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Smart Hybrid Solar Wind Power Management System Using ESP32

[1]Dr. S. Seenivasan, [2]Gopika Sri, [3]Hemambika, [4]Sasitha, [5]Wahid

[1]Assistant Professor, Department of Electrical and Electronics Engineering, Government College of Engineering, Dharmapuri, Tamilnadu, India

[2,3,4,5]Student, Department of Electrical and Electronics Engineering, Government College of Engineering, Dharmapuri, Tamilnadu, India

***Abstract* - The increasing demand for electricity and the environmental impact of conventional power generation have created the need for sustainable energy solutions. Renewable energy sources such as solar and wind power offer a clean and eco-friendly alternative to traditional energy systems. However, the intermittent nature of these sources requires an efficient hybrid system to ensure reliable power generation.**

This project presents a hybrid solar–wind power generation system with battery storage to provide a stable and continuous energy supply. The system integrates solar photovoltaic (PV) and wind energy sources, where the generated energy is stored in a battery and supplied to the load when required. To enhance system monitoring and control, an ESP32-based IoT monitoring system is implemented.

The system is integrated with the Blynk IoT platform, which enables real-time monitoring through a mobile application. Important parameters such as battery voltage, charging voltage, load current, and load power are measured and displayed on the Blynk dashboard. This system improves energy efficiency, ensures better utilization of renewable energy sources, and provides a convenient method for remote monitoring and management of the hybrid power system.

Keywords: Solar Energy, Wind Energy, Internet of Things, IoT, Wireless-Fidelity, Direct Current, Smart hybrid, Photovoltaic (PV).

I. INTRODUCTION

The increasing demand for sustainable and reliable energy sources has accelerated the adoption of renewable energy systems, particularly solar and wind power. However, conventional systems are typically based on a single energy source and involve manual switching mechanisms, resulting in inefficient energy utilization, lack of continuous power supply, and inadequate battery management. Furthermore, the absence of real-time monitoring and intelligent control limits system performance and reliability. Recent studies have attempted to address these challenges. Ahmed et al. (2021) developed an IoT-based solar monitoring system using ESP8266, enabling remote monitoring; however, wind energy integration was not considered. Li et al. (2022) proposed a smart hybrid system with MPPT and DC–DC converters to improve efficiency, but the system involved complex control logic and lacked a user-friendly monitoring interface. Balasundaram et al. (2024) introduced a hybrid microgrid integrating solar, wind, and battery storage systems with effective power management strategies, yet their work focused more on microgrid-level optimization rather than real-time embedded implementation using microcontrollers. To overcome these limitations, this project proposes a smart hybrid solar–wind power management system using ESP32. The system integrates both solar and wind energy sources to ensure continuous power generation under varying environmental conditions. DC–DC converters regulate source voltages, while the ESP32 enables automatic switching, efficient energy flow control, and battery charging management. Key parameters such as battery voltage, charging voltage, load current, and power are measured using sensors and monitored in real time through the BlynkIoT platform. This system provides an efficient, reliable, and user-friendly solution for renewable energy management with enhanced monitoring and control capabilities.

II. OVERVIEW

The Smart Hybrid Solar–Wind Power Management System is designed to efficiently utilize renewable energy sources for sustainable power generation. The system integrates two major renewable sources, namely solar energy and wind energy, to ensure a reliable and continuous energy supply. Since both solar and wind resources are naturally available but intermittent, combining them in a hybrid system improves overall energy availability and system reliability. In this system, solar panels convert sunlight into electrical energy, while a wind turbine generates electricity from wind energy. The generated power from both sources is regulated and stored in a battery for later use. The stored energy can then be supplied to electrical loads based on demand. To

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enhance monitoring and control, an ESP32 microcontroller is used to collect and process important system parameters. The system is integrated with the Blynk IoT platform, which enables real-time monitoring through a mobile application. Parameters such as battery voltage, charging voltage, load current, and load power are continuously measured and displayed on the Blynkdashboard. This hybrid renewable energy system improves energy efficiency, enhances reliability, and enables remote supervision of system performance, making it suitable for residential and small-scale power applications.

