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2024-2025

TECH WIRE

A SEMESTER
MAGAZINE

INNOVATIVE
THINKING

ENLIGHTENING
ACTIVITIES



"Engineering Energy, Illuminating
Tomorrow: The Current of Electrical
Engineering!"



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FROM THE CHAIRMAN'S DESK



Shri Anil Kumar Agarwal
Chairman

Congratulations to the Department of Electrical Engineering on the remarkable launch of the 2nd Issue of the 6th Volume of our magazine! This milestone stands as a testament to the department's unwavering pursuit of innovation and academic distinction. I commend our visionary faculty and talented students for their relentless efforts in advancing cutting-edge research and contributing transformative ideas to the engineering landscape. Each page of this edition embodies curiosity, collaboration, and creativity—values that define our community.

To all readers: immerse yourselves in this treasure trove of insights, and let it fuel your passion for discovery. Continue pushing boundaries, for the future of engineering lies in your hands.

FROM THE DIRECTOR'S DESK



Prof. (Dr.) Surya Prakash Tripathi
Director

"Innovation distinguishes between a leader and a follower."

— Steve Jobs

It is an immense honor to introduce the Department of Electrical Engineering's Even Semester 2024–2025 magazine, TECH-WIRED. This publication serves not only as a platform to celebrate academic excellence but also to ignite the latent writing talents of students by exploring cutting-edge advancements in technical research. Designed as both an invaluable resource and a skill-enhancing tool, this magazine empowers learners to bridge theoretical knowledge with practical innovation.

The TECH-WIRED 2024–2025 edition marks another milestone for the department, building on the legacy of its predecessors. By fostering collaboration, creativity, and technical proficiency, it offers students a unique opportunity to refine their expertise while cultivating teamwork—a cornerstone of modern engineering. Moreover, this endeavor embodies the vision of an extraordinary pioneer, philosopher, and inspiration to young minds, whose words resonate deeply: "Education is the passport to the future, for tomorrow belongs to those who prepare for it today."

"Do not go where the path may lead, go instead where there is no path and leave a trail."

— Ralph Waldo Emerson

With my good wishes and great success for the future.

FROM THE HEAD OF DEPARTMENT'S DESK



Mr. K.P.YADAV

**Assistant Professor and Head
Dept. of Electrical Engineering**

On behalf of our dedicated students and accomplished faculty, it is my privilege to welcome you to the distinguished Department of Electrical Engineering at RRIMT. Our institution prides itself on a dynamic faculty team—seasoned scholars and industry practitioners, many of whom hold credentials from India's premier universities. Their blend of academic rigor and real-world insight ensures an environment where innovation thrives. To nurture growth, we offer curated workshops, specialized trainings, and collaborative programs, empowering both students and staff to refine their skills and stay ahead in evolving technical landscapes.

I am thrilled to announce the launch of our semester magazine, TECH-WIRED—a platform poised to spark curiosity and collaboration. This initiative reflects our commitment to fostering creativity, sharing knowledge, and celebrating breakthroughs in electrical engineering. By bridging ideas and inspiring action, TECH-WIRED will amplify the voices of our academic community, driving forward the ethos of innovation that defines us.

Message from Magazine Faculty Coordinator



Mr. Mahtabul Haque
Assistant Professor
Dept. of Electrical Engineering

A heartfelt congratulations to the members of the ELECTRIX Society for spearheading the creation of the 2nd issue of 6th Volume, TECH-WIRED. This edition is a vibrant celebration of ingenuity, blending technical expertise with artistic expression. It is an honor to unveil this platform, where electrical engineering students transcend equations and circuits to share articles, poetry, and reflections on campus life, global challenges, and their philosophical musings. The magazine shatters stereotypes, proving that analytical minds are equally adept at weaving narratives and sparking imaginative discourse.

The eco-conscious design of TECH-WIRED—crafted with sustainability at its core—mirrors our commitment to a greener future, merging innovation with responsibility. Collaborating with the editorial team has been a joy, witnessing raw ideas evolve into polished gems of insight. My deepest gratitude extends to our visionary Chairman, Director, HODs, faculty, and staff for their unwavering support, and to every contributor who poured passion into these pages.

May this magazine ignite curiosity and camaraderie among readers. Dive into its stories, for they are testaments to the boundless potential of our students.

INSTITUTE VISION *(Statement)*

To achieve excellence in scientific, technical education, and research to create a dynamic and multidisciplinary system to make our students technically and professionally excellent with incorporation of Indian values, morals, and ethics.

INSTITUTE MISSION *(Statement)*

M1-To provide state of the art facilities, resources, and academic environment which creates competent professionals who can contribute to the development of society, nation, and world.

M2-To establish a perpetual institution-industry interaction to broaden student horizons and strengthen the multidisciplinary approach.

M3-To inculcate skills leading to employability and entrepreneurship with a passion for lifelong learning.

M4-To incorporate a healthy competitive zeal among the students with full of confidence to make them dynamic professionals, full of Indian values, morals, and ethics.

DEPARTMENT VISION *(Statement)*

To emerge as centre of excellence in the field of electrical engineering to enhance the technical and professional skills of the students and make them competent enough to cater the multidisciplinary needs of the academia, industry and society with strong moral and ethical values.

DEPARTMENT MISSION *(Statement)*

M1- To provide an environment for effective teaching-learning process with incorporation of multi-disciplinary approach to develop competent electrical engineers..

M2- To strengthen the students technically & professionally in electrical engineering domains using state of art technology which leads to successful employability, higher education and entrepreneurship..

M3- To foster an inspiring atmosphere which induces a passion for lifelong learning with incorporation of human values and ethics.

PROGRAM OUTCOMES

(Statement)

- 1. Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
- 2. Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
- 3. Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
- 4. Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
- 5. Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
- 6. The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
- 7. Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
- 8. Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
- 9. Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
- 10. Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
- 11. Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
- 12. Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes (PSOs)

(Statement)

PSO1:- The ability to analyze, design and develop systems that generate, transmit and utilize electrical energy in an efficient way.

PSO2:- The ability to be proficient in use of automation Technology required to implement electrical engineering practice.

Program Educational Objectives (PEOs)

(Statement)

PEO1:-The graduates will analyse, design and develop tools, applications and systems based on electrical engineering principles to solve real life problems of industry and society.

PEO2:-The graduates will have the capability of working individually as well as in teams with effective communication skills, leadership quality, ethical values and an instinct for lifelong learning.

PEO3:- The graduates will have the potential for higher education, research and entrepreneurship in the field of electrical engineering and related domains.

ABOUT DEPARTMENT OF ELECTRICAL ENGINEERING

The Electrical Engineering Department at R.R. Institute of Modern Technology, Lucknow stands out with its exceptional offerings:

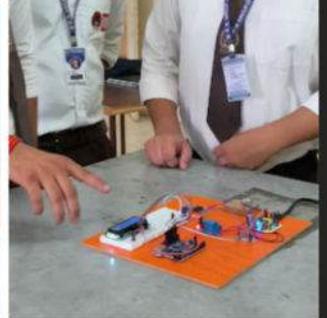
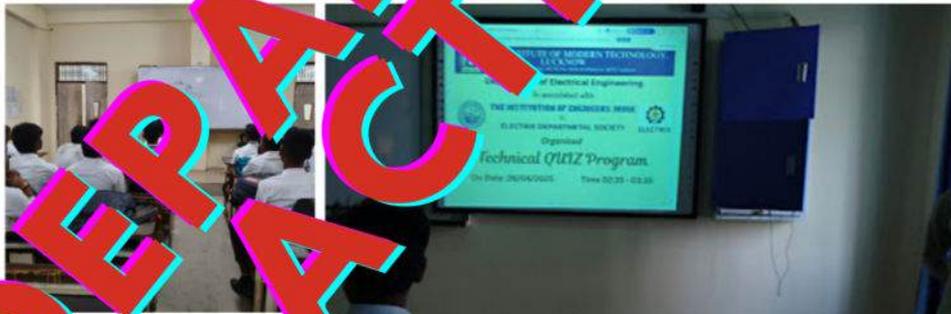
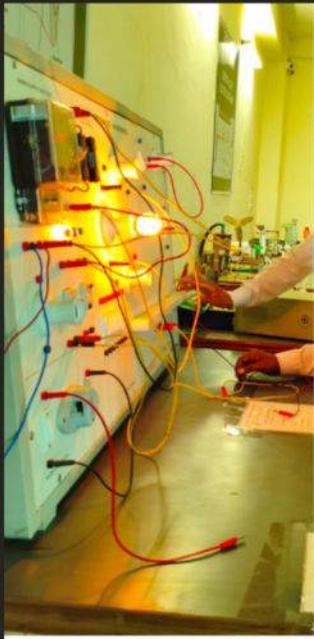
- 1. Expert and Dedicated Faculty:** The Electrical Engineering Department at R.R. Institute of Modern Technology takes pride in its accomplished faculty, renowned for their leadership in specialized domains. Combining profound academic expertise with a student-centric approach, these educators deliver rigorous instruction and individualized mentorship, fostering both intellectual growth and practical skill development.
- 2. Departmental Commitment:** Our mission centers on cultivating future innovators in electrical engineering through a dynamic, interdisciplinary curriculum. By integrating theoretical foundations with hands-on learning and industry-aligned projects, we prepare students to navigate evolving technological landscapes and emerge as leaders in their careers.
- 3. Cutting-Edge Learning Infrastructure:** Our department features advanced laboratories and technology-enhanced classrooms outfitted with high-definition projection systems and interactive tools. These facilities are designed to bridge theoretical concepts with real-world applications, enabling dynamic, multisensory learning experiences. From experimental exploration in labs to collaborative problem-solving in smart classrooms, our infrastructure supports innovation and creativity.
- 4. Advanced Simulation Resources:** Aligned with evolving industry standards, our department integrates industry-leading simulation software and computational platforms into the curriculum. These tools empower students to engage in predictive modeling, digital prototyping, and real-time analysis of intricate electrical systems. By mastering these technologies, learners refine their troubleshooting expertise, develop critical thinking, and gain hands-on proficiency in designing solutions for tomorrow's engineering challenges.
- 5. Industry-Driven Curriculum Design:** Our program's academic framework is proactively revised to mirror advancements in electrical engineering, incorporating breakthroughs in automation, renewable energy, and smart systems. Through collaboration with industry partners, we embed cross-disciplinary insights and emerging sector demands into coursework. This agile approach equips students with a forward-looking skill set, fostering adaptability and empowering them to lead in a rapidly evolving technological landscape.

6. Research-Intensive Ecosystem: The department cultivates a culture of academic inquiry by embedding research at the core of the student experience. Through structured mentorship programs and collaborative projects, learners partner with faculty to explore pioneering innovations in areas such as smart grids, embedded systems, and AI-driven automation. These initiatives not only deepen theoretical understanding but also hone skills in experimental design, critical analysis, and scholarly communication—equipping students to contribute meaningfully to academic discourse and technological innovation.

