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Integrated Power Generation Using a Tri-Mode Hybrid Technique

Dr. Rekha P S , Rohith T , Anirudh N, Shashank D, Tarun S
Dept. of Electrical Engineering
S J B Institute of Technology
Bengaluru, India

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ABSTRACT: The increasing demand for energy coupled with the depletion of fossil fuel reserves has spurred interest in exploring renewable energy sources. These sources, although intermittent and location-specific, offer promising alternatives. To address the challenges posed by their intermittency and the limitations of specific geographical locations, this paper introduces a novel solution: a hybrid energy system (HES) designed for off-grid operation, particularly suitable for high-altitude areas where accessing the national grid is difficult. The proposed system integrates various renewable energy sources with energy storage capabilities. The paper discusses in detail the essential design considerations and modeling of each component within the HES.

I.INTRODUCTION

Electricity is indispensable in our daily lives, and its generation can stem from both conventional and non-conventional energy sources. The ideal energy source should be dependable, environmentally friendly, and cost-effective. Non-conventional energy resources present promising alternatives to conventional ones, with options such as solar, tidal, wind, piezo, and geothermal energy. Solar and wind energy, being widely available, can be harnessed together under favorable weather conditions.In rural areas, where access to electricity is limited, a system utilizing DC supply from batteries, converted to AC with appropriate circuits, can prove invaluable for electrification efforts.

Hybrid wind power generation involves integrating wind energy with other complementary power sources to enhance reliability and efficiency. This strategy mitigates the intermittency and variability of wind power by combining it with consistent power sources, such as solar energy, battery storage, or traditional fossil fuel generators.

The escalating global energy demand and the urgent need for sustainable solutions have spurred a quest for innovative powerGeneration methods. This paper introduces a pioneering approach, the Integrated Power Generation System employing a

Tri-Mode Hybrid Technique, aimed at addressing thesechallenges. While traditional power sources struggle to meet rising demands while minimizing environmental impact, our proposedsystem harnesses the strengths of renewable energy, conventional power generation, andadvanced energy storagetoprovide a comprehensive and adaptable solution. The escalating global energydemand and the urgent need for sustainable solutions have spurred a quest for innovative power generation methods.

This paper introduces a pioneering approach, the Integrated Power Generation System employing a Tri-Mode Hybrid Technique, aimed at addressing these challenges. While traditional power sources struggle to meet rising demands while minimizing environmental impact, our proposed system harnesses the strengths of renewable energy, conventional power generation, and advanced energy storage to provide a comprehensive and adaptable solution.This introduction highlights the urgent challenges in the current energy landscape, stressing the limitations of traditional power generation methods and the growing significance of sustainable alternatives. Subsequent sections of this paper delve into the technical intricacies of the Integrated Power Generation System, elucidating the synergies among the three modes and presenting a comprehensive analysis of its performance, applicability, and potential impact on transitioning towards a more sustainable and resilient energy future.

Numerous hybrid wind/PV power system designs employing Maximum Power Point Tracking (MPPT) control have been explored in prior research. Many of these configurations employ distinct DC/DC boost converters in parallel within the rectifier stage to execute MPPT control for individual renewable energy sources. However, a

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more straightforward multi-input arrangement has been proposed, consolidating the inputs from the DC end while still ensuring MPPT for each renewable source. The proposed structure, as delineated by [author], integrates elements of both the buck and buck-boost converter, streamlining the system. The structure proposed by [author] is a fusion of the buck and buck-boost converter. Existing systems often require passive input filters to eliminate high-frequency

Current harmonics injected into wind turbine generators. These harmonics can reduce the generator's lifespan and increase power loss due to heating. In this paper, an alternative multi-input rectifier structure is proposed for hybrid wind/solar energy systems.

Here is an introduction to the key aspects of hybrid wind power generation:

I.wind power overview

Wind power entails capturing the kinetic energy present in the wind to produce electricity. Through wind turbines, this energy is transformed into electrical power. However, the generated output may vary due to changes in wind speed and direction.

II. Hybridization with other energy sources

Hybrid wind power systems are crafted to address the intermittent nature of wind energy. By integrating wind power with alternative energy sources like solar, storage solutions, or conventional power plants, the system gains enhanced stability and reliability.

