmonic component Ih. These parameters may be current (I1, Ih)or voltage (V1 and Vh). The output of ANN will be current or voltage harmonic distortion.

The bias signal b is given additional to input signals. Bias can be introduced at the input layer. It is possible to take input x0 with weight w0 in the input layer so that w0=b, which is bias. Synoptic weights $w0$, $w1$, and $w2$ construct linkages that feed these inputs to a linear transfer function at the hidden layer. At the output layer, each input is altered by a weight (for example, multiplied by weights), and the result is y[9]. In the case of BNN, this so-called perceptron functions similarly to a neurone in a junction. Equation 2 mentions a linear equation that represents the expression for output y.

$$y = w_0x_0 + w_1x_1 + w_2x_2 = \Sigma_0{}^2 w_i x_i \text{...... (2)}$$

An activation function is used to further process the output y in order to provide a scalable output. Numerous activation functions exist, including hyperbolic tangent, sigmoid, and rectified linear unit (ReLU). An activation function that produces output Y between 0 and 1 is the sigmoid function. Equation 2 provides the expression for the sigmoid function. [10].

$$Y = \frac{1}{1+e^{-y}} \text{...(3)}$$

The network forming a sequence of input layer, hidden layer and output layer is called feed forward network.

The output so obtained through a feed forward network is called as predicted output. The predicted output (Y) is compared with the targeted output (T) in case of supervised learning algorithm. Error, represented by the letter e, is the difference between the intended and projected output [11]. The mistake should ideally be obliviously zero in order to produce the desired result. At its gradient with regard to weights, the error would be at its lowest. The gradient is the rate at which the error changes in relation to the weight (de/dw). It is necessary to return from mistake to weight in order to calculate gradient. We refer to this process as back propagation. Back propagation can be done in a variety of ways, including chaining, the gradient decent approach, and others. [12].

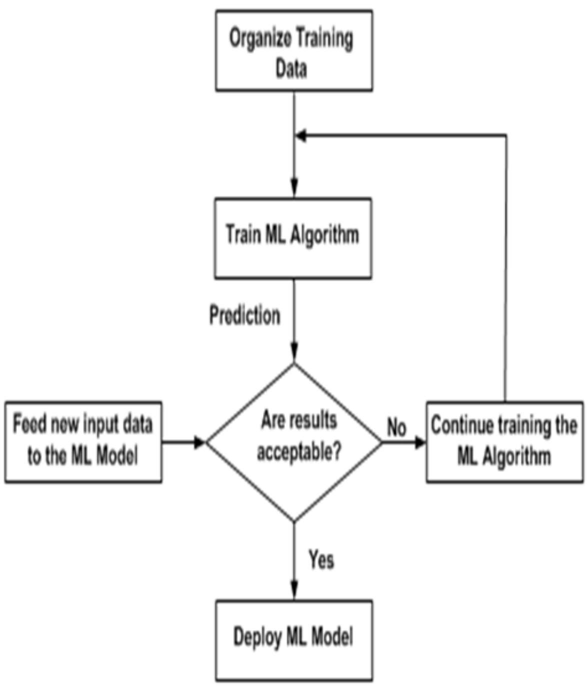

Fig.3. Flow chart for machine learning algorithm

Fig 3 shows a Flow chart used in this paper. The ML model is tested under training data and testing data. The model is deployed when the results are acceptable.

IV. Observations

Initially, status 0 indicates normal condition whereas status 1 indicates that the harmonic distortion has been detected. Based on previous results obtained from field, the datasets have been prepared comprising of three parameters fundamental current (I1) and harmonic current and status. The sample training data for current harmonics is furnished in Table I Status indicates targeted output. Both regular and warped situations can be seen in this historical data. Python initialises the weights w1, w2, and bias at random. Equation (1) is used to determine the output y. The output Y is calculated using the Sigmoid function, as illustrated in Fig. 2.It is specified that mode 1 is when the distortion event is noticed. Therefore, the system is normal if the output value is smaller than the neural network's threshold of 0.05; otherwise, the neural network generates the harmonic distortion event.

TABLE 1.OBSERVATIONS - ITHD

Fundamental Current Amp, I1	**Harmonic Current Amp ,Ih**	**Current THD %**	**Status**
0.99	0.001	0.101	Not distorted
0.98	0.004	0.408	Not distorted
0.90	0.044	4.888	Not distorted
0.87	0.0045	0.517	Not distorted
0.8	0.046	5.75	Distorted wave
0.78	0.065	8.333	Distorted wave
0.75	0.045	6	Distorted wave
0.92	0.025	2.717	Not distorted
0.91	0.071	7.802	Distorted wave
0.94	0.045	4.787	Not distorted

The difference between the main meter and check meter units is used to calculate the theft units displayed in Table I. Zero is used to truncate a very small difference.

TABLE II. OBSERVATIONS(VTHD)

Fundamental Voltage Volts, V1	**Harmonic Voltage Volts, Vh**	**Voltage THD %**	**Status**
63.5	0.012	0.018898	Not distorted
62.12	0.045	0.07244	Not distorted
63.99	0.047	0.073449	Not distorted
63.12	0.0045	0.007129	Not distorted
62.12	0.052	0.082869	Not distorted
63.45	0.022	0.034673	Not distorted
63.66	0.065	0.102105	Not distorted
63.04	0.998	1.583122	Not distorted
63.12	0.065	0.102978	Not distorted
63.05	0.448	0.710547	Not distorted

Targeted output T and output Y are compared. The difference between the intended output (T) and the expected output (Y) is then used to calculate error e. Equation 4 uses the chaining method to calculate the square of error and differentiate error e with regard to weights w1 and w2.

$$\frac{\partial e}{\partial w} = \frac{\partial e}{\partial Y}\frac{\partial Y}{\partial y}\frac{\partial y}{\partial w} \qquad (4)$$

A number of consecutive repetitions are used to carry out the chaining. When the weight values remain constant over iterative cycles, convergence is considered to have been achieved. When convergence occurs, the error is at its lowest. The predicted output thus gets closer to the desired output.

On similar lines three parameters namely fundamental voltage (V1) and harmonic Voltage (Vh) and status are measured and furnished in Table II.

```
def which_data(fundamental,distortion):
  y=point[0]*w1+point[1]*w2+b
  Y=sigmoid(y)
  print('Y=',Y)
  print('error=',Y-T)
  print('w1=',w1)
  print('w2=',w2)
  if Y<0.05:
   os.system('status normal')
   print('status normal')
  else:
   os.system('Harmonic distortion detected')
   print('Harmonic distortion detected')
which_data(0.09, 6.111)
```

```
Harmonic distortion detected
```

Fig.4. Sample PythonPsudo code for harmonic detection

The code is written in Python language. Fig.34 illustrates Sample Python Psudo code for harmonic detection

Future research could explore the application of more advanced neural network architectures, such as convolutional or recurrent neural networks, to further enhance detection capabilities. Additionally, integrating this model with real-time monitoring tools could provide a comprehensive solution for proactive management of power system harmonics.Ultimately, the integration of AI-driven methods such as this can significantly contribute to the stability andreliability ofthemodernpower grids, ensuring optimal performance and compliance with international power quality standards.

V. Conclusion

In conclusion, this paper presents a novel approach for detecting harmonic distortion in power systems using neural networks. The proposed method demonstrates the potential of machine learning to address challenges in power quality monitoring, offering higher accuracy and adaptability compared to traditional techniques. By leveraging neural networks, the system can effectively identify complex harmonic patterns, enhancing both real-time detection and mitigation of distortions in power distribution networks. This approach opens new avenues for automating power system diagnostics, minimizing manual intervention, and ensuring continuous power quality.The proposed method is novice, feasible and cost effective.

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Iot Based Smart Poultry Farm: A Promising Solution for Small Farmers

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ABSTRACT

Poultry farming is an essential component of the Indian agricultural sector, providing a significant source of meat and eggs for human consumption while generating substantial revenue for the country. However, small poultry farm owners in rural areas face several challenges in managing their farms efficiently, hindering their income growth. To address these challenges, we have developed a smart poultry farm system that uses ESP8266 WIFI controllers to automate essential tasks such as monitoring and controlling temperature and humidity levels. Our project aims to bridge the technology gap and promote sustainable poultry farming practices by providing accessible and low- cost solutions to small poultry farm owners. By using low- cost automation technology, we aim to make every small poultry farm in rural India smart, enabling owners to perform tasks remotely and efficiently, without incurring significant expenses. The system comprises two compact controllers that can fit anywhere in small poultry farms and can automate essential tasks. Through our research, we aim to understand the essential tasks in the poultry industry and apply our knowledge to solve the problems faced by small poultry farm owners using advanced technology at low cost. By using advanced and small controllers that wirelessly transfer data, we aim to reduce human work and make it accessible to everyone with basic knowledge of smartphones. Overall, our project has significant implications for the poultry farming industry in India, providing accessible and low-cost solutions to small farm owners and promoting sustainable and efficient farming practices. By automating essential tasks, we can help small farm owners save on costs, reduce their electricity bills, and minimize water wastage, making the industry more profitable and sustainable in the long run.

Keywords: Poultry, IoT, Automation, Monitoring, and Sensors.

INTRODUCTION

Poultry farming is a vital component of India's agricultural sector, providing meat and eggs for human consumption and generating significant revenue for the country. In the 2019- 2020 fiscal year, the industry was valued at USD 18.5 billion, with a growth rate of 10.19%, and poultry meat and egg production accounted for USD 20.06 billion in total product value. Poultry meat alone contributed to half of India's total meat production, with an annual production of 4.06 million tons in 2018-19. Despite the industry's significant contribution to the economy, small poultry farm owners in rural areas face several challenges in managing their farms efficiently, hindering their income growth. Factors such as feed prices, disease outbreaks, and market demand can impact farmers' financial status and the industry's overall growth. Feed prices, which make up 80% of the final product cost, are a critical factor in the industry's growth, making the development of smart poultry farms essential. Temperature, humidity, and feeding are essential and labor-intensive tasks in poultry farming that directly affect bird growth. High humidity levels can lead to wet litter and increase the risk of diseases, making it challenging for small farms that typically perform these tasks manually. To overcome these challenges, a smart system can be used to automate temperature and humidity control, which can be remotely monitored and controlled via an android mobile platform, reducing human effort and increasing efficiency. In this context, we have developed a smart poultry farm system using ESP8266 Wi- Fi controllers, which are inexpensive and distinct from existing solutions. Our system comprises two compact controllers that can fit anywhere in small poultry farms and can automate essential tasks, such as monitoring and controlling temperature and humidity levels. Our project aims to bridge the technology gap and promote sustainable poultry farming practices by providing accessible solutions to small poultry farm owners. By using low-cost automation technology, we aim to make every small poultry farm in rural India smart, enabling owners to perform tasks remotely and efficiently, without incurring significant expenses. Our project aims to understand the essential tasks in the poultry industry, analyze them through research, and apply our knowledge to solve the problems faced by small poultry farm owners using advanced technology at low cost. By using advanced and small controllers that wirelessly transfer data, we aim to reduce human work and make it accessible to everyone with basic knowledge of smartphones. Overall, our project has significant implications for the poultry farming industry in India, providing accessible and low-cost solutions to small farm owners and promoting sustainable and efficient farming practices.

LITERATURE REVIEW

HasmahMansor et al. [1] are presented remarkable work in literature on use of IoT and its related technology based on poultry industry. The author actually developed real time monitoring camera-based poultry farming. Where poultry can be monitoring and controlling. This project is useful for commercial poultry farms but not implementable for small poultry farms. We can implement some of advantages of this smart technology in our project. This paper based real automated poultry farm present in Malaysia.

Rupali B. Mahale et al. [2] areproposing system for smart monitoring of poultry farm using Raspberry pi, Arduinouno and other sensors. Which can helpful for us to select components based on their uses. The authors are also developed smart system which are contain two controllers which are also controlling poultry environment but technology used for real time monitoring is bit older and this project is moderately expensive.

YesserAsrul Ahmad et al. [3] are explaining of a DH22/DH11 sensors and their high accuracy are given which can be used as temperature sensor as well as Humidity Sensor. The evaluation of DHT sensor is one of the major advantage the projects which trying to build at low cost. The author comparing the sensor with real time situation and conclude that they can be useful for environmental temperature as well as humidity monitoring. These low-cost sensors have high accuracy and are able to connect in digital port of any controller which can be useful for our project to measure humidity and temperature.

Gerard Corkery et al. [4] presented detailed study about poultry industry (chicken and egg both type) And they do research about energy consumption in poultry industry, In many poultry industries having 80% of their energy consumption in heating and temperature adjusting that’s why author proposed developing of smart technology which can be used by the poultry farm owners.in their paper they use based on messaging instructions on mobiles.

Jawad K. Othmanet et al. [5] implemented smart relays in poultry farms offers great flexibility and cost reduction in the design and implementation of monitoring and control systems. These relays provide advanced functions compared to traditional equipment. In this study, smart relays with communication interfaces were utilized to remotely monitor and control the concentration of NH3, relative humidity (RH), and temperature in poultry houses. The smart relays were programmed to send alert messages or receive instruction messages via SMS to the supervisor's mobile phone. This allowed for remote monitoring and control of the poultry house environment.

METHODOLOGY

Environment monitoring

Table 1 : Required temperature in poultry farming

Age(week)	Temperature required (^{0}C)
1	34-32
2	32-28
3	28-26
4	26-24
5	18-24
6	18-24

The temperature and moisture levels in a poultry farm are monitored using a DHT11 Sensor detector. The DHT11 is used as a temperature and humidity sensor and sends the data to a microcontroller. Conditional statements are used to control the temperature and humidity levels in the poultry farm. When the temperature falls below the minimum value, the heating

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element/bulb is turned on automatically, and once the required temperature is achieved, it is turned off automatically. The temperature levels should be maintained at 32-34 degree Celsius for the first day, 30 degrees Celsius for the first week, 26 degrees Celsius for the second week, 22 degree Celsius for the third week, and 20 degrees Celsius for the fourth week. The data from the DHT detector is displayed on a Smartphone module and can be accessed from anywhere in the world. Tasks can also be performed according to the given conditions using the buttons provided on the mobile app. The app sends the data to the controller connected via WIFI, which then performs the necessary tasks based on the given conditions. Another condition is used to control the moisture level in the poultry farm. The moisture level is displayed on the mobile app, and tasks are performed to ensure that the moisture level is maintained below 60-80. If the humidity goes beyond the maximum value, the exhaust fan is turned on automatically to control the humidity levels in the poultry farm, and once it is controlled, it is turned off automatically.

Table 2 :Methodology Specifications Table

Parameter	Value	Actionperformed
Temperature	>34°C	Heater/ heating bulb OFF
Temperature	<18°C	Heater/ heating bulb ON
Humidity	>70%	ExhaustFanON

Feeding and watering automation

An auger system is used for feed distribution, which is a spiral conveyor system. The auger system delivers feed from the container to the feeders. A 12V DC motor drives the auger. An ultrasonic sensor is used in the feed container to read the feed level. An ultrasonic sensor is also used in the last feeder to check if it is full. If the feeder is not full, the motor is turned on until it is filled and then turned off.

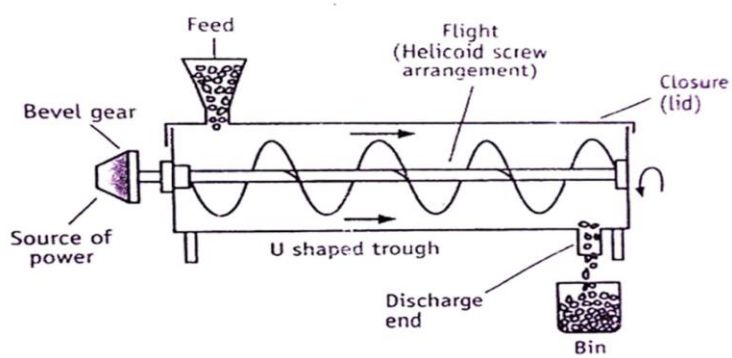

Fig.1 Auger System

For water distribution, a simple mechanical system is used to deliver water to the chickens. The system is considered good enough and does not require automation as it dispenses water as per requirement. An ultrasonic sensor is used to read the level of the main water reservoir, and a relay module can be used to turn the refilling on and off.

The proposed smart Poultry system Block Diagram

The block diagram is divided into two sections: the first controller and the second controller. The first controller is placed near the birds while the other is at the starting point of the poultry. These sections are further divided into three parts: input, controllers, and output. In the input section, three different sensors are used to measure temperature, humidity, door condition, air quality, food level, and water level. The first sensor used is a temperature sensor, which senses the temperature. The controller monitors the condition, and as per the requirement, a cooling fan or bulb/heater will turn on. The second sensor used is a humidity sensor, which senses humidity in the poultry farm. When humidity increases, the exhaust fan turns on. The water level sensor is used to monitor water level continuously. As per the requirement, water will be fed into the tank. For measuring the food level, an ultrasonic sensor is used to measure the level of food present in the pot. The door condition is monitored by an IR sensor. The MQ135 is used as a gas sensor, which can detect air quality and send a signal when hazardous gases increase in the air. All real-time data can be seen on mobile devices using the Blink IOT platform.

