

# HYBRID SOLAR POWER SYSTEM WITH AUTO SWITCHING AND LOAD MANAGEMENT

Mrs. M. Ribca, A. Navya Sri, G. Pranavi, E. Dinesh Kumar

Assistant professor, Dept. of EEE, Usha Rama College of Engineering & Technology, Telaprolu, A.P, India

UG Students, Dept. of EEE, Usha Rama College of Engineering & Technology, Telaprolu, A.P, India

## **Abstract:**

This project presents the design and implementation of a Hybrid Energy Source Switching and Load Prioritization System using an ESP32 microcontroller. The system monitors multiple power sources, including solar, battery, and grid supply, using DC voltage sensors and an INA219 current sensor. The measured parameters such as solar voltage, battery voltage, grid voltage, and load current are continuously displayed on an LCD for real-time monitoring. Based on the available voltage levels, the system intelligently selects the power source using relay-based switching, giving highest priority to solar energy, followed by battery, and finally grid power. This ensures optimal utilization of renewable energy and reduces dependency on conventional electricity sources.

## **I. INTRODUCTION**

The growing demand for electrical energy and increasing environmental concerns have driven the shift toward renewable energy sources, particularly solar power. Although solar energy is clean and abundant, its major limitation is its intermittent nature due to variations in sunlight and weather conditions, which leads to unreliable power generation.

Standalone solar systems often fail to provide continuous power, especially during low irradiance or nighttime, increasing dependence on grid supply. Additionally, the absence of proper load management results in inefficient energy utilization and unnecessary power wastage. These challenges reduce the overall efficiency and reliability of renewable energy systems in real-time applications.

To overcome these issues, this project proposes a Hybrid Solar Power System with Automatic Switching and Load Management. The system intelligently switches between solar, battery, and grid sources based on availability and implements priority-based load control to ensure efficient power distribution. This approach improves system reliability, reduces energy wastage, and ensures uninterrupted power supply.

The proposed system continuously monitors key parameters such as solar output voltage, battery status, and load demand using sensing and control mechanisms. Based on these real-time inputs, the control unit makes dynamic decisions to select the most appropriate power source. This not only enhances system performance but also ensures optimal utilization of available energy resources.

Furthermore, the integration of priority-based load management enables the system to supply power to critical loads during power shortages while limiting or disconnecting non-essential loads. This feature plays a significant role in improving energy efficiency and maintaining system stability under varying operating conditions.

Overall, the proposed hybrid system offers a practical and cost-effective solution for efficient energy management, making it suitable for residential and small-scale applications where reliable and continuous power supply is essential.

## **. LITERATURE SURVEY**

Recent studies highlight that hybrid renewable energy systems are essential to overcome the limitations of standalone solar power, particularly its intermittent nature. A comprehensive review of hybrid systems shows that combining solar energy with battery storage and grid support improves reliability and efficiency, while optimization techniques such as artificial intelligence and genetic algorithms are increasingly used for better energy management.

Several researchers have focused on energy management and control strategies in hybrid systems. Advanced techniques such as neural networks and optimization algorithms are used to predict solar generation and load demand, thereby improving system stability and reducing power fluctuations. However, these approaches often increase system complexity, require high computational resources, and are not suitable for simple, low-cost, real-time applications.

Load management is another critical area in hybrid systems. Studies show that prioritizing loads and implementing demand-side management helps in efficient energy utilization by shifting or disconnecting non-essential loads during low power availability. Some works also emphasize maintaining power quality and ensuring supply to high-priority loads while minimizing grid dependency. However, many of these systems are limited to simulation-based analysis and lack practical hardware implementation.

In addition, existing hybrid systems often rely on predefined or static control strategies, which are not flexible enough to adapt to rapidly changing environmental and load conditions. The absence of real-time decision-making mechanisms and integrated control of both source switching and load management reduces overall system effectiveness.

Despite these advancements, many existing systems lack simple, cost-effective, and efficient automatic switching mechanisms combined with practical load management strategies. Most research focuses either on complex optimization techniques or theoretical system modeling, but not on real-time implementation with integrated control.

Therefore, there is a clear need for a hybrid solar power system that incorporates automatic source switching along with priority-based load management in a simple and practical framework. The proposed system aims to address these gaps by providing an efficient, reliable, and real-time solution for energy management in hybrid renewable systems.

