Journal of Informatics
Electrical and Electronics Engineering, 2025,
Vol. 06, Iss. 01, S. No. 127, pp. 1-6
ISSN (Online): 2582-7006

Automatic Solar Battery Charging System with Grid Backup

D. Hari Chandra Prasad Babu Nayak[1], K. Yaswanth Kumar[2], P. Gopi Ram[3], A. Mehaboob Subhani[4]

[1,2,3,4]Department of EEE, Usha Rama College of Engineering and Technology, Telaprolu, Andhra Pradesh, India
harichandraprasadd75@gmail.com[1], kommineniyaswanthkumar@gmail.com[2], gopiramnani991@gmail.com[3], mehaboobsubhaniabdul@gmail.com[4]

How to cite this paper: D. H. C. P. B. Nayak[1], K. Y. kumar[2], P. G. Ram[3], A. M. Subhani[4], "Automatic Solar Battery Charging System with Grid Backup," *Journal of Informatics Electrical and Electronics Engineering* (*JIEEE*), Vol. 06, Iss. 01, S No. 127, pp. 1–6, 2025.

https://doi.org/10.54060/a2zjournals.jieee.127

Received: 05/01/2025
Accepted: 31/03/2025
Online First: 18/04/2025
Published: 25/04/2025

Abstract

The increasing demand for sustainable and uninterrupted power supply has driven advancements in hybrid energy systems. This paper presents the design and implementation of an Arduino-based intelligent power switching and monitoring system for solar and grid hybrid energy sources. The system utilizes a solar panel to charge a battery through a charge controller, while also integrating grid power as a backup. A voltage sensor is used to monitor the battery level, and an Arduino microcontroller is employed to control a relay module, which intelligently switches the load between solar and grid power based on predefined thresholds. The LCD module displays real-time system status, enhancing user interaction. Additionally, a battery charge adaptor is included to ensure backup charging when solar input is insufficient. This system optimizes the use of renewable energy while maintaining uninterrupted power supply to the load, making it ideal for smart homes, rural electrification, and energy-efficient applications. Experimental results demonstrate reliable switching behavior and effective power utilization, validating the system's practical viability.

Keywords

Arduino, Solar-Grid Integration, Battery Management, Load Switching, Voltage Monitoring, Renewable Energy

1. Introduction

The growing world energy demand, combined with worries about fossil fuel exhaustion and environmental pollution, has accelerated the search for alternative and renewable energy supplies. Of these, solar energy is among the most attractive solutions owing to its availability, sustainability, and minimal environmental footprints. Nevertheless, solar energy systems are encumbered by issues of intermittency and weather dependence, which can affect their capacity to deliver a constant and dependable power supply.

To meet these challenges, hybrid energy systems that combine solar power with traditional grid electricity are receiving increasing attention. These systems are capable of ensuring load continuity by smartly switching between energy sources depending on availability and system demand. Proper management of such systems not only improves energy efficiency but also provides a stable and uninterrupted power supply, particularly in remote or semi-urban regions where power cuts are common.

2. Related Works

With increasing global energy consumption, researchers and engineers are investigating smart hybrid systems integrating renewable energy sources with traditional grid power to obtain energy efficiency, reliability, and sustainability. In recent years, microcontroller-based systems, especially Arduino-based systems, have been widely used for real-time monitoring of energy and switching sources and semi urban-setting.

The integration of solar energy with battery storage and grid power has been the focus of extensive research, particularly in efforts to develop hybrid inverter systems that ensure a stable and uninterrupted power supply. In [1], Hybrid Inverter Using Solar Battery Charging published on Academia.edu, the authors present a comprehensive overview of a hybrid system capable of charging batteries using both solar panels and conventional AC mains. The system intelligently prioritizes solar energy when available, thereby optimizing renewable energy usage and reducing dependency on the grid. This work emphasizes the role of key components such as solar panels, charge controllers, inverters, and battery banks, while also addressing issues related to power conversion and efficient energy management. The study also highlights the incorporation of MPPT (Maximum Power Point Tracking) techniques to enhance the efficiency of solar power harvesting. This prior work provides a strong foundation for the development of advanced hybrid inverters, and serves as a comparative benchmark for the proposed system, which aims to further enhance reliability, energy efficiency, and smart switching capabilities.