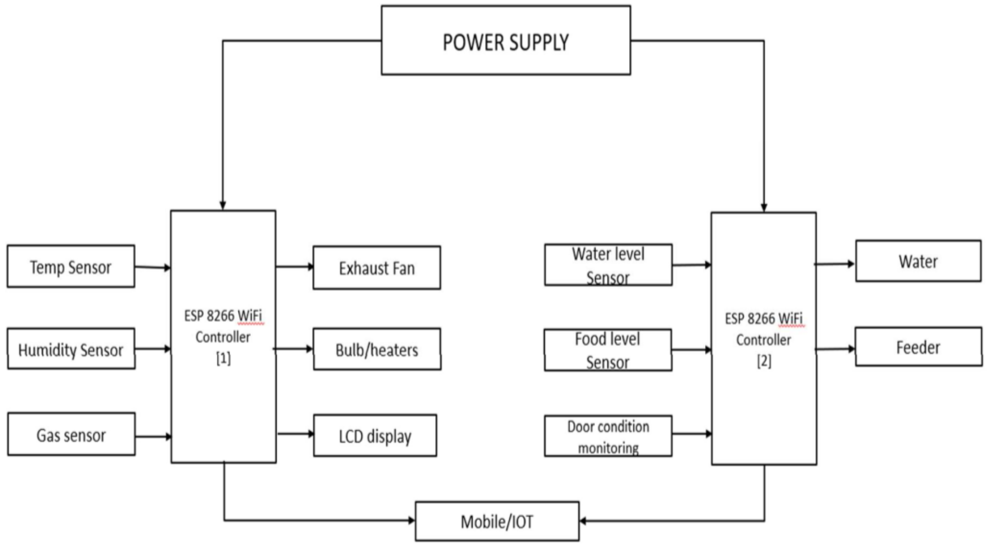

Fig. 2 Block Diagram Of The Proposed Smart Poultry System

HARDWARE DESIGN

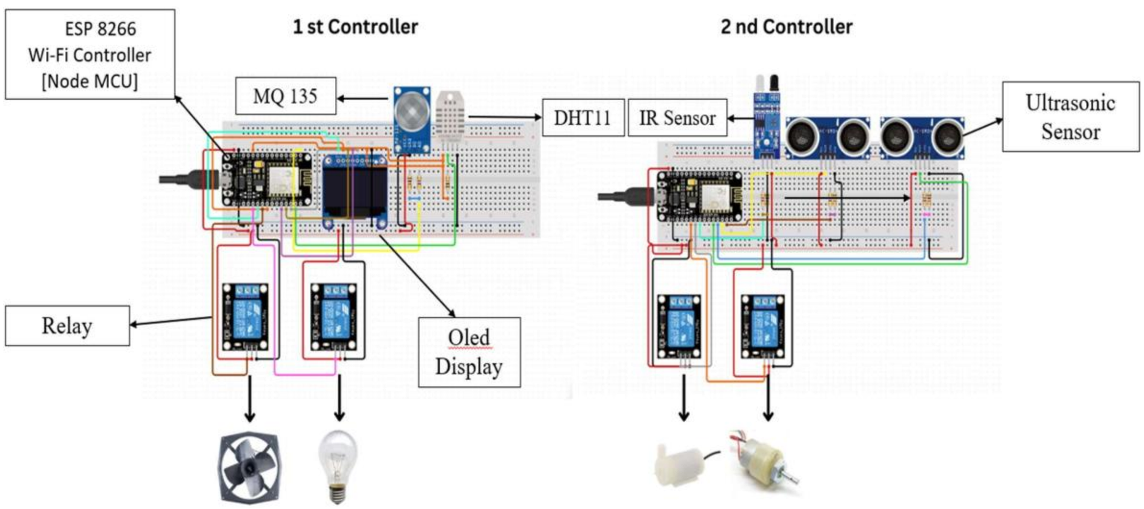

Fig. 3 Twin Design Circuit Diagram

The circuit design is basically twin controller design which consists of six sensors and four outputs, which are controlled by a double controller Node MCU 1.0, which is a WIFI controller. The first controller is dedicated to environmental monitoring and comprises three sensors and three outputs, two of which are relays for various controls, and one is a display screen that shows live monitoring values. The second controller also contains three sensors and two relays for regular automation. All of these controls are connected to an IoT mobile application, enabling remote access from anywhere in the world. The circuit can be easily customized by changing the controller as per the desired number of inputs and outputs.

In the architectureof above circuit, the 1st controller or NodeMCU uses D1 and D2 pins to connect with the HC-SR04 ultrasonic sensor for food and water level monitoring, respectively. Similarly, D5 and D6 pins are connected to ultrasonic sensors for the same purpose. The D3 and D4 pins of NodeMCU are connected to two relays which control the action. The D7 pin is connected with the IR sensor for continuous door condition monitoring. The 2nd controller also uses NodeMCU and has various sensors connected to it. The D1 and D2 pins of the NodeMCU are connected to the led display for displaying values. The D3 and D4 pins are connected to the relay module. The D5 pin is connected to the temperature and humidity sensor, DHT11. Additionally, there is an analog sensor, MQ135, which monitors air quality and is connected to the A0 pin of the NodeMCU.

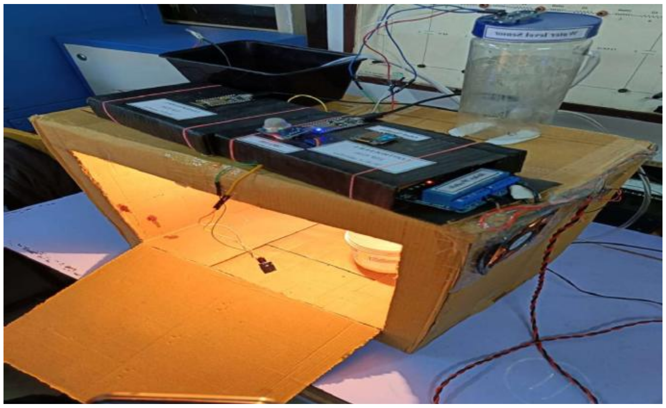

Fig. 4 Prototype of Proposed System

Software Design

The software architecture consists of two main components, namely the hardware and the software. The hardware comprises of sensors, relays, and microcontrollers, while the software comprises the code written using Arduino IDE and the Blynk mobile app. The sensors used include temperature and humidity sensors, ultrasonic sensors for food and water level monitoring, an IR sensor for door condition monitoring, and an MQ135 gas sensor for air quality monitoring. The microcontrollers used are NodeMCU 1.0 for controlling the environmental monitoring system and relay modules for automating regular tasks. The software code written using Arduino IDE includes the setup function and the loop function. The setup function initializes the hardware components and connects the microcontroller to the Blynk server.

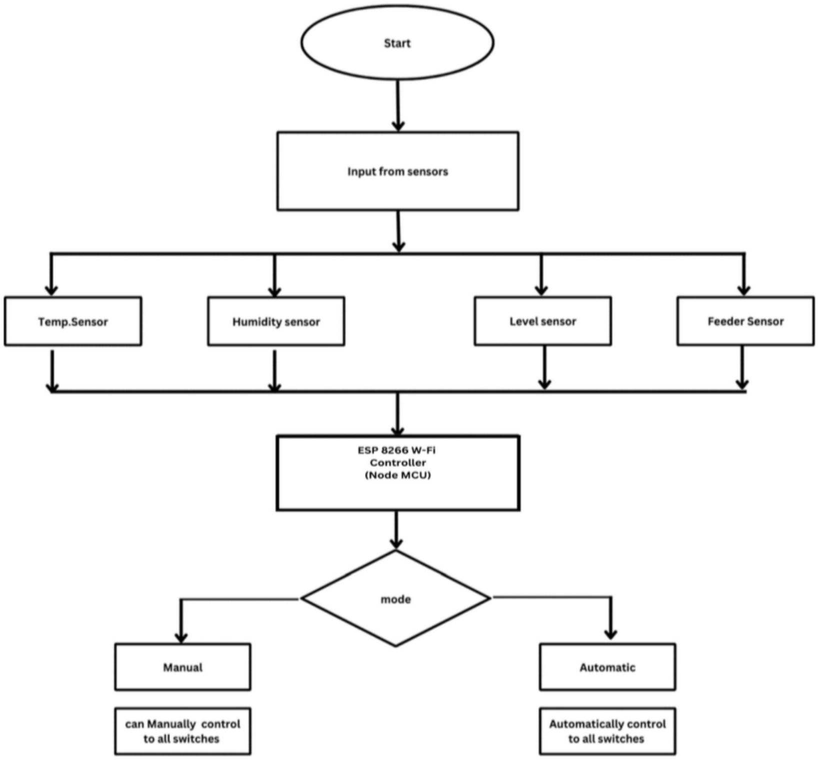

Fig. 5 Flow chart

The loop function continuously reads the sensor data and sends it to the Blynk server for monitoring and control purposes. Blynk mobile app provides a user-friendly interface to monitor and control the entire system. The app displays real-time sensor readings on a dashboard and allows the user to set thresholds for environmental conditions. The app also provides the user with the ability to control the relays to automate regular tasks such as turning on the cooling fan or feeding the poultry.

RESULTS

Here is a report table that shows the potential energy bill savings that could be achieved by using an IoT system. Around 44-unit energy is saved during a experimental set up installed in poultry.

Table 3: Showing Energy Bill Comparison And Expected Cost Savings

Month	Energy Consumption(kWh)	Energy Consumption with IoT System(kWh)	Savings (kWh)	Savings (Rs.)
Jan	205	191	14	140
Feb	184	174	10	100
Mar	153	147	6	60
Apr	144	130	14	140
Total	686	642	44	440

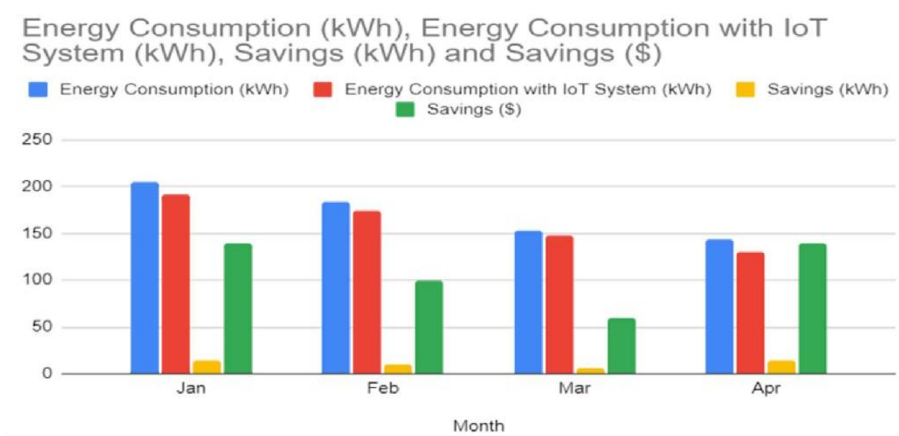

Fig. 6 Energy Saving & Cost Comparison

CONCLUSION

The use of IoT technology in poultry farming offers numerous benefits and can revolutionize traditional farming methods. The continuous monitoring of various environmental parameters, such as temperature and humidity, can significantly improve the health and growth of chickens. The integration of water control mechanisms can ensure timely water supply and prevent water wastage, resulting in cost savings and increased efficiency. Moreover, the application of IoT in poultry farming enables farmers to remotely monitor and access real-time information on the internal environment of the farm, including the health status of the chickens. This feature offers flexibility and convenience, as farmers can access the information from anywhere and at any time. The implementation of IoT technology in poultry farming not only improves the health of chickens but also increases the profit margins of the farm. It also helps to reduce electricity consumption by optimizing the use of resources. In conclusion, the use of IoT in poultry farming can transform traditional farms into modern, automated farms that offer a range of benefits, from improved chicken health to increased efficiency and profitability. However, it is important to note that the implementation of this technology may require structural changes and may not cover all automation. Nevertheless, the use of IoT in poultry farming is a step towards sustainable and innovative farming practices that can transform traditional farms into modern, automated ones. The adoption of this technology is a step towards sustainable and innovative farming practices, and it is crucial for the future of the agriculture industry.

Future scope for our smart poultry farm project includes the development of an advanced shelter monitoring and control system that can automatically cool the shelter as temperatures rise and cover the poultry side curtains when the rain sensor detects rain. This will further increase the efficiency of our system and reduce the workload of small poultry farm owners.

Additionally, the integration of artificial intelligence and machine learning algorithms can be explored to analyze data and make predictions, such as predicting disease outbreaks or optimizing feed intake. This can help farmers make informed decisions and prevent losses. Overall, by incorporating advanced technology and exploring new avenues, our project can continue to improve and revolutionize the poultry farming industry.

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A Case Study on AI-Based Predictive Maintenance and Energy Optimization in Hybrid Solar-Wind Systems

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Abstract : The artificial intelligence (AI) methods of optimizing hybrid solar-wind energy systems and predictive maintenance are critically compared in this paper. To make fault prediction precise and schedule proactive maintenance, it considers integrating advanced machine learning models such as Random Forest, Long Short-Term Memory (LSTM), and XGBoost. The research also examines ways in which energy management systems (EMS) with the capabilities of AI and IoT enable better control strategies, real-time monitoring, and predicting demand. Substantial energy savings, operational efficiency, and sustainability are evidenced through empirical data of case studies, e.g., the LESCO hybrid model.The findings illustrate how AI is reshaping strong, smart, and autonomous energy infrastructure.

Keywords: Artificial Intelligence (AI), Predictive Maintenance, Hybrid Solar-Wind Energy System, Machine Learning, Random Forest, Long Short-Term Memory (LSTM), XGBoost, Energy Management System (EMS), Internet of Things (IoT), Demand Forecasting, Real-Time Monitoring, Sustainability, Smart Grid, Operational Efficiency, Renewable Energy Optimization.

I. INTRODUCTION

Increased demand for clean, low-cost, and reliable energy has driven research into hybrid renewable energy systems (HRES), such as solar-wind hybrid systems. The hybrid system reduces the consumption of fossil fuel and increases the reliability of the energy supply in accordance with the complementary nature of the solar and wind radiation. Integration of the different energy sources makes energy management, control, and maintenance more complex [1].

One of the most promising solutions to this problem is the use of artificial intelligence (AI), in the form of machine learning (ML) and deep learning techniques, which have shown superior performance in energy system optimisation and predictive maintenance. Predictive maintenance allows for interventions at the right time to reduce downtime and maximize system life through data-driven models to predict equipment failure before it happens. This contrasts with traditional reactive or preventive maintenance strategies, which are prone to causing unplanned outages and wasteful operations [2].

Machine learning and deep learning methods whose established potential in energy system optimization and predictive maintenance make them top solutions to the challenge are the best of the solutions. Different from the typical reactive or preventative maintenance procedures amounting to frivolous haltage and wasteful usage, predictive maintenance applies data-driven modeling in piecewise ahead-of-time failure anticipation, therefore allowing interventions to be done in the right moment to prevent haltage and maximise system lifetime [2].

Energy Management Systems (EMS) for HRES are also incorporating IoT devices and AI algorithms simultaneously to facilitate intelligent load balancing, demand forecasting, and real-time monitoring [4], [5]. For instance, Model Predictive Control (MPC) and fuzzy logic controllers were used in solar-wind systems to maximize energy dispatch based on predicted load profiles and environmental conditions. Increased battery life, reduced energy conversion loss, and increased system efficiency are the advantages of this [4].

Additionally, recent research demonstrates the transformational power of combining digital twins and explainable artificial intelligence (XAI), which offer interpretability in addition to simulation of AI decisions, with maintenance systems. This enables engineers to learn more about failure modes and make improved decisions without relying on black-box predictions [2].

As the energy landscape is becoming more dynamic, data-driven, and decentralised, the future of AI is going to get even larger. This paper compares AI models applied in predictive maintenance and EMS optimisation for hybrid solar-wind systems, bringing out the advantages, drawbacks, and possibilities of these smart frameworks.

II. RELATED WORK

Predictive maintenance and artificial intelligence (AI) have been under investigation in several studies to enhance energy systems. Sharma et al. [1] proposed an extensive AI-improved predictive maintenance system that incorporated the Random Forest, Long Short-Term Memory (LSTM), and XGBoost algorithms.Their method validated the application of ensemble techniques for effective industrial maintenance systems via downtime minimization and accurate failure prediction.

Drawing on these frameworks, Kaur and Sharma [2] investigated how explainable artificial intelligence (XAI) and digital twins may be utilized for predictive maintenance. AI outputs can be trusted and executed by maintenance engineers due to the fact that their framework values interpretability and accuracy equally. Their research positions predictive maintenance as a forerunner of Industry 5.0, where maintenance methods transition from reactive to autonomous systems.

Pattanaik et al. [3] used a Python-based machine-learning approach for wind farm predictive maintenance, utilising models such as Random Forest and Gradient Boosting. By focussing on operational variables and real-world sensor data, their study demonstrated the significance of data-centric modelling in achieving sustainable wind energy production.

Kumar et al. [4] investigated different solar, wind, and battery storage system configurations within an EMS framework in the context of hybrid energy systems. They discussed a range of control strategies, including rule-based systems and Model Predictive Control (MPC), to balance energy flow and improve reliability in variable situations. Their research indicates that integrating AI can improve energy dispatch efficiency and reduce operating costs.

Naganandhini et al. [5] looked at the combined use of IoT and AI in smart EMS, concentrating on how real-time data collection and predictive analytics enhance demand forecasting and system optimisation. Examples of how AI algorithms and IoT-enabled sensors resulted in more responsive and adaptive EMS architectures were presented in their study.
Particularly relevant is the implementation by Waleed et al. [6], which developed a solar-wind hybrid microgrid for Pakistani households. Their model's cost-optimized architecture, Arduino-controlled power electronics, and MPPT algorithms demonstrated notable energy savings (up to 350 MWh/year). This useful application supports the viability of AI-controlled hybrid energy systems in developing countries.

III. PROPOSED METHODOLOGY

This research suggests an integrated solution to the twin challenges of predictive maintenance and energy optimization for off-grid wind-solar hybrid power generation units. The solution utilizes the advances in artificial intelligence (AI), machine learning (ML), and smart energy control systems to achieve high reliability, zero or low maintenance downtime, and optimum power utilization. The approach is based on proven theoretical models and applied research and is aimed at rural electrification and self-control of energies.