III. PROBLEM FORMULATION

Rapid growth in electricity consumption and the environmental impact of conventional power generation have created significant challenges for modern energy systems. Most traditional power plants rely on fossil fuels such as coal, oil, and natural gas, which not only deplete over time but also contribute to air pollution and climate change. These concerns highlight the importance of developing sustainable and environmentally friendly energy solutions. Clean energy technologies such as solar and wind power offer promising alternatives for electricity generation. Solar photovoltaic (PV) panels convert sunlight into electrical energy, while wind turbines generate power from the kinetic energy of wind. Although these renewable resources are abundant and eco-friendly, their output is highly dependent on environmental conditions, which can cause fluctuations in power generation. To enhance reliability and ensure a stable energy supply, combining multiple renewable sources in a Hybrid Renewable Energy System (HRES) is an effective approach. By integrating solar and wind energy within a single system, the availability of power generation can be improved. In addition, incorporating battery storage allows excess energy produced during favorable conditions to be stored and utilized when generation levels are low. Another important aspect of renewable energy systems is the continuous monitoring and management of system performance. Conventional monitoring methods often lack real-time data access and remote supervision capabilities. The integration of Internet of Things (IoT) technology provides an efficient solution for collecting, analyzing, and displaying system parameters remotely. In this project, a hybrid solar–wind power management system with battery storage and IoT-based monitoring is developed. An ESP32 microcontroller is used to measure system parameters and transmit data to the Blynkplatform for real-time monitoring through a mobile application. Important parameters such as battery voltage, charging voltage, load current, and load power are displayed on the Blynk dashboard. This approach improves system reliability, enables efficient energy management, and provides convenient remote supervision of the hybrid renewable energy system.

IV. MATERIALS AND METHOD

Table 1: Hardware requirement

Components	Specification	Quantity
Solar panel	12v,0.5A	1
Wi-Fi Module	ESP32	1
Transformer	Step-down transformer	1
Battery	Li-ion 12	1
Resistors	1kΩ	5
Transistors	BC547	3
LED	5mm	3
Adaptor	AC100,240V-50/60Hz0.3A	1

4.1 Block Diagram

The figure 1 represents the Smart Hybrid Solar–Wind Power Management System integrated with IoT monitoring. The system combines solar and wind energy sources to ensure reliable and continuous power generation. The solar panel converts sunlight into DC electrical energy, which is regulated using a DC–DC buck/boost converter to maintain a stable voltage level. Similarly, the wind turbine generates electrical energy from wind, and its output is converted into DC using a bridge rectifier and then regulated through another DC–DC converter.

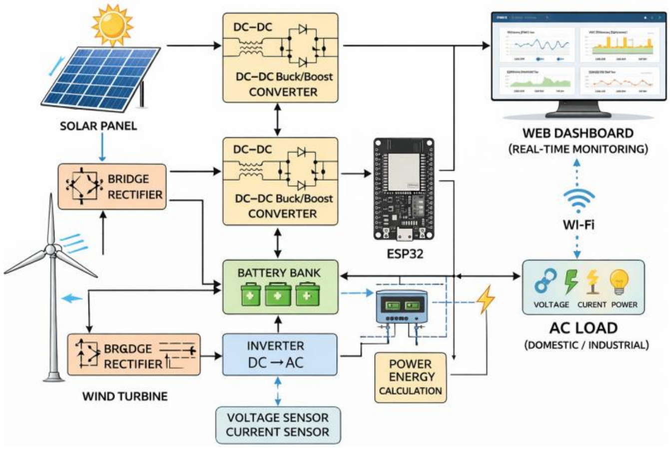

Figure 1: Block Diagram

The conditioned power from both sources is stored in a battery bank, which acts as an energy storage unit to supply power during fluctuations in renewable sources. The stored DC energy is then converted into AC using an inverter to power the connected load. For monitoring purposes, voltage and current sensors measure key electrical parameters. The ESP32 microcontroller processes this data and transmits it via Wi-Fi to the Blynk IoT platform, where parameters such as battery voltage, charging voltage, load current, and load power are displayed in real time. This enables efficient system supervision and performance monitoring.

