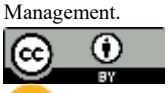
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AI-Based Hybrid Solar Power Generation with Smart Energy Management Using IOT

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ABSTRACT

This paper presents an AI-based hybrid solar-wind power generation system with smart energy management and IoT monitoring. Solar panels and a wind turbine work together to generate electricity from available renewable sources. A battery stores excess energy and supplies power when generation is insufficient. The intelligent energy management system considers power load demand to control energy distribution effectively. IoT technology enables real-time monitoring of generation, storage, consumption, and system status. The AI-based approach helps the system respond to changing environmental and load conditions. The proposed system aims to improve renewable energy utilization, reduce power wastage, and decrease dependence on conventional energy sources, providing a practical solution for sustainable small-scale power applications.

INTRODUCTION

The growing demand for reliable electricity and the environmental impact of conventional power generation have increased the importance of renewable energy sources such as solar and wind. However, their power generation depends on changing weather conditions, making continuous power supply difficult when used independently. A hybrid solar-wind system can overcome this limitation by combining both sources. Recent development in Artificial Intelligence (AI) and Internet of Things (IoT) enable intelligent analysis of power generation, battery conditions, and energy demand for better energy management.

This work proposes an **AI-based hybrid solar-wind power generation system integrated with smart energy management and IoT monitoring.** The system uses AI to make adaptive decisions based on available renewable energy, battery status, and load demand. IoT provides real-time monitoring and communication of solar output, wind generation, battery status, and energy consumption through a connected platform. The proposed system aims to improve energy reliability,



optimize battery utilization, reduce energy losses, and provide a practical and sustainable solution for residential, rural, and small-scale applications.

LITERATURE SURVEY

[1] A. K. Bansal et al. (2022) Reviewed PV-wind hybrid systems, focusing on system sizing, forecasting, and optimization for reliable renewable power.

[2] L. EI Boujdaini et al. (2022) Studied optimal sizing of PV-wind-battery systems to reduce energy cost while maintaining reliable power supply.

[3] A. Mahesh and G. Sushilingdha (2022) Proposed an optimization-based energy management method considering renewable generation and battery conditions for power balance.

[4] M. P. Bonkile and V. Ramadesigan (2022) Analyzed battery sizing and degradation in PV-wind systems, highlighting the importance of effective battery management.

[5] D. Fares et al. (2022) Compared optimization methods for PV-wind-battery sizing with emphasis on reducing cost and maintaining power reliability.

[6] G. T. Udeh et al. (2022) Presented a rule-based energy management strategy considering cost, reliability, and emissions for hybrid energy systems.

[7] M. M Ibrahim (2023) Reviewed energy management methods for hybrid renewable systems and discussed factors affecting source and battery coordination.

[8] A. Bhimaraj and A. Mahesh Reviewed PV-wind hybrid systems and emphasized integrated control, storage, monitoring, and automated energy management.

[9] M. F. N. Mohd Farid and A. A. Bohari (2024) Developed a small-scale hybrid renewable system with IoT-based monitoring for continuous performance observation..

[10] Lopez-Monsalve et al Proposed an AI-assisted energy management system for a rural solar-wind IoT-based monitoring and load management.

[11] Milton et al Developed an IoT-enabled solar-wind system with battery storage for energy coordination and real-time system monitoring.

[12] Adithiyan et al. Investigated automatic load sharing and priority switching in hybrid solar-wind systems for maintaining reliable power supply.

BLOCK DIAGRAM



Fig 1: Block diagram of Ai-based hybrid solar-wind power generation with smart energy management using IoT

Fig 1 The system combines solar and wind sources, regulates power through controllers, stores energy in a battery, and



uses ESP32 with AI and IoT for monitoring, control, and efficient load management.

HARDWARE REQUIREMENTS

Solar panel



Fig 2: Solar Panel

A solar panel converts sunlight into electrical energy.

Wind turbine



Fig 3: Wind turbine

The wind turbine converts wind energy into electrical energy using a small generator.

ESP32 controller



Fig 4: ESP32 controller

ESP32 controls the system and enables IoT-based monitoring.

Battery



Fig 5: Battery

The battery stores the electrical energy for later use.

Charge controller



Fig 6: Charge controller

A charge controller regulates the battery charging and provides protection.