III.Solar wind hybrid systems

The combination of wind and solar power represents a prevalent hybrid strategy. Wind and solar resources frequently complement each other: wind speeds tend to be higher at night and during winter, whereas solar power is most abundant during daylight hours. This synergy contributes to achieving a more steady and uninterrupted power output.

II.METHODOLOGY

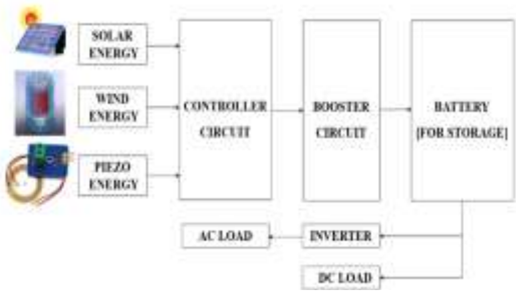

Fig.1: Block Diagram

This study aims to develop and evaluate an innovative approach for integrated power generation using a tri-mode hybrid technique. Beginning with a comprehensive review of existing literature on hybrid power systems, the research will establish a conceptual framework for the proposed system. The methodology involves designing and modeling the integrated power generation system using appropriate software tools, selecting energy sources, sizing components, and defining simulation scenarios. Practical implementation and experimental testing will validate the system's performance under various operating conditions. Results will be analyzed to assess efficiency, reliability, and environmental impact, providing insights into the viability and potential benefits of the tri-mode hybrid technique compared to conventional power generation methods.

The proposed methodology also includes an experimental phase for testing and validation of the tri-mode hybrid system. Real-world data will be collected to assess the system's performance and validate the accuracy of the simulation models. Performance metrics such as energy yield, capacity factor, and levelized cost of electricity (LCOE) will be used to evaluate the effectiveness and efficiency of the hybrid system.

Finally, the results of the study will be analyzed and discussed in detail. Insights gained from the analysis will be used to draw conclusions regarding the feasibility, performance, and potential applications of the tri-mode hybrid technique for integrated power generation. Recommendations for further research and practical implementation will also be provided based on the findings of the study.

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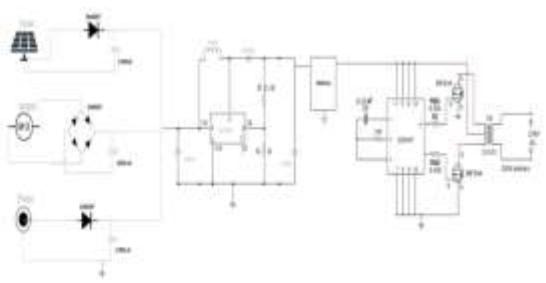

Fig.2: Circuit Diagram

Overall, this methodology provides a structured framework for conducting research on integrated power generation using a tri-mode hybrid technique, encompassing literature review, conceptual framework development, system design and optimization, simulation, experimental testing, and analysis of results.

B. Proposed Equipment Used

1. 12V Solar panel: A 12-volt solar panel is designed to harness solar energy and generate electrical power with a nominal output voltage of 12 volts. These panels find widespread use across various applications, from small off-grid setups to charging batteries for recreational vehicles, boats, and other 12-volt electronic devices. Comprised of photovoltaic (PV) cells, usually crafted from semiconductor materials like silicon, these panels operate by converting sunlight into direct current (DC) electricity through the photovoltaic effect. Available in a range of power ratings, from a few watts to several hundred, these panels vary in efficiency, which denotes the percentage of sunlight they can convert into electricity. Panels with higher efficiency are typically more compact and deliver greater power output per unit area.

Fig.3: Solar Panel

2. Piezoelectric Sensors: Piezoelectric sensors are instruments that capitalize on the piezoelectric effect to detect alterations in pressure, acceleration, temperature, or force, transforming them into an electric charge. This effect pertains to the capacity of specific materials to produce an electric charge when subjected to mechanical stress. Widely utilized across different sectors and technologies, these sensors are valued for their sensitivity, robustness, and capability to convert mechanical energy into electrical signals.