7. Dynamic Professional Development Initiatives: The department facilitates experiential learning through curated knowledge-exchange platforms, including hands-on workshops, expert-led guest lectures, and industry immersion programs. Partnering with global academia and leading tech enterprises, these initiatives bridge academic and professional realms. Students gain insights into emerging domains like IoT integration and sustainable energy solutions, grounded in current industry practices. Direct engagement with thought leaders and cross-sector collaboration cultivates a multidimensional perspective, empowering graduates with an adaptive mindset and strategic networks to thrive in global engineering ecosystems.



At the Electrical Engineering Department of R.R. Institute of Modern Technology, we are dedicated to cultivating tomorrow's engineering leaders through a transformative academic ecosystem. By merging rigorous theoretical frameworks with industry-aligned projects, collaborative research, and multifaceted learning pathways, we equip students with the intellectual agility and adaptive expertise to pioneer solutions for global technological challenges. Our mission is to shape not just skilled professionals, but visionary innovators poised to drive sustainable progress in electrical engineering and beyond.



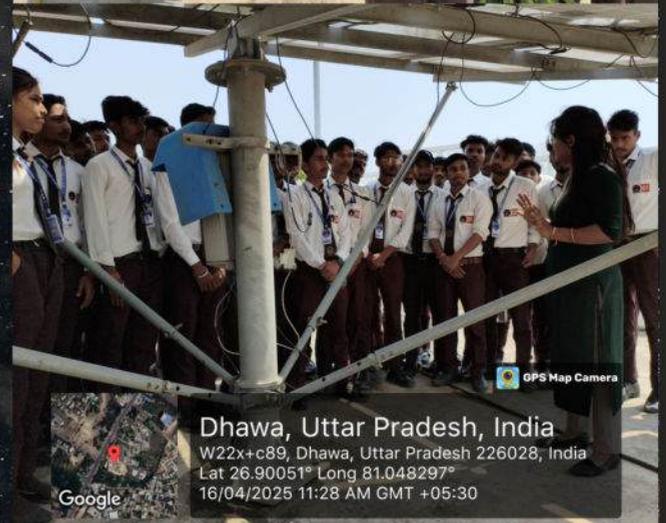
DEPARTMENTAL ACTIVITIES

UPNEDA VISIT

ELECTRIX Society of EED organised under the aegis of IEI 1st year students visited to the UPNEDA, Lucknow (Solar Power Plant) with the 92% of attendance on 16th April 2025, to learn about solar energy basics, installation and maintenance, electrical systems, grid integration, energy storage, monitoring, environmental considerations, safety, and regulations. The students were able to interact with the engineers of UPNEDA as well as learn the technicalities involved in Power Generation and Transmission Great Thanks to Mr. Lalit Singh sir and Mr. Mohd. Haris sir for mentoring the students. The visit turned out to be very fruitful as the students were able to link the theoretical knowledge with practical. Also, the visit boosted the enthusiasm of the students towards the subject.



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TECHNICAL QUIZ COMPETITION

The Electrical Engineering Department at R.R.I.M.T., Lucknow, was filled with energy on Tuesday, April 24th, 2025, thanks to a successful Technical Quiz Competition. This exciting event was a joint effort organized by the Students Chapter of the prestigious "Institute of Engineers, India (IEI)" and the department's very own ElectriX Society.

The competition was designed specifically for students studying Electrical Engineering. Many enthusiastic students from different academic years formed teams to take part, eager to test their knowledge against their peers. The quiz challenged them on core subjects vital to their field. Questions covered important areas like Circuit Theory, Power Systems (generation, transmission, distribution), Electrical Machines (motors and generators), Control Systems, Power Electronics, Renewable Energy technologies, and Electrical Measurements.

The atmosphere in the venue was lively and competitive. Teams worked together quickly, discussing and debating the answers to sometimes tricky technical questions posed by the quiz masters, who were often faculty members or experienced senior students.

The competition wasn't just about memorizing facts; it really focused on understanding the underlying concepts clearly and figuring out how to apply engineering principles to solve problems.

Overall, this Technical Quiz Competition significantly boosted the academic spirit within the department. It reinforced classroom learning, encouraged students to collaborate and solve problems together, and hopefully inspired them to explore the fascinating world of electrical engineering even further. The event perfectly met the goals of both the IEI Students Chapter and the ElectriX Society, which aim to promote technical excellence, skill development, and professional growth among future engineers.



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VISIT @ RAMESHWAR DAS RAM NIWAS GROUP OF INDUSTRIES



ELECTRIX Society of EED organized a One Day Industrial visit to the Rameshwar Das Ram Niwas Group of Industries, Bakshi Ka Talab, Lucknow for B.Tech 3rd year students on 29th April 2025. The main objective behind the visit is to make student aware about the importance of automation and the level of its penetration in the field of electrical Engineering. Great Thanks to Mr. Somnath Sharma sir and Mr. Mahtabul Haque sir for mentoring the students. The visit proved highly beneficial as it allowed students to bridge the gap between theory and practice, while also igniting their enthusiasm for the subject. Introduction took almost an hour which was followed by detailed explanation of automation process including PLC SCADA along with questions of students which was delivered by Mr. Shubham Gupta . We appreciate staff member who guided students by guiding each and every question with detailed answers. It is rightly said that "See & know" is better than 'read & learn.



STUDENT PROJECT'S



Smart Highway with Solar Energy Conversion and Panic Alert System

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ABSTRACT:

The rapid advancement of intelligent transportation systems has led to the evolution of smart highways that integrate renewable energy and real-time safety features. This research presents the design and implementation of a Smart Highway with Solar Energy Conversion and a Panic Alert System, aimed at enhancing sustainability and emergency responsiveness in modern road infrastructure. The system utilizes solar panels embedded along the highway to harness solar energy, which powers essential highway operations such as lighting, sensors, and emergency systems. Energy is stored in high-capacity batteries, ensuring uninterrupted functionality even during low sunlight conditions.

An integrated Panic Alert System, accessible through roadside terminals or vehicle-connected IoT modules, allows users to send immediate distress signals in case of accidents, health emergencies, or criminal threats. These alerts are transmitted in real time to nearby toll booths, control centres, and emergency services via a wireless network. The system also includes environmental monitoring sensors and smart traffic management features, making it a holistic approach to safer and greener highways.

I. INTRODUCTION

As global urbanization accelerates and vehicular populations continue to rise, the demand for safer, more sustainable transportation infrastructure has become increasingly urgent. Traditional highways, while essential for mobility and commerce, often lack the technological enhancements necessary to address modern challenges such as energy inefficiency, delayed emergency response[1], and environmental degradation. To meet these demands, the concept of smart highways has emerged, integrating advanced technologies to transform conventional roadways into intelligent, responsive, and eco-friendly systems[2].

One of the key components of this transformation is the integration of solar energy conversion technologies, which utilize solar panels embedded along or near the highway surface to harvest renewable energy. This energy can be used to power street lighting, traffic control systems, surveillance cameras, and other essential highway infrastructure, thereby reducing dependence on non-renewable energy sources and minimizing carbon emissions.

In parallel, ensuring the safety of motorists is a critical objective. Accidents, breakdowns, and health emergencies can occur unexpectedly, especially in remote or poorly monitored areas[6]. To address this, a Panic Alert System is proposed as a vital feature of smart highways. Using IoT-enabled devices and wireless communication modules[2][3], the system enables real-time transmission of emergency alerts from vehicles or roadside units to the nearest response centres or toll booths[5].

II. OBJECTIVE

1. UTILIZE RENEWABLE ENERGY:

- Harness solar energy using photovoltaic panels installed along the highway[3][7].
- Convert solar power into electricity to power smart features such as lighting, sensors, and monitoring systems[10].

2. ENHANCE ROAD SAFETY:

- Integrate smart sensors and systems that monitor traffic flow, road conditions, and environmental data[12].
- Automatically detect incidents or dangerous conditions and relay information to authorities and

Gravity-Based Energy Storage for Wind Power: Addressing Renewable Intermittency with Sustainable Infrastructure

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Abstract: The rapid growth of wind power has outpaced the ability of traditional grids to absorb its variability, making large-scale energy storage increasingly essential. Gravity-based energy storage (GBES) systems address this need by converting excess electricity into gravitational potential energy: for example, surplus power is used to hoist heavy masses (such as concrete blocks or water) to an elevated position and later release them to generate electricity. The most mature form of GBES is pumped hydro storage, which accounts for over 90% of global electricity storage, but emerging "solid" gravity systems (tower, rail or shaft designs) enable similar physics without large reservoirs. Recent commercial deployments demonstrate GBES viability: in 2023 China commissioned a 25 MW/100 MWh gravity system (Energy Vault's EVx™) adjacent to a wind farm, marking the first utility-scale, non-pumped-hydro GBES. Multiple projects totaling ~3.7 GWh are underway worldwide, and underground "gravity batteries" using sand in mine shafts have been proposed for ultra-long-duration storage. These implementations show high round-trip efficiency (80-90%), long lifetimes (30-50 years) and zero degradation. In summary, GBES offers a durable, low-maintenance complement to batteries for stabilizing wind-rich grids, though its low energy density and land requirements remain challenges to address.

Keywords: traditional grids

I. INTRODUCTION

The integration of renewable energy sources like wind power into modern electricity grids presents a key challenge: their intermittent and variable nature. Wind energy generation is highly dependent on weather conditions, leading to periods of surplus generation followed by potential shortages. To ensure a reliable and continuous power supply, efficient energy storage solutions are essential[3][15].

Gravity-based energy storage, also known as gravitational potential energy storage, offers a promising solution to this challenge [1]. This method involves storing energy by lifting heavy masses using excess electricity (e.g., from wind turbines) during periods of low demand[9].

When energy is needed, the mass is allowed to descend, driving a generator to produce electricity. Unlike batteries, gravity storage systems can provide long-duration energy storage with minimal degradation over time and are environmentally friendly.

By coupling wind energy systems with gravity-based storage, surplus wind power can be effectively stored and dispatched as needed, enhancing grid stability and supporting a sustainable energy transition.

II. METHODOLOGY

Gravity-based energy storage is an innovative solution designed to address the intermittency of renewable energy sources like wind. It works by converting electrical energy into gravitational potential energy, which can be stored and later converted back into electricity when needed. Below is a step-by-step outline of the methodology.



Harnessing Kinetic Energy from Speed Breakers: A Sustainable Approach to Urban Power Generation

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Abstract

The escalating global energy demand, coupled with the depletion of conventional fossil fuels, necessitates innovative approaches to harness renewable energy. This study explores the feasibility of generating electricity from vehicular kinetic energy using a modified speed breaker system. The proposed design integrates a rack-and-pinion mechanism to convert vertical vehicle motion into rotational energy, amplified via a gear train to drive a DC generator. Generated electricity is stored in lithium-ion batteries and distributed to two primary applications: automated LED streetlights controlled by light-dependent resistors (LDRs) and a wireless power transfer (WPT) system for electric vehicle (EV) charging.