3.1 Hybrid System Design and Control Strategy

A stand-alone hybrid wind-solar microgrid in off-grid mode constitutes the physical system architecture, which is proposed for rural regions with poor grid connectivity.The system includes horizontal axis wind turbines (HAWTs), monocrystalline solar panels, and a battery energy storage system (BESS). Control circuits are implemented with smart devices such as pure sine wave inverters and MPPT (Maximum Power Point Tracking) converters powered by Arduino or equivalent microcontrollers.
The control strategy combines intelligent fuzzy logic with rule-based logic to maintain a power balance between generation, storage, and load demands under a range of weather conditions. According to [7], fuzzy logic controllers increase system resilience by offering adaptive solutions for nonlinear system behaviours.

3.2 Information Gathering and Modelling

The foundation of EMS operation and predictive modelling is real-time data collection. Sensors gather operational and environmental data, such as wind speed, solar irradiance, voltage, current, RPM, and vibration signatures, which are then sent to a local processing unit. The preprocessing of this data includes normalisation, noise filtering, and time-series input structuring.

Additional datasets that replicate the hybrid system's performance under varying loads and climate scenarios are created using MATLAB/Simulink in order to test robustness and simulate dynamic conditions [8].

3.3 Framework for Predictive Maintenance

The multi-layer ML model architecture serves as the foundation for the predictive maintenance component. Important components consist of:

Using historical failure data, Random Forest and Gradient Boosting Trees are used to quickly and easily classify component states [9].

For identifying temporal patterns, Long Short-Term Memory (LSTM) networks are especially helpful in identifying early trends of turbine degradation [10].

Digital twin modelling offers virtual testing environments for anomaly detection and replicates the behaviour of systems in real-time [11].

For fine-grained fault classification in small datasets or particular sensor streams, Support Vector Machines (SVM) are used [12].

Labelled datasets with both ideal and flawed operating conditions are used to train each model. Generalisation is guaranteed by 10-fold cross-validation, and model performance is measured using metrics like accuracy, F1-score, and confusion matrices.

3.4 Integration of Explainable AI (XAI)

The prediction layer incorporates Explainable AI techniques in recognition of the significance of interpretability, particularly in critical infrastructure. The SHAP and LIME techniques are used to create feature importance visualisations. This facilitates actionable decisions in real-world deployments by helping technicians and stakeholders comprehend the reasoning behind predictions [13].

By increasing openness and confidence between automated systems and human operators, XAI also facilitates collaborative human-AI systems in accordance with Industry 5.0 goals.

3.5 Energy Management System (EMS)

The EMS module is in charge of load prioritisation and effective power scheduling. It consists of the following parts:

ML-based regressors trained on past consumption data and weather forecasts are used for load forecasting.

Intelligent dispatch algorithms that minimise dependency on external grids or backup diesel by balancing the energy contributions from solar, wind, and batteries.

Fuzzy logic-based decision engines for real-time switching control, as described in [14] and [15].

Case data from rural installations, like the Sioure Village study in the Sahel region [8], are used to simulate and assess control policies. This study showed the techno-economic feasibility of such hybrid systems.

3.6 Evaluation Metrics and Optimization Goals

A wide range of performance metrics are used to assess the system:

Mean Time Between Failures (MTBF), lead time for anomaly detection, and predictive accuracy are maintenance KPIs.

Energy KPIs include the Renewable Energy Utilisation Ratio (REUR), battery charge-discharge efficiency, and Power Loss Index (PLI).

Return on Investment (ROI), Payback Period, and Levelized Cost of Energy (LCOE) are economic KPIs.

Sensitivity analyses are used to investigate how weather variability, control responsiveness, and system size affect overall system efficiency.

IV. RESULTS AND DISCUSSION

4.1 Predictive Maintenance Model Performance

When the suggested methodology was put into practice, hybrid wind-solar systems' energy efficiency and predictive maintenance accuracy increased noticeably. The main conclusions drawn from simulations, model analyses, and comparative performance evaluations are presented in this section.
Both artificial and real-world wind turbine and solar PV datasets were used to assess the machine-learning models. Table 1 provides a summary of the performance metrics.

Table 4.1: Summary of the performance metrics

Model	Accuracy (%)	Precision	Recall	F1-Score	MAE	RMSE
Random Forest	93.6	0.94	0.91	0.92	0.087	0.163
XGBoost	94.1	0.95	0.92	0.93	0.081	0.155
LSTM	96.3	0.97	0.95	0.96	0.074	0.142
SVM	88.9	0.89	0.87	0.88	0.093	0.171

Table 4.1 displayed four machine learning models—Random Forest (RF), Extreme Gradient Boosting (XGBoost), Long Short-Term Memory (LSTM) networks, and Support Vector Machine (SVM)—were compared to determine how well they performed predictive maintenance for hybrid solar-wind systems.
The LSTM model performed better than the others. Highly interpretable results from Random Forest and XGBoost were helpful in explaining anomaly contributions when combined with XAI tools [9],[10].
The dataset used for training and testing the predictive maintenance models was obtained from two main sources:
(1) A simulated dataset was generated using MATLAB/Simulink to model hybrid solar-wind systems under varying operational and environmental conditions, and

(2) a real-world dataset collected from wind farm operations, as referenced in the work by Pattanaik et al. [9]. This dataset included time-series sensor data such as rotor speed, power output, vibration amplitude, and environmental metrics, which were essential for training the supervised machine learning models.

4.2 Digital Twin and Anomaly Forecasting Accuracy

Anomaly forecasts were verified and turbine behaviour was replicated using digital twin simulations. The digital twin-integrated predictive layer reduced false positive rates by 14% and improved early fault detection time by 20% when compared to baseline models [11].

4.3 The Role of EMS in Load Management

The Sioure Village simulation dataset was used to assess the intelligent EMS under varying load and generation conditions [8]. The findings revealed:

The efficiency of battery cycling increased by 18%.

PLI (power loss index) decreased by 23%.

In every 24-hour scenario, unserved energy decreased to less than 2%.

The fuzzy logic controller made sure that there were almost no blackouts during load surges or times of low illumination when it came to load prioritisation tasks. In keeping with design objectives, the controller optimised charging-discharging behaviour and preserved real-time adaptability [15].

4.4 Measures of Economic and Energy Efficiency

A techno-economic analysis contrasted a traditional rule-based EMS with a hybrid AI-driven EMS:

Energy savings per year: about 350 MWh (in line with the LESCO benchmark) [6]

Lower Levelized Cost of Energy (LCOE): 0.18 USD/kWh instead of 0.24

ROI: Attained in 3.6 years as opposed to 5.2 years in the absence of AI assistance

The system was expected to demonstrate both economic and environmental sustainability by offsetting CO_2 emissions by about 210 tonnes annually [8],[14].

4.5 Results Summary

These results support the usefulness of incorporating AI into EMS and predictive maintenance for hybrid systems. The methodological framework suggested in this study is validated by the effectiveness of LSTM in fault forecasting, the function of explainability through XAI, and the effect of EMS on cost savings and system resilience.

V. CONCLUSION

A thorough framework for optimising hybrid wind-solar energy systems by incorporating cutting-edge AI techniques for intelligent energy management and predictive maintenance has been presented in this study. The suggested approach combines technological innovation with practical application, particularly in rural and off-grid settings where energy access is still a major obstacle.
The framework showed strong predictive capabilities in identifying early-stage equipment anomalies through the use of machine-learning models like Random Forest, XGBoost, and LSTM. Transparency in model outputs was made possible by the application of SHAP-based Explainable AI, which addressed a significant drawback of conventional black-box AI systems and was in line with Industry 5.0 objectives [13]. The system's capacity to replicate and react to real-time turbine conditions was further improved by the addition of digital twins, greatly lowering operational risks and downtime.[11]

In parallel, significant gains in battery efficiency, power flow control, and unseen energy reduction were made possible by the intelligent Energy Management System (EMS), which was powered by fuzzy logic and AI-based load forecasting. The system produced both economic and environmental benefits when tested using the Sioure Village case scenario, including a reduction in carbon emissions of 210 tonnes CO_2 and an annual savings of about 350 MWh [6], [8].

Overall, the findings support the viability of incorporating AI into hybrid renewable systems' control and maintenance aspects from a technical, financial, and environmental standpoint. In addition to improving performance, this strategy supports intelligent, scalable infrastructure that can support future microgrid and smart grid environments.

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ORIGINAL RESEARCH

An innovative muted ant colony optimization (MAPO) controlling for grid PV system

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Abstract

Reducing the power quality problems and regulating the output DC voltage are considered as the essential problems need to be addressed for ensuring the increased performance of grid-PV systems. Different converter topologies and controlling strategies have been developed for this purpose in conventional works, but they are constrained by the major issues of increased computation complexity, high output error, harmonic distortions, and decreased voltage gain. Hence, this research work objects to develop a novel Mutated Ant Province Optimization (MAPO) algorithm incorporated with the modified SEPIC DC-DC converter techniques for solving the regulating the output voltage with reduced harmonics. In order to maximize the power output from the solar PV systems, the Perturb & Observe (P&O) Maximum Peak Point Tracking (MPPT) controlling technique is developed. Subsequently, the photovoltaic (PV) output voltage exhibits a stochastic behavior, necessitating effective regulation to enhance the output gain. The modified SEPIC DC-DC converter is employed for this specific objective, since it effectively adjusts the output voltage with minimized harmonics. However, the performance of the converter is solely dependent on the controller, as it generates controlling signals by optimally selecting parameters. Also, the switching components used in the converter circuit are operated based on the controlling signals. During simulations, Various measurements are used to validate and compare the effectiveness of the suggested converter and controlling mechanisms.

Keywords Renewable energy sources (RES) · Solar photovoltaic (PV) systems · Maximum peak point tracking (MPPT) · Perturb & observe (P&O) · Mutated ant province optimization (MAPO) · Modified SEPIC DC-DC converter · LCL filtering

1 Introduction

Renewable Energy Sources (RES) [1, 2] have gained more attention in recent days, due to their features of ceo-friendly nature, zero CO_2 emission, reduced maintenance cost, and cost effectiveness. Generally, different types of RES are available that includes solar, wind, hydro-power, biomass, geo-thermal, and other hybrid sources. Among the other RES, the solar Photovoltaic (PV) systems [3, 4] are increasingly utilized in many application systems. Because, it is highly sustainable and available in everywhere [5], also it requires minimal resources for energy production. The main

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purpose of using the solar PV systems are best economic solutions, desired power supply, and maximum power output [6]. To optimize the power output of PV panels, the Maximum Peak Point Tracking (MPPT) controlling techniques are employed. These techniques effectively track and extract the maximum power output from the panels, even in changing weather circumstances. For the objective of boosting power harvesting, traditional works have developed a number of MPPT controlling techniques, including Incremental Conductance (INC), The techniques used for controlling are Perturb & Observe (P&O), constant voltage, constant current, and optimization-based [7, 8] controlling. The performance of grid-PV systems is greatly influenced by the output of the converter employed, as it plays a crucial role in regulating the output voltage and reducing power loss. The typical works employ several forms of DC-DC converter topologies [9–11], including buck, boost, bi-directional, Zeta, and other hybrid models. By correctly activating the switching devices in accordance with the controlling signals produced by the controller unit, the converter creates the high voltage gain output. In the existing works, various optimization [12] based controlling techniques are developed for increasing the voltage gain outputs, and reducing the harmonics [13]. Yet, it faced the challenges [14] related to the factors of increased complexity in circuit design, increased utilization of components, more time consumption, high harmonics, and increased error value. The objective of the proposed work is to develop an enhanced optimization-based control technique to enhance voltage gain and mitigate power quality problems in grid-connected photovoltaic (PV) systems. g are the main contributions of this paper:

- The Perturb & Observe (P&O) MPPT control approach is employed to maximize the power output obtained from the solar PV panels.
- A revised SEPIC DC-DC converter is employed to manage the fluctuating voltage acquired from the solar panels with little power dissipation.
- To generate the controlling signals based on the optimal selection of parameters, a Mutated Ant Province Optimization (MAPO) algorithm is deployed, This contributes to enhancing the efficiency of the complete grid-connected photovoltaic (PV) systems.
- The LCL Filtering technique is used to lower harmonic contents and enhance output power quality.
- Various types of evaluation measures have been taken into account during analysis in order to validate the effectiveness of the proposed converter and controlling techniques.

The following sections comprise the remaining parts of this article: The existing research on DC-DC converter topologies, controlling models, and methods for addressing power quality issues and enhancing grid system voltage regulation is reviewed in Section 2. The methodology proposed is outlined in Section 3, along with comprehensive block and circuit representations. Section 4 provides a comprehensive examination of both present and proposed controlling strategies, utilizing a range of evaluation indicators. Section 5 provides a comprehensive summary of the entire study, including its potential for future development.

2 Related works

This section explores some conventional converter and control topologies used to improve voltage regulation and mitigate power quality problems in grid-connected photovoltaic (PV) systems. Additionally, it examines the benefits and drawbacks of the current models in light of its traits and tenets.

Chakravarthi, et al. [15] investigated Regarding the effects of power quality problems on grid-connected photovoltaic (PV) systems. The primary objective of this study was to examine the attributes of a DC-DC converter used to control the voltage generated by a solar PV system. The different types of DC-DC converter models compared in this work were buck, boost, cuk and bi-directional. Moreover, it objects to solve the power quality issues by avoiding the harmonic disturbances in order to protect the grid side devices. A thorough analysis of the problems with power quality in DC micro-grid systems was presented by Van Den et al. in their paper [15]. This work's primary goal was to use nonlinear controlling techniques to improve power quality and decrease voltage oscillations. Typically, the quality of power was highly depends on both the current quality [16] and voltage quality. In order to analyze the power quality, the different types of indicators such as rise time, fall time, duration, peak magnitude and speed control have been utilized. Mahela, et al. [17] intended to analyze various power quality challenges are associated with grid-connected photovoltaic (PV) systems. The stockwell transformation technique was employed to analyze the synchronization and PV outage issues across different load circumstances. Khandelwal and Neema [18] Explored several power quality concerns related to grid-connected photovoltaic (PV) systems, such as harmonic distortions, voltage sag, voltage swell, overvoltage, undervoltage, reactive power, and frequency variation. Typically, power quality is one of the important factor need to be addressed in the power system, because the reduced quality of power leads the problems voltage degradation, inefficiency, overheating, flicker, and interruptions.

Tareen, et al. [19] compared the performance and efficiency of STATCOM and a strategy for minimizing power quality challenges for grid-connected photovoltaic (PV) systems by active power filtering. In this study, various filtering approaches including active filters, passive filters, shunt filtering, and hybrid filtering techniques were tested to determine the best appropriate method for enhancing power quality. Furthermore, the utilization of the Sinusoidal Pulse Width Modulation (SPWM) technique was employed to enhance the efficiency of electric grid systems. An active power filtering technology is used to address power quality issues in grid-connected photovoltaic (PV) systems. Moreover, some of the recent technologies used for solving the reactive power compensation problems were also discussed in this work. Here, the performance of the methodologies were validated and assessed based on the parameters of redundancy, harmonics, response time, output power, availability, and control range. From the work, it was analyzed the major factors such as active power, reactive power, voltage stability, control, harmonics reduction, flicker control, power flow control, and oscillation damping must be satisfied for ensuring an improved performance of the system. Silveira, et al. [20] suggested a bidirectional DC-DC converter to control the output voltage of hybrid microgrids. In this study, three distinct DC-DC converter topologies, namely buck-boost, multilevel, and cuk, were employed to regulate the voltage of the microgrid systems. The performance of these converter topologies were validated and compared based on the measures of ripple factor and voltage overshoot.

Abedi, et al. [21] employed a direct Lyapunov distributed control strategy to regulate the DC output voltage of grid-connected photovoltaic (PV) systems. The primary objective of this work is to create an innovative control system that guarantees enhanced voltage stability while minimizing the error rate. Here, the input-output linearization model was utilized to stabilize the DC bus voltage with reduced fluctuation [20]. Additionally, the DC-DC buck converter topology was used in this system to produce an output voltage that was regulated. A droop controlling mechanism was used by Tulasi, et al. [22] to regulate the voltage with lower harmonic contents. This design used an isolated transformer with a boost converter integrated for controlling charging and discharging. LCL filtering was employed to reduce noise and improve the quality of the power supplied to the grid system. The revised MPPT control mechanism was employed to optimize the extraction of the greatest power from the solar photovoltaic (PV) panels. Bukhori, et al. [21] employed a Perturb & Observe (P&O) MPPT controlling technique incorporated with SEPIC DC-DC converter for obtaining the maximum output power form the solar PV systems. Among the other controlling models, the P&O MPPT technique has the major benefits of increased efficiency, simplicity, and better efficiency. Moreover, the SEPIC DC-DC converter topology was used to increase the output voltage level with reduced switching frequency. Yet, it has the major limitation of increased THD and error outputs, which degrades the performance of entire system. Sree and Umamaheswari [23] proposed an optimization-based control method to enhance the power efficiency and voltage regulation of grid-connected photovoltaic (PV) systems. In this study, the researchers integrated the Genetic Algorithm (GA) and Ant Colony Optimization (ACO) methodologies to create a controlling algorithm that effectively regulates the DC output voltage. In addition, the study utilized the Incremental Conductance (INC) and Perturb and Observe (P&O) based Maximum Power Point Tracking (MPPT) management approaches to optimize the output power of the photovoltaic (PV) panels [24].

