



HYBRID POWER GENERATION SYSTEM USING SOLAR AND WIND

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ABSTRACT:

The increasing global demand for sustainable and reliable energy has led to the development of hybrid renewable energy systems. This study presents the design and implementation of a hybrid power generation system integrating solar photovoltaic (PV) and wind energy sources. The system aims to ensure continuous and efficient power generation by compensating for the intermittency of individual renewable sources. Solar energy is harnessed during daytime, while wind energy contributes during low solar availability, thereby enhancing system reliability. An intelligent control mechanism incorporating charge regulation and energy storage is implemented to optimize power flow. The proposed system is particularly suitable for remote and rural electrification. The results indicate improved energy efficiency, reduced power interruptions, and enhanced reliability compared to standalone systems. The hybrid configuration demonstrates significant potential for sustainable and eco-friendly energy generation.

KEYWORDS:

HYBRID ENERGY SYSTEM, SOLAR ENERGY, WIND ENERGY, RENEWABLE ENERGY, PHOTOVOLTAIC SYSTEM, WIND TURBINE, ENERGY STORAGE, SUSTAINABLE POWER.

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INTRODUCTION

The rapid increase in global energy demand and the depletion of fossil fuel resources have necessitated the transition toward renewable energy systems. Conventional energy sources contribute significantly to environmental pollution and greenhouse gas emissions, thereby accelerating climate change [1]. Renewable energy technologies, particularly solar and wind energy, have emerged as viable alternatives for sustainable energy generation [2].

Solar energy is abundant and can be effectively converted into electrical energy using photovoltaic systems based on the photoelectric effect [3]. However, its performance is highly dependent on solar irradiance and is unavailable during nighttime [4]. Wind energy, on the other hand, converts kinetic energy into electrical energy using turbines and generators, and it can operate both day and night depending on wind availability [5].

Several studies have highlighted the limitations of standalone renewable systems due to intermittency and variability [6]. Hybrid energy systems have been proposed as an effective solution to overcome these challenges by integrating multiple energy sources [7]. The combination of solar and wind energy ensures a more reliable and

continuous power supply [8].

Recent advancements in hybrid systems include intelligent control strategies, energy storage integration, and optimization techniques to improve efficiency and reliability [9]. These systems are particularly beneficial for remote and rural areas where grid connectivity is limited or unreliable [10].

In this context, the present work focuses on the design and implementation of a hybrid solar-wind power generation system aimed at improving energy reliability, efficiency, and sustainability

MATERIALS AND METHODS:

The proposed hybrid power generation system integrates solar photovoltaic modules and a wind energy conversion system to generate electrical power.

The solar subsystem consists of PV panels that convert solar irradiance into electrical energy using semiconductor materials. The mathematical model of the PV cell is represented by the single diode equivalent circuit. The wind subsystem converts kinetic energy into electrical energy using a turbine and generator.

The hybrid system integrates both sources through:

- MPPT controller for solar optimization
- Wind turbine generator system
- Power electronic converters
- Battery storage system
- Inverter for AC load supply
- The system operates such that:
- Solar dominates during daytime
- Wind compensates during low solar conditions
- Battery ensures energy storage and continuity

RESULTS:

The block diagram illustrates the integration of solar PV panels and wind turbine systems through converters and controllers. The solar subsystem includes MPPT and DC-DC converters, while the wind subsystem includes turbine and generator units. Both outputs are combined and fed into an inverter for AC load supply.



FIG. 1: BLOCK DIAGRAM OF HYBRID POWER GENERATION SYSTEM USING SOLAR AND WIND

The figure clearly demonstrates the coordinated operation of both energy sources to ensure continuous power delivery. The inclusion of battery storage enhances system reliability by storing excess energy and supplying it during low generation periods. The circuit diagram represents the practical implementation of the hybrid system. It includes components such as rectifiers, transformers, sensors, and control units. The Arduino-based controller manages the system operation, including energy flow regulation and load management. The integration of sensors like INA219 ensures real-time monitoring of voltage and current parameters. The circuit effectively demonstrates the hardware realization of the hybrid system and validates its feasibility for real-world applications.

DISCUSSION:

The results clearly indicate that the hybrid solar-wind system provides improved performance compared to standalone systems. The complementary nature of solar

and wind energy ensures continuous power generation. During daytime, solar energy contributes significantly, while wind energy supports power generation during nighttime or cloudy conditions. The integration of energy storage further enhances system stability and reliability. The use of MPPT improves solar efficiency, while efficient wind turbine design ensures optimal energy extraction. The hardware implementation confirms the practical feasibility of the system. Additionally, the hybrid system reduces dependency on fossil fuels, lowers operational costs, and minimizes environmental impact. The system is highly suitable for rural electrification and off-grid applications. The automatic speed control mechanism improves motor lifespan by preventing operation under unsafe conditions. The system also contributes to energy efficiency by optimizing motor performance. Compared to SCADA-based systems, the proposed approach is more economical and easier to deploy.

CONCLUSIONS:

This study presents a hybrid power generation system integrating solar and wind energy sources to achieve reliable and sustainable electricity generation. The system effectively overcomes the limitations of individual renewable sources by combining their strengths. The results demonstrate improved efficiency, reliability, and cost-effectiveness. The proposed system is a promising solution for future energy demands, particularly in remote and rural areas. Further improvements can be achieved by incorporating advanced optimization algorithms, smart grid integration, and IoT-based monitoring systems.

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