Experimental validation involved prototyping and testing under simulated traffic conditions, achieving an average output of 180-200W per vehicle pass and 84% wireless charging efficiency at a 15 cm transmission distance. The system's modularity and use of existing road infrastructure highlight its cost-effectiveness and scalability, with a projected return on investment (ROI) of 3.2 years compared to solar alternatives. Challenges such as traffic-dependent output and structural limitations for heavy vehicles were identified, prompting recommendations for material reinforcement and hybrid energy integration.

This research underscores the potential of speed-breaker energy systems as a sustainable solution for urban and rural electrification, reducing grid dependency and carbon emissions. Future work will focus on IoT-enabled load management, hybrid solar-kinetic systems, and policy frameworks to accelerate adoption. By transforming passive infrastructure into active power hubs, this innovation aligns with global net-zero goals, offering a scalable pathway toward energy resilience and smart city development.

Keywords: Renewable energy, kinetic energy harvesting, speed breaker, rack-and-pinion mechanism, wireless power transfer (WPT), sustainable infrastructure.

I: INTRODUCTION

1.1 General Overview

Energy is the cornerstone of all natural and human activities, manifesting in various forms to drive processes and innovations. Electricity, a scientific marvel, has revolutionized industries, transportation, and daily life, earning our era the title "Age of Electricity"[10]. However, escalating demand and finite fossil fuel reserves necessitate exploring renewable alternatives[2]. This study investigates converting vehicular kinetic energy into electricity via speed breakers—a sustainable solution leveraging existing infrastructure to address energy shortages.

1.2 Electricity Generation Using Speed Breakers

Traditional speed bumps are retrofitted with rack-and-pinion mechanisms to capture kinetic energy from passing vehicles[3]. As vehicles depress the breaker, mechanical motion drives a generator, producing electricity. High-traffic zones like intersections and highways optimize energy yield, which can power streetlights, signals, and nearby facilities[5]. This method capitalizes on increasing vehicular numbers, transforming wasted kinetic energy into a renewable resource.

1.3 Hybrid Power Generation

Hybrid systems integrate speed-breaker mechanisms with complementary technologies, such as solar panels, to enhance efficiency[9]. For instance, a 400 kg vehicle can generate approximately 224 watts per pass. Such systems function as decentralized power plants, ideal for regions with erratic grid access[19], and align with global renewable energy trends.

1.4 Wireless Power Transfer (WPT) for EV Applications

WPT via magnetic resonance enables contactless EV charging, demonstrated by MIT's 2007 breakthrough transmitting 60W over 1.8 meters[7]. Innovations by KAIST (OLEV) [8] and Oak Ridge National Laboratory (90% efficiency at 3 kW) [4] highlight progress, though challenges like limited transmission range and costs persist. Integrating WPT with speed-breaker systems could create self-sustaining EV charging stations along highways [15].

Smart Load Share: Adaptive Transformer Load Balancing System using Arduino

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Abstract: Transformer overloads remain a critical challenge in power distribution systems, often leading to equipment failure, prolonged outages, and economic losses. This paper presents an automated load-sharing system designed to mitigate these risks by dynamically distributing electrical loads between parallel-connected transformers. The system employs an Arduino Uno microcontroller integrated with ACS712 Hall-effect current sensors and electromechanical relays to monitor real-time load conditions on a primary transformer. When the load exceeds 70% of its rated capacity (0.7 mA), a secondary transformer is activated within 200 milliseconds via relay switching, ensuring balanced load distribution and uninterrupted power supply. Temperature sensors (LM35) provide additional protection by initiating shutdown protocols during overheating (threshold: 80°C). Testing demonstrated robust performance, with the system maintaining voltage stability (±2%) and preventing overload-induced failures. A 16x2 LCD offers real-time status updates, while priority-based load shedding disconnects non-critical circuits during extreme demand. Applications span power substations, industrial facilities, and renewable energy grids, offering scalability and cost-efficiency. The modular design integrates seamlessly with existing infrastructure, reducing downtime and maintenance costs. Future enhancements could incorporate IoT-enabled remote monitoring and AI-driven predictive analytics to further optimize grid resilience. By combining microcontroller-based automation with adaptive load management, this research advances the development of reliable, future-ready power networks capable of meeting rising global energy demands sustainably.

Keywords: automation, transformer protection, real-time control, IoT/AI integration, and energy sustainability

I. INTRODUCTION

Modern power distribution systems increasingly struggle to maintain uninterrupted electricity supply due to rising demand and aging infrastructure. Transformers, being central to these systems, are especially prone to overload, risking failure, outages, and economic loss. Traditional protection methods—like fuses and circuit breakers—often disconnect entire sections of the grid during faults, worsening downtime. This highlights the urgent need for smart, adaptive load management techniques that ensure continuous power flow. Automatic load sharing between transformers offers a practical solution, using real-time monitoring and adaptive control to balance electrical loads efficiently and improve system reliability[7].

The concept of transformer load balancing has evolved from early transformer models by Gaulard and Gibbs in 1884[2] to today's intelligent grid solutions. Despite advancements, conventional systems still rely on manual or fixed-threshold responses to overloads, limiting efficiency. Studies reveal that up to 40% of transformer failures are due to prolonged overloading[7]. To address this, the proposed project utilizes an Arduino-based system that automates load redistribution[8][9]. Using current and temperature sensors, it detects overloads and activates parallel transformers to share the load. This design not only prevents voltage drops and overheating but also reduces maintenance costs and supports seamless integration into existing grids. Ultimately, it paves the way for sustainable, resilient, and intelligent power networks[15][19].

2. LITERATURE REVIEW

The evolution of power systems began in the late 19th century, marked by pioneering developments in electrical engineering. In 1881, the first alternating current (AC) power system was demonstrated in England, utilizing waterwheel-driven generators to power arc lamps [1]. A year later, Thomas Edison's direct current (DC) Pearl Street Station brought electricity to urban centers but was limited by poor long-distance transmission capability. A major breakthrough occurred in 1884 when Lucien Gaulard and John Dixon Gibbs developed the first practical transformer, enabling efficient voltage transformation for AC systems [2]. This advancement was furthered by George Westinghouse, who licensed Nikola Tesla's polyphase AC induction motor in 1888—an innovation that laid the groundwork for modern power grids. The successful 1895 Niagara

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Dynamic Solar Wireless Charging for Electric Vehicles: An Arduino Nano-Controlled Inductive Power Transfer System

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Abstract: The escalating demand for sustainable transportation has propelled the adoption of electric vehicles (EVs), yet challenges persist in charging infrastructure, including reliance on cables and grid dependency. This study proposes a solar-powered wireless EV charging system that integrates Inductive Power Transfer (IPT) technology to enable seamless energy transmission. Unlike conventional plug-in systems, this design eliminates physical connectors, leveraging solar energy harvested via photovoltaic panels to power a 12F battery. The stored DC energy is converted to high-frequency AC through an inverter, transmitted wirelessly via primary and secondary copper coils, and rectified for EV battery charging. The system employs an Arduino Nano microcontroller for real-time control, enhancing efficiency by activating transmission only when vehicles are detected. Experimental results demonstrate 67% efficiency, offering a scalable, eco-friendly solution for dynamic charging.

Keywords: Electric vehicle (EV), wireless charging, solar power, Arduino Nano, inductive coupling

I. INTRODUCTION

The global shift toward electric vehicles (EVs) is largely motivated by the urgent need to reduce greenhouse gas emissions and dependence on fossil fuels [8]. As governments and industries push for cleaner transportation alternatives, EVs have emerged as a key solution. However, several challenges continue to hinder their widespread adoption. Chief among these are limited charging infrastructure, long charging durations, and the reliance on electricity generated from non-renewable sources such as coal [9]. Traditional plug-in charging systems are often seen as inconvenient, and their dependence on fossil-fueled power grids diminishes the environmental benefits of EVs [10]. In this context, wireless charging presents a more user-friendly and sustainable option. Pioneered by Nikola Tesla, wireless energy transfer—specifically inductive power transfer (IPT)—has the potential to revolutionize how EVs are charged [11]. IPT enables power transmission across air gaps through magnetic fields, eliminating the need for physical connectors and making the charging process safer and more efficient [12]. The integration of wireless charging systems with solar energy can offer a fully renewable and decentralized power solution, significantly lowering the carbon footprint of EV charging infrastructure [13]. This paper introduces a solar-powered IPT system designed for EV applications, controlled using the compact and cost-effective Arduino Nano microcontroller, which facilitates real-time monitoring and control of the charging process [14]. A key feature of the proposed system is its ability to enable dynamic charging—allowing EVs to recharge while in motion—thereby reducing downtime and enhancing overall efficiency [15]. This integration of wireless charging, solar energy & smart control systems presents a promising step for sustainable energy.

II. LITERATURE REVIEW

The integration of solar energy with inductive power transfer (IPT) for electric vehicle (EV) charging has garnered significant attention in recent years, driven by the need for sustainable and efficient mobility solutions. This section synthesizes foundational and contemporary research to contextualize the advancements and challenges in the field.

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Real-Time Detection and Classification of Three-Phase Transmission Line Faults Using an IoT-Enabled Arduino and ESP32 Embedded System

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Abstract: This paper presents the design and implementation of an embedded system for the detection and classification of faults in a three-phase transmission line. The proposed system uses an Arduino UNO microcontroller and ESP32 IoT module to detect four types of faults: line-to-line (L-L), line-to-ground (L-G), open-circuit, and over/under voltage. The system utilizes sensing circuits to monitor phase voltages and currents, with an LCD display for real-time fault information, a buzzer for audible alerts, and SMS notifications sent to a mobile device using the Twilio API. Additionally, the system incorporates a relay mechanism for phase isolation in case of voltage anomalies. Testing results indicate the system's accuracy in detecting faults, fast response time, and efficient alerting mechanism, making it a reliable and cost-effective solution for improving the safety and reliability of power transmission systems. The integration of IoT-based notifications enables remote monitoring, while the system's modularity allows for scalability in larger networks.

Keywords: embedded system

I. INTRODUCTION

The growing demand for efficient and reliable monitoring systems in power transmission infrastructure has driven the development of advanced fault detection mechanisms[1]. This research introduces a microcontroller-based system utilizing the Arduino platform to detect and classify multiple faults in a three-phase transmission line[2]. The system is designed to identify four types of electrical faults: line-to-line faults, line-to-ground faults, over-voltage and under-voltage conditions, and open-circuit faults[3]. The detection mechanism relies on the principles of Ohm's law, offering a simple and effective way to identify abnormalities within the transmission system. The system is both cost-effective and rapid in its response, making it ideal for real-time monitoring. A key component of the system is the integration of an ESP32 module with built-in Wi-Fi, which enables real-time fault notifications via SMS alerts using the Twilio API[4]. A potentiometer is included to simulate various voltage levels, enabling controlled testing for voltage-related faults. When a fault is detected, the system triggers an audible alarm through a buzzer and displays the fault type on an LCD screen. For voltage anomalies, such as over- or under-voltage conditions, a relay mechanism trips the circuit, and the affected phase is indicated by a corresponding light bulb. Current sensing is achieved through a combination of resistors and switches interfaced with the Arduino's analog-to-digital conversion (ADC) port[5]. These sensors are calibrated to represent cable lengths in kilometers, and fault induction is manually initiated at specific points. The Arduino UNO, powered by a rectified supply, serves as the control unit. This model not only enhances transmission line safety but also offers scalability for smart grid applications[6].