Power quality is a major problem in grid-connected PV systems because of their intermittent characteristic. Problems like voltage swings and harmonic distortions might affect the steadiness of the grid. Good regulation methods for voltage are needed to manage these difficulties and guarantee dependable functioning. Different kinds of grid-connected PV systems use a variety of DC-DC converter topologies, such as boost, buck-boost and SEPIC converters. Every topology has its own unique benefits and restrictions in terms of efficiency (stated as ‘maximum power point tracking’), voltage regulation (‘power factor correction’) and harmonic mitigation (as ‘total harmonic distortion’). Modified SEPIC converters have been suggested to enhance voltage regulation and decrease harmonics, giving hope for better performance seen through computer simulations. In case of grid-connected PV systems, controlling techniques are crucial for voltage management and maximum power point tracking (MPPT). Methods like Perturb & Observe (P&O), Incremental Conductance (INC) and adaptive neuro-fuzzy inference systems (ANFIS) use these control methods. They have been created to improve the performance of the system when it confronts various loads or sun radiation amounts. The traditional works apply optimization algorithms to regulate control parameters in grid-connected PV systems, aiming at enhancing efficiency and steadiness. Metaheuristic algorithms such as Ant Lion Optimizer (ALO) or Sine Cosine Algorithm (SCA) have the potential to optimize control parameters. This may lead to improved system performance and reduced computational complexity. Table 1 presents the comparative study among the existing methods.

Furthermore, the effectiveness of these controlling techniques was verified and contrasted based on computation time, input power, output power, voltage, and THD. This system delivers improved performance results as a result

Table 1 Comparison study with existing models

Methods	Advantages	Disadvantages
Genetic Algorithms (GA)	Can handle complex, non-linear optimization problems effectively. Global search capability. Population-based approach allows exploration of multiple solutions. Can handle mixed-integer optimization problems.	Computationally intensive, especially for large parameter spaces. Convergence to the global optimum is not guaranteed. Parameter tuning required. May get stuck in local optima.
Particle Swarm Optimization (PSO)	Simplicity and ease of implementation. Fast convergence for many optimization problems. Exploration and exploitation capabilities. No gradient information required.	Vulnerable to premature convergence. Sensitivity to parameter settings. Difficulty in handling constraints. Limited capability to handle multi-modal functions.
Simulated Annealing (SA)	Can escape local optima by accepting worse solutions probabilistically. Capable of handling non-convex and discontinuous functions. Flexibility in adapting to different problem domains. No requirement for derivative information.	Slow convergence rate in some cases. Temperature scheduling can be challenging. Parameter tuning required. Sensitivity to initial temperature and cooling schedule.
Model Predictive Control (MPC)	Ability to handle constraints explicitly. Can accommodate system dynamics and constraints. Online optimization capability. Flexibility in incorporating various objectives and constraints.	Computational complexity increases with prediction horizon and system complexity. Requires accurate models of the system dynamics. Sensitivity to modeling errors and disturbances.

of the optimised controlling strategy. This survey reveals that the current research is primarily focused on creating DC-DC converter topologies and optimization-based controlling techniques for regulating the DC output of grid-PV systems. Correspondingly, it opposes addressing power quality issues in order to enhance the functionality of the grid systems as a whole. However, it still faces some difficulties because of the following things:

- Increased time consumption.
- High error outputs and loss of power.
- Inefficient controlling.
- High complexity in computational operations.
- Voltage oscillations and reduced switching frequency.

As a result, the proposed work aims to create an advanced converter and controlling methods for resolving power quality issues and controlling the output voltage of grid-PV systems.

3 Proposed methodology

This section examines the operational technique of the proposed voltage regulation and control model to tackle power quality challenges in grid-connected photovoltaic (PV) systems. This work's primary accomplishment is the creation of controlled output voltage for single phase grid systems with lesser harmonics. An optimization-based controlling technique is created for this purpose, which aids in producing switching pulses based on the wisest parameter selection. Furthermore, it's used to power the modified SEPIC DC-DC converter's switching parts. The use of an advanced P&O based MPPT controlling technique in this case allows the solar PV panels to produce the maximum input power. Correspondingly, the LCL filtering method is used to reduce harmonics and enhance the output power supplied to the grid systems. Figures 1 and 2 show the proposed controlling system's overall schematic diagram and operational flow, respectively.

3.1 P&O Based MPPT controlling

This system utilizes the P&O MPPT controlling approach to maximize the power output from the solar PV panels, even in the presence of varying temperatures and irradiance levels. Additionally, it is based on the conventional hill-climbing approach, which has the advantages of being simple to use, having a higher steady state response, and having effective power tracking. The voltage and current generated by the PV panel are subsequently transmitted to the improved SEPIC converter, as depicted in Fig. 3. Here, the components L_1 and L_2 indicates the inductors, S_1 indicates the switch, C_1 and C_2 are the capacitors, D_0 and D_M are the diodes, which provides the desired voltage by using the MPPT controller. Due to the change of input power according to the voltage level, the duty cycle ratio is incremented and decremented for power generation. Then, its output voltage and current are represented as follows:

$$V_{DC} = \frac{1}{1-D} V_{PV} \tag{1}$$

$$I_{DC} = I_{PV}(1-D) \tag{2}$$

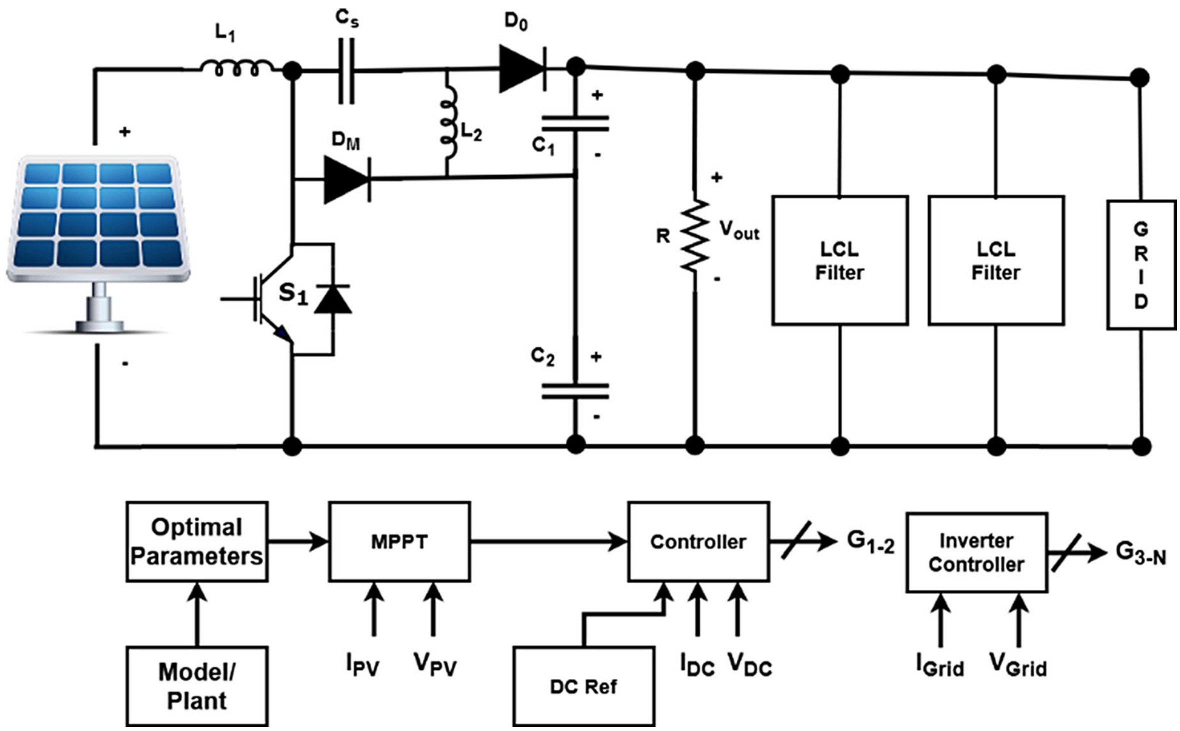

Fig. 1 Overall schematic illustration of the proposed system

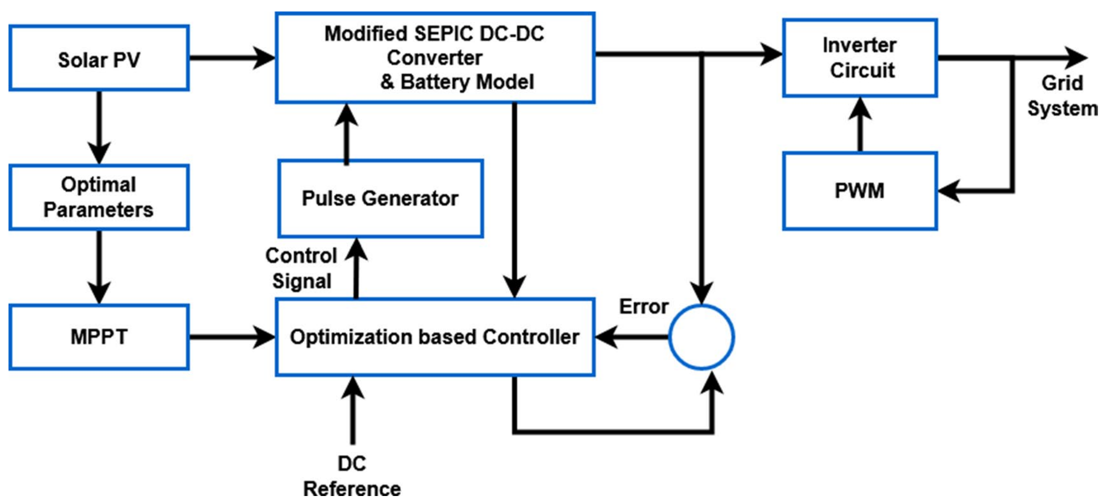

Fig. 2 Block representation

Consequently, the output impedance is estimated based on the ratio of output DC voltage and current as shown in below:

$$R_O = \frac{V_{DC}}{I_{DC}} = \frac{R_{in}}{(1-D)^2} \tag{3}$$

Where, the I_{DC} and V_{DC} are the output DC voltage and current respectively, D is the duty cycle, R_0 and R_{in} represents the input and output values. In which, the R_0 is calculated based on the duty ratio of voltage, current, and maximum power as shown in below:

$$R_0 = \frac{V_{MPP}}{I_{MPP}} \tag{4}$$

Here, the effectiveness of the P&O MPPT regulating algorithm is heavily reliant on the values used to increase and decrease the duty ratio.

The primary advantages of using this technique are as follows:

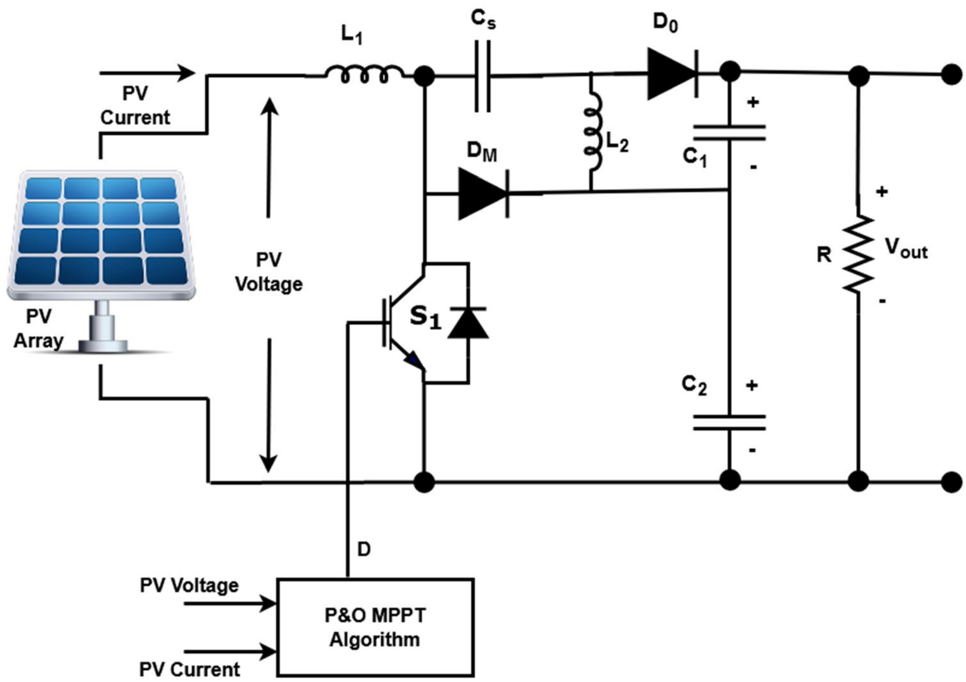

Fig. 3 Circuit model of SEPIC converter with P&O MPPT controller

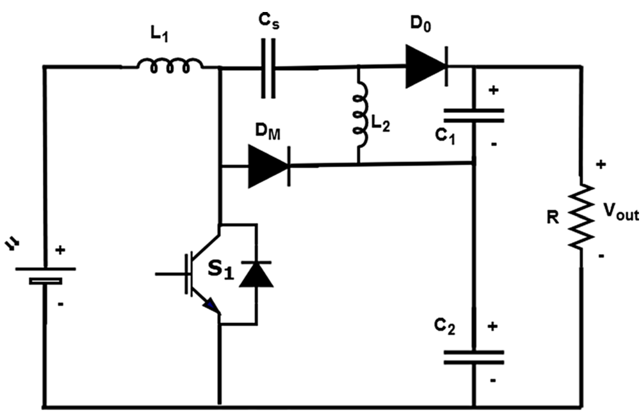

Fig. 4 Modified SEPIC DC-DC converter

- Maximum power yield.
- It efficiently extracts the power under varying irradiation and temperature conditions.
- Simple to implement.

3.2 Modified SEPIC DC-DC converter

The improved SEPIC DC-DC converter is employed to properly adjust the voltage with little power loss after harvesting power from the PV panels. Normally, the output PV voltage is random, and is not directly used to the grid systems due to the harmonics and oscillations. Therefore, it is necessary to regulate it before supplying power to the grid systems by employing the DC-DC converter. In this study, a modified SEPIC DC-DC converter is used to effectively control the output voltage while reducing harmonic distortions. The device is a hybrid buck-boost DC-DC converter that is widely utilized in many power application systems to regulate and increase voltage. Also, it has the following benefits:

- Non-inverted output.
- High voltage gain.
- Reduced operating duty cycles.
- Increased robustness.

Fig. 4 depicts the schematic for the improved SEPIC DC-DC converter, and Fig. 5 (A) and (B) demonstrate how it operates (b).This converter can be operated according to the controlling signals provided by the controller unit. Furthermore, the converter's performance is heavily reliant on the switching pulses. This is because the controller generates these pulses to operate the switching modes and increase the output voltage. The converter's switch can be operated in either the ON state or OFF State, as illustrated in Fig. 5 (A) and (B) correspondingly. The converter utilizes inductors, capacitors, diodes, and resistors as its components

Here, the switching duty cycle is estimated as follows:

$$D = \frac{V_{out} - V_{in}}{V_{out} + V_{in}} \tag{5}$$

The inductance and capacitance are computed by using the following models:

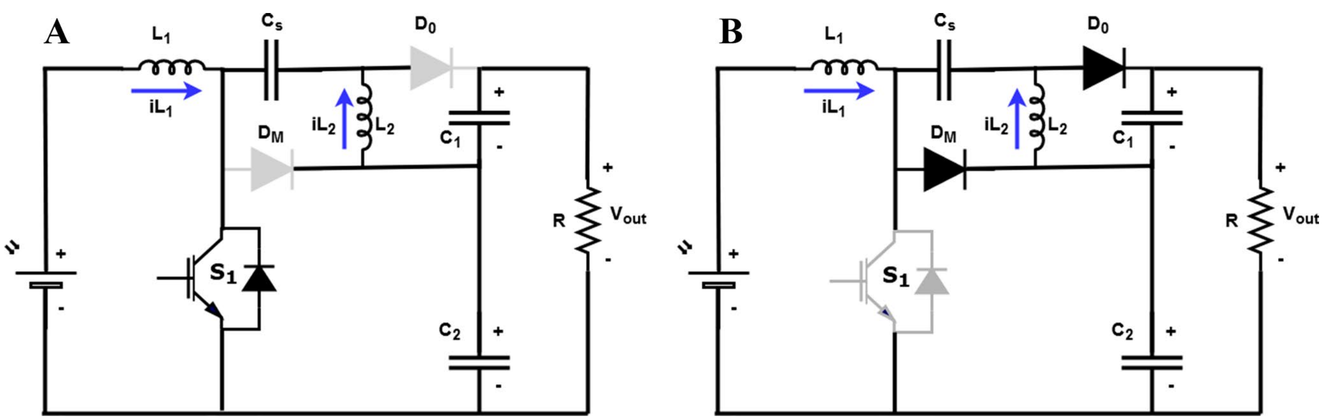

Fig. 5 (**A**) Mode 1 – Switch ON condition. (**B**) Mode 2 – Switch OFF condition

$$L1 = L2 = \frac{V_{out}D}{\Delta\, i_L f} \tag{6}$$

$$C_S = \frac{I_{out}}{\Delta\, V_c f} \tag{7}$$

$$C1 = C2 = \frac{1}{2}\left(\frac{D}{R(\Delta\, V_{out}/V_{out})f}\right) \tag{8}$$

$$\Delta\, V_c = \left(\frac{V_{in}}{1 - D}\right) \times 0.1 \tag{9}$$

where V in and V out are the input and output voltages, respectively; L1 and L2 are inductors; and C1 and C2 are capacitors.

3.3 Mutated ant province optimization (MAPO) based controlling mechanism

This study introduces a new technique called Mutated Ant Province Optimization (MAPO) for creating regulating signals by selecting optimal parameters. The generated signals can be given to the DC-DC converter for actuating the switching devices, and the increased voltage gain output is highly depends on the modes of operations of the switching devices. The main goal of using the MAPO technique in this situation is to choose the appropriate parameters based on the overall best solution. Additionally, this technique's main benefit is that it has a faster convergence rate and identified the best fitness function with fewer iterations. In this method, the entry state and subsequent state of the set of populations are determined after initialization. The fitness function is then calculated using the deposit, deamon, and evaporate pheromones. This mechanism considers numerous triats, including the number of ants, alpha, beta, evaporation rate, and number of parameters.