Voltage sensor



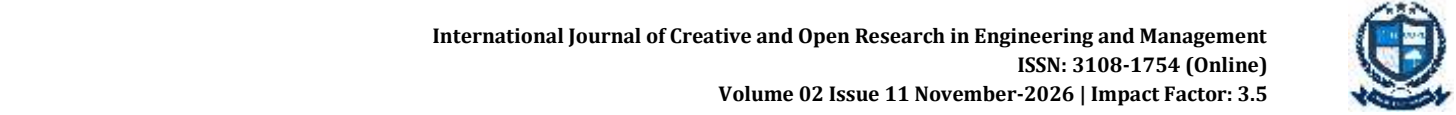
Fig 7: voltage sensor

A voltage sensor measures the voltage of the system.

Current sensor



Fig 8: Current sensor



A current sensor measures the amount of electrical current flowing through the circuit.

Relay module



Fig 9: Relay module

A relay module automatically switches the connected load or power path.

LCD display



Fig 10: LCD display

The LCD (Liquid Crystal Display) shows real time system parameters and battery status.

Load



Fig 11: Load

The load is the device that uses the electrical energy generated by the system.

SOFTWARE REQUIREMENTS

Arduino IDE

The Arduino IDE programs the ESP32 and controls the hybrid energy system.

Embedded c/c++

Embedded c/c++ processes sensor data and manages energy flow.

ESP32 Wi-Fi programming

The ESP32 Wi-Fi transfers the system data wirelessly for monitoring.

IoT monitoring platform

An IoT platform displays solar, wind, battery, and load parameters remotely.

Python

Supports AI-based energy analysis and decision-making

MATLAB/Proteus

Used for system simulation and performance analysis.

METHODOLOGY

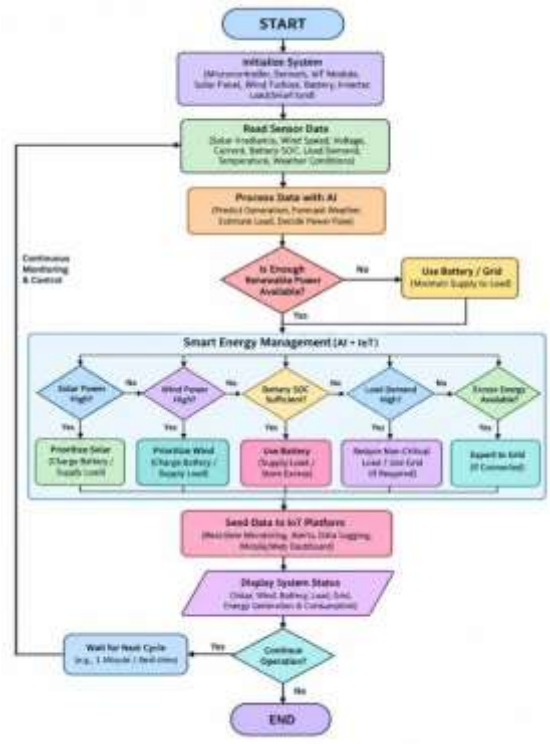


Fig 12: methodology for AI-Based Hybrid Power Generation With Smart Energy Management Using IoT



The proposed AI-Based Hybrid Solar-Wind Power Generation with Smart Energy Management using IoT integrates solar panels, a wind turbine, battery storage, sensors, ESP32, AI, and IoT technology. The system collects real-time data such as solar irradiance, wind speed, generated power, battery status, and load demand. The AI-based controller analyzes this information to manage power distribution, battery charging, and load supply according to energy availability. IoT technology enables real-time remote monitoring of system parameters through a dashboard. This continuous process of generation, sensing, prediction, energy management, and monitoring improves the utilization of renewable energy and provides efficient control of the hybrid power system.

CONCLUSION

The proposed system combines solar and wind energy sources with battery storage, intelligent energy management, IoT based monitoring, and fault detection. The implementation of these features enables coordinated management of renewable power generation, and energy storage, and load requirements. IoT monitoring provides continuous information about important operating parameters, while the implemented fault detection mechanism helps identify abnormal operating conditions and supports reliable system operations. The combination of renewable sources and storage improves energy utilization and power availability. Overall, the implemented system provides a practical approach for monitoring, managing, and detecting faults in small-scale renewable energy applications.

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[6] A. Javaid et al**., “Sustainable urban energy solutions: Forecasting energy production for hybrid solar-wind systems,”** *Energy conservation and management*, vol. 302, Art. No. 118120, 2024. The study uses a **Transformer-based machine-learning approach** to forecast solar and wind energy production in a hybrid PV-wind system.