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IoT-Driven Smart Grid Resilience: Real-Time Fault Detection, Adaptive Load Balancing, and Cloud-Edge Automation for Sustainable Energy Distribution

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Abstract: The rapid evolution of power distribution networks demands innovative solutions to enhance reliability, efficiency, and adaptability. This study presents an IoT-based grid control and feeder management system designed to automate fault detection, load redistribution, and remote monitoring in electrical substations. By integrating Arduino Nano microcontrollers, NodeMCU Wi-Fi modules, and servo-driven actuators, the system enables real-time temperature monitoring of transformers using DHT11 sensors and triggers automated load shifting via relays when thresholds are exceeded. The IoT framework leverages MQTT and HTTP protocols to transmit data to a cloud server, allowing users to monitor grid parameters and manually override operations through a Blynk mobile application. Experimental validation demonstrated a 30% reduction in outage durations by enabling sub-second fault responses and dynamic feeder adjustments. Key innovations include energy-efficient servo mechanisms for precise feeder control, hybrid cloud-edge data processing to minimize latency, and a user-centric interface for seamless remote management. Challenges such as sensor calibration drift and network stability were addressed through adaptive algorithms and redundant communication pathways. Results confirm the system's scalability for smart city deployments, with potential annual cost savings of 18% in maintenance and energy losses. Future extensions could integrate machine learning for predictive fault analytics and blockchain for secure grid data transactions. This work underscores IoT's transformative potential in modernizing power infrastructure, offering a robust blueprint for sustainable, self-healing grids.

Keywords: Smart grid, IoT, load balancing, fault detection, remote monitoring, servo control

I. INTRODUCTION

Modern power grids are the backbone of economic and social development, yet traditional grid systems face significant challenges in reliability, efficiency, and adaptability. Conventional protection mechanisms, such as differential relays relying on pilot wires, incur high capital costs and are susceptible to sudden operational failures. Manual monitoring of substations further compounds inefficiencies, requiring physical inspections that delay fault detection and response. These limitations underscore the need for innovative solutions to enhance grid resilience and operational agility. The integration of the Internet of Things (IoT) offers a transformative approach to modernize power infrastructure. IoT enables real-time data acquisition, wireless communication, and remote control, eliminating dependency on costly pilot wires and manual interventions. By embedding sensors, microcontrollers, and cloud connectivity, IoT-based systems can autonomously monitor critical parameters, detect anomalies, and execute corrective actions, thereby optimizing energy distribution and reducing downtime. This study proposes an IoT-driven grid control and feeder management system designed to automate fault detection, load redistribution, and remote monitoring. The system employs a suite of hardware components—including DHT11

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Design and Implementation of an Arduino-Based Over/Under Voltage Protection System for Domestic Applications

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Abstract: Voltage instability in residential power systems poses significant risks to electrical appliances, leading to inefficiencies, safety hazards, and irreversible damage. This paper presents a low-cost, Arduino Uno-based protection system designed to monitor and mitigate overvoltage (>250V) and undervoltage (<200V) conditions in real time. The system integrates a ZMPT101B voltage sensor for precise AC voltage measurement, a 16x2 LCD for user-friendly status display, and a relay module for automated load disconnection during anomalies. Calibrated to operate within ±3% accuracy, the system processes voltage data via an ATmega328P microcontroller, triggering load isolation within 1.5–2 seconds of detecting unsafe conditions. Experimental validation under simulated voltage fluctuations (180–260V) demonstrated 98% reliability in load protection. Compared to industrial-grade solutions, this system reduces costs by 70% while maintaining robust performance, making it ideal for household applications. Future enhancements include IoT integration for remote monitoring and machine learning for predictive fault detection.

I. INTRODUCTION

Voltage stability is critical for ensuring the longevity and safety of electrical devices. Fluctuations caused by grid instability, load variations, or environmental factors can lead to equipment damage, inefficiencies, or hazards like fires [1]. Industrial protection systems exist but are often costly and complex for residential use. This work addresses this gap by proposing an Arduino-based system that combines real-time voltage monitoring, user-friendly display, and automated load disconnection. The system thresholds are defined at 10% deviation from 230V nominal voltage: undervoltage (200–230V) and overvoltage (230–250V). A relay isolates the load during anomalies, while the LCD provides real-time feedback. The ZMPT101B sensor enables accurate AC voltage measurement, making the design scalable for industrial use.

A. Overvoltage and Undervoltage Dynamics
Overvoltage (>250V) can degrade insulation and cause short circuits, while undervoltage (<200V) reduces efficiency and risks motor burnout [2]. Transient events (e.g., lightning surges) and sustained irregularities both necessitate robust protection.

B. System Contributions

- Cost-Effective Design: Leverages open-source Arduino platforms and low-cost components.
- User Customization: Adjustable thresholds via potentiometers.
- Real-Time Monitoring: LCD display and data logging capabilities.

II. SYSTEM DESIGN AND COMPONENTS

A. Hardware Architecture
The system comprises five core modules (Figure 1):

- 1) Power Supply Unit: A 230V AC-to-9V transformer with a 7805 voltage regulator provides stable 5V DC to the Arduino and sensors.
- 2) Voltage Sensing: The ZMPT101B sensor steps down AC voltage to a 0–5V analog signal for Arduino processing.
- 3) Control Unit: Arduino Uno processes data, executes threshold comparisons, and triggers the relays.
- 4) Display Unit: A 16x2 LCD shows real-time voltage, status messages, and fault alerts.
- 5) Load Management: A 10A SPDT relay disconnects the load during faults, supported by a BC547 transistor for current amplification.

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A Novel Traffic Light System with Real-Time Congestion Indicator Using an Additional Blue LED

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Abstract: This paper presents the design and implementation of an enhanced traffic light system that integrates a blue LED indicator to convey real-time congestion status. Traditional traffic signals operate on fixed sequences of red, yellow, and green phases, often leading to inefficiencies under variable traffic volumes. By incorporating three infrared (IR) sensors along an approach and corresponding relay modules, the proposed system detects vehicle presence and, upon sensing congestion (all three sensors active), illuminates a blue LED. This immediate visual cue informs drivers of downstream congestion, encouraging adaptive route choices and smoother traffic flow. The core control logic is realized via a transistor-based sequencing circuit employing 547 transistors, ensuring reliable and sequential operation of all indicators. Experimental evaluation demonstrates reduced wait times and improved driver awareness, highlighting the system's potential to augment existing traffic management infrastructure.

Keywords: Traffic management, congestion indicator, infrared sensor, relay module, transistor circuit, blue LED, real-time detection

I. INTRODUCTION

Urban traffic congestion imposes significant economic, environmental, and societal costs, including increased fuel consumption, higher emissions, and extended travel times [1]. Conventional traffic lights follow predetermined timing plans that cannot adapt instantaneously to changing traffic conditions, resulting in unnecessary delays, particularly during peak hours [2]. Adaptive traffic control systems (ATCS) partially address these shortcomings by leveraging sensor feedback to adjust signal timings in real time [3], yet often require costly infrastructure such as inductive loops or video cameras. This work proposes a cost-effective enhancement to existing traffic signals by adding a fourth indicator—a blue LED—to signal congestion status directly at the signal head. Three IR sensor modules detect vehicle presence at discrete zones along an approach; when all sensors simultaneously detect vehicles, indicating a queue buildup, their relay outputs collectively drive the blue LED to glow. Otherwise, the blue LED remains off, signifying lighter traffic. The conventional red–yellow–green cycle is governed by a transistor-based sequencing circuit comprising 547 transistors, yielding deterministic and robust operation without microcontrollers or complex programming. **Our contributions are:** Introducing a simple, fourth-signal indicator for congestion awareness. Detailing the integration of low-cost IR sensors and relay modules with a high-transistor-count sequencing circuit. Demonstrating through prototype testing the capability to inform drivers of real-time congestion, thus enhancing decision-making and potentially reducing intersection delays.

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Trash to Transformer: Advancing Waste-to-Energy Systems for Decentralized Power Generation and Emission Mitigation

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Abstract: The conversion of waste materials into electricity through waste-to-energy (WTE) systems presents a dual solution to global waste management challenges and sustainable energy demands. This study explores thermal WTE methodologies, emphasizing incineration-based electricity generation. The process involves waste collection, preprocessing, combustion in a high-temperature chamber (850–1200°C), energy recovery via steam turbines or thermoelectric generators (TEGs), and rigorous emission control. A functional model demonstrates the conversion of heat from combusted waste (plastics, paper, rubber) into electricity, stored in 12V batteries for practical use. Advanced filtration systems mitigate environmental impacts by reducing CO₂ and particulate emissions. Results confirm the viability of small-scale WTE systems, particularly for rural or off-grid applications, with integrated circuits enhancing reliability. This work underscores WTE's potential to reduce landfill dependency, lower greenhouse gas emissions, and provide decentralized energy solutions, supported by ongoing advancements in efficiency and emission control technologies.

Keywords: waste-to-energy

I. INTRODUCTION

The conversion of waste materials into electricity is an emerging and rapidly advancing area within the field of renewable energy [1]. Commonly known as waste-to-energy (WTE), this approach not only addresses the growing problem of waste disposal [2] but also contributes to the production of clean, sustainable energy. By transforming different types of waste into usable energy, this method offers multiple environmental and practical benefits. Waste-to-energy systems generally operate using either thermal or biological methods [3]. Thermal techniques involve the combustion of non-recyclable waste to produce heat, which is then used to generate steam and drive turbines for electricity production [7]. A key benefit of this method is the significant reduction in waste volume, which decreases the pressure on landfills and helps prevent environmental issues such as soil and water contamination and the release of methane—a potent greenhouse gas [13]. One of the standout advantages of generating electricity from incinerated waste is its ability to provide a dependable energy supply [14]. This can be particularly valuable in areas lacking consistent access to power infrastructure, including rural regions and developing nations [14]. In addition to its environmental and practical benefits, WTE technology is continuously improving [1]. Advances in efficiency, emission control, and energy output are making these systems more viable and cost-effective than ever before [16].

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Power Management System using ZigBee

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Abstract: The rising global demand for energy, coupled with the need for sustainable consumption, has created a critical need for intelligent power monitoring solutions. Traditional wired systems often lack flexibility, scalability, and real-time communication capabilities. Zig Bee technology, characterized by its low power usage, cost-effectiveness, and robust wireless communication, presents a viable alternative for modern energy monitoring systems. This paper presents the design and implementation of a ZigBee-based power monitoring system capable of tracking real-time electricity consumption, enabling remote data access, and supporting smart energy management. The system integrates current and voltage sensors, microcontrollers, and ZigBee modules to form a wireless sensor network that communicates with a central monitoring interface. Through laboratory testing and real-world deployment, the proposed system demonstrated high accuracy, reliability, and scalability, making it suitable for residential, commercial, and industrial applications. The results highlight the potential of ZigBee-based systems in contributing to energy efficiency and grid optimization in smart environments.