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4.2 Circuit Diagram

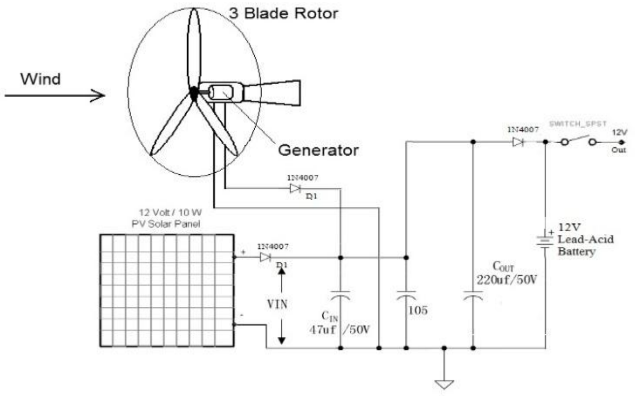

Figure 2: Solar Wind circuit diagram

The figure 2 represents a small-scale hybrid renewable energy system that integrates both wind and solar power sources to charge a 12 V battery and supply DC output. The main objective of this circuit is to improve energy availability by utilizing two renewable sources simultaneously.

In this system, a three-blade wind rotor is used to capture wind energy. The rotor drives a generator that converts mechanical energy from wind into electrical energy. The generated DC power passes through a 1N4007 diode (D1), which acts as a blocking diode. This diode prevents reverse current flow from the battery to the generator when wind speed is low or when the generator is not producing power.

Similarly, a 12 V / 10 W photovoltaic (PV) solar panel converts solar energy into electrical energy. The output of the solar panel is also connected through another 1N4007 diode to the common DC bus. This diode ensures that current flows only from the solar panel to the battery and prevents backflow of current between the two energy sources.

The outputs from both sources are combined at a common node and filtered using capacitors such as 47 µF input capacitor (CIN) and 220 µF output capacitor (COUT). These capacitors reduce voltage fluctuations and stabilize the DC supply. An additional 105 capacitor further smooths the voltage by filtering high-frequency noise.

The stabilized DC power is then stored in a 12 V lead-acid battery, which acts as an energy storage unit. A Single Pole Single Throw (SPST) switch is provided at the output stage to control the delivery of power to the load. The final output provides a regulated 12 V DC supply.

Overall, this hybrid configuration increases system reliability and ensures continuous power generation even when one renewable source is unavailable.

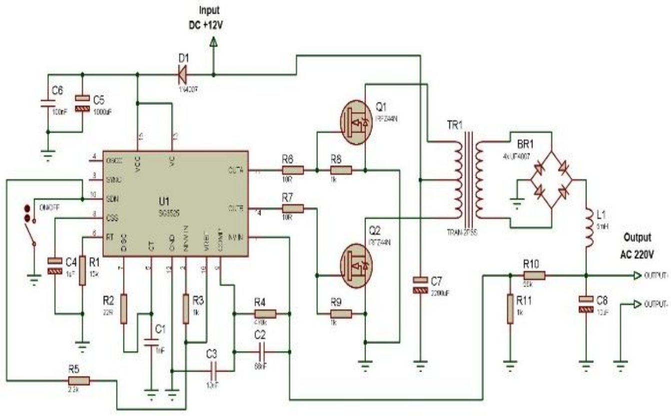

Figure 3: Inverter Circuit

The figure 3 illustrates a DC–AC inverter system designed to convert a 12 V DC input into a 220 V AC output using a switching control technique. The core component of the circuit is the SG3525, which functions as a pulse-width modulation (PWM) controller. This IC generates two complementary PWM signals that drive the power switching stage. The oscillation frequency is determined by the timing components (R1, R2, and C1), ensuring stable switching operation.