Step 1: Initialization of Parameters

Set up the algorithm's necessary parameters like ant count, alpha (pheromone influence), beta (heuristic factor), evaporation rate, iterations count, parameter number and initial pheromone level.

Step 2: Initialize Pheromone Trails

Initialize the pheromone trails matrix with initial pheromone levels for each parameter.

Step 3: Ant Movement.
For each iteration

Generate ant solutions:
For each ant:
Create a solution in which parameter values are chosen probabilistically, considering pheromone levels and heuristic information (alpha and beta).

Step 4: Fitness Evaluation.
Evaluate the fitness of each ant solution using a fitness function.

The fitness function must evaluate how good the solution is, according to goals set for this optimization problem.

Step 5: Update Pheromone Trails.
Update the pheromone trails based on the fitness of the ant solutions:

Deposit pheromones on paths taken by ants that produced better solutions.
Evaporate pheromones to mimic natural pheromone decay and prevent stagnation.

Step 6: Solution Selection.

Select the best solution among the ant solutions based on the fitness function.

Step 7: Mutation.

Introduce mutation to explore new solutions and avoid local optima:

Perturb the selected parameters of the best solution to generate diverse solutions.

Step 8: Convergence Check;

Obtain the best fitness value over iterations.

The Mutated Ant Province Optimization (MAPO) algorithm, a fresh method to deal with parameter control in grid-connected PV systems, is characterized by its new way of doing things and better performance when compared to similar existing works. Common optimization methods like genetic algorithms and particle swarm optimization have been used a lot in many tasks involving optimization including tuning parameters for PV systems. But what makes MAPO different from others is it provides a special structure that uses the group understanding based on how ant colonies behave which helps in exploring space of parameters effectively as well as strong moving towards best solutions. This makes it different from traditional optimization methods, giving a more flexible and powerful way to manage parameters for improving grid-connected PV systems' performance. Also, MAPO shows enhanced adaptability and optimization when compared to usual methods of control like PID control and model predictive control. In the regular PID control method, fixed parameters are employed that don't adjust effectively with changes in environmental situations or system dynamics. On the other hand, MAPO modifies parameters dynamically based on developing system traits which enhances its toughness while attaining ideal performance. In comparison to other optimization-focused methods such as model predictive control (MPC), which have slower convergence rates and may deliver solutions of lesser quality; MAPO stands out for quicker convergence speed together with high-quality results. This implies that it can optimize power generation from PV systems while minimizing harmonic distortions, helping to maintain grid stability. The uniqueness of the MAPO algorithm is shown by these comparisons, stating it might lead to a notable alteration in parameter control for grid-connected PV systems and help advance renewable energy technology.

Additionally, the following are the main advantages of this controller:

- Reduced computational complexity.
- Requires minimum number of sensors.
- Minimized computational time for tuning the controlling parameters.
- Increased efficiency.

Figure 6 shows the proposed MAPO algorithm's operational flow.

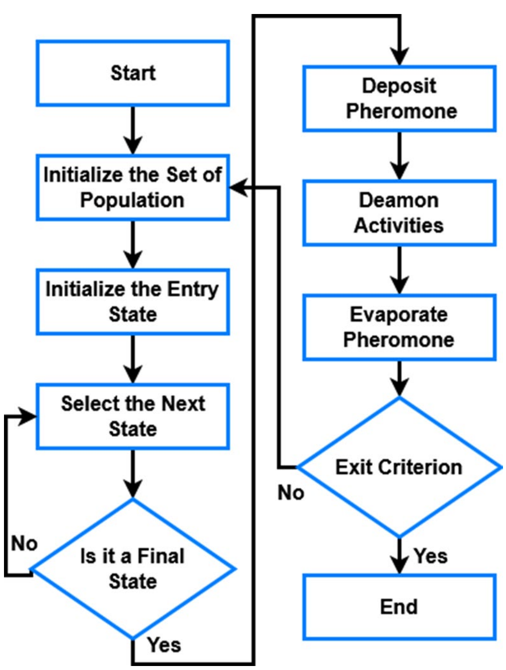

Fig. 6 Flow of the proposed MAPO algorithm

3.4 LCL filtering

For efficiently suppressing the harmonics and increase the voltage gain output, the LCL filtering technique is utilized in the proposed system [25]. Due to its strong attenuation, it is more capable to work under varying frequency ranges. Moreover, it effectively minimize the harmonic contents, when compared to the other L and LC filtering techniques. Moreover, this filtering model is designed based on the combination of L1 + R1, L2 + R2, and C + RC components as illustrated below:

$$\begin{cases} L_1\frac{di_1}{dt} + R_1 i_1 = u_i - u_c - R_c i_c \\ L_2\frac{di_g}{dt} + R_2 i_2 = u_c - u_g - R_c i_c \\ C\frac{du_c}{dt} = i_c \\ i_1 = i_g + i_c \end{cases} \tag{10}$$

Where, L_1 and L_2 are the inductors, R_1, R_2, R_c represents the resistors, C defines the conductor, and i is the current. The key benefits of using this methodology are listed below:

1. Minimized weight.
2. Efficient in harmonic suppression.
3. Minimal cost.

Finally, the noise free and regulated high gain voltage is fed to the grid systems for further processing.

4 Results and discussion

This part focuses on the evaluation of the performance of the suggested converter and regulating models through the utilization of diverse metrics. The MATLAB/SIMULINK tool was used to examine the results, which were then compared to the latest state-of-the-art models to demonstrate the improvement of the suggested system. Figure 7 (a) and (b) depict the current-voltage (IV) and power-voltage (PV) characteristics of the Perturb and Observe (P&O) Maximum Power Point Tracking (MPPT) control technique in relation to different voltage levels. The power tracking efficiency and performance of the MPPT regulating model are often validated and assessed by analyzing the IV and PV characteristics. Additionally, it signifies the highest level of voltage and power generated by the photovoltaic (PV) panels in

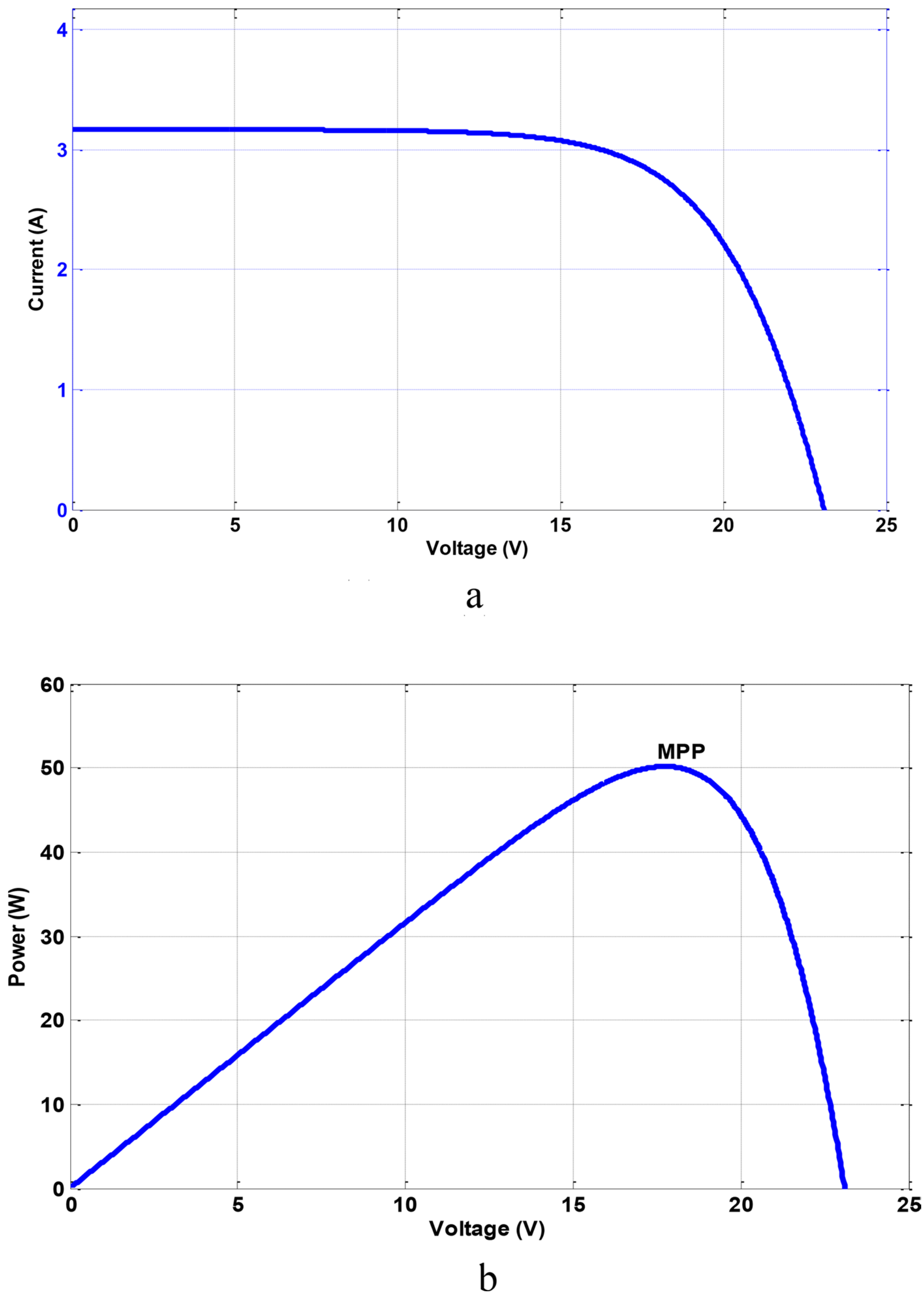

Fig. 7 (**a**) IV characteristics. (**b**) PV characteristics

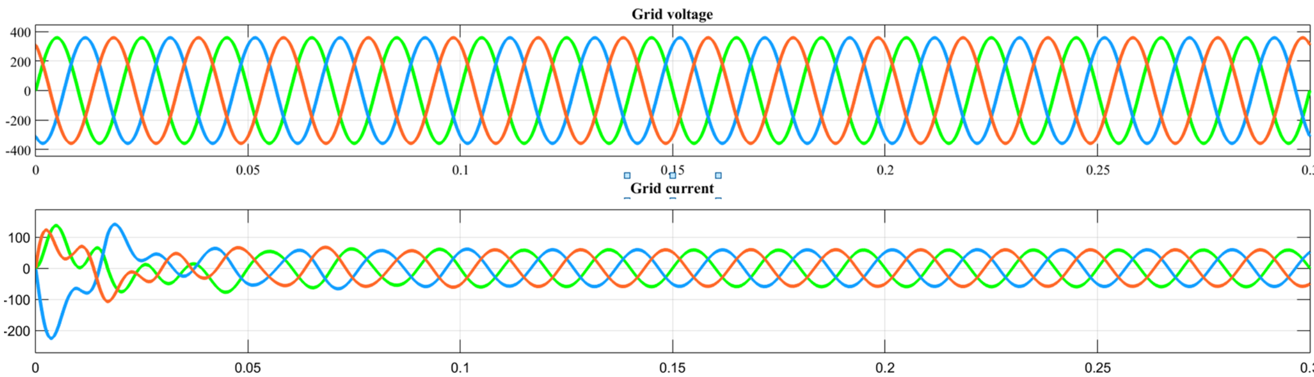

Fig. 8 Grid Voltage and current

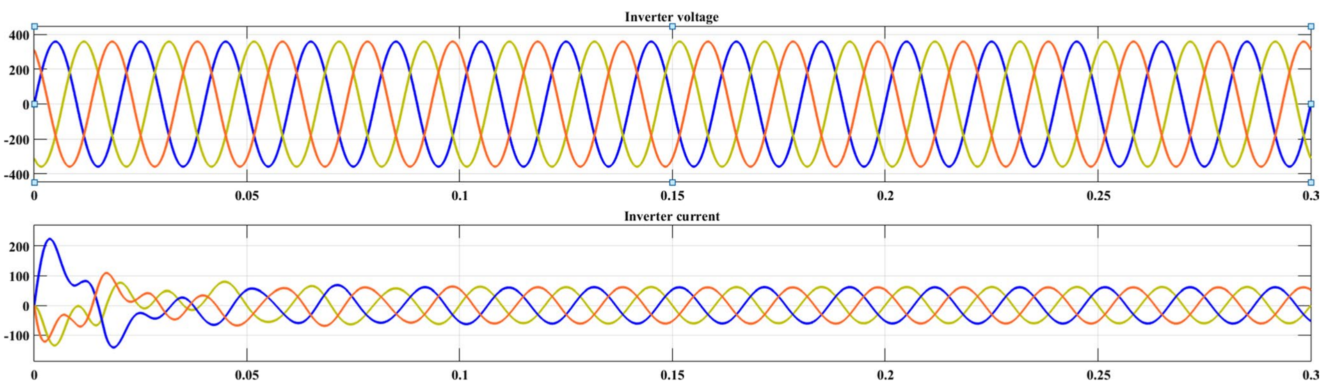

Fig. 9 Inverter voltage and current

varying weather circumstances. The analysis of the results indicates that the P&O MPPT technique enhances power output by precisely detecting the peak point.

Typically, the solar power inverters are highly essential for synchronizing the frequency according to the grid voltage and current. Moreover, the output current of controller is measured by the grid current, which helps to track the reference current. Moreover, these values are used to estimate the reactive power that is actually immersed by the inverter unit. Then, the desired level of both voltage and current should be minimized for avoiding the unnecessary power losses in the grid-PV systems. Figure 8 illustrates the grid voltage and current of the proposed regulating technique. The waveforms demonstrate that the output voltage is efficiently managed with minimized power loss.

Typically, the LLC inverter is more capable to control the high voltage systems with reduced harmonics. Here, the inverter voltage output and current are show in Fig. 9 (a) and (b) respectively. Moreover, the efficiency of inverter unit is determined based on the voltage output and current during signal conversion. From the results, it is evident that the inverter voltage and current have been perfectly maintained under varying load changes.

Figure 10 assesses the Total Harmonic Distortion (THD) of the suggested control mechanism over several frequency ranges, measured in Hz. The overall performance of the grid-connected photovoltaic (PV) system is assessed by evaluating the extent of harmonics and the stability of the output voltage. Furthermore, it is crucial to mitigate the harmonic components in order to guarantee minimized power dissipation and enhanced system efficiency. The analysis of the data indicates that the Total Harmonic Distortion (THD) of the proposed regulating system has been decreased to 1.40% by effective voltage regulation.

Table 2 and Fig. 11 compare the present [28] and proposed converter topologies based on how many switches, inductors, diodes, and capacitors are used in each. Each DC-DC converter's voltage gain is also evaluated based on how its components are used. Non-inverting high gain DC-DC, quadratic boost DC-DC, high gain step-up DC-DC, high step-up DC-DC, ultra step-up DC-DC, quadratic boost DC-DC, interleaved boost DC-DC, and quad-isolated DC-DC are the various converter types used in this analysis. Based on the findings, The analysis concludes that the suggested redesigned SEPIC converter necessitates a reduced number of components and provides increased output voltage gains.

Based on the measurements of overshoot, rise time, and settling time, Table 3 and Fig. 12 compare existing [26] and proposed Innovative Mutated Ant Province Optimization

Fig. 10 THD analysis

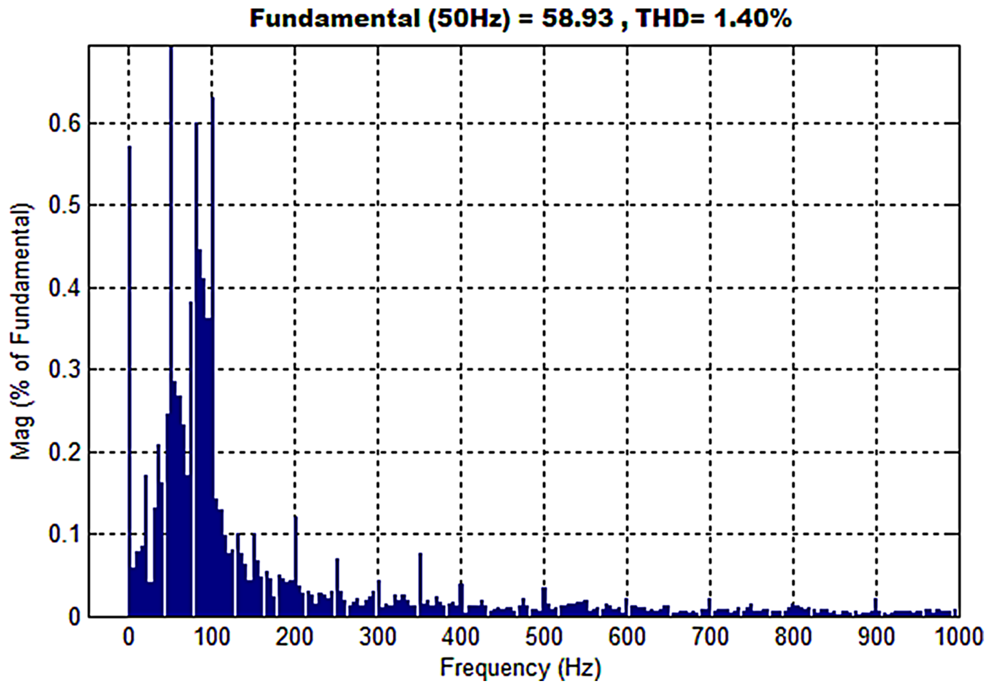

Table 2 Comparative study of the proposed and existing converter topologies

References	No of switches	No of inductors	No of diodes	No of capacitors	Voltage gain
Non-inverting high gain DC-DC	1	2	6	5	12
Quadratic Boost DC-DC	1	1 + 1 coupled inductor	5	3	10
High step-up DC-DC	1	2	4	5	6
Ultra step-up DC-DC	1	2	5	4	7
Quadratic Boost DC-DC	1	3	5	3	8
High gain DC-DC	2	2	5	4	6
Interleaved Boost DC-DC	6	6	14	8	7
Quad isolated DC-DC	2	4	9	1	5
Modified SEPIC	1	2	2	3	15

Table 3 Analysis of existing and proposed control methods in comparison

Measures	PI Controller	FLC Controller	Proposed MAPO controller
Overshoot	2.58	0.18	0.13
Rise time (s)	0.0066	0.0078	0.0064
Settling time (s)	0.015	0.016	0.010

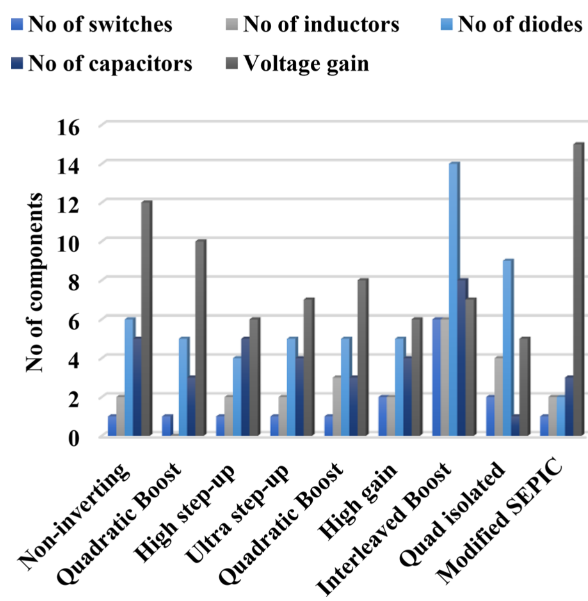

Fig. 11 Comparison chart between the conventional and modified Sepic DC-DC converters based on the utilization of components

(MAPO) techniques. Usually, the reduced values of these measures are used to calculate the improved performance of the controller. This analysis examines two existing controlling strategies: the Proportional Integral (PI) controller and the Fuzzy Logic Controller (FLC). The suggested MAPO outperforms existing techniques, as evidenced by the results, which demonstrate reduced overshoot, rise time, and settling time.