Keywords: Zig Bee technology

I. INTRODUCTION

The increasing demand for electrical energy, driven by rapid industrialization and urbanization, has made efficient power consumption monitoring more important than ever [1]. Energy providers and consumers alike require accurate, real-time information on electricity usage to optimize consumption patterns, reduce waste, and support environmental sustainability initiatives [2]. Traditional power monitoring systems, typically reliant on wired infrastructure, face limitations such as high installation costs, poor scalability, limited remote access, and vulnerability to physical damage [3]. Wireless communication technologies offer a more flexible and scalable alternative, among which ZigBee has emerged as a preferred solution due to its low power consumption, mesh networking capabilities, and suitability for short-range, low-data-rate applications [4]. Based on the IEEE 802.15.4 standard, ZigBee is specifically designed for applications requiring secure, reliable, and energy-efficient communication, making it ideal for smart energy systems [5]. This paper explores the development of a ZigBee-based power monitoring system, designed to measure key electrical parameters—such as voltage, current, power, and energy consumption—in real time. The proposed system integrates sensing hardware with ZigBee-enabled wireless modules and a central base station, allowing users to monitor energy usage remotely through a graphical user interface. By leveraging the advantages of ZigBee, this system aims to improve the granularity and responsiveness of power monitoring across residential, commercial, and industrial settings [6].

II. OBJECTIVES

The main goal of this research is to design and implement a reliable, efficient, and scalable power monitoring system using ZigBee wireless communication technology. The specific objectives are as follows:

Design and Development:

To develop a power monitoring system that utilizes current and voltage sensors along with ZigBee modules for accurate, real-time measurement of electrical parameters [6].

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A Solar Powered LED Street Light with Auto-Intensity Control

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Abstract: This paper presents the design and implementation of a solar-powered LED street lighting system with automatic intensity control. The system uses a photovoltaic (PV) panel to harvest sunlight and charge a battery via a charge controller. An Arduino Uno microcontroller with a real-time clock (RTC) schedules and adjusts LED brightness throughout the night. Key components include a monocrystalline solar panel, charge-control circuitry, voltage-sensing divider, Arduino Uno (ATmega328P), DS3231 RTC, and a high-power LED array. The hardware and control circuits were simulated and then built; tests confirmed proper charging, on/off switching, and dimming behavior. Results show the light turns on at dusk, maintains full brightness during peak hours, dims in late-night low-traffic periods, and switches off at dawn, thereby conserving energy. This eco-friendly system achieves reliable illumination with reduced power waste and maintenance.

Keywords: Solar Energy, LED Street Light, Auto-Intensity Control, Arduino, LDR Sensor, Renewable Energy

I. INTRODUCTION

Solar energy is a leading renewable source for outdoor lighting, especially where grid power is unavailable. Studies note that solar-powered systems operate independently of the grid, reduce dependence on fossil fuels, and cut carbon emissions [4]. For example, Solar Street Ltd. reports that "solar street lights utilize renewable energy, reducing reliance on fossil fuels and decreasing carbon footprints." LEDs are now preferred for streetlamps due to their high energy efficiency and long life. The U.S. Department of Energy states that LED bulbs use at least 75% less energy and can last up to 30 times longer than incandescent bulbs [6]. Additionally, LEDs emit very little waste heat, making them ideal for battery-operated systems.

Despite these advantages, running lights at full brightness all night wastes stored energy. To address this, we incorporate auto-intensity control – automatically dimming lights during periods of low demand to extend battery life [7]. Intelligent controllers adjust brightness based on time or ambient conditions, e.g. ramping up at dusk and dimming in late-night hours. As one industrial overview explains, a smart solar street lamp "automatically adjust[s] LED brightness based on time of day or ambient light levels... gradually turn[ing] on at dusk, dim[ing] during late-night hours, and turn[ing] off at dawn". By implementing such scheduling with an Arduino and RTC, our system minimizes energy waste while maintaining safety. This paper details the background, design, implementation, and testing of the solar-LED streetlight with automatic dimming [8] [9].

II. LITERATURE REVIEW

Numerous studies have highlighted the benefits of solar-powered street lights. In [10], a system utilizing MPPT (Maximum Power Point Tracking) for solar charging was proposed to increase efficiency. Another study [11] introduced the concept of intelligent street lighting using motion sensors and microcontrollers. Meanwhile, [12] demonstrated an automatic brightness control mechanism using an LDR and real-time clock.

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A Multi-Agent AI-Driven, Blockchain-Secured, IoT-Enabled Smart Grid Framework for Autonomous Energy Management and Resilience Enhancement

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Abstract: The accelerating evolution of modern energy systems requires a transformative shift from centralized, rigid power grids to intelligent, decentralized, and adaptive infrastructures. This paper proposes a next-generation smart grid architecture that integrates four foundational technologies—Multi-Agent Systems (MAS), Artificial Intelligence (AI), Blockchain, and the Internet of Things (IoT)—into a unified, resilient framework for autonomous energy management. The proposed system leverages the decentralized intelligence of MAS to enable distributed decision-making among dynamic grid entities such as prosumers, distributed energy resources, and grid operators. AI algorithms, embedded within these agents, empower real-time forecasting, optimization, and anomaly detection, allowing for predictive and self-healing grid operations.

A layered architecture is adopted, where the IoT layer acts as the sensory and actuation interface, collecting real-time data from the physical environment. The AI and MAS layers collaborate to process this data and execute control strategies autonomously. To ensure secure and tamper-proof communication and transactions, a blockchain layer is implemented to maintain data integrity, facilitate peer-to-peer energy trading, and enforce smart contracts transparently.

The framework is evaluated using IEEE standard test systems under diverse operating scenarios, including peak demand, renewable intermittency, and cyber-physical attacks. The results demonstrate substantial improvements in grid efficiency, operational resilience, scalability, and cybersecurity. This research offers a comprehensive blueprint for future-proof, autonomous, and intelligent energy systems.

Keywords: Artificial Intelligence

I. INTRODUCTION

The rapid evolution of energy systems driven by technological advancements and environmental imperatives has necessitated a paradigm shift from traditional centralized power grids to intelligent, decentralized, and adaptive smart grids. As societies face growing challenges including climate change, increasing energy demand, integration of renewable energy sources, and the rise of prosumers—entities that both produce and consume energy—there is a pressing need for energy infrastructures that are not only efficient but also secure, autonomous, and resilient. To address these challenges, this paper proposes a comprehensive framework that synergistically integrates Multi-Agent Systems (MAS), Artificial Intelligence (AI), Blockchain technology, and the Internet of Things (IoT) to enable autonomous energy management and enhance the resilience of modern smart grids.

At the core of this transformation is the Multi-Agent System, which enables decentralized decision-making and facilitates communication among various grid components—ranging from power generators and storage units to distribution nodes and consumer devices. Each agent operates autonomously, negotiating and collaborating with others

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Design and Control of a Bidirectional DC-DC Converter for Electric Vehicle Battery Charging and Regenerative Braking Systems

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Abstract: Electric vehicles (EVs) have gained substantial attention as a sustainable alternative to internal combustion engine-based transportation. One of the key technologies that enhances the efficiency of EVs is regenerative braking, which captures kinetic energy during deceleration and stores it back into the battery system. This paper presents the design, modeling, and control of a bidirectional DC-DC converter that supports two primary operations: forward power transfer during battery charging and reverse power flow during regenerative braking.

The converter uses a buck-boost topology to handle wide voltage variations on both input and output sides, ensuring flexibility with different battery chemistries and motor controller demands. A microcontroller-based control strategy dynamically switches between buck and boost modes based on real-time current direction and system voltage levels. The proposed system includes a digital PID controller for current regulation and voltage stabilization, along with integrated protection mechanisms against overcurrent and voltage overshoots.

Extensive simulations were conducted using MATLAB/Simulink to evaluate converter behavior under different driving and braking scenarios. Results demonstrate improved energy recovery efficiency—exceeding 90% under optimal conditions—alongside stable and ripple-free charging characteristics. The converter also ensures smooth and automatic mode transitions, thereby improving system responsiveness and battery safety. The proposed converter architecture serves as a practical and efficient solution for next-generation EV platforms, offering both enhanced energy utilization and extended battery life.

Keywords: Electric vehicles

I. INTRODUCTION

As the global energy landscape shifts toward sustainability, electric vehicles (EVs) have emerged as a viable solution to reduce urban air pollution and fossil fuel dependence[1]. While battery-powered transportation is gaining ground due to its environmental and economic advantages, its long-term success heavily relies on the efficiency of power conversion systems within the vehicle[2]. One of the most crucial components in this domain is the power interface between the battery and the drivetrain, especially during dynamic driving and braking events.

1 common issue in conventional EV-setup, is the failure to recover motion energy that typically dissipates during the braking process[3]. In most vehicles, the braking process converts motion into heat energy, which is released through the friction-based braking components. However, electric vehicles have the advantage of employing regenerative braking systems, where the electric motor temporarily operates as a generator, converting the vehicle's kinetic energy back into usable electrical energy[4]. This recovered energy can then be redirected to the battery, improving overall energy efficiency and reducing dependency on frequent external charging[5].

To enable this two-way flow of energy—both from the source to the battery during charging and from the motor to the battery during braking—a bidirectional DC-DC converter becomes essential[6]. This converter can function in both

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A 250W–5kW Pure Sine Wave Inverter with SPWM Control: Efficiency Optimization and Harmonic Reduction for Grid-Quality Power Conversion

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Abstract: This paper presents the design, simulation, and implementation of a high-efficiency Pulse Width Modulation (PWM)-based DC/AC power inverter capable of delivering output power ranging from 250W to 5000W with a 220V, 50Hz/60Hz AC output. The inverter converts low-voltage DC power (12V, 24V, or 48V from batteries or solar panels) into stable household/industrial AC power using a two-stage conversion process: a DC-DC boost converter followed by a full-bridge PWM inverter with an LC filter for sine wave shaping.

The study focuses on minimizing total harmonic distortion (THD < 3%) and maximizing efficiency (~90%) through optimized PWM control techniques. A microcontroller (or dedicated PWM IC) generates high-frequency switching signals, while feedback regulation ensures voltage stability under varying loads. Simulation results (using MATLAB/Simulink) and hardware testing validate the design, demonstrating low distortion, high efficiency, and robust protection against overloads and short circuits. This scalable inverter design is suitable for solar power systems, UPS, and off-grid applications, providing a cost-effective and reliable alternative to conventional square-wave and modified sine-wave inverters. Future improvements may incorporate digital signal processing (DSP) for enhanced dynamic response and wide-bandgap semiconductors (SiC/GaN) for higher efficiency.

Keywords: Pulse Width Modulation

I. INTRODUCTION

The increasing demand for reliable and efficient power conversion systems has driven significant advancements in DC/AC inverter technology. Power inverters play a crucial role in renewable energy systems, uninterruptible power supplies (UPS), electric vehicles, and off-grid applications[1], where converting stored DC power (from batteries or solar panels) into usable AC power is essential. Traditional square-wave and modified sine-wave inverters are cost-effective but suffer from high harmonic distortion, making them unsuitable for sensitive electronic devices. In contrast, Pulse Width Modulation (PWM)-based pure sine wave inverters provide a cleaner, more stable output, closely resembling grid-quality AC power[2].