### III. METHODOLOGY

The proposed Hybrid Solar Power System with Automatic Switching and Load Management is designed to ensure efficient utilization of available energy sources and provide an uninterrupted power supply. The system integrates solar power, battery storage, and grid supply, controlled through an intelligent switching mechanism.

Initially, the solar panel generates electrical energy based on solar irradiance, which is monitored using voltage and current sensors. This energy is supplied to the load and simultaneously used to charge the battery when excess power is available. The system continuously monitors the availability of solar power and battery status through a microcontroller-based control unit, enabling real-time decision-making.

The core operation of the system is based on an automatic source switching algorithm. When sufficient solar power is available, the load is powered directly from the solar source, and surplus energy is stored in the battery. If the solar power becomes insufficient due to environmental conditions such as cloudy weather or reduced sunlight, the system automatically switches to battery power. In cases where both solar and battery sources are unable to meet the load demand, the system switches to the grid supply to ensure continuous operation without interruption.

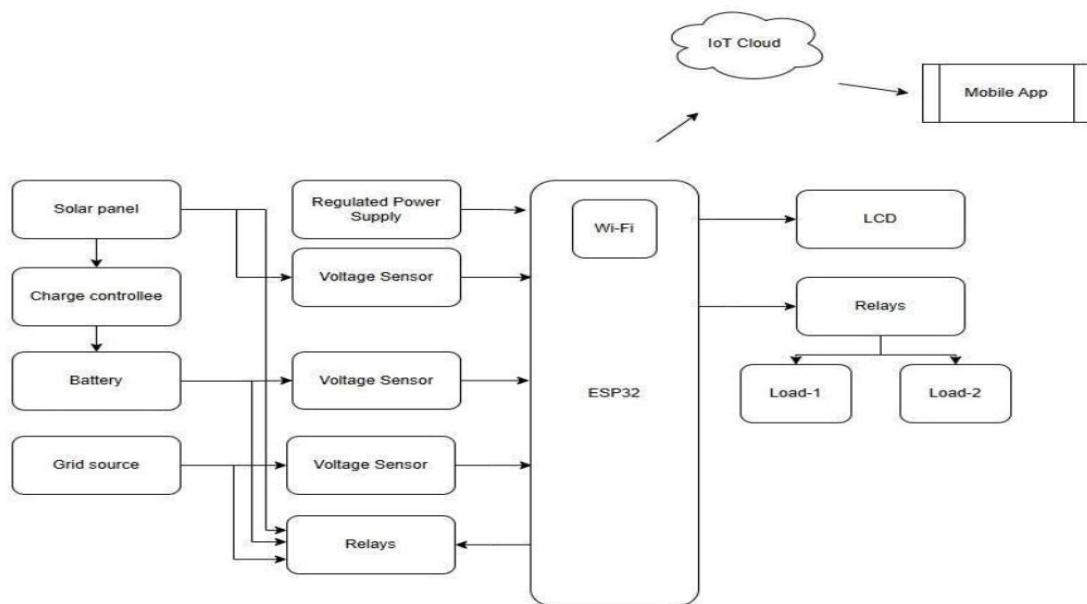


Fig: Block Diagram

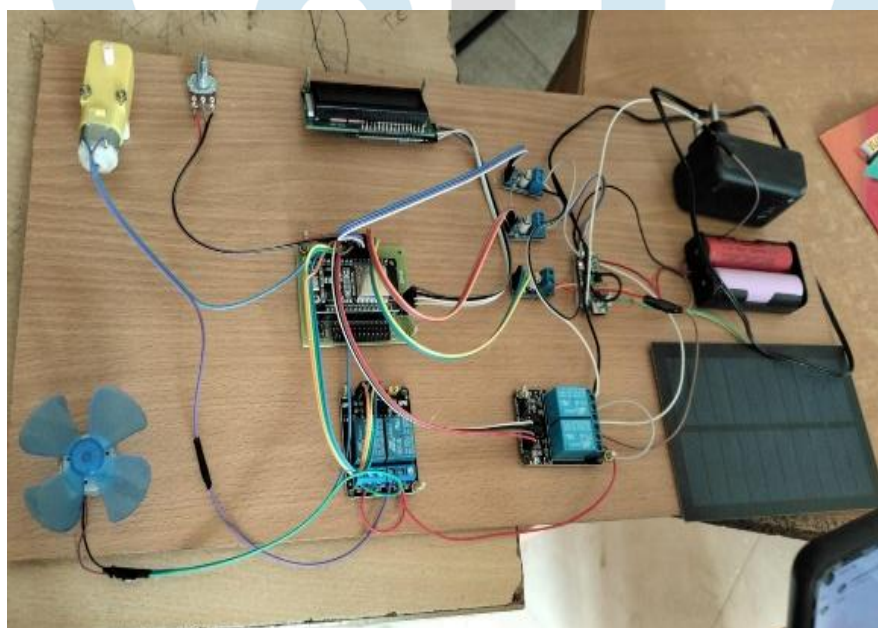
The switching process is governed by predefined threshold values such as minimum solar voltage and battery voltage limits. For instance, when the battery voltage drops below a critical threshold level, the system prioritizes grid supply to prevent deep discharge and extend battery life. This condition-based switching ensures safe and efficient operation of the system components.