Fig.4: Piezoelectric Sensors

3.Battery:A battery serves as a storage unit for electricity, particularly favored in applications requiring low power and high frequency owing to its rapid-switching attributes. The energy storage capacity of a battery is pivotal and typically quantified in terms of ampere-hours (Ah) for smaller units and kilowatt-hours (kWh) for larger systems, indicating the amount of energy it can retain. Certain batteries exhibit optimized performance within temperature ranges, with extreme temperatures capable of influencing both their operational efficiency and lifespan.

Fig.5:Battery

4. IN4007 Diodes: The 1N4007 diode stands out as a versatile and extensively utilized rectifier diode, ideal for various electronic applications necessitating AC-to-DC conversion. With voltage and current ratings conducive to low to moderate power scenarios, it finds its place in power supplies, rectifiers, and general diode circuits. Being a silicon rectifier diode, the 1N4007 demonstrates its versatility when used in series to manage higher voltages, while its availability in through-hole packaging simplifies its integration into prototyping

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and circuit design endeavors. In the part number, the "400" signifies a peak repetitive reverse voltage rating of 1000 volts for the 1N4007. Consequently, it can withstand a maximum reverse voltage of 1000V. Notably, the diode boasts a maximum average forward current (IF) of 1.0 ampere.

Fig.6:IN4007 Diodes

5. Resistors:Resistors serve as fundamental electronic elements that hinder the passage of electric current within a circuit. Their primary function is to regulate or restrict the flow of electric current, thereby introducing resistance and transforming electrical energy into heat. This inherent property proves invaluable across a spectrum of electronic applications. Tolerance denotes the acceptable deviation from the designated resistance value, while the power rating of a resistor specifies the utmost level of power it can dissipate without incurring damage.

Fig.7:Resistors

6. Capacitors:A capacitor represents a fundamental component in electronics responsible for storing electrical energy within an electric field. Its structure typically comprises two conductive plates isolated by an insulating medium known as a dielectric. Across electronic circuits, capacitors find extensive application for diverse functions such as energy storage, filtering, and coupling. Functionally, capacitors store and subsequently discharge electrical energy. Upon applying voltage across the plates, an electric field forms, resulting in the accumulation of charge on the plates. This stored charge remains available for release as necessitated by the circuit's operation.

Fig.8. Capacitor

7. Inductors: An inductor serves as a passive electronic component that retains electrical energy by generating a magnetic field when subjected to an electric current. Typically, it comprises a coil of wire wound around a core, with the core material varying based on application requirements. Within electronic circuits, inductors fulfill a range of functions including energy storage, filtering, and facilitating inductance-based impedance matching. They accumulate energy in the form of a magnetic field upon current passage. Additionally, they exhibit resistance to alterations in current flow and, when coupled with capacitors, contribute to the formation of resonant circuits.

Fig.9: Inductors

8. XL6009 Switching Regulator: The XL6009 stands as a type of integrated circuit (IC) utilized extensively in electronic circuits for voltage regulation through boosting or step-up conversion. Tailored for efficiently elevating input voltage to achieve a higher output voltage, it finds applicability across diverse scenarios requiring stable voltage amplification. Operating as a step-up (boost) voltage regulator, the XL6009 effectively raises input voltage levels. Typically, its switching frequency falls within the range of hundreds of kilohertz to several megahertz. Primarily employed in elevating

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low voltages from batteries to higher levels, its adjustable output voltage, commendable efficiency, and incorporated protection features render it suitable for a multitude of applications.

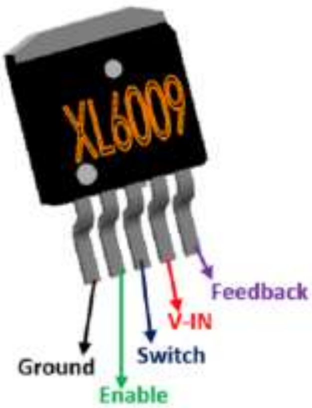

Fig.10:XL6009 Switching Regulator

9.IN5822 Diodes: It appears there may be a slight mix-up. The commonly referenced standard diode is the 1N5822, not IN5822. Functioning as a Schottky diode, the 1N5822 finds extensive utilization in electronic circuits for rectification and power-related purposes. Its applications span rectification within power supplies, voltage regulation, and inclusion in protection circuits. Its popularity stems from its fast-switching characteristics, rendering it suitable for use in both low-power and high-frequency scenarios.