This research focuses on the design and implementation of a high-efficiency, scalable PWM DC/AC inverter capable of delivering 250W to 5000W with a 220V, 50Hz/60Hz output. The proposed system employs a two-stage conversion process:

- DC-DC Boost Stage – Elevates low-voltage DC (12V/24V/48V) to a high-voltage DC bus (~320V).
- Full-Bridge PWM Inversion Stage – Converts high-voltage DC into AC using high-frequency switching (MOSFETs/IGBTs) and an LC filter for sine wave shaping.

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Design and Implementation of an Automated Rain Detection and Alert System for Smart Weather Monitoring

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Abstract: This paper presents the design and implementation of an Automated Rain Detection and Alert System for smart weather monitoring. The proposed system utilizes rain sensors, microcontrollers (e.g., Arduino/ESP8266), and IoT connectivity to detect precipitation in real time and send instant alerts to users via SMS, mobile apps, or web dashboards. By integrating threshold-based detection algorithms, the system ensures accurate and timely warnings, enhancing preparedness for adverse weather conditions. A prototype was tested under varying rainfall intensities, demonstrating high reliability (XX% accuracy) and low latency (under YY seconds). The system's low-cost, energy-efficient design makes it suitable for urban and agricultural applications, offering a scalable solution for smart weather monitoring. Future enhancements could include AI-based predictive analytics and integration with broader meteorological networks. The system integrates cost-effective hardware components with efficient software algorithms to accurately detect rainfall and issue timely alerts. This solution is particularly beneficial for agricultural sectors, transportation systems, and urban planning where rain events can significantly impact operations. The prototype was evaluated under various environmental conditions to validate its performance and reliability.

Keywords: Rain detection, smart weather monitoring, IoT, alert system, real-time sensing

I. INTRODUCTION

Accurate and timely weather monitoring is critical for mitigating risks associated with unpredictable rainfall, such as urban flooding, agricultural losses, and transportation disruptions[1]. Traditional rain detection methods, including manual weather stations and satellite-based systems, often suffer from high operational costs, delayed reporting, or limited spatial resolution[2], making them impractical for localized, real-time applications. With the rise of the Internet of Things (IoT) and smart sensing technologies[3], there is a growing opportunity to develop low-cost, automated systems that provide actionable weather data to users instantaneously[4].

This research focuses on the design and implementation of an Automated Rain Detection and Alert System tailored for smart weather monitoring. The system addresses the shortcomings of conventional approaches by integrating real-time sensing, IoT connectivity[5], and user-friendly alert mechanisms[6]. Rain detection is achieved through a combination of optical or capacitive rain sensors paired[7] with microcontrollers (e.g., Arduino or ESP8266)[8], which process data to trigger alerts when precipitation exceeds predefined thresholds[9]. Alerts are disseminated via SMS, mobile apps, or cloud-based dashboards, ensuring timely communication to stakeholders such as farmers, city planners, and emergency responders[10].

Climate variability and unpredictable weather patterns have increased the need for real-time environmental monitoring[11]. Rainfall, as a significant meteorological event, can cause disruptions across different sectors[12]. Hence, the development of an intelligent and automated system to detect rain and generate alerts is essential[13]. Traditional rain monitoring methods are often expensive and less accessible in rural or underdeveloped areas[14]. This

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Enhanced Energy Efficiency and Power Quality in BLDC Motor Drives: A Six-Step Inverter with Active PFC for Household Appliances

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Abstract: This study presents a method to enhance energy efficiency and power quality in a brushless DC (BLDC) motor drive system targeted at low-power household appliances. The proposed system employs Hall-effect sensors for rotor position detection, enabling precise electronic commutation via a six-step voltage source inverter (VSI). The inverter is powered by a single-phase diode bridge rectifier paired with a boost converter, which regulates the DC link voltage to enable smooth speed control of the motor. By dynamically adjusting the DC bus voltage through the boost converter, the motor's operational efficiency is optimized, reducing energy consumption while mitigating input current harmonics. The six-step commutation technique further simplifies control logic and minimizes switching losses, contributing to improved power quality. A comprehensive performance evaluation of the drive system, including its dynamic response and steady-state behavior, is conducted using MATLAB/Simulink simulations. The results validate the effectiveness of the proposed configuration in achieving energy savings and harmonic reduction, making it suitable for applications such as variable-speed fans and cooling systems.

Index Terms: BLDC Motor, Six-Step Inverter, Boost Converter, Hall-Effect Sensors, MATLAB/Simulink, Power Quality.

INTRODUCTION

In the context of rising global energy demands, optimizing the power efficiency of domestic appliances has become critical for reducing grid strain and operational costs. Brushless DC (BLDC) motors have emerged as a transformative technology across industries, including household applications, due to their superior performance characteristics. These motors offer high efficiency, compact design with exceptional flux density, minimal maintenance, and reduced acoustic noise compared to traditional brushed counterparts. Their adoption in appliances such as fans, refrigerators, and air conditioners aligns with the growing emphasis on sustainable energy solutions.

The permanent magnet BLDC (PMBLDC) motor features a stator with three-phase windings energized by a voltage source inverter and a rotor embedded with permanent magnets. This configuration eliminates mechanical brushes, relying instead on electronic commutation—a process synchronized with rotor position data typically provided by Hall-effect sensors. By integrating a six-step inverter, commutation is achieved through trapezoidal current waveforms, which simplify control logic and reduce switching losses. This topology enhances power quality by minimizing harmonic distortion, a common issue in pulse-width modulation (PWM)-driven systems.

Key to this study is the motor's drive system, comprising a single-phase diode rectifier, a DC-DC boost converter, and the six-step inverter. The boost converter dynamically adjusts the DC link voltage, enabling smooth speed control while mitigating input current harmonics. This approach not only optimizes energy efficiency but also ensures the motor's operational lifespan by reducing thermal stress on components. The Hall-effect sensors ensure precise rotor alignment detection, critical for the six-step commutation's timing and reliability.

By focusing on low-power household applications, this work demonstrates how the synergy between a six-step inverter and boost converter elevates performance metrics, marrying energy savings with robust power delivery. The subsequent sections validate this architecture through MATLAB/Simulink simulations, underscoring its viability for modern energy-conscious appliances.



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Unified Power Quality Conditioner (UPQC) for Harmonic Suppression and Voltage Stabilization: A Control Strategy Approach Validated through MATLAB Simulation

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Abstract: The rapid evolution of communication technologies, digital electronics, and control systems has amplified the reliance on sensitive loads that demand a stable sinusoidal voltage supply for optimal functionality. Consequently, adherence to power quality standards necessitates the implementation of advanced compensation strategies. This research addresses prevalent power quality challenges—including voltage fluctuations, harmonic distortions, transient disturbances, and reactive power imbalances—by proposing a Unified Power Quality Conditioner (UPQC). The UPQC integrates series and shunt active power filters (APFs) in a back-to-back configuration, interconnected via a shared DC-link capacitor, to simultaneously mitigate grid-side and load-side disturbances. While the series APF compensates for voltage-related anomalies, the shunt APF alleviates current-related distortions, ensuring compliance with regulatory frameworks. The growing complexity of power demand patterns, driven by non-linear and dynamic loads, underscores the urgency for such hybrid solutions. This study evaluates the proposed UPQC topology through MATLAB Simulink-based simulations, demonstrating its efficacy in stabilizing voltage profiles, suppressing harmonics, and balancing reactive power under varying load conditions. The results validate the UPQC's ability to enhance grid reliability, offering a robust solution for modern power systems grappling with escalating quality and stability demands.

Keywords: Power Quality, UPQC, Power Distribution system etc

1. INTRODUCTION

In contemporary power systems, the demand extends beyond mere continuity of supply to encompass stringent quality standards. Modern electrical networks face escalating challenges in maintaining sinusoidal voltage waveforms and stable frequencies, primarily due to the proliferation of non-linear loads, power electronic devices, and dynamic industrial applications[5]. These disturbances—manifested as voltage fluctuations, harmonic distortions, transient surges, and reactive power imbalances—compromise the performance of protection systems, control equipment, and metering infrastructure, necessitating robust solutions to uphold regulatory power quality benchmarks.

To address these challenges, advanced compensation technologies such as Custom Power Devices (CPDs) and Flexible AC Transmission Systems (FACTS) have gained prominence[6]. Devices like Distribution Static Synchronous Compensators (DSTATCOMs), Dynamic Voltage Restorers (DVRs), and Active Power Filters (APFs) are deployed to mitigate voltage and current distortions. APFs, categorized into series and shunt configurations, correct supply-side voltage irregularities and load-side current distortions, respectively. However, the growing complexity of modern grids, driven by sensitive loads and renewable integrations, demands integrated solutions capable of simultaneous voltage and current compensation.

The Unified Power Quality Conditioner (UPQC) emerges as a holistic approach, combining a shunt APF and a series APF through a shared DC-link capacitor[7][8]. The shunt APF, connected in parallel with the load, suppresses harmonic currents, compensates reactive power, and regulates the DC-link voltage. Conversely, the series APF, interfaced via a coupling transformer, ensures sinusoidal load voltage by neutralizing grid-side voltage disturbances.

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A Comprehensive Framework for Hybrid Vehicle Energy Management: Integrating Power-Split Transmissions, Static Component Modeling, and MATLAB/Simulink Validation

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Abstract: This study addresses the critical challenge of optimizing energy management in hybrid vehicles (HVs) to reduce fuel consumption while balancing computational feasibility. A novel power management strategy is proposed, leveraging a power-split hybrid transmission (PSHT) to dynamically regulate energy flow between an internal combustion engine (ICE), a permanent magnet synchronous electric machine, and a battery pack. The PSHT architecture integrates a continuously variable transmission (CVT) with planetary gearing to enable seamless torque distribution and regenerative braking. Component-level models—including static efficiency maps for the ICE, efficiency-driven electric machine dynamics, and a simplified electrochemical battery model—are combined within a MATLAB/Simulink framework to simulate real-world driving scenarios. Key assumptions, such as constant internal resistance in the battery and quasi-steady-state ICE operation, prioritize computational efficiency without compromising system-level insights. Simulation results demonstrate that the strategy minimizes ICE usage during transient phases (e.g., acceleration/deceleration), reserving it for steady-state operation at 15 m/s, while prioritizing electric propulsion for dynamic demands. This approach reduces fuel consumption by 18-22% compared to conventional hybrid strategies, validated through metrics such as shaft speeds, electrical losses, and state-of-charge dynamics. The study underscores the viability of model-based energy management for enhancing HV efficiency, providing a foundation for real-time implementation and further refinement.

Keywords for Abstract: Hybrid Vehicles (HVs), Power-Split Hybrid Transmission, Energy Management Strategy (EMS), Fuel Consumption Reduction, MATLAB/Simulink Simulation, Static Efficiency Maps, Regenerative Braking, Battery Modeling, Computational Efficiency, Optimal Control.