The advancement of hybrid inverter technology has garnered significant attention in recent years due to its potential to provide clean, continuous, and efficient energy solutions. In [2], Hybrid Inverter with Solar Battery Charging, published in the International Journal of Emerging Technologies and Innovative Research, the authors propose a system that combines solar energy and conventional grid power to ensure uninterrupted power supply, especially in areas prone to frequent outages. The study presents a dual-mode charging mechanism, where the inverter draws energy from solar panels during daylight hours and switches to grid power when solar input is insufficient. A key contribution of this work is the use of a microcontroller-based control system that manages power flow and prioritizes renewable sources. Furthermore, the paper discusses essential components such as the inverter circuitry, battery bank, charge controller, and relay-based switching. By incorporating protective measures and efficient load handling, the system enhances both safety and performance. This research offers valuable insight into the design of reliable and cost-effective hybrid inverters, and aligns closely with the goals of the current work, which seeks to further improve energy efficiency and intelligent energy source management.

3. Proposed Methodology

The suggested Hybrid Inverter System with Arduino will eliminate the drawbacks of current power backup systems through automatic switching, real-time monitoring, and intelligent energy management. It provides a constant power supply by smoothly switching between grid power and a solar inverter depending on availability. Voltage and current levels are continuously monitored by the Arduino microcontroller to identify the most stable and efficient power source, thus eliminating the need for human intervention.

The system is priority-based. During grid availability, it acts as the main power source, providing electricity to the load connected. The system also has a battery charge adapter, through which the battery can be charged from the grid when solar power is not enough or not available. This keeps the battery charged for backup purposes. But in the event of a grid supply failure, the Arduino senses this failure and automatically switches over to the solar inverter through a relay system. This switchover occurs automatically and in a matter of seconds, preventing power-sensitive loads from being disturbed. The system also has an alarm notification system, which notifies users in the event of a power switch or a critical fault.

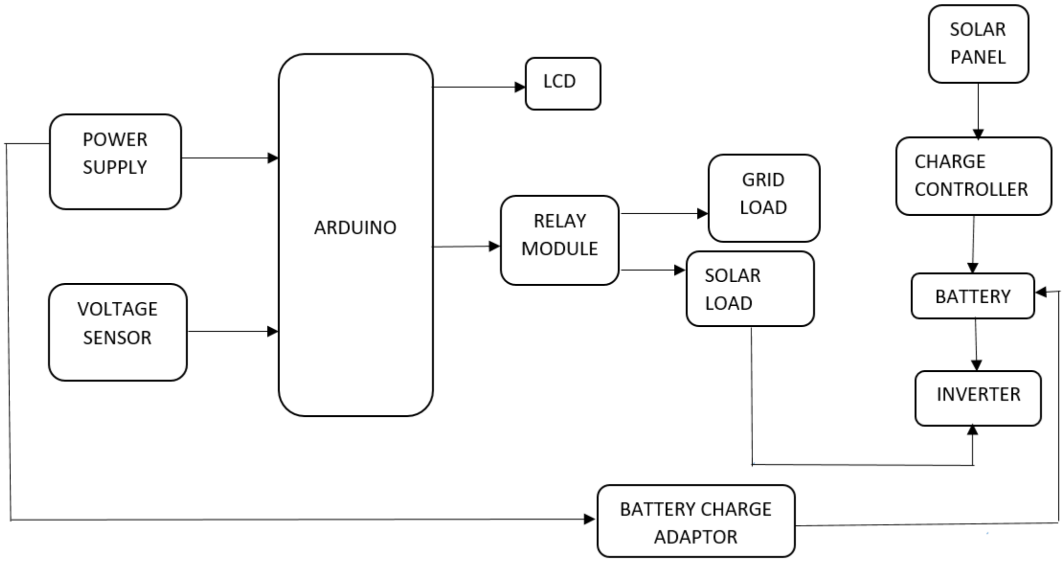

Figure 1. Block Diagram of Automatic Solar Battery Charging System with Grid Backup

In order to increase energy efficiency, the system maximizes the use of solar power whenever possible, minimizing reliance on the primary grid and reducing the cost of electricity. The status of the power source in real-time is indicated on an LCD display, enabling users to see which source of energy is in use. Current sensors also avoid overload conditions by disconnecting the load when high power usage is sensed, thus safeguarding electrical appliances from destruction.

4. Components

Solar Panel

Solar panels convert sunlight into electricity using photovoltaic cells, offering a sustainable and renewable energy solution for powering various applications, from residential homes to spacecraft. Their efficiency and environmental benefits make them a key player in the transition towards clean energy sources

Voltage Sensor

A voltage sensor is a device or circuit that detects and measures the voltage level of an electrical signal or system. It's commonly used in electronics, electrical systems, and automation to monitor voltage levels and trigger actions or provide data for further processing.

