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Static Ups System Using Dual Power Source and Wireless Control

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Abstract

Uninterruptible Power Supply (UPS) systems are important in providing continuous power for sensitive electrical equipment during power interruptions or outages. However, conventional UPS systems rely heavily on grid power. This project aims to design and develop a static UPS system using dual power sources consisting of grid supply and solar energy, intergrated with wireless monitoring and control capability. The system incorporates a solar charge controller, battery bank, inverter, automatic switch, and Wi-Fi-enabled smart breakers to ease the power transfer and remote operation. Hardware assembly were carried out, followed by performance testing under different operating conditions. Experimental results show reliable automatic source switching, stable output voltage, effective battery charging, and successful real-time monitoring and remote control. In conclusion, the proposed hybrid static UPS improves power reliability, reduces grid dependency, and provides a practical and cost-effective solution for small-scale residential and commercial applications.

1. Introduction

The increasing dependence on electrical and electronic equipment in residential, commercial, and industrial sectors has heightened the demand for reliable and uninterrupted power supply. Power disturbances such as voltage fluctuations, short interruptions, and blackouts can lead to equipment malfunction, data loss, and operational downtime. Uninterruptible Power Supply (UPS) systems are therefore widely used to provide clean and continuous power during grid failures.

Traditional UPS systems typically rely on grid power and battery storage, offering limited flexibility and efficiency. With growing environmental concerns and rising energy costs, the integration of renewable energy sources, particularly solar photovoltaic (PV) systems, has gained significant attention. Hybrid UPS systems that combine grid supply, renewable energy, and battery storage can reduce grid dependency while improving system sustainability.

Recent developments in Internet of Things (IoT) technology have enabled intelligent monitoring and control of power systems. However, many existing UPS designs still lack real-time monitoring, wireless control, and smart load management. This paper proposes a static hybrid UPS system using dual power sources and Wi-Fi-enabled smart breakers to enhance reliability, efficiency, and user accessibility.

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2. Literature Review

This chapter summarizes the major literature areas related to UPS systems, solar integration, IoT monitoring, and hybrid energy management. Each study offers important contributions but also shows specific gaps that justify the need for the proposed hybrid UPS prototype.

Table 1: Literature Gaps

Study / Literature Area	Key Contributions	Identified Gaps (Based on Components)	Relevance to Current Project
Static, Rotary & Hybrid UPS Concepts (Aamir et al., 2016)	• Clear explanation of UPS topologies and switching modes.	• No study uses Wi-Fi breakers for user-level AC control. • No reference design using simple automatic switch + inverter + PV in a compact system.	Supports design of a simplified static UPS using inverter + automatic switch.
PV-Integrated UPS Systems (Siraj et al., 2020; Prado et al., 2024; Lim et al., 2022)	• Effective solar integration using MPPT and energy management.	• Most systems use complex converters, not simple solar charge controller + inverter combinations. • No study focuses on small-scale solar panel integration for domestic UPS.	Aligns with the design of using only a solar panel + charge controller + inverter.
Real-Time UPS Energy Management (Boros et al., 2025)	• Neural network control and optimized energy routing.	• Existing methods are too complex for projects using simple charge controller and automatic switch.	Real-Time UPS Energy Management (Boros et al., 2025)
Wireless PV/Storage Monitoring (IoT) (Milton et al., 2024)	• Demonstrates IoT data acquisition for PV voltage/current.	• Lack of IoT applied to grid/UPS breaker control. • No use of Wi-Fi breakers to control UPS load flow.	Supports the use of IoT for monitoring the solar panel + load.
Battery Monitoring & Smart Switching (Jegadeesh Kumar et al., 2024)	• Automated switching between supply sources.	• Switching units used in studies are not integrated with Wi-Fi control. • No simple automatic switch used with PV + inverter.	Justifies including an automatic switch as a practical, low-cost solution.
IoT UPS Monitoring Systems (Apriani et al., 2022; Oktopryadin & Purnama, 2025)	• Real-time UPS status monitoring using IoT dashboards.	• Systems do not integrate solar charge controller data + Wi-Fi breaker control + inverter output. • Monitoring only; no AC breaker control.	Supports adding Wi-Fi breakers to enable both monitoring and AC load control.
IoT Smart Load/Breaker Management (Prasath et al., 2023; Mohd Shuhaimi & Kamarudin, 2024)	• IoT monitoring of voltage, load, and breaker status.	• Not applied within UPS systems. • No integration with solar panel, charge controller, or inverter.	Justifies using Wi-Fi breakers as IoT load management inside the hybrid UPS.
Wireless PV/Storage Monitoring (IoT) (Milton et al., 2024)	• Demonstrates IoT data acquisition for PV voltage/current.	• Lack of IoT applied to grid/UPS breaker control. • No use of Wi-Fi breakers to control UPS load flow.	Supports the use of IoT for monitoring the solar panel + load.