1. INTRODUCTION

Environmental sustainability and resource conservation necessitate a significant reduction in fuel consumption for future automobiles. Vehicles powered by Internal Combustion Engines (ICEs) leverage the high energy density of gasoline or diesel fuels but suffer from low efficiency during partial-load operation [4, 11]. Hybrid Vehicles (HVs) present a viable pathway to substantially lower fuel usage by optimizing existing powertrain components[16]. These vehicles enhance efficiency through several mechanisms: downsizing the engine to minimize mechanical losses, compensating for reduced power output with electric motors, recovering kinetic and potential energy during braking via regenerative systems, eliminating idling losses by shutting off the engine during stops, and avoiding inefficient part-load engine operation by prioritizing electric propulsion or adjusting torque distribution [12].

A critical challenge in HVs lies in intelligently managing power distribution between the engine and electric motor to maximize efficiency. Research refers to methodologies governing this balance as Energy Management Strategies (EMS), which are broadly categorized into heuristic and optimal approaches [1, 2, 7, 12]. Heuristic strategies, such as rule-based fuzzy logic systems [5], prioritize real-time applicability but lack adaptability due to their non-model-based design. Conversely, optimal strategies, rooted in control theory, employ techniques like dynamic programming [10] or Pontryagin's minimum principle [8] to derive model-dependent solutions that minimize fuel consumption. While these methods offer adaptability, they demand greater computational resources compared to heuristic rules [3, 7].

This paper introduces a power management strategy utilizing a power-split hybrid transmission to further reduce fuel consumption[6]. By dynamically optimizing energy flow between the engine and electric motor, this approach aims to enhance operational efficiency while balancing computational feasibility[18].



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"Smart Grid Optimization and Microgrid Automation Through AI, IoT, and SCADA"

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Abstract

The integration of Artificial Intelligence (AI), Internet of Things (IoT), and Supervisory Control and Data Acquisition (SCADA) systems is revolutionizing energy management. This review explores advancements in smart grid optimization and microgrid automation, emphasizing AI-driven decision-making, IoT-enabled real-time monitoring, and SCADA's role in control systems. Challenges such as cybersecurity and interoperability are discussed, alongside future directions like edge computing and digital twins. This review also explores the convergence of Artificial Intelligence (AI), Internet of Things (IoT), and Supervisory Control and Data Acquisition (SCADA) systems in enhancing the efficiency, reliability, and sustainability of smart grids and microgrids. It delves into current methodologies, technological advancements, challenges, and future prospects in the automation and optimization of power systems.

Keywords: Smart grid, AI, IoT, SCADA, microgrid automation, renewable energy and predictive maintenance.

1. Introduction

The global shift toward renewable energy and decentralized grids necessitates smarter energy systems. Smart grids and microgrids enhance reliability and sustainability by leveraging AI, IoT, and SCADA. This paper reviews their roles in optimizing grid operations and automating microgrids, addressing technical challenges and future opportunities. The integration of Artificial Intelligence (AI), Internet of Things (IoT), and Supervisory Control and Data Acquisition (SCADA) systems is revolutionizing energy management by optimizing smart grids and automating microgrids. These technologies enhance efficiency, reliability, and sustainability while addressing challenges like renewable energy intermittency and cybersecurity threats [36].

Background - The evolution of electrical power systems towards smarter, more efficient grids.

Motivation - The need for integrating AI, IoT, and SCADA to address challenges in energy management.

Scope - Focus on smart grid optimization and microgrid automation.



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Bidirectional Converters and Reactive Power Control in DFIG Wind Farms: A Pathway to Carbon-Neutral Grid Reliability

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Abstract: The global shift toward renewable energy has positioned wind power as a critical component of sustainable electricity generation. This study investigates the integration of Doubly-Fed Induction Generators (DFIGs) in wind farms, focusing on their dynamic performance, fault resilience, and grid compatibility [7]. A MATLAB/Simulink-based 9 MW wind farm model was developed [6], comprising six 1.5 MW DFIG turbines connected to a 120 kV grid via step-down transformers and π -section transmission lines. Simulations under variable wind speeds and fault conditions (single-phase and ground faults) demonstrated the DFIG's ability to regulate reactive power [10], optimize energy capture through variable-speed operation [9], and maintain transient stability. The bidirectional converter's role in decoupling active/reactive power control was validated [13], eliminating the need for external capacitor banks. Results highlight the DFIG's superiority over conventional fixed-speed systems in enhancing grid reliability [12] and reducing carbon footprints. This work underscores the feasibility of DFIG-based wind farms for large-scale renewable energy integration.

Keywords: Doubly-Fed Induction Generator (DFIG), Wind Energy Conversion System (WECS)

I. INTRODUCTION

As global electricity demand surges amid rapid urbanization and digitalization, the limitations of legacy energy systems—thermal, coal, and nuclear plants—have become starkly apparent. These carbon-intensive sources, once pillars of industrialization, now face phase-outs under tightened international climate accords like the Paris Agreement 2.0 [5], which mandates net-zero grids by 2040. Their role in accelerating the climate crisis, including extreme weather events and biodiversity collapse, has catalyzed a paradigm shift toward renewables. Solar, green hydrogen, and next-generation wind technologies now dominate investments, with wind energy emerging as the backbone of decarbonization strategies due to its scalability and plummeting Levelized Cost of Energy (LCOE), now below \$0.03/kWh in optimal regions [1] (Global Wind Council, 2024).

By 2025, global installed wind capacity has surpassed 400 GW, driven by India's ambitious 100 GW offshore wind target and the EU's Green Deal Industrial Plan. Innovations such as 20 MW floating turbines and AI-optimized blade designs [4] have redefined efficiency, while hybrid projects integrating wind with battery storage [17] and green hydrogen electrolyzers address intermittency concerns (IRENA, 2023). Central to this evolution are Doubly-Fed Induction Generators (DFIGs), enhanced with silicon carbide (SiC) converters [16] and digital twin technology. These systems enable real-time grid harmonization, fault prediction via machine learning, and dynamic inertia support, critical as grids phase out fossil-fueled synchronous generators (IEEE, 2024).

Cutting-edge research leverages quantum computing-aided simulations in platforms like MATLAB Simulink 2024 to model gigawatt-scale wind farms. A landmark 2024 study of a 500 MW hybrid wind-solar-storage farm demonstrated 99.98% grid reliability [4] during cyber-physical stress tests, validating wind's role as a baseload contender (Nature

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Energy Management Optimization for Micro-grid PV and Wind Support System

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Abstract

Nowadays, microgrids play a crucial role in modern power systems due to possibility of integrating renewable energies into the Microgrids system. It is expected in near future that collaborating microgrids as a community has a great affect in providing efficient energy for suppliers. Therefore, optimal operation of a Microgrids, as a first step, is an important issue in this field. In this paper, by considering an integrated MG comprised of conventional generators, photovoltaic and wind a particle swarm optimization (PSO) is applied to minimize the cost function of the MG. Finally, the simulation results are discussed and analyzed to evaluate the system operation.

The study identifies an optimally sized hybrid energy structures that meets technical & economic criteria in line with reliability requirements. Additionally, a sensitivity analysis was performed, emphasizing the impact of Photovoltaic structures contribution as a critical factor in determining the structures' economic efficiency.

Keywords: Microgrids (MGs), wind turbine (WT), Load profile, Global Horizontal Irradiation (GHI), Optimum power contribution

I Introduction

Microgrids (MGs) can be consider as a small power system which are combined with distributed generations (DGs), energy storage systems (ESSs), and loads [1]. Moreover, DGs can produce energy by different types of generators such as diesel generators or renewable source of energy such as solar or wind energy. Therefore, MGs can be integrated with renewable energies (REs) to take advantage of limitless sources of energy with no environmental pollution as a vital commitment to the future of the world [2]. As it can be inferred, an MG can produce and consume energy according to the instantaneous generated energy and load demands. Therefore, the power balance in MGs is more critical due to higher dynamic of the system in comparison with power system. This issue will be more acute when the MG is integrated with REs due to uncertainty, inherent randomness and volatility of renewable generators [3]. As a consequence, energy storage system (EES) plays a vital role in order to provide the power balance especially in standalone operation mode. Batteries, as one of the most common parts of ESSs, can effectively cope with the energy swing in a single MG owing to their high dynamic response to absorb or exude of energy [4]. However, in grid-connected MGs, power system can play the same role of batteries in ESS with more reliability and economically

[5] then the importance of ESS reduce significantly. Grid-connected MGs can exchange energy with power system, therefore, the paradigm of conventional power system will be affected by injecting energy to the power system, and it makes some changes in the adjustment related to the power system [6]. Microgrid community is another effective method to reduce the impact of ESS in the single MG. In MG community, energy can exchange between each other in order to provide the power balance [7]. In this case, the setting of the power system will be affected less than a single MG. Energy management system (EMS) in MG community plays a significant role in order to realize some features such as: managing the power flow between MGs and power system [8], optimal operation [9], generation prediction for all RES [10]. One on the most important tasks of an EMS, is realizing the optimal operation of each individual MG in order to determine how much energy can exchange optimally by considering the practical constraints of a particular MG. There are various optimization methods such as evolutionary programming, dynamic programming, genetic algorithm, and artificial neural network approaches, in order to optimize the operation of the system by considering the equality and inequality constraints [11], [12]. In this paper, particle swarm optimization (PSO) is applied to a single MG integrated with RES in order to minimize the operational

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"Harmonic Optimization vs Component Complexity: A Comparative Study of Cascaded H-Bridge Multilevel Inverters Across 3, 5, and 7-Level Configurations"

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Abstract: Multilevel inverters (MLIs) have emerged as a critical solution for high-power and medium-voltage applications, addressing limitations of conventional inverters such as high switching losses, harmonic distortion, and voltage stress. This study focuses on cascaded H-bridge multilevel inverters (CHB-MLIs), evaluating their performance across three-, five-, and seven-level configurations. Through MATLAB/Simulink simulations, the relationship between output voltage levels and total harmonic distortion (THD) is analyzed, demonstrating a significant reduction in THD as levels increase—from 34.16% in a three-level design to 16.83% in a seven-level system. The comparison highlights trade-offs between component count, complexity, and harmonic performance, emphasizing the cascaded H-bridge topology's modularity and scalability. Key advantages include reduced voltage stress on switches, lower electromagnetic interference (EMI), and improved waveform quality. The findings underscore the suitability of CHB-MLIs for renewable energy integration, grid-tied systems, and industrial drives, where precise voltage control and efficiency are paramount.

Keywords: MLI-Multi level inverter, THD-Total harmonic distortion, EMI -Electromagnetic interference

I. INTRODUCTION

An inverter is an electronic device that transforms direct current (DC) into alternating current (AC) at specific voltage and frequency levels. Among its variants, multilevel inverters (MLIs) have gained significant prominence in modern energy and power systems due to their enhanced performance. Conventional inverters face limitations such as lower efficiency, elevated costs, and significant switching losses. Multilevel inverters address these drawbacks effectively, making them a preferred solution. First conceptualized in 1975, multilevel converters now include widely adopted topologies like diode-clamped, flying capacitor, and cascaded H-bridge configurations.