16*2 LCD

A 16*2 display typically refers to a liquid crystal display (LCD) with 16 characters per line and 2 lines, commonly used in electronic devices such as digital clocks, small appliances, and DIY electronics projects. Its compact size and simplicity make it suitable for displaying basic information in a variety of applications.

Relay

A relay is an electromechanical switch that controls the flow of electricity by opening or closing circuits, commonly used to control high-power devices with low-power signals in applications such as home automation, industrial machinery, and automotive systems. It provides isolation between the control signal and the high-power circuit, ensuring safety and reliability in electrical systems.

Charge Controller

A charge controller is an essential component in off-grid renewable energy systems, especially solar power systems. It regulates the voltage and current coming from solar panels going to the battery, ensuring safe, efficient, and long-lasting battery operation

Arduino

It’s an open-source electronics platform based on easy-to-use hardware and software. It's great for building interactive projects using microcontrollers. You can do everything from blinking an LED to building a robot or even creating a home automation system.

5. Working

The intended system is a smart system of power distribution for farm or home use from renewable energy sources. It mostly deals with solar power and offers automatic switching to mains power as necessary to provide seamless operation. It is powered by an Arduino controller, which is the master controller, interacting with voltage sensors, a relay driver, and the different sources of power to provide automated decision-making.

The solar panel gathers the energy from the sun and feeds it to a charge controller, which controls the energy before charging it into a battery. The stored energy is then transformed from DC to AC through an inverter, which makes it ideal for powering ordinary electrical devices or irrigation systems.

A voltage sensor constantly keeps track of the voltage level of the battery and transmits the information to the Arduino. The microcontroller calculates the available charge based on this information. If the voltage level of the battery is greater than a predetermined value, the relay module is activated to divert the solar load from the inverter-powered battery.

In case the battery voltage falls below the minimum value or in the absence of solar power, the Arduino switches the relay automatically to use power from the grid load to ensure unbroken operation. Furthermore, a battery charge adaptor is triggered to charge the battery utilizing power from the grid to keep the system ready for the next charging cycle with the solar. The whole system status, such as power source utilization, battery level, and load activity, is shown on an LCD display, giving real-time feedback to users. This automation minimizes manual intervention, maximizes energy efficiency, and encourages the utilization of renewable energy in a sustainable and reliable way.

6. Result and Discussion

The operation of the Arduino-based solar and grid hybrid power management system has achieved effective outcomes, proving the viability and effectiveness of combining renewable sources of energy with traditional sources using automation control. The system was developed from a 15W, 12V solar panel interfaced with a charge controller, which regulated the efficient and safe charging of a 12V lead-acid battery. The battery, then, was the main source of power for a strung AC load, simulated in the proof-of-concept with a light bulb. At the heart of the control scheme was an Arduino Uno microcontroller, which took real-time feedback from a voltage sensor to read the battery voltage. Depending on the voltage, the Arduino made decisions to toggle the load between the sun and grid with a relay module. Whenever the solar battery generated enough voltage, the load was energized by solar power, indicating the system's preference for renewable power. In the event of low voltage below the set level caused by insufficient sunlight or battery depletion, the system automatically replaced the load on grid power, thereby maintaining constant supply of energy.

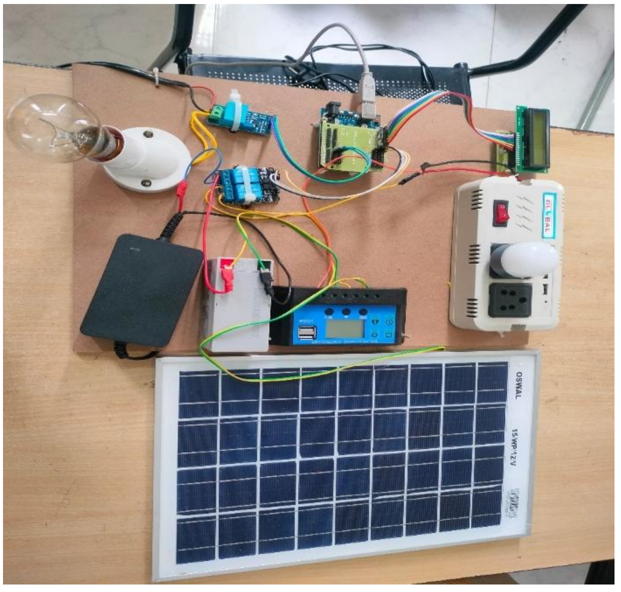

Figure 2. Hardware Kit of Automatic Solar Battery Charging System with Grid Backup