The PWM outputs are applied to two power MOSFETs, IRFZ44N (Q1 and Q2), through gate resistors. These MOSFETs operate in a push–pull configuration to alternately switch current through the primary winding of the transformer (TR1). As a result, the transformer steps up the low DC voltage into a higher AC voltage.

On the secondary side, a bridge rectifier composed of UF4007 diodes forms BR1, while filtering components such as inductors and capacitors smooth the waveform. Additional capacitors and resistors ensure voltage stability, noise filtering, and protection of the control circuitry, resulting in a regulated 220 V AC output suitable for powering electrical loads.

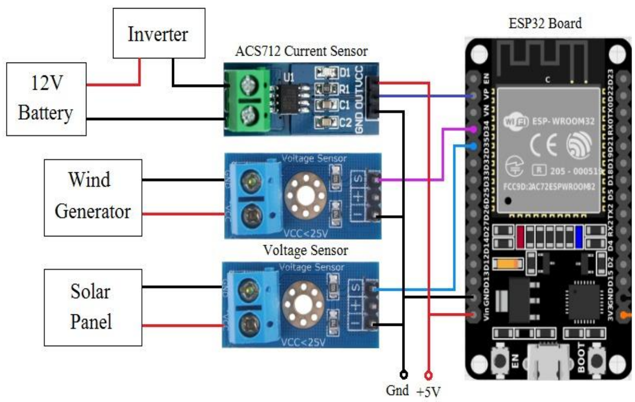

Figure 4: ESP32 circuit diagram

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The figure illustrates a smart monitoring system for a hybrid solar–wind power generation setup using a microcontroller-based platform. The system integrates a 12 V battery, wind generator, and solar panel to supply power, while sensors continuously monitor electrical parameters for efficient energy management.

The core processing unit of the system is the ESP32, which collects and processes data from the connected sensors. Current measurement is performed using the ACS712, which measures the current flowing from the battery through the inverter and provides an analog output proportional to the load current.

Voltage levels from the wind generator and solar panel are monitored using dedicated voltage sensor modules, which scale down the input voltage to a safe level suitable for the analog input pins of the ESP32. These sensors allow real-time monitoring of the voltage generated by each renewable energy source.

The ESP32 processes the measured voltage and current values and can transmit the data wirelessly for remote monitoring. This configuration enables efficient performance analysis, system protection, and intelligent management of hybrid renewable energy systems.