Similarly, Table 4 and Fig. 11 compares the rise time and settling time of existing [22] and proposed optimization

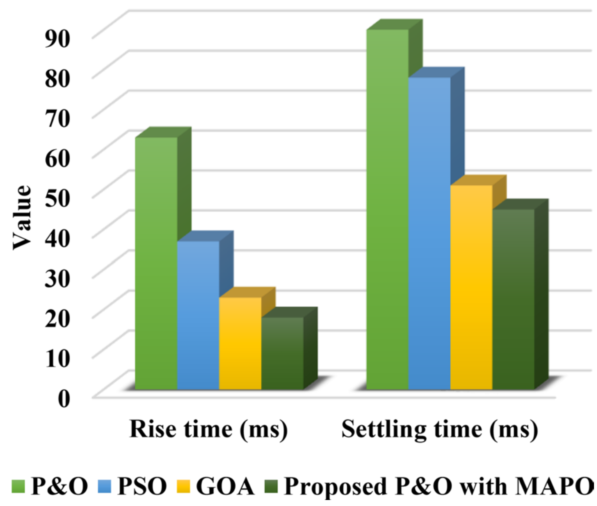

Fig. 12 Comparative analysis between existing and proposed optimization techniques based on time

Table 4 Rise time and settling time of existing and proposed optimization techniques

Parameters	*P*&O	PSO	GOA	Proposed *P*&O with MAPO
Rise time (ms)	63	37	23	18
Settling time (ms)	90	78	51	45

based controlling techniques. It includes the conventional Perturb & Observe (P&O), Particle Swarm Optimization (PSO), and Grasshopper Optimization Algorithm (GOA). Based on the results, it is evident that the proposed P&O integrated with MAPO technique produces the reduced rise time and settling time, when compared to the other techniques, which shows the improved performance and efficiency of the proposed system.

5 Conclusion

This study presents an improved converter and controlling strategies for grid-PV system voltage regulation and harmonic reduction. The P&O based MPPT controlling technology is used to track the maximum amount of power of the solar PV panels, even when there are changes in environmental circumstances. Additionally, the output random PV voltage is regulated, and the modified SEPIC DC-DC converter is used to lessen power loss in grid-PV systems. Additionally, the MAPO-based controlling technique has been created to generate the controlling signals needed to actuate the switching elements incorporated into the converter circuit. With fewer iterations, this method chooses the ideal number of parameters based on the best fitness value. Moreover, the output DC voltage's harmonics or noise are suppressed using the LCL filtering technique. The following are the main benefits of the suggested system: increased convergence rate, reduced complexity, minimum time consumption, error rate, and increased voltage gain. Different types of evaluation metrics, including rise time, settling time, overshoot, and the number of components utilized, are taken into account to validate the efficiency and effectiveness of the suggested system. The efficacy of the proposed strategy is subsequently proved by juxtaposing the outcomes with those of alternative contemporary methodologies. The analysis of the results shows that the proposed MAPO-SEPIC converter offers superior performance to the other methods.

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Author contributions The author **S. Muthu Balaji** was involved in the architectural design, implementation, and evaluation process presented in the paper. The author **Vijaykumar Kamble** contributed and put effort on paper to organize the Paper. Developed the theoretical formalism, performed the analytic calculations, and performed the numerical simulations and analyzed the data, technically contributed, and made English Corrections and grammar checking. The author **Vaishali Kuralkar was** involved and helped to derive the mathematical equation. **Tushar Waghmare** carried background study of the Paper and helped with the mathematical derivations. The author **T. Jayakumar** was involved and provided a factual review and helped edit the manuscript.

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Data availability and materials Data sharing not applicable to this article as no datasets were generated or analyzed during the current study. The datasets used and analysed during the current study are available from the corresponding author on reasonable request.
All data generated or analysed during this study are included in this published article4.

Declarations

Competing interests The authors have no competing interests to declare relevant to this article's content.

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Simulation Of Seven Level Asymmetric Multilevel Inverter.

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***Abstract*-Multilevel inverters are popular in industry as they provide more than two levels of voltages to achieve smoother and less distorted Dc to AC power conversion. This paper presents seven level asymmetric multilevel inverter. This paper also presents the most relevant control and modulation method developed for this inverter: multicarrier pulse width modulation. Special attention is dedicated to the MATLAB simulation of H-bridge seven level multilevel inverter . Line to line and phase voltages are plotted using simulation. Finally FET analysis is carried out to find THD.**

***Index* Terms-Multilevel inverters, power converters, H-Bridge inverters.**

I. Introduction

Power-electronic inverters are becoming popular for various industrial drives applications. It is necessary that the output voltage waveform of an ideal inverter should be sinusoidal. The voltage waveforms of practical inverters are, however, non-sinusoidal and contain certain harmonics. Square wave or quasi-square wave voltage may be acceptable for low and medium power applications but for high power applications low distorted sinusoidal waveform are required. MULTILEVEL INVERTERS have gained popularity in high power applications due to their low switching frequency, low harmonics and modularity. Today these inverters are considered as the most suitable power converters for high-voltage-capability and high-power-quality demanding applications. Lower common-mode voltages, near-sinusoidal outputs, together with small *dv/dt*'s, are some of the characteristics that have made these power converters popular for industry and research [4]. Multi-level inverters can operate not only with PWM techniques but also with amplitude modulation (AM), improving significantly the quality of the output voltage waveform. With the use of amplitude modulation, low frequency voltage harmonics are perfectly eliminated, generating almost perfect sinusoidal waveforms, with a THD lower than 5 % [5].

The main advantages of multilevel inverters are

1. Low harmonic distortion of the generated output voltage
2. Low electromagnetic emissions.
3. High efficiency.
4. Capability to operate at high voltages, and modularity.

Each converter operated at a low switching frequency, reducing the semiconductor stresses, and therefore reducing the switching losses. The development of multilevel inverters over the last decades has matured into three widely accepted topologies:

1. neutral point clamped (NPC)
2. flying capacitor (FC)
3. cascaded H-bridge inverter.

II Multilevel inverter

The principal function of the inverters is to generate an ac voltage from a dc source voltage. If the dc voltage is composed of many small voltage sources connected in series, it becomes possible to generate an output voltage with several steps. Multilevel inverters include an arrangement of semiconductors and *dc* voltage sources required to generate a stair case output voltage waveform. The H-bridges multilevel inverter introduces the idea of using Separate DC Sources (SDCSs) to produce an AC voltage waveform. Each H-bridge inverter is connected to its own DC source *Vdc*. By cascading the AC outputs of each H-b ridge inverter, an AC voltage waveform is produced. Fig. 1 provides an illustration of a single-phase cascaded H-bridges multilevel inverter using 3-SDCSs [8]. By closing the appropriate switches, each H-bridge inverter can produce three different voltages: +*Vdc*, 0 and -*Vdc*.

As mentioned earlier, each H-bridge inverter produces an AC voltage *vi*, where *i* stands for one particular H-bridge inverter. Fig.1 contains three such H-bridges, one for each DC source. Therefore, to obtain the total AC inverter phase voltage, these three distinct AC voltages are added together [7].

Fig. 2 provides an illustration of these ideas [8]. It also illustrates the idea of "levels" in a cascaded H-bridges multilevel inverter. The smallest number

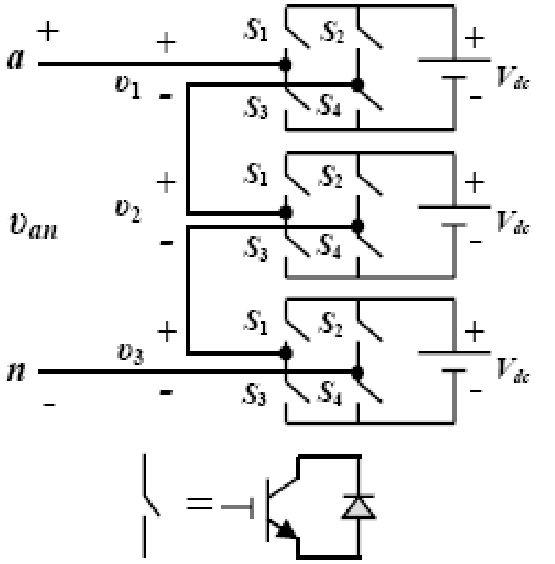


Fig1.H-bridge Multilevel Inverter using 3-SDCS

of voltage levels for a multilevel inverter using cascaded inverter with SDCSs is three. To achieve a 3-level waveform, a single full-bridge inverter is employed. In Fig. 2, one notices that three distinct DC sources (s = 3, where s is the number of DC sources) can produce a maximum of (l = 7 distinct levels) in the output phase voltage of the multilevel inverter. More generally, a cascaded H-bridges multilevel inverter using s - SDCSs can produce a maximum number of levels given by the equation:

$$l=(2s + 1) \quad (1)$$

Where, l is the distinct number of levels in the output phase voltage.

And s is the number of SDCSs

The concept of cascaded multilevel inverter with SDCSs is very interesting due to many reasons. This topology requires the least number of components, among all multilevel inverters, to achieve the same number of voltage levels. It is also possible to modularize circuit layout

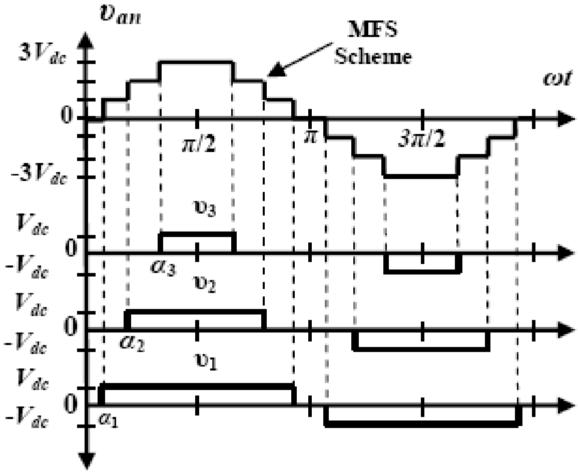


Fig2. Output Voltage of H-bridges 7-level Inverter

and packaging because each level has the same structure, and there are no extra clamping diodes or voltage balancing capacitors. In addition, soft switching technique can be applied in this structure to avoid bulky and resistor-capacitor-diode snubbers with losses, as part of future work.

Multilevel inverters are implemented with small dc sources, used to form a stair case ac waveform, which follows a given reference template. The AC voltage waveform resulting produced from these DC voltages is approximately sinusoidal. By switching the DC voltages to the AC output, a staircase (stepped) waveform can be produced which approaches the sinusoidal waveform with minimum THD. The waveforms are of better harmonic spectrum and attain higher voltages with a limited maximum device rating.

III ASYMMETRIC MULTILEVEL INVERTER

In all the well-known multilevel converter topologies, the number of power devices required depends on the output voltage level needed. However, increasing the number of power semiconductor switches also increases converter circuit and control complexity and cost. To provide a large number of output levels without increasing the number of converters, asymmetric multilevel converters (AMC) can be used.

Traditionally, each phase of a cascaded multilevel inverter requires 'n' dc sources for 2n+1 levels. For many applications, it is difficult to use separate dc sources and too many dc sources will require many long cables and could lead to voltage imbalance among the dc sources. To reduce the number of dc sources required for the cascaded H- bridge multilevel inverter, an asymmetric topology is proposed as shown in Fig.3.This provides the capability to produce higher voltages at higher speeds with low switching frequency.

Fig.4 shows a detail of the partial cells and the main notations used. Each couple of switches $S\,jx$ and $S'\,jx$ (x = 1,2; j = 1..K) is controlled by a couple of switching functions

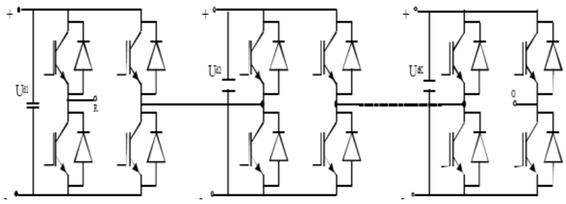


Fig3. Series-connected inverters topology with *K* cells per phase

$M\,jx$ and $M'\,jx \in \{0,1\}$.[6]

The output voltage of each cell is given by

$$U_{pj}=F_j*U_{dj}, U_{pj} \in \{-U_{dj}, 0, U_{dj}\} \quad (2)$$

Equation 2 shows that each partial cell can generate three different levels. The output voltage of the multilevel converter is given by :

$$U_s = U_{p1}+U_{p2}+..+U_{pK} \quad (3)$$

A series-connected multilevel inverter is known as asymmetric, if at least one to the dc voltage sources feeding the partial inverters is different of the others. Three conditions have been established for the design of a regular step AMI :

1) the dc-voltage sources must be arranged in an increasing way

$$U_{d(h-1)} \leq U_{dh}, \quad \forall h=2\ldots K; \quad (4)$$

2) the ratio between two consecutive inverters must be an integer

$$U_{dh}/U_{d(h-1)} = \delta_h,\ \delta_h \in N^* ; \quad (5)$$

3) the jth partial cell must be fed by the voltage $U\,dj$ such that

$$U_{dj} \leq 2\left(\sum_{l=1}^{j-1} Udl\right)+1 \quad (6)$$

If these three conditions are satisfied, the multilevel inverter will generate an output voltage *Us* with *N* regular different levels.

The DCVS levels can be chosen according to a geometric progression with a factor of two or three. Equations 7 and 8 summarize the relationships between *N* and *K*. These approaches are only two particular cases.

$$N = 2^{(K+1)} - 1 \quad \text{if} \quad U_{dj} = 2^{(j-1)}.U_{d1} \quad (7)$$

$$N = 3^{K} \quad \text{if} \quad U_{dj} = 3^{(j-1)}.U_{d1} \quad (8)$$

This approach allows to take accurately into account the particularity of power devices and the other design constraints. It provides more flexibility due to its easy expansion, and a large number of degrees of freedom to the designer.

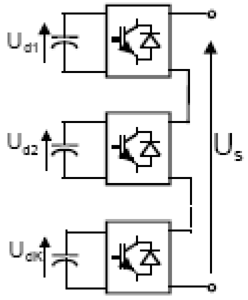


Fig 4. Partial cells used

Total and partial asymmetry factors :

The first fundamental concept of asymmetric multilevel converters is based on the fact that the DC voltages U_{dj} ($j = 1\ldots.K$) supplying each partial inverter are a ratio of the equivalent total DC-link voltage of the converter, *Ue*. These ratio factors are denoted λ_j and are called the total asymmetry factors.

$$\lambda_j = \frac{Ue}{Udj}, \quad \forall\, j = 1\ldots..K \quad (9)$$

The equivalent total DC-link voltage *Ue* is given by the following relationship :

$$U_e=2\sum_{j=1}^{K} Udj \quad (10)$$

The second fundamental concept is based on the ratio between DC-voltages supplying consecutive partial inverters. These ratio factors are denoted δ_h ($h = 2..K$) and are called partial asymmetry factors.

$$\delta_h = \frac{Udh}{Ud(h-1)}, \quad \forall\, h = 2\ldots.K \quad (11)$$

The advantages of asymmetric topology are:

1. The number of separate DC supplies used is reduced in this configuration.
2. Due to the different input voltages of the cells, high-voltage switches presenting low relative conduction

losses are combined with low-voltage switches having low commutation time. Naturally, for most operating points, the switching frequency of low voltage cells is higher. Thus low output switching frequency is required.