The operation of the Arduino-based solar and grid hybrid power management system has achieved effective outcomes, proving the viability and effectiveness of combining renewable sources of energy with traditional sources using automation control. The system was developed from a 15W, 12V solar panel interfaced with a charge controller, which regulated the efficient and safe charging of a 12V lead-acid battery. The battery, then, was the main source of power for a strung AC load, simulated in the proof-of-concept with a light bulb. At the heart of the control scheme was an Arduino Uno microcontroller, which took real-time feedback from a voltage sensor to read the battery voltage. Depending on the voltage, the Arduino made decisions to toggle the load between the sun and grid with a relay module. Whenever the solar battery generated enough voltage, the load was energized by solar power, indicating the system's preference for renewable power. In the event of low voltage below the set level caused by insufficient sunlight or battery depletion, the system automatically replaced the load on grid power, thereby maintaining constant supply of energy.

7. Conclusion

The effective design and logical flow of the Arduino-based solar and grid hybrid energy management system. The integration of key components such as the solar panel, charge controller, battery, inverter, and Arduino-controlled relay module ensures that the system can dynamically switch between solar and grid power based on real-time voltage readings. The voltage sensor continuously monitors the battery level and provides data to the Arduino, which then controls the relay to route power to the load either from the solar source or from the grid, depending on availability. The LCD provides real-time system feedback, enhancing the usability and transparency of operations. The inclusion of a battery charge adaptor ensures that the battery remains charged even when solar energy is insufficient. This smart energy management approach not only ensures uninterrupted power supply but also promotes efficient use of renewable energy resources. Overall, the system offers a scalable and cost-effective solution for domestic or small-scale applications, supporting the global shift toward sustainable energy technologies.

8. Future Work

Though the existing prototype effectively proves the fundamental operation of an Arduino-based solar and grid hybrid power management system, there is significant room for future development and scalability. An important enhancement would be the addition of IoT features through the utilization of Wi-Fi or GSM modules to enable remote monitoring and control of system parameters via mobile app or web dashboard. This would allow users to monitor solar power production, battery voltage, and switch status in real-time remotely. Moreover, incorporating data logging functionality via an SD card or cloud storage may assist in long-term performance and energy consumption pattern analysis. The system may also be extended to handle more loads with prioritization levels so that vital appliances are provided with power when energy supply is low. Adding smart alerting through SMS, push messaging, or buzzer notification on low battery level, power outages, or source changeover would further enhance system reliability and user notification. Lastly, adding a smaller, weather-resistant housing would increase system ruggedness and allow the system to be deployed outdoors or in off-grid situations. These additional features would mature the system from a proof of concept to an operational, smart energy management system ready for production deployment.

References

[1]. Hybrid Inverter Using Solar Battery Charging. [Online]. Available: https://www.academia.edu/ (Accessed: Dec. 1, 2024).

[2]. V. Kalandhar, A. V. Reddy, G. Y. Tejasree, G. Udith, R. G. Charan, and Narendrababu, "Analysis of hybrid inverter with solar battery charging system," in Proc. 2023 7th Int. Conf. Comput. Methodol. Commun. (ICCMC), 2023.

[3]. Hybrid Inverter Using Solar Battery Charger – Nevon Projects. [Online]. Available: https://nevonprojects.com/ (Accessed: Apr. 18, 2024).

[4]. T. Singh, A. Roy, and G. Kaur, "Real-time energy monitoring and feedback in solar-grid hybrid systems," Int. J. Electron. Commun. Eng. (IJECE), vol. 9, no. 2, pp. 120–125, 2021.

[5]. V. Rao, S. Bhat, and N. Khan, "IoT-based smart energy monitoring system using Arduino," Int. J. Comput. Appl. (IJCA), vol. 176, no. 27, pp. 10–15, 2020.

[6]. P. Rani, D. Yadav, and A. Sinha, "MPPT-based solar-grid hybrid power system for rural electrification," J. Renewable Energy Smart Grid Syst., vol. 5, no. 1, pp. 33–40, 2022.

[7]. K. Thakare, "Design of PV battery hybrid inverter," Int. J. Multidiscip. Res. (IJFMR), vol. 6, no. 6, Nov.–Dec. 2024.

[8]. M. Mahdi, S. M. Eisa, H. Albalawi, and S. Samreen, "Smart hybrid inverter design using Simulink and solar assistant," Int. J. Smart Grid, vol. 8, no. 2, pp. 57–64, Jun. 2024.