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Design of PV Battery Hybrid Inverter

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Abstract

Renewable energy sources are inexhaustible, eco-friendly, and cost-effective, offering a cleaner alternative to fossil fuels by producing no greenhouse gases. As global electricity demand rises, sustainable solutions like solar power are essential. However, on-grid solar systems can face interruptions during grid outages, creating the need for a more resilient approach. In this research paper, we have explored the integration of hybrid renewable energy systems with advanced autonomous control mechanisms to address the limitations of traditional on-grid systems. We present an innovative approach that combines solar energy with additional renewable sources and energy storage solutions to create a resilient and flexible power supply system. Our methodology includes adaptive control algorithms that dynamically respond to changing environmental and grid conditions, ensuring continuous energy availability. By simulating various demand scenarios, we demonstrate the system's capability to optimize energy flow and improve reliability. The findings suggest that a hybrid model not only enhances power resilience but also reduces the overall carbon footprint, offering a sustainable pathway for future energy infrastructure.

Keywords: Renewable energy, Hybrid Inverter, Seamless transition, Uninterrupted Power supply.

Introduction

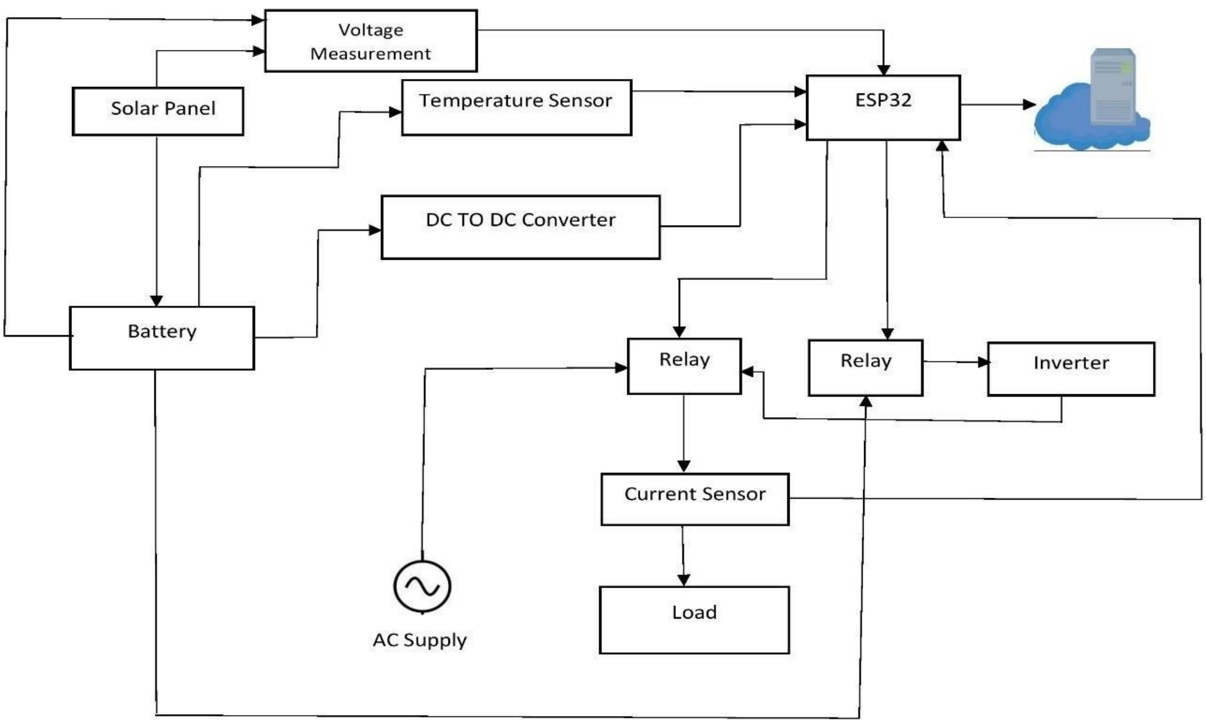
Renewable energy sources are endless, economical, and environmentally benign. Since they don't emit greenhouse gases, they provide a cleaner alternative to fossil fuels. The increasing demand for electricity worldwide necessitates the use of sustainable options like solar power. However, on-grid solar systems can face interruptionsduring grid outages, creating the need for a more resilient approach. A hybrid solar power inverter addresses this by ensuring continuous power supply through distributed, autonomous energy management. Integrating renewable sources and advanced control systems enhances the power system's resilience and supports sustainable energy demands. This approach also contributes to reducing the overall carbon footprint and mitigating environmental impact. By combining multiple renewable sources, hybrid systemsprovide a flexible and reliable solution for future energy needs.