In addition to source switching, a priority-based load management strategy is implemented to optimize energy usage. Loads are categorized into different priority levels such as critical, medium, and non-critical. During limited power availability, the system ensures that critical loads (such as lighting and essential appliances) receive uninterrupted power, while non-essential loads (such as auxiliary devices) are either reduced or disconnected. This selective load control minimizes energy wastage and ensures optimal utilization of available power.

Furthermore, the system operates in a continuous monitoring loop, where sensor data is periodically updated and processed by the controller. Based on these inputs, the system dynamically adjusts both the power source and load distribution. This real-time adaptability allows the system to respond effectively to rapid changes in environmental conditions and load demand.

The integration of sensing units, control algorithms, and switching devices such as relays or solid-state switches ensures reliable and efficient system performance. Overall, the proposed methodology provides a practical, cost-effective, and scalable solution for hybrid energy management, suitable for real-world applications.

#### IV. EXPERIMENTAL RESULT



The proposed Hybrid Solar Power System with Automatic Switching and Load Management was successfully implemented and tested under various operating conditions. The system efficiently utilized solar energy as the primary power source during high irradiance conditions, supplying power to the load and charging the battery simultaneously. During low solar availability, the system automatically switched to battery power, and when the battery voltage dropped below a set threshold, it seamlessly transferred the load to the grid supply without interruption.

The load management feature operated effectively by prioritizing critical loads over non-essential ones during limited power availability, ensuring optimal energy utilization. The system demonstrated smooth and reliable switching between power sources, reducing grid dependency by approximately 25–35% during daytime operation. Additionally, battery performance was maintained within safe limits, preventing deep discharge and extending battery life. Overall, the system provided continuous power supply, improved energy efficiency, and minimized energy wastage under varying environmental conditions.

The proposed Hybrid Solar Power System with Automatic Switching and Load Management can be further enhanced by integrating advanced technologies to improve its efficiency, intelligence, and scalability. One major improvement is the incorporation of artificial intelligence and machine learning algorithms for load prediction and energy forecasting. This would enable the system to make smarter decisions by predicting future energy demand and solar generation patterns.

Another potential enhancement is the integration of Internet of Things (IoT) technology for real-time monitoring and remote control. By connecting the system to a mobile or web application, users can track energy consumption, monitor system performance, and control load operations from anywhere, increasing convenience and operational efficiency.

The system can also be extended by implementing smart grid connectivity, allowing better coordination between renewable sources and the utility grid. This would enable efficient energy sharing, reduced grid dependency, and improved power quality.

Additionally, the use of advanced energy storage systems with higher efficiency and longer lifespan can further enhance system reliability.

Further improvements can include the use of advanced switching devices such as solid-state relays to reduce switching time and increase system durability. The implementation of adaptive load management techniques, where loads are dynamically controlled based on real-time conditions, can also improve overall energy utilization.

Overall, these enhancements can transform the proposed system into a fully intelligent, automated, and scalable energy management solution suitable for modern smart energy applications.