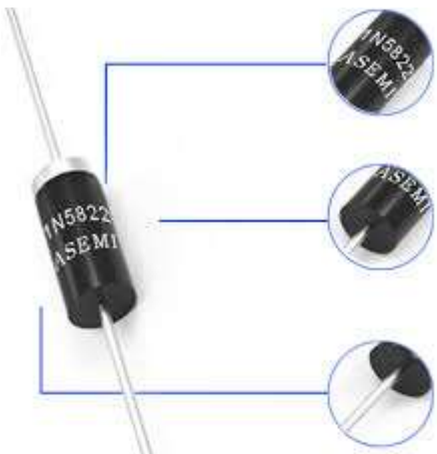

Fig.11:IN5822 Diodes

10.IC CD4047:The CD4047 represents an integrated circuit (IC) belonging to the 4000 series of CMOS (Complementary Metal-Oxide-Semiconductor) logic ICs, functioning as a monostable/astable multivibrator. It serves the purpose of generating square wave signals within electronic circuits. Tailored for astable and monostable applications, the CD4047 operates effectively across a broad spectrum of supply voltages, typically ranging from 3V to 15V. Frequently employed in oscillator circuits, it proves indispensable where the generation of a stable square wave signal is imperative.

Fig. 12:IC CD4047

11. IRFZ44 Mosfet: The IRFZ44 stands out as a favored N-channel metal-oxide-semiconductor field-effect transistor (MOSFET), frequently integrated into electronic circuits for switching purposes. MOSFETs enjoy broad utilization due to their capability to manage high currents and voltages while demanding minimal power input. Being an N-channel MOSFET, the IRFZ44 functions when a negative voltage is applied to the gate concerning the source. Notably, it boasts a typically high voltage rating, enabling it to effectively manage voltages ranging in the tens of volts.

Fig.13:IRFZ44 Mosfet

12. Step up Transformer: A step-up transformer refers to a specific transformer variant designed to elevate the voltage level from its primary winding to the secondary winding. Transformers function according to electromagnetic induction principles, wherein a fluctuating magnetic field triggers a

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voltage in an adjacent coil of wire. The primary objective of a step-up transformer lies in voltage augmentation. As alternating current (AC) courses through the primary winding, it generates a dynamic magnetic field. This fluctuating magnetic field, in turn, induces a heightened voltage within the secondary winding.

Fig.14:Step up Transformer.

13. DC Generator: Permanent magnet direct current (DC) machines serve dual purposes as conventional motors or DC wind turbine generators, with no inherent structural disparity between the two. Consequently, a single permanent magnet DC (PMDC) machine can function interchangeably as either an electrically driven motor for mechanical tasks or a mechanically driven generator to generate voltage output, rendering it ideal for wind turbine applications.In motor mode, the armature rotates at a fixed speed dictated by the connected supply voltage and magnetic field intensity, generating torque. However, when the armature is mechanically rotated at a speed surpassing its designated motor speed, typically facilitated by rotor blades, the PMDC machine seamlessly transitions into a DC generator. In this mode, it produces an electromotive force (emf) output directly proportional to its rotational speed and magnetic field strength. Conventional DC machines typically feature field windings on the stator and armature windings on the rotor. Consequently, their output coils rotate alongside a stationary magnetic field, thereby generating the requisite magnetic flux. Electrical power is extracted directly from the armature via carbon brushes, while the magnetic field, which governs power output, is supplied by either permanent magnets or an electromagnet.

Fig.15:DC Generator

III. RESULT

Hybrid energy systems leverage existing infrastructure while incorporating additional components to cut costs, lessen environmental impact, and minimize system disruptions. Planning such systems prioritizes market needs over specific technologies, aiming for an efficient and reliable mix of energy sources. However, scalability is often limited due to reliance on small conventional power facilities and storage devices to manage intermittent renewable sources.

The popularity of hybrid energy systems stems from their utilization of multiple energy sources, making them efficient for power generation, particularly in remote areas. They offer a solution to the high costs of oil and can optimize power supply in rural regions, despite being initially expensive and challenging to integrate.