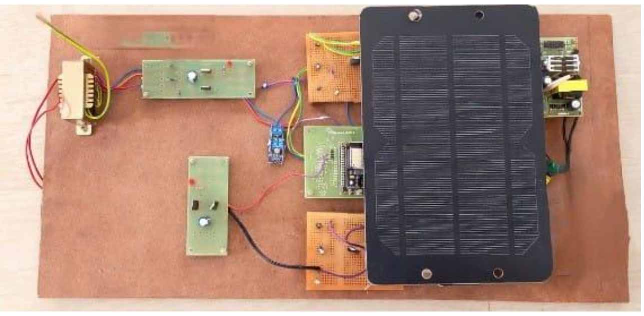

Figure 5: Components mounted on board

4.3 Project Implementation

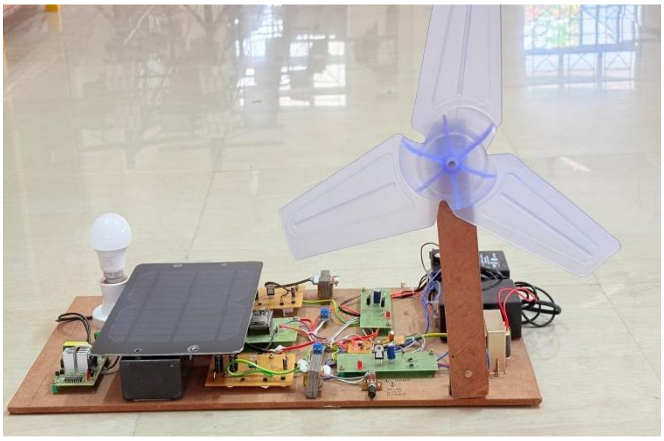

Figure 6: Final Project Implementation

V. SOFTWARE TOOLS USED

5.1 ESP32

The ESP32, developed by Espressif Systems, is a highly integrated and cost-effective microcontroller widely used in modern Internet of Things (IoT) applications. It is equipped with a dual-core Tensilica processor that delivers high computational performance while maintaining low power consumption. The ESP32 features built-in Wi-Fi and Bluetooth (Classic and BLE), enabling reliable wireless communication for connected devices.

Additionally, it supports a wide range of peripheral interfaces, including General Purpose Input/Output (GPIO), Analog-to-Digital Converter (ADC), Digital-to-Analog Converter (DAC), UART, SPI, and I2C, allowing seamless integration with sensors, actuators, and external modules. The device is compatible with multiple development environments such as Arduino IDE, MicroPython, and ESP-IDF.

Due to its versatility, scalability, and energy efficiency, the ESP32 is extensively utilized in smart home systems, industrial automation, wearable devices, and real-time data monitoring applications.

5.2 Blynk Application

Blynk app is used for connecting smart devices to the cloud so we can interact and communicate with it, allowing us to develop great interfaces for our project. It has many widgets through which we can choose which to apply in our project, like buttons, led etc.

Start working on your app. Then, on whichever Blynk-compatible device you're using, use the Blynk library you downloaded in step 2 to create code that instructs the machine what to do when a user interacts with the widgets on the new app you're developing in the Blynk app on their phone.

VI. RESULTS AND DISCUSSION

6.1 Solar Energy Output

The figure 7 illustrates the solar energy output stage of the proposed smart hybrid solar–wind power management system. A photovoltaic panel serves as the primary energy source, converting solar radiation into electrical energy through the principle of the photovoltaic effect. The generated DC power is regulated using a charge controller circuit to maintain a stable output and protect downstream components from overvoltage and fluctuations. The regulated power is then stored in a rechargeable battery, ensuring energy availability during low irradiance conditions. Power conditioning circuits are incorporated to optimize efficiency

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and provide a consistent supply to connected loads, such as the lighting unit shown in the setup. Indicator LEDs are used for real-time monitoring of system status and power flow. This configuration enhances reliability by efficiently harnessing solar energy and integrating it with hybrid sources, making the system suitable for sustainable and standalone energy applications

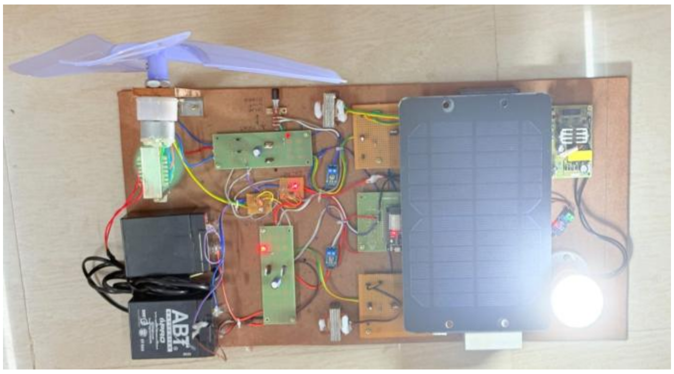

Figure 7: Energy generated is consumed by bulb

The wind energy subsystem in the proposed hybrid renewable energy system is designed to convert kinetic energy from airflow into electrical energy using a small-scale wind turbine. The turbine consists of rotor blades coupled to a DC generator, which produces electrical power proportional to wind speed.

When wind flows over the blades, rotational motion is induced, driving the generator to produce DC voltage. The generated output is initially unregulated and varies with wind velocity.

Therefore, a rectification and regulation stage is incorporated to stabilize the output before integration with the main power system.