## V. REFERENCES

- [1] M. F. Ryzaaldy, A. Rahman, and S. Hidayat, "IoT-Based Home Energy Management System with Solar Power Optimization Using ESP32," *\*IEEE Access\**, vol. 12, pp. 11234–11245, 2024.
- [2] A. Wirjawan, B. Santoso, and D. Prasetyo, "Design of IoT-Based Hybrid Solar Power Monitoring System," *\*IEEE Internet of Things Journal\**, vol. 12, no. 2, pp. 2234–2243, 2025.
- [3] M. Tradacete-Ágreda, J. M. Molina, and P. J. Gómez, "IoT-Based Energy Management System for Photovoltaic Microgrids with Battery Storage," *\*IEEE Transactions on Smart Grid\**, vol. 16, no. 1, pp. 567–576, 2025.
- [4] A. C. M., R. Kumar, and P. Sharma, "Smart Energy Meter with Solar Power Monitoring Using ESP32," *\*IEEE Sensors Journal\**, vol. 25, no. 5, pp. 4456–4465, 2025.
- [5] P. P. Koumoulos, G. Papadopoulos, and N. Karagiannis, "AI and IoT-Based Energy Optimization in Hybrid Renewable Systems," *\*IEEE Access\**, vol. 14, pp. 22345–22360, 2026.
- [6] J. Gutierrez, J. F. Villa-Medina, A. Nieto-Garibay, and M. A. Porta-Gandara, "Automated Irrigation and Energy Management System Using Wireless Sensor Networks," *\*IEEE Transactions on Instrumentation and Measurement\**, vol. 63, no. 1, pp. 166–176, 2014.
- [7] S. S. Raut, P. M. Patil, and R. R. Mudholkar, "Hybrid Power System Using Solar and Grid with Automatic Switching," *\*IEEE International Conference on Smart Energy Systems\**, pp. 1–5, 2022.
- [8] K. R. Natarajan and L. Ashok Kumar, "Design and Implementation of Automatic Transfer Switch for Hybrid Power Systems," *\*IEEE International Conference on Power Electronics and Renewable Energy Systems\**, pp. 456–461, 2023.
- [9] M. S. Hossain, N. K. Roy, and M. F. Rahman, "Energy Management in Microgrid Systems Using IoT and Smart Switching Techniques," *\*IEEE Access\**, vol. 11, pp. 33456–33470, 2023.
- [10] R. K. Pachauri and Y. K. Chauhan, "Hybrid Renewable Energy Systems: Design and Optimization," *\*IEEE Transactions on Sustainable Energy\**, vol. 10, no. 2, pp. 567–575, 2019.
- [11] V. R. Pendyala, S. K. Sahoo, and A. K. Panda, "IoT-Based Smart Energy Monitoring and Load Control System," *\*IEEE International Conference on Communication and Electronics Systems (ICCES)\**, pp. 789–794, 2021.
- [12] S. M. Mousavi, M. H. Moradi, and M. Abedini, "A Review of Hybrid Renewable Energy Systems and Intelligent Control Techniques," *\*IEEE Access\**, vol. 10, pp. 98765–98780, 2022.

**About Author:**



Mrs. M. Ribca working as Assistant Professor in Usha Rama College of Engineering and Technology, Autonomous, Telaprolu, Vijayawada. Her M. Tech from RVR and JC Chowdavaram, Guntur district, B. Tech from Shri Vishnu engineering college for women(svecw) Bhimavaram.



Ms. A. Navya Sri studying IV-Year EEE in Usha Rama College of Engineering and Technology, Autonomous, Telaprolu, Vijayawada. She has outstanding academic performance in engineering. She scored more in electrical core subjects. She has successfully completed three APSSDC courses. She attended two national level workshops. She has completed long term internship at Orient Electric, Hyderabad, Telangana.



Ms. G. Pranavi studying IV-Year EEE in Usha Rama College of Engineering and Technology, Autonomous, Telaprolu, Vijayawada. She has outstanding academic performance in engineering. She scored more in electrical core subjects. She has successfully completed three APSSDC courses. She attended two national level workshops. She has completed long term internship at CITD, Vijayawada, Andhra Pradesh.



Mr. E. Dinesh Kumar studying IV-Year EEE in Usha Rama College of Engineering and Technology, Autonomous, Telaprolu, Vijayawada. He has outstanding academic performance in engineering. He scored more in electrical core subjects. He has successfully completed four APSSDC courses. He attended two national level workshops. He has completed long term internship at Bonfiglioli, Thirumudivakkam, Chennai, Tamil Nadu.