3. Low switching losses occur as the number of semiconductor devices are reduced.
4. From the voltage resolution point of view, with the same number of cells, the asymmetrical multilevel inverter allows a higher resolution than symmetrical multilevel inverters. In the symmetrical case, the number of levels grows proportionally to the number of cells, in the asymmetrical case, it grows exponentially.
5. High conversion efficiency is achieved.
6. Flexibility to enhance the performance using various control strategies are possible.
7. Reduction in complexity and cost is achieved due to lesser number of semiconductor devices and hence simpler commutation and triggering circuits.

One major demerit of asymmetric configuration is that the cells have to be insulated from each other; this constitutes the major complexity of these structures.

IV Seven Level Asymmetric Inverter

In seven-Level Asymmetrical Inverter each leg of a single phase contains 2 DCVS (DC Voltage Source) of 100V and 200V unlike the 3 DCVS of 100V each in 7-Level Symmetrical Inverter. This arrangement thus reduces the number of voltage supplies used. Also the number of IGBTs used are only 24 unlike 36 in the symmetric configuration. Here too the H-Bridge topology is used. Each H-Bridge has 4 IGBTs in it. And each leg has 2 such H-Bridges. To prevent commutation errors, same switching pulses are provided to IGBT (1, 2), (3, 4), (5, 6), (7, 8) and so on in the other two phases as well. Due to the different input voltages of the cells, high-voltage switches presenting low relative conduction losses are combined with low-voltage switches having low commutation time. Naturally, for most operating points, the switching frequency of low voltage cells is higher. Together with the switch characteristics, one can take advantage of this specificity. The three legs are star connected and neutral is earthed. Inports are connected to all IGBTs to provide switching pulses. Three connection ports are provided in all three phases, namely, A, B and C. These ports are provided to carry out voltage measurements, namely, line voltage and the phase voltages. Subsystem of this is created and the arrangement is as shown in Fig 7. The Pulse generation circuit that employs the pulse width modulation technique with switching frequency of low voltage cells being higher than that of high voltage cells [14]. The waveforms of the triangular carrier waves and the sinusoidal reference wave are shown in Fig 5. Fig 6 shows the pulse train generated. The line-line voltage and the phase voltage are shown in Fig 8 and Fig 9 respectively. The *powergui* block is used to carry out the FFT analysis which is shown in Fig 10. The THD comes out to be 12.97% in the asymmetrical configuration.

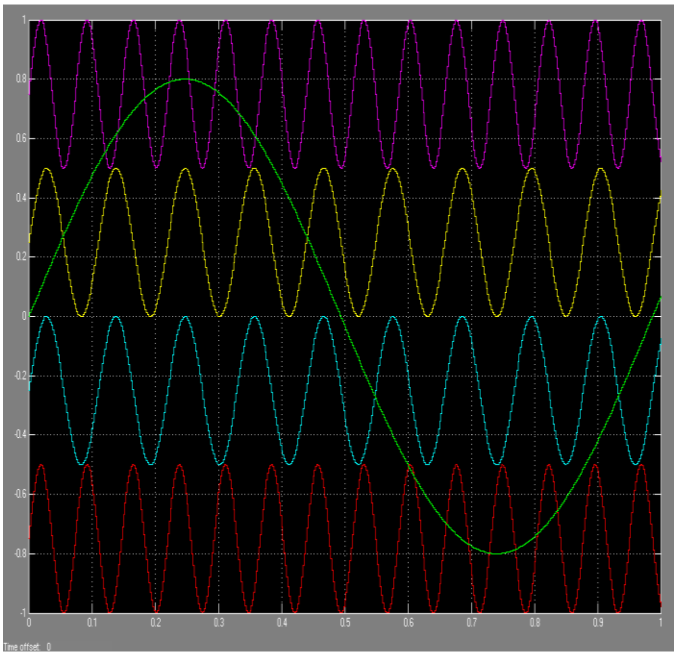
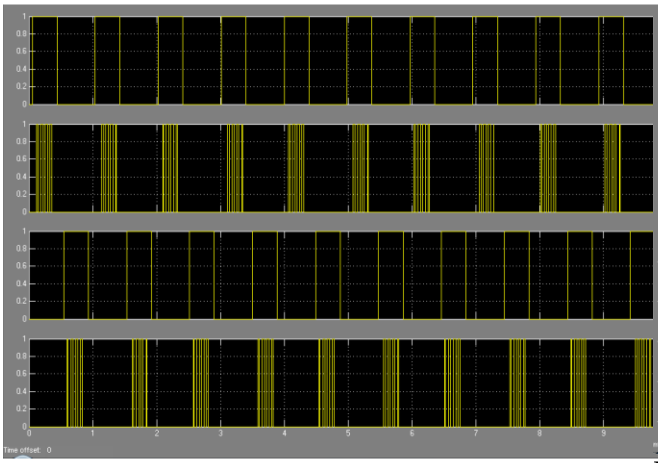


Fig5. Waveforms of Carrier and Reference waves for asymmetric configuration



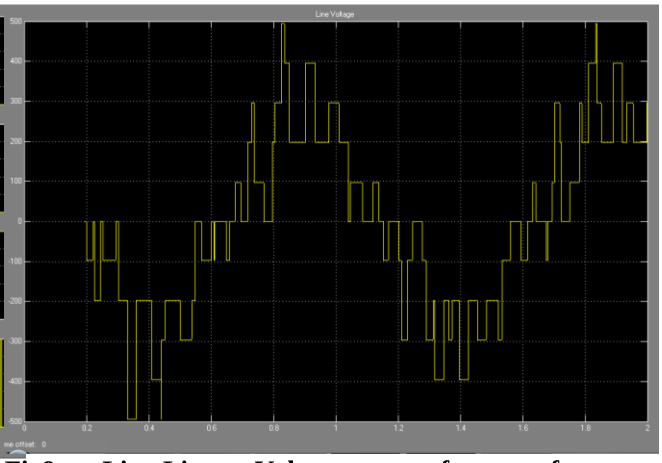


Fig8. Line-Line Voltage waveform of asymmetrical configuration

Fig6. Pulse train for asymmetric configuration

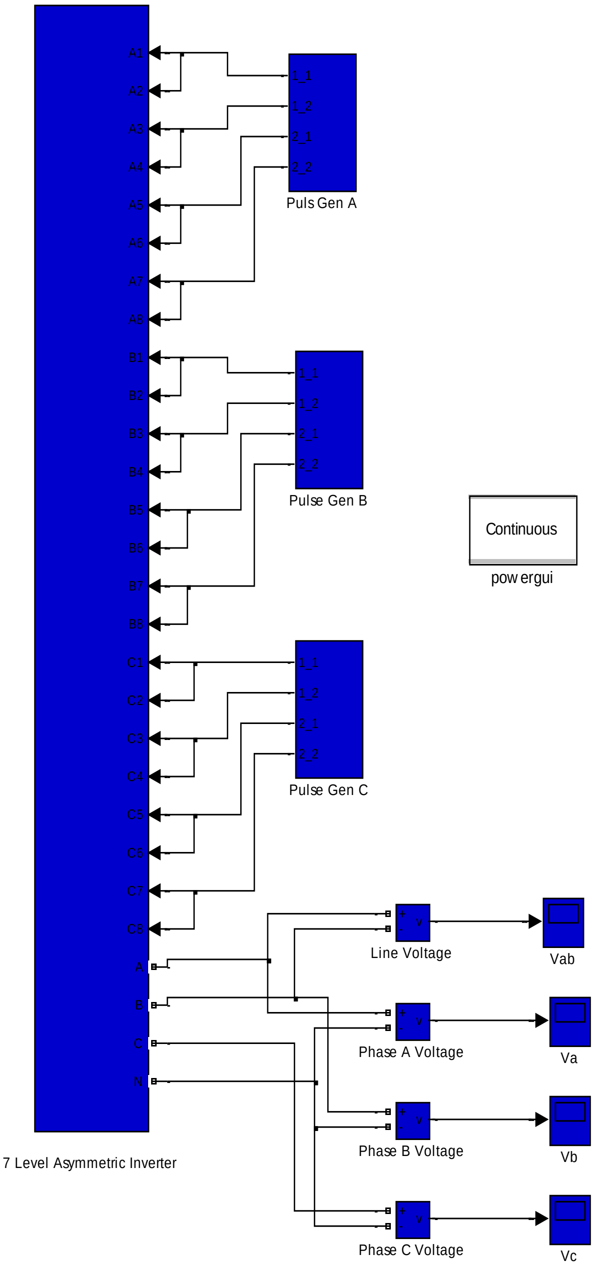


Fig7. Simulated 7-Level Asymmetric Inverter Circuit

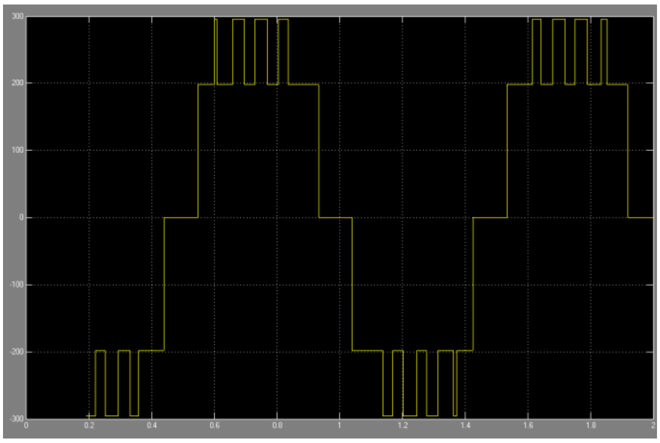


Fig9. Phase Voltage waveform of asymmetrical configuration

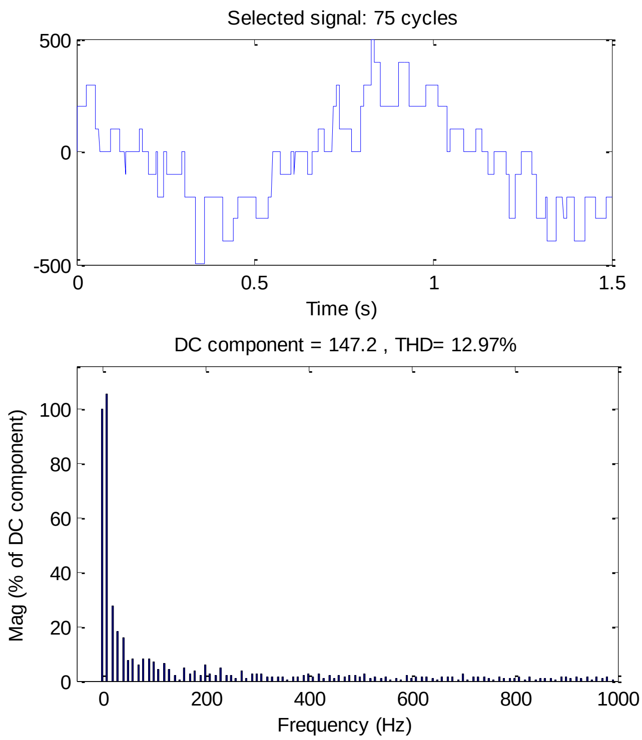


Fig10. The FFT analysis of the asymmetrical configuration

Conclusion

The modeling of 7-level asymmetric inverter was done and simulated using MATLAB/SIMULINK. The total harmonic distortion (THD) of the asymmetric configuration was found to be only 12.97%, which is much lesser than that of the conventional configuration. The simulation result shows that the harmonics have been reduced considerably. The 7-level asymmetric inverters have been successfully simulated and the results of line-line voltage waveforms, phase voltage waveforms and the FFT analysis are obtained. The inverter system can be used in industries for the adjustable speed drives and significant amount of energy can be saved as the system has less harmonic losses.

References

[1] Samir Kouro, *Student Member, IEEE*, Jaime Rebolledo, *Student Member, IEEE*, and José Rodríguez, *Senior Member,IEEE* Reduced Switching-Frequency-Modulation Algorithm for High-Power Multilevel InvertersVol. 54, No. 5, October 2007

[2] Juan Dixon (SM) Luis Morán (F)
High-Level Multi-Step Inverter Optimization, Using A Minimum Number Of Power Transistors

[3] J. Song-Manguelle and Prof. A. Rufer Multilevel Inverter for Power System Applications : Highlighting Asymmetric Design Effects From a Supply Network Point of View 2003 IEEE Journal

[4] J.S.Mangulle, A.Ruffer Asymmetrical multilevel inverter for large induction machine drives Electrical drives and Power Electronics,International Conference, Solvakia 3rd – 5th October 2001

[5] J. Song-Manguelle, S. Mariethoz, M. Veenstra and Prof. A. Rufer A Generalized Design Principle of a Uniform Step Asymmetrical Multilevel Converter For High Power Conversion IEEE, 1999

[6] S. Mariethoz, A. Rufer New configurations for the three-phase asymmetrical multilevel inverter

[7] Richard Lund, Madhav D. Manjrekar, Peter Steimer, Thomas A. Lipo Control Strategies for a Hybrid Seven-level Inverter

[8] A. Tahri, A. Draou Comparative Modelling Study of PWM Control Techniques for Multilevel Cascaded Inverter*IEEE-APEC'98 Conference Proceedings*, pp. 523-529, 1998.

Shubhangi Sudhir Landge received the M. E. degrees in electrical engineering from the Shivaji University Kolhapur, in 2003. From 2002 to 2007 she worked as a lecturer in Sir visweshwaraya Memorial Engineering college Chincholi, Nasik. From 2007 onwards she is working as a lecturer in AISSMS's Institute of Information Technology Pune. Her main research areas are in high-power electronics converter and application issues. She has authored 7 technical papers in national and international journals.

Department Activities:

(Professional Chapter, PQ Cell, REC Cell, Student Association)

IE (I) and ISTE:

Dr. V. P. Kuralkar- coordinator

Department of Electrical Engineering has professional chapters namely The **Institution of Engineers IE(I)** and **Indian society of technical education (ISTE)**, the headquarters of IE(I) is at Kolkata.

The aim of establishing these chapters is to conduct various technical as well extracurricular activities for students to develop the overall personality of the students apart from the academics. Financial help is also provided by these chapters to the students. These activities provide a platform for the personality development of the students and also help to bridge the gap between the academics and the industries.

1) Under these chapters various technical activities such as paper presentation, project competition, model making, technical quiz etc are conducted. These activities enhance the technical skills as well as verbal and communication skillset of the students.
2) Workshops (PLC, Programing, electronics, microprocessor etc.) are also conducted for the students and are sponsored by the chapters. These workshops are conducted by highly proficient and skilled industrial experts.
3) Expert lectures, technical demonstrations, industrial visits, tutorials, special technical talk sessions, career guidance lectures, mock interviews, group discussions are also some of the activities organized under these chapters.

Internal and external evaluators evaluating a project in project competition **Technokratia25**

Internal and external evaluators evaluating a project in project competition **Technokratia 25**

Organized an expert lecture of Mr. P. R. Mehetre. IIT Powai, under Sustainable Engineering subject for TY & SY B. Tech Electrical on 23rd December 2024.

Felicitation of Expert Er. Pravin Mehetre by HOD Dr. A. D. Shiralkar

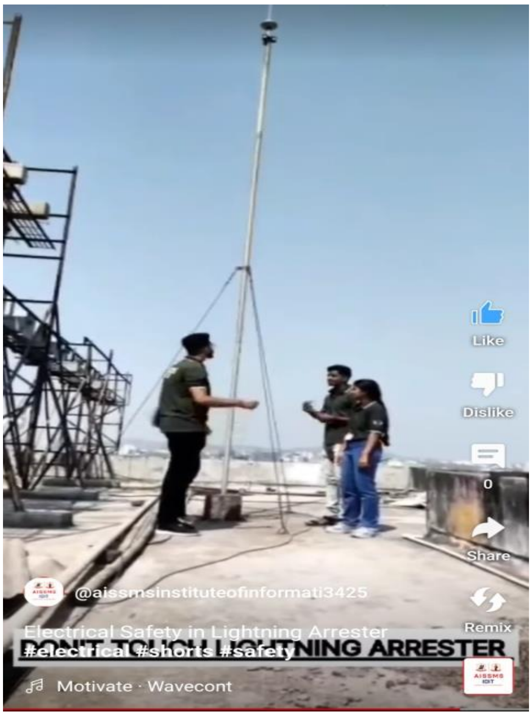
National Federation Of Engineers For Electrical Safety

Students' Chapter

- Create awareness on electrical safety, improve skills of practicing electrical engineers, improve safety measures followed in the industry, Introduce modern safety measures in engineering & Improve quality of electrical installation.
- Facilitate accreditation system for engineering professionals and providing better employability. Create a platform in which professionals are accepted globally with the accreditation system.
- Support standardization, R&D, test laboratories.
- Working with governments for improving electrical safety scenario, reduce the number of accidents and fatality, support in creating Chartered Electrical Safety Engineer. Support and research on new technologies such as Solar PV, EV, micro grid.

Activities:

Expert Lecture on "Electrical Safety"	29/08/2024
Short video making by the Girls on "Electrical Safety while doing Electrical Practical"	08/03/2025
Health Awareness programme for girl student on Women's Day	05/04/2025



Reel making contest on electrical safety 15/04/2025

Reel making contest on electrical safety 15/04/2025

IEEE Students Chapter:

Dr. A. D. Shiralkar - coordinator

Institute of Electrical and Electronics Engineers (IEEE), is the world's largest professional association. It is dedicated to advancing technological innovation and excellence for the benefit of humanity. IEEE and its members inspire a global community through IEEE's highly cited publications, conferences, standards, professional and educational activities.

IEEE students Chapter, AISSMS IOIT was formed in the year 2014. It is dedicated to serving the purpose of helping its members to enrich their technical knowledge and expertise. Currently, 30 students are active members of the branch volunteering various activities, and 160 students are members. The main focus of this branch is to conduct technical, social, and techno social activities such as webinars, expert lectures, workshops, hands on sessions, and competitions, etc. for students of all branches. It also creates awareness and encourages students to utilize the benefits of IEEE membership, including competitions, and international conference grants.