Implementing hybrid systems, which typically combine sources like solar panels, wind turbines, and piezoelectric materials, involves converting outputs to usable forms via converters and storing excess power in battery banks for continuous supply. Converting the output to 220-volt AC enables driving AC loads.

In summary, hybrid energy systems offer a promising solution for diverse energy needs, though their integration requires careful planning and investment.

IV. FUTURE SCOPE

Future enhancements and considerations for this Integrated Power Generation System could include:
Advanced Energy Storage: Implementing cutting-edge battery technology for efficient storage and

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management of excess energy, ensuring reliable power supply during low-generation periods.

Smart Grid Integration: Incorporating smart grid technology enables dynamic monitoring and control of energy flow, optimizing distribution and enhancing system resilience.

IoT and Remote Monitoring: Utilizing Internet of Things (IoT) devices for remote monitoring and predictive maintenance, improving system reliability and reducing downtime.

Grid Interconnection: Exploring options for grid interconnection to facilitate energy exchange with the broader power network, enabling greater flexibility and stability.

By continuing to innovate and refine this Tri-Mode Hybrid Technique, we can develop a robust and sustainable Integrated Power Generation System capable of meeting the evolving energy needs of communities and industries.

V. CONCLUSION

In conclusion, the integration of a Tri-Mode Hybrid Technique for power generation represents a promising and innovative solution to address the challenges faced by conventional and renewable energy systems. The comprehensive approach of combining renewable energy sources, conventional power generation, and energy storage has been explored to optimize energy production, enhance system resilience, and contribute to environmental sustainability.

The study has demonstrated that the Tri-Mode Hybrid Technique effectively addresses the intermittency issues associated with renewable sources, ensuring a reliable and continuous power supply. The intelligent control and switching mechanisms enable the system to adapt to varying energy demands and resource availability in real-time, maximizing overall efficiency.

In summary, the Integrated Power Generation Using a Tri-Mode Hybrid Technique presents a robust and adaptive solution that aligns with the evolving energy landscape, offering a pathway towards a resilient, efficient, and sustainable power generation paradigm. The insights gained from this study contribute to the broader conversation on advancing clean energy technologies and fostering a more sustainable and resilient global energy infrastructure.

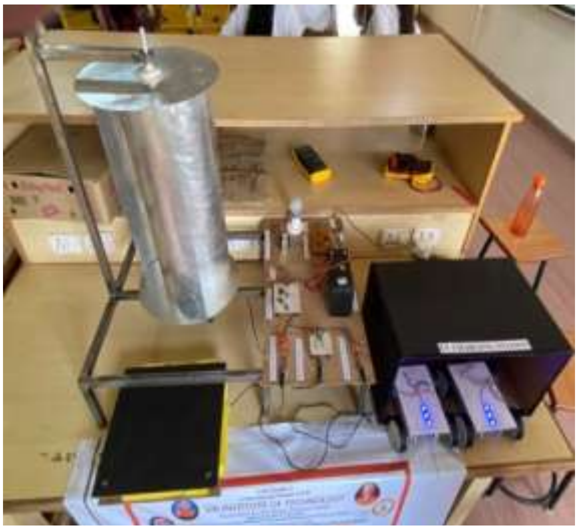

Fig.16: Proposed model

Fig.17: Top view of Proposed model

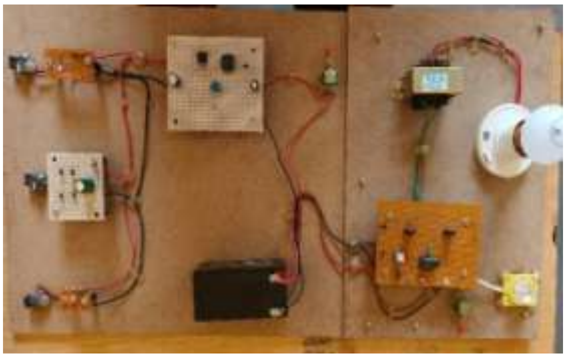

Fig.18: Controller Circuit

Fig.19: EV Charging Station Prototype.

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