abhirup bhowmick in their paper explain the simulation of a single-phase inverter model designed for Various loading conditions it revealed the need for harmonic reduction. Implementing proper filtering is essential to enhance the output waveform quality [1]. Saurabh Pardeshi suggest that the inverter effectively manages battery charging and incorporates essential safety features for system protection. This approach demonstrates reduced energy costs, lower carbon emissions, and a reliable, sustainable power solution for homes and buildings [2]. Another author Kunal Thakare findings indicate that this system provides uninterrupted power supply to the grid or load, with lower costs and reduced control complexity comparedto voltage regulator or DAB-based ESS configurations. The buck-chopper ESS configuration is shown to be effective for grid-connected systems, while the bi-directional chopper ESS is suitable for standalone applications. Controller-in-loop simulations demonstrate the system's responsive dynamics to changes in irradiance and smooth control transitions during mode shifts [3].L. Barote and C. Marinescu paper highlights on the grid-connected hybrid PV-wind system, using a standalone inverter, effectively operates in both grid-connected and standalone modes. It ensures uninterrupted power supply during grid fluctuations or outages by automatically switching to an emergency output circuit with a true sinusoidal voltage, demonstrating successful operation and stability [5]. In this paper, a chopper-based Energy Storage System (ESS) designed for Cascaded H-Bridge (CHB)- based Power Conversion Systems (PCS) is reviewed. The findings indicate that this system provides uninterrupted power supply to the grid or load, with lower costs and reduced control complexity compared to voltage regulator or DAB-based ESS configurations. The buck-chopper ESS configuration is shown tobe effective for grid-connected systems, while the bi-directional chopper ESS is suitable for standalone applications. Controller-in-loop simulations demonstrate the system's responsive dynamics to changes in irradiance and smooth control transitions during mode shifts [8].

In this paper hybrid inverter system for household devices has been presented. Simulation of hybrid inverter proposed using SIMULINK. A 500W hybrid energy system is practically implemented and tested. The features of this circuit are: Individual and combined operation is supported, Load demand is met from the individual as well as combination of PV array, wind turbine and the battery, Additional input filters are not necessary to filter out high frequency harmonics. This hybrid system is controlled and monitored to get maximum power from solar array and wind turbine [10].