<table>
<tr><th colspan="2">IEEE ACTIVITIES</th></tr>
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<td>

The Electrical Engineering department in association with PES_IAS Chapter of IEEE Pune Section conducted "The Fourth D.M.Tagare Memorial Lecture" on "Business and Technology Under Emerging Challenges on 27th Mar. 2025.
</td>
<td>


IEEE Women in Engineering Scholarship 2024-25, Laptop Distribution Event for shortlisted female students from Maharashtra funded by Quest Global was held on 22nd Apr. 2025 at our institute.
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POWER QUALITY CELL

POWER QUALITY (PQ) CELL ESTABLISHED IN 2017 AIMS TO PROVIDE HANDS-ON EXPERIENCE TO THE STUDENTS AND HELP VARIOUS INDUSTRIES FOR SOLVING THE PROBLEMS RELATED TO ELECTRICAL POWER QUALITY.

Consultancy Provided to:

1. Elmack Engineering Services Pvt Ltd,
2. pqExcel Solutions LLP,
3. PPS Energy Solutions Pvt. Ltd.
4. Conductor Core Technologies India Pvt. Ltd.,
5. NSK Engineers,
6. Western Metal Industries Private Limited,
7. Crown Pipese

A.Y.: 2024-25
Consultancy offered
4,16,000/-

Training Provide to:

Vulcan India, Bosch Chasis, Mahindra and Mahindra, Finolex Industries

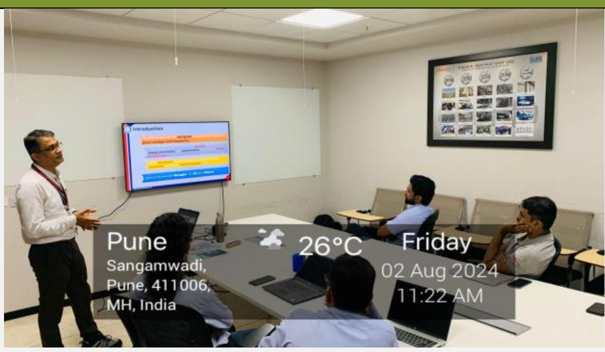
PQ cell Benefits to Students:

- Internship opportunities provided: Total of 04 Students
- Total Final Year Projects – 02
- Products developed – 07
- Hands-on experience opportunities provided – 22 students.
- Placements – 00

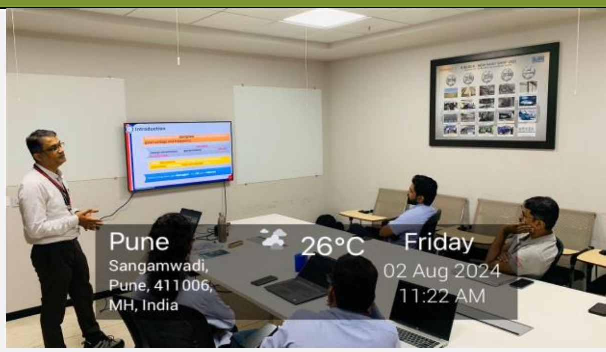
Power Quality Audit Glimpses

PQ Audit , Students accompanying PQ cell in charge Mr. S. V. Shelar (31/08/2024)

PQ Club members at MERC E-Hearing at COEP (27/02/2025)



Session on "Basics of Power Quality" to Mahindra and Mahindra Chakan Engineering (02/08/2024)



Interaction with PQ Cell industry mentor - Mr. Sanjay Gandekar (02/09/2025)

Renewable energy club (REC)

Dr. K. S. Gadgil - coordinator

The department of electrical engineering established the **Renewable energy club (REC)** in 2007 under the guidance of the then HOD Mrs. M. H. Dhend. The club was initially funded by **MEDA (Maharashtra Energy Development Agency)** and MNRE (Ministry of New and Renewable energy sources).

The club was established to enhance the knowledge of students about renewable energy sources and carry out various activities like energy conservation drives, poster competitions, quizzes, slogan competitions etc.

The students of the department carry out energy conservation drives and also celebrates Akshay Urja diwas on 20th August every year.

This A. Y. 2024-25 the Department REC club Activities

20/08/2024	Akshay Urja Diwas Celebration SY Btech:35, TY Btech: 08, BE:04 Expert Lecture by Mr. Rahul Nalawade Former President CEO Panama Renewable energy limited
05/09/2024 to 20/09/2024	Awareness Drive SY Btech:22, TY Btech: 09

Electrical Engineering Students' Association (EESA)

Dr. V. P. Kuralkar – Faculty coordinator
Kunal Chaudhari – EESA President

EESA provides platform for the development of all rounded individuals through co-curricular and extra-curricular activities and which positively impact students' emotional, intellectual, social, and inter-personal development. EESA not only renders forum for students to approach real world tasks but also develop innovative, socially responsible Engineers with High Human Values.

Selection Process

In Electrical Department SE, TE, BE students are members of Electrical Engineering Students' Association. Students nominate themselves for various post of the EESA committee. Under the guidance of Head of the Department, Senior Faculties & EESA coordinator, interview rounds are conducted for various posts of EESA committee to select committee members and further they execute Cultural, Technical & Sports activities throughout the academic year.

EESA Committee Role
General Secretory
Joint General Secretory
Treasurer
Technical Head
EESA Event Coordinator
Renewable Energy Club Coordinator
Sports Secretary
Executive Members Sports Section
T and P Coordinator
Study Circle Coordinator
Library In-charge Study Circle Coordinator
Cultural Event Coordinator

By working together with other individuals, students learn to negotiate, communicate, manage conflict, and lead others. Taking part in these out-of-the-classroom extracurricular and co-curricular activities helps students to understand the importance of critical thinking skills, time management, and academic and intellectual competence.

Each year EESA receives overwhelming response for social activities such as Tree Plantation, Social awareness drive, Food-clothing Donation campaign, Blood Donation Drive, Fort-Hill cleanliness drive.

The Enthusia event held at AISSMS Institute of Information Technology (IOIT) on September 25th and 26th,2023, marked a vibrant and dynamic celebration of talent and innovation. Under the esteemed leadership of Dr. P.B. Mane, the Principal of AISSMS IOIT, the event commenced with an inaugural ceremony that set the tone for two days of engaging activities.
The event encompassed diverse domains, including cultural, technical, and training and placement departments, reflecting the holistic development focus of the institution. Participants and attendees were treated to a spectrum of activities, ranging from cultural performances that showcased the artistic prowess of the students to technical competitions that demonstrated their innovative and problem-solving skills.
The report will delve into the specifics of each department's contributions, highlighting the notable achievements and showcasing the collaborative spirit that defined Enthusia 2024.

Puzzles and Quiz

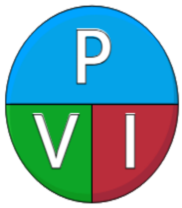
Basic Electrical concept Series and Parallel Puzzle

Mrs. S. D. Raste

Ohm's Law

Formula Permutations

Voltage = Current x Resistance
Current = Voltage ÷ Resistance
Resistance = Voltage ÷ Current



Power, Voltage, & Current

Formula Permutations

Power = Voltage x Current
Voltage = Power ÷ Current
Current = Power ÷ Voltage

Formula Term	Unit
Current (I)	amps (A)
Power (P)	watts (W)
Resistance (R)	ohms (Ω)
Voltage (V)	volts (V)

Series Puzzle 1

Can you type in the missing values? Pay attention to the units!

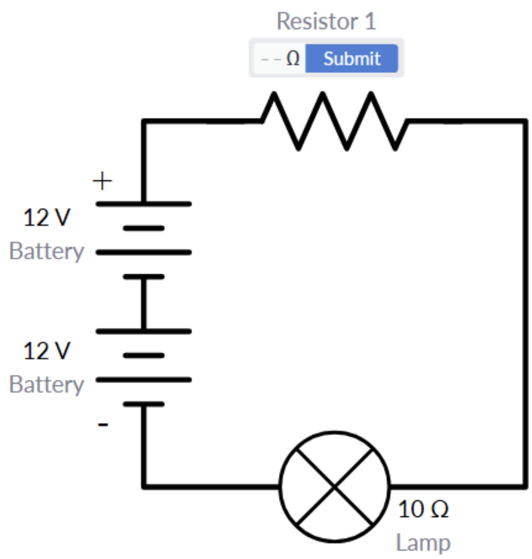
What is the voltage drop across Resistor 1? - - V Submit

What if...?

If the value of Resistor 1 drops to 0 Ω, what would happen to the lamp?

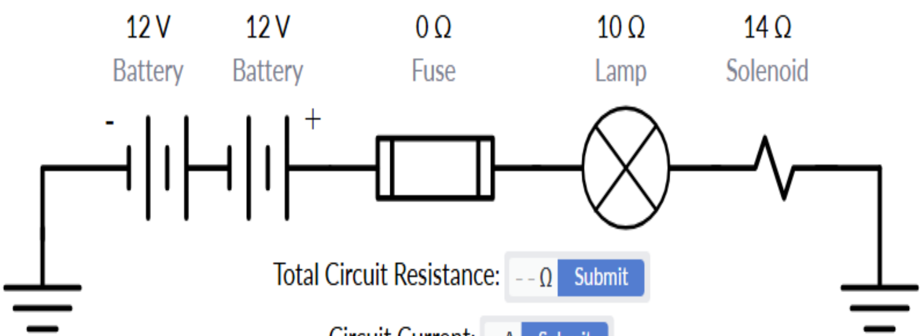
- ☐ The lamp would become dimmer, because the current in the circuit would decrease without the extra resistance.
- ☐ The lamp would become brighter, because the current in the circuit would increase without the extra resistance.

Submit



Total Circuit Resistance: 24 Ω

Circuit Current: - A Submit



Total Circuit Resistance: - - Ω Submit

Circuit Current: - A Submit

Series Puzzle 2

How about this circuit? Enter the missing values.

What is the voltage drop across the solenoid? - - V Submit

How much power is the lamp using?

- - W Submit

Series Puzzle 3

Circuit Resistance:

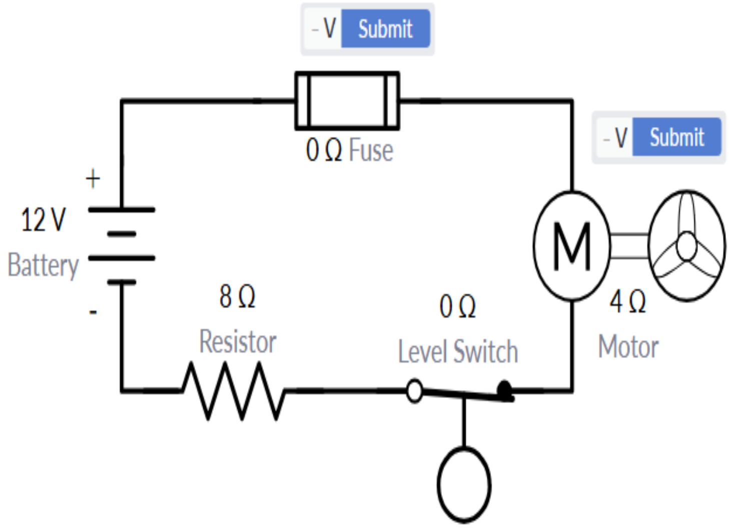
- - Ω Submit

Circuit Current:

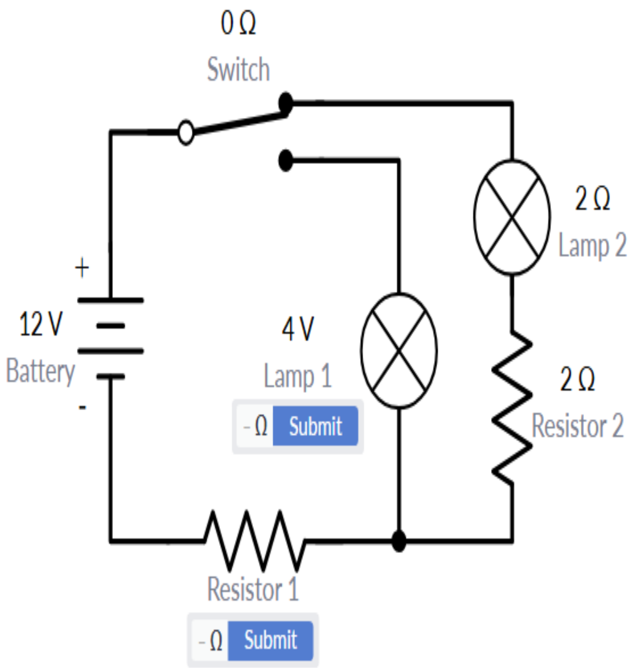
- A Submit

What if...?

If the switch is opened, how many watts will the motor use? - W Submit



Series Puzzle 4



Circuit Current:

1000 mA

(when switch is toggled as shown in schematic)

What if...?

If the switch is operated to the opposite position, what will the circuit current be?

- - - - mA Submit

****

Technical Activities Glimpses

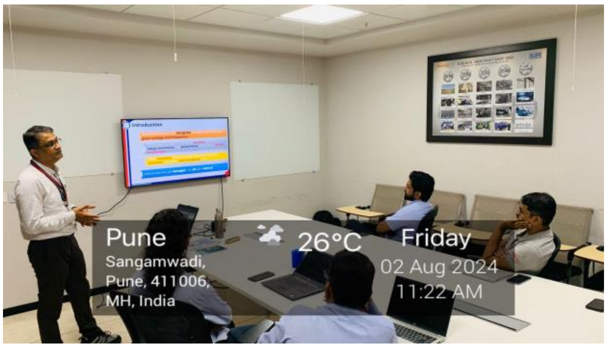
GLIMPS OF THE ACTIVITIES

INDUSTRY INSTITUTE INTERACTION	
 Industrial Visit to 220 KV Parvati Substation on 25th Feb. 2025	 Expert Lecture by Mr.Ankit Javeri on **Design and Costing of Residential and Commercial Wiring** dated **17th Mar. 2025**
 Industrial Visit to 50 MW, Solar Power Plant, Shirsuphal, Baramati, Pune on 8th April 2025	 Expert Lecture byMr. Mukund Kulkarni ,Head – Education and Channel ,EPLAN Software Pvt. Ltd ,Pune on**15/01/2025**

Power Quality and Energy Conservation Cell Activities

PQ Audit , Students accompanying PQ cell in charge Mr. S. V. Shelar (31/08/2024)

PQ Club members at MERC E-Hearing at COEP (27/02/2025)

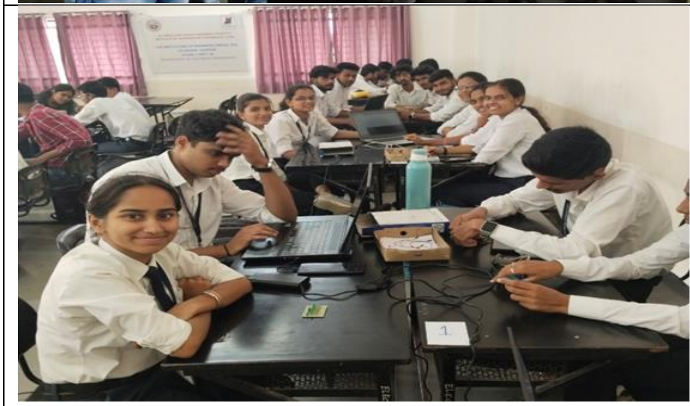


Session on "Basics of Power Quality" to Mahindra and Mahindra Chakan Engineering (02/08/2024)

Interaction with PQ Cell industry mentor - Mr. Sanjay Gandekar (02/09/2024)

WORKSHOPS

1 day hands-on training workshop on “Residential Wiring Design using AUTOCAD” for TY Btech on 15th Apr. 2025



3 Days hands on training workshop on "Internet of Things (IoT)" for TY Electrical during 07.10.2024 to 09.10.2024

Two Days Workshop on Industrial Approach of Electrical and Electronic circuits on 12/08/2024 and 13/08/2024

IEEE ACTIVITIES

The Electrical Engineering department in association with PES_IAS Chapter of IEEE Pune Section conducted "The Fourth D.M.Tagare Memorial Lecture" on "Business and Technology Under Emerging Challenges on 27th Mar. 2025**.**

IEEE Women in Engineering Scholarship 2024-25, Laptop Distribution Event for shortlisted female students from Maharashtra funded by Quest Global was held on 22nd Apr. 2025 at our institute**.**

Renewable Club Activities

Felicitation of guest Mr. Rahul Nalawade,Former President CEO Panama Renewable energy limited by HOD , Dr. A. D. Shiralkar on the occasion of Akshay Urja Diwas on 20/08/2024

Interaction of the guest Mr. Rahul Nalawade with students n the occasion of Akshay Urja Diwas on 20/08/2024

Awareness Drive on Energy Conservation and awareness about Renewable Energy sources - Students giving presentation in schools in and around Pune

Energy Conservation Day celebrated in the department of Electrical Engineering on 16th December 2025 by conducting Online Quiz for SY & TY students.

Winner of Quiz - Mr. Gaurang Panganti from TY Electrical

ISTE and IE (I) Activities

Internal and external evaluators evaluating a project in project competition **Technokratia25**

Internal and external evaluators evaluating a project in project competition **Technokratia 25**

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Felicitation of Expert Er. Pravin Mehetre by HOD Dr. A. D. Shiralkar

TY Activities

TY Student group activity on 5-S organised by TY GFM Mr. A. A. Joshi

5-S Group Activity

ACADEMIC YEAR :

2024-2025

Magazine Editor

Student Editor:

Mukul Fulak
(Student-T. Y. Electrical)

Faculty Editor:

Mr. Sandip Raste
(Assistant Professor)