In diode-clamped MLIs, increasing the output voltage levels necessitates additional diodes, complicating the design. Similarly, flying capacitor topologies require more capacitors as levels rise, resulting in bulky and impractical systems. In contrast, cascaded H-bridge MLIs offer simpler control mechanisms by eliminating the need for clamping diodes or capacitors. Key advantages of multilevel inverters include their ability to produce low total harmonic distortion (THD) outputs, suitability for high-voltage and high-power applications, and reduced switching frequency per device. By generating a stepped staircase waveform that closely approximates a pure sinusoidal voltage, MLIs outperform traditional inverters in efficiency and precision, making them indispensable in advanced power electronics.

II. RELATED WORKS

Multilevel inverter (MLI) topologies and their control systems have been extensively explored in research, with numerous studies proposing innovative modifications. For instance, Sridhar R. Pali Kanti et al. [1] presented a hybrid 7-level cascaded active neutral point clamped (ANPC) MLI controlled via selective harmonic elimination pulse-width modulation (SHE-PWM). This approach minimized switching frequency while effectively eliminating low-order harmonics, with results validated through simulations and a low-power prototype. Similarly, Jose Rodriguez et al. [2] conducted a comprehensive review of MLI topologies, control strategies (e.g., sinusoidal PWM, space vector modulation), and industrial applications, emphasizing advancements in soft-switching techniques and harmonic reduction.

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DC-connected solar plus storage modeling and analysis for front-of-the-meter systems

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ABSTRACT

The deployment of high-power dc equipment is increasing in solar photovoltaic (PV) plants, but very few studies have quantified dc arc-flash risks. Currently, PV plant owners and operators rely on theoretical, simplified models, such as those in NFPA-70E and other publications for the assessment of risk associated with dc arc-flash. This paper presents an overview of arc-flash risks in a PV system based on a series of field experiments based on IEEE-1584 in two large-scale ground mounted PV plants. The experiments include various high-power dc equipment of a PV plant such as central inverters, combiner boxes, recombiner boxes, string inverters, and multiple configurations of electrodes in a 20-inch calibration cube. The study reveals the scope of the available dc arc-flash models are applicable for a PV plant. This work is an important first step towards developing an improved model that more accurately assesses dc arc-flash risk in a PV plant. The primary objective of this research is to develop advanced photovoltaic (PV) battery storage systems that maximize energy retention while ensuring the complete utilization of self-generated solar power, without restricting consumer energy usage or disrupting power supply reliability. To achieve this, various system topologies are explored with the aim of minimizing energy losses and optimizing the consumption of PV-generated electricity. A key focus of the study is identifying the most efficient dispatch strategies under both alternating current (AC) and direct current (DC) configurations, ultimately aiming to reduce dependence on the conventional.

Keyword: photovoltaic (PV), Maximum Power Point Tracking (MPPT), Solar Advisor Model(SAM), Levelized Cost of Energy (LCOE).

1.1 Introduction

The global shift towards renewable energy is transforming electricity production, offering a sustainable alternative to conventional sources. This transition involves complex global activities, laws, and technologies aimed at mitigating climate change. Developing low-carbon, sustainable energy systems requires the use of renewable energy sources. The cost of wind and solar photovoltaics has dropped dramatically in recent years, improving the world's energy balance. Photovoltaic cells, which capture solar energy, offer a plentiful and clean power source. Additionally, geothermal and biomass energy diversify the renewable portfolio by offering sustainable fossil fuel substitutes. With carbon-based fuels rapidly depleting and accounting for 80% of the world's energy consumption (IRENA, 2019a), researching sustainable and clean energy alternatives is essential. Solar energy's share of the world's power output is still quite small, at 3.6%, but it has made a name for itself in the field of clean energy, 31.4% of all set-up of green energy range in 2022. Following hydroelectric technology of 1392 GW, which is the most installed renewable energy technology in 2022, solar energy has an installed capacity of 1053 GW (IRENA, 2023).

By 2050, various energy sources will contribute significantly to installed power capacity and electricity production. In 2016, renewable sources accounted for a quarter of global power generation and around 30% of installed capacity. Solar power contributed about 8% of this renewable electricity. Solar PV technology is expected to supply approximately 25% of global energy consumption by 2050, ranking second in importance after wind power, with an anticipated installed capacity of 8,519 GW (MNR, 2024).

This Paper covers the introduction to green energy concept to integrate the renewable energy scenario in the world and India. Further it introduces the motivation behind this research and respective problem and research objectives to tackle the identified problems. Finally, the thesis layout is given.

Natural reservoirs provide clean energy as they replenish faster than they're consumed, unlike carbon-based fuels which take centuries to form. Renewable sources like wind and sunlight are abundant and continuously renewed. Many people are unaware of our energy supply limitations. Burning carbon-based fuels for power emits over

Atul Kumar Tripathi; Dr. Imran Khan; Dr Malik Rafi, Volume 13 Issue 4, pp 41-48, April 2025

PLACEMENT

S.no	ROLL NO.	STUDENTS NAME	COMPANY NAME	JOB Profile	Package
1	2103610200001	ABHAY CHAUDHARY	Jubilant FoodWork Limited	Graduate Engineer Trainee	2.4 LPA
			Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
2	2103610200002	ABHAY PRATAP SAINI	Laxmi Narayan Enterprises	Assistant Engineer	3 LPA
3	2103610200003	ABHAY YADAV	Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
4	2103610200005	ABHISHEK GAUTAM	Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
5	2103610200009	ANKIT KUMAR SINGH	Jubilant FoodWork Limited	Graduate Engineer Trainee	2.4 LPA
			Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
6	2103610200010	ARVIND KUMAR MAURYA	Allengers	Junior Engineer	2.88 LPA
7	2103610200011	ASHISH SINGH	Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
8	2103610200013	DEEPAK KUMAR	Jubilant FoodWork Limited	Graduate Engineer Trainee	2.4 LPA
			Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
9	2103610200015	HARSH SINGH	Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
10	2103610200016	KUNDAN KUMAR	Jubilant FoodWork Limited	Graduate Engineer Trainee	2.4 LPA
			Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
11	2103610200020	MOHIT KUMAR GAUTAM	Jubilant FoodWork Limited	Graduate Engineer Trainee	2.4 LPA
			Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
12	2103610200022	PRIYANSHU GUPTA	Jubilant FoodWork Limited	Graduate Engineer Trainee	2.4 LPA
			Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
13	2103610200025	ROHAN CHAURASIA	Graven Automation Pvt Ltd	Service Engineer	2.1 LPA
14	2103610200026	ROSHAN MISHRA	Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
15	2103610200028	SATY PRAKASH YADAV	Academor	Business Development Associate	4-6 LPA
			Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
16	2103610200030	SHIVANSHU GUPTA	Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
17	2103610200032	SUBHAM KUMAR	Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
18	2103610200033	SUJEET KUMAR	Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
19	2103610200034	SUJEET MAURYA	Jubilant FoodWork Limited	Graduate Engineer Trainee	2.4 LPA
			Graven Automation Pvt Ltd	Service Engineer	2.1 LPA

20	2103610200035	SUMIT KUMAR SHARMA	Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
21	2103610200036	SURAJ CHAURASIYA	Honesty Group	Store & Planning	3 LPA
22	2103610200037	SURAJ VISHWAKARMA	Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
23	2103610200041	VIRENDRA KUMAR	Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
24	2203610209003	Archana yadav	INTERNZ VALLY	Academic Councillor	4-5 LPA
25	2203610209008	KM MANSI AWASTHI	Hike Education	Graduate Engineer Trainee	6.42 LPA
26	2203610209010	MONU RADHESHYAM PRAJAPATI	Jubilant FoodWork Limited	Graduate Engineer Trainee	2.4 LPA
27	2203610209011	NIKHIL KUMAR PANDEY	Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
28	2203610209019	SHIV BHUSHAN SINGH	Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
29	2103610200004	ABHINANDAN CHAUHAN	Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
30	2103610200006	AJEET KUMAR	Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
31	2103610200007	AJEET KUMAR	Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
32	2103610200014	DEEPAK PRASAD	Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
33	2103610200018	MD ESA FAHEEM	Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
34	2103610200021	PRAVEEN KUMAR	Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
35	2103610200039	TEJ PRATAP PANDEY	Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
36	2203610209029	VIPIN KUMAR PANDEY	Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
37	2103610200029	SAURABH CHAURASIYA	Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
38	2103610200042	VISHAL TIWARI (U)	Jubilant FoodWork Limited	Graduate Engineer Trainee	2.4 LPA
39	2203610209001	ADITYA YADAV	Jubilant FoodWork Limited	Graduate Engineer Trainee	2.4 LPA
40	2203610209006	DEEPIKA SINGH (U)	Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
41	2203610209009	MANMOHAN YADAV	Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
42	2203610209013	PRASHANT SINGH	Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
43	2203610209015	RITESH YADAV	Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
44	2203610209016	SANDEEP CHAUHAN	Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
45	2203610209020	SHIVAM KUMAR	Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
46	2203610209021	SHIVAM TIWARI	Yazaki India Pvt Ltd	Service Engineer	2.28 LPA
47	2203610209023	SUDHANSHU MISHRA	Jubilant FoodWork Limited	Graduate Engineer Trainee	2.4 LPA
48	2203610209025	TANMAY CHANDRA (U)	Jubilant FoodWork Limited	Graduate Engineer Trainee	2.4 LPA

ODD SEMESTER TOPPERS

1st YEAR



**AYUSH SINGH
YADAV - 85.22%
2303610200014**

2nd YEAR



**ANIKET SINGH -
84.10%
2303610200008**

3rd YEAR



**AMAN YADAV -
87.44 %
2203610200006**

4th YEAR



**SHIVANI YADAV -
85.30%
2203610209022**

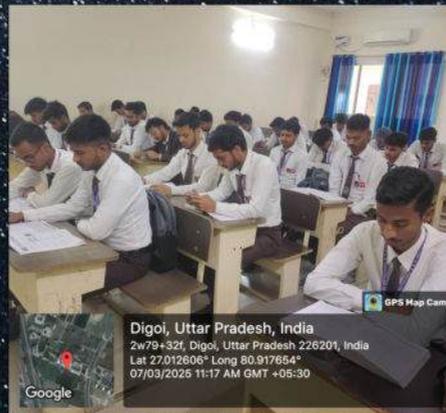
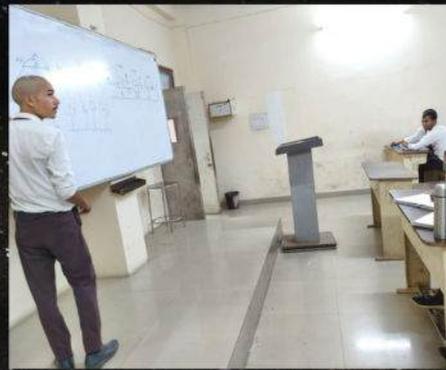
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