The output power from the wind turbine can be expressed as:

$$P = \frac{1}{2}\rho A v^3 C_p$$

Where:

P = Power generated (W)
P = Air density (kg/m^3)
A = Swept area of turbine blades (m^2)
V = Wind speed (m/s)
C_p = Power coefficient of the turbine

The cubic relationship between wind speed and power indicates that even small increases in wind velocity significantly enhance energy generation.

In the implemented prototype, the wind turbine produces a low-voltage DC output, which is conditioned using a DC-DC converter to match the system voltage level. The regulated output is then either directly supplied to the load or stored in the battery for later use.

Experimental observations show that the wind energy source provides supplementary power during low solar conditions, thereby improving system reliability and ensuring continuous energy availability. The hybrid integration of wind energy enhances overall efficiency and reduces dependency on a single energy source.

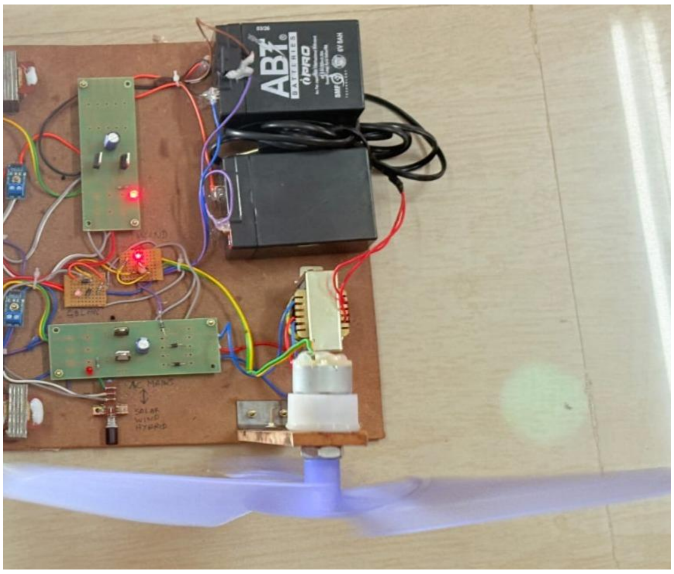

Figure 8: Led bulb glow due to wind energy

6.2 Output on Blynk app

As solar panels get energy from sunlight and, after that, will charge the battery and charging indications using a gauge, we will get on the Blynk app through Wi-Fi-module. Also, we can control the load on the cloud from anywhere; we can turn on/off the bulb as it is part of home automation. The results are shown in figure 10.

Figure 9: Output for on state in blynk app

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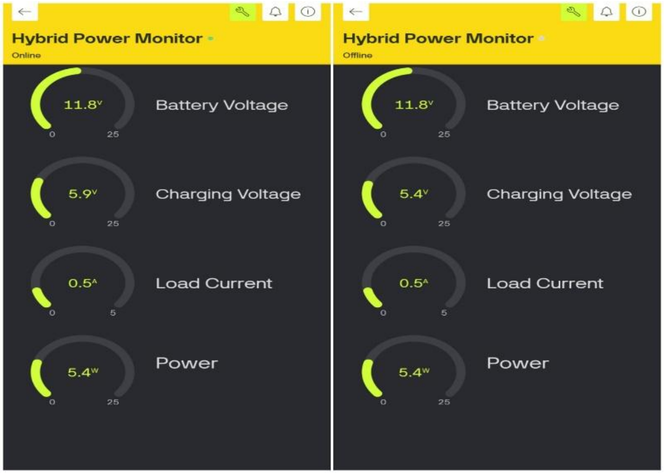

Figure 10: Indication of battery voltage, charging voltage, load current and load power

VII. CONCLUSIONS

This paper presented the design and implementation of a smart hybrid solar–wind energy management system aimed at improving the reliability and efficiency of renewable energy generation. The proposed system integrates photovoltaic and wind energy sources through a coordinated power management architecture, ensuring continuous and stable power delivery under varying environmental conditions.