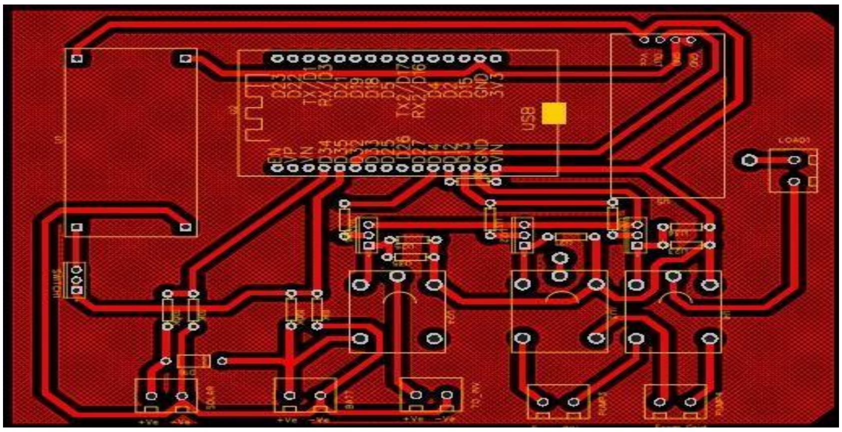
Methodology

Fg 1: Block Diagram



In this proposed system, we use the ESP32 microcontroller, a versatile 32-bit controller well-suited for IoT and embedded applications due to its powerful feature set, including Wi-Fi and Bluetooth connectivity, low power consumption, and flexibility. Programmed via Arduino IDE, the ESP32 manages mode switching between renewable energy sources and the grid. The system integrates a 20W solar panel and AC source, with the ESP32 controlling a Double Pole Double Throw (DPDT) relay for switching. When the solar panel generates over 5W, the system automatically switches to renewable energy; if output drops, it reverts to grid mode. The DPDT relay facilitates this seamless switching to maintain continuous power supply. To monitor system performance, we collect parameters such as voltage, current, and temperature, allowing us to calculate power output and assess battery safety. This data is transferred to a cloud server, enabling remote monitoring via mobile devices or other platforms. This approach ensures efficient power management, real-time monitoring, and secure, uninterrupted operation through seamless source transitions.

Fig 1.2: PCB Design Design



Result

This system presents the design and implementation of a hybrid inverter that utilizes solar energy, battery, and grid supply as power sources. An ESP32 microcontroller is employed to manage the seamless transition between power sources, prioritizing renewable energy i.e solar. In the absence of solar energy, the system draws power from charged battery packs and subsequently from the grid when required. The hybrid inverter system integrates multiple functionalities, including real-time monitoring of battery temperature, voltage levels, and load energy consumption. This data is recorded and fed into a cloud platform for remote access and analysis. By prioritizing solar energy, the system effectively reduces dependency on the grid, promoting sustainability and energy efficiency. This work demonstrates a practical approach to integrating renewable energy into conventional power systems.

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Fig 1.3 : Result

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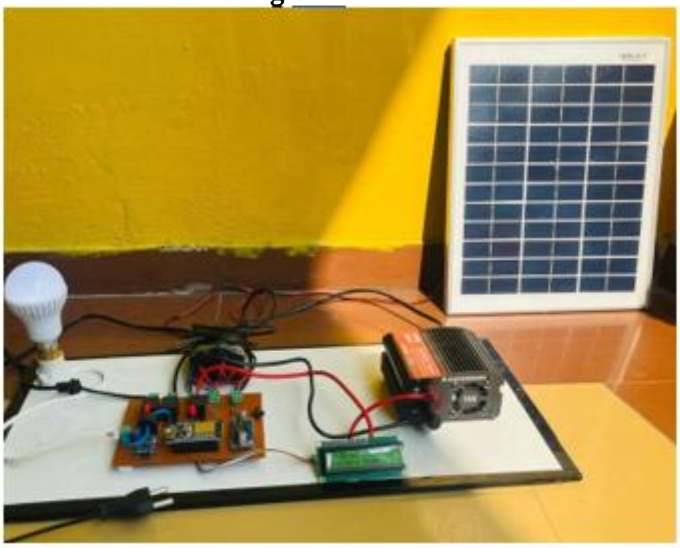
Time	Temperature	Volt	Unit(KWH)
2024-09-25 04:11:43	33	12	2
2024-09-25 06:53:55	28	14	0.02
2024-09-25 06:54:21	28.06	14	0.07
2024-09-25 06:54:48	28.06	14	0.12
2024-09-30 03:24:46	30.81	14	0.04
2024-09-30 07:14:33	30.25	14	0.03
2024-09-30 07:14:59	30.25	13	0.11
2024-09-30 07:19:56	31.06	14	0.03

Fig 1.4 : Model



Conclusion

This hybrid inverter system demonstrates an effective solution for integrating renewable energy with conventional grid power, prioritizing sustainability and efficiency. Its adaptability across various applications from rural electrification to smart home integration, also critical applicaion where uninterrupted supply is required which highlights its potential impact in reducing dependency on non-renewable sources. By utilizing the ESP32 microcontroller for smart energy management and cloud-based monitoring, the system enables seamless power transitions, real-time data access, and improved reliability. With further enhancements, such as IoT connectivity, AI-based predictive maintenance, and scalability, this project could play a pivotal role in advancing resilient and eco-friendly energy systems for a sustainable future.

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