The experimental results validate that the photovoltaic subsystem acts as the primary energy source under standard irradiance conditions, while the wind energy subsystem provides auxiliary support during periods of reduced solar availability. The hybrid configuration effectively mitigates the intermittency of individual sources, resulting in enhanced system reliability and improved energy utilization.

The incorporation of DC–DC converters and control circuitry ensures efficient power conditioning, voltage regulation, and load compatibility. Furthermore, the inclusion of a battery storage unit enables energy buffering, allowing excess generated power to be stored and utilized during peak demand or low-generation intervals. This significantly enhances system stability and operational continuity.

Performance analysis indicates that the proposed system achieves improved energy efficiency and reduced dependency on a single renewable source. The modular and scalable design makes it suitable for standalone and off-grid applications, particularly in remote and rural regions.

In conclusion, the developed hybrid energy system provides a sustainable and economically viable solution for decentralized power generation. Future work will focus on the implementation of advanced energy management algorithms, real-time monitoring using IoT-based platforms, and optimization of system components to further enhance efficiency and adaptability.

REFERENCES

[1] Kavita Sharma, Prateek Haksar, "Designing of Hybrid Power Generation System using Wind Energy- Photovoltaic Solar Energy- Solar Energy with Nano antenna." *International Journal of Engineering Research And Applications (IJERA)* Vol. 2, Issue 1, Jan-Feb 2018, pp.812-815.

[2] Jenkins, P. Elmnifi, M., Younis, A. and Emhamed, A, "Hybrid Power Generation by Using Solar and Wind Energy: Case Study." *World Journal of Mechanics*, 9, pp 81-93, 2019.

[3] Sandeepkumar, Vijay Kumar Garg, "A Hybrid Model of Solar-Wind Power Generation System", *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, Vol. 2, Issue 8, Aug 2017.

[4] Abhishek Kumar Gupta, M. Shasilal, "A review on Renewable Energy Sources for Hybrid Power Generation." *International Journal of Creative Research Thoughts*, vol. 6, Issue 1, Jan 2018.

[5] T.S. Balaji Damodhar and A. Sethil Kumar, "Design of high step upmodified for hybrid solar/wind energy system," *Middle- East*.

[6] Rakeshkumar B. Shah, "Wind solar hybrid energy conversion system-literature review," *International Journal of Scientific*.

[7] S. Jain, and V. Agarwal, "An Integrated Hybrid Power Supply for Distributed Generation Applications Fed by Nonconventional Energy Sources," *IEEE Transactions on Energy Conversion*, vol.23, June 2008.

[8] A.O. Ciuca, I.B.Istrate, and M.Scripcariu, "Hybrid Power-Application for Tourism in Isolated Areas," *World Academy of Science, Engineering and Technology*, vol. 53, pp 264-269, 2009.

[9] D. Sharma, N.K. Yadav, "Impact of Distributed generation on voltage profile using different optimization techniques." *International conference on control, computing, communication and materials, Allahabad*, pp. 1-6, 2016.

[10] Ahmed, N.A., Miyatake, M., and Al-Othman, A.K. "Power Fluctuations Suppression of Stand-Alone Hybrid Generation Combining Solar Photovoltaic/Wind Turbine And Fuel Cell.

[11] Deshmukh, M.K., Deshmukh, S.S. "Modeling Of hybrid Renewable Energy Systems", *Renewable and Sustainable Energy Reviews*, vol.12, no. 1, pp. 235-249.

[12] Tina, G., Gagliano, S., and Raiti, S. "Hybrid solar/wind power system probabilistic modelling for long-term

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https://doi.org/10.47001/IRJIET/2026.104010

performance assessment", *Solar Energy*, Vol. 80, pp. 578-588, 2006.

[13] Celik, A.N. "Techno-Economic Analysis Of Autonomous PV-Wind Hybrid Energy Systems Using Different Sizing Methods", *Energy Conversion And Management*, Vol. 44, pp. 1951-1968, 2003.

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