The proposed system forms the basis of a simplified hybrid static UPS system and integrates dual power sources consisting of grid supply and solar-battery backup. It utilizes a solar panel, charge controller, battery bank, and inverter for backup operation and demonstrates static UPS operation without the use of rotating machinery. In addition, Wi-Fi-enabled smart breakers are incorporated for monitoring and load control, supporting real-time electrical parameter monitoring and remote switching.

3. Methodology

This chapter describes the methodology used for the design, development, and testing of the UPS system. The methodology includes system design, component selection, circuit modelling, control strategy development, and performance evaluation. Systematic implementation of both hardware and software components to achieve an intelligent, reliable, and energy-efficient UPS system.

The static switch operates by monitoring the main power supply. In normal condition, the grid power become the primary source of the load. When a power failures or abnormal voltages occurs, the switch will instantly transfer the load to the backup source (battery) without any interruptions or delay. By the time the voltage stabilises or the power backed on, the switch will transfer the load back to the main supply.

3.1 System Block Diagram

The system block diagram represents the hybrid UPS architecture, showing the interaction between major components. It serves as the foundation for understanding the flow of power and controlling signals throughout the system. Figure 1 shows both the grid and solar panel are connected through an automatic source switch, which determines the most appropriate source to supply power to the loads.

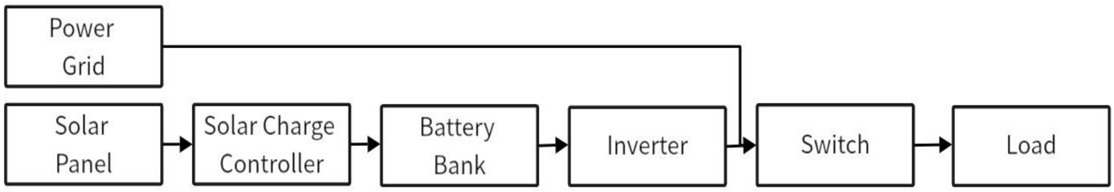

Fig.1: System block diagram

3.2 Circuit Design

The system design phase involves creating a detailed one-line diagram using AutoCAD software. The one-line diagram translates the block diagram into a technical representation suitable for practical implementation. It shows all major components, electrical connections, and power flow paths in a single line, making it easier to plan wiring, component placement, and safety considerations. Figure 2 presents the AutoCAD one-line diagram that outlines the electrical configuration of the hybrid static UPS system.

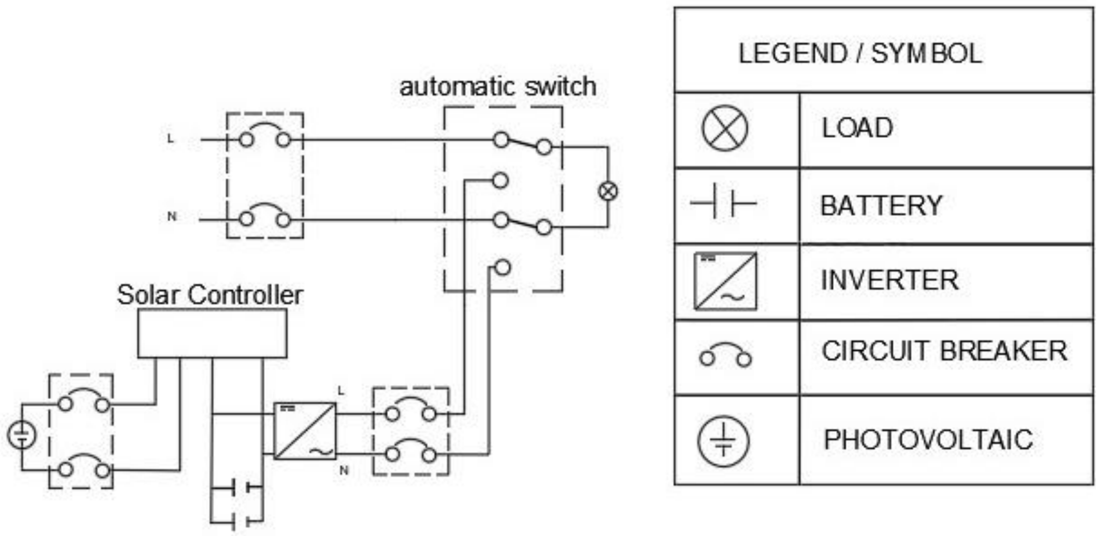

Fig.2: Circuit diagram

The circuit design uses a hybrid static UPS system that uses two power sources: the main grid and a solar-battery backup. The grid will be supplying the load during normal operation while the battery, charged by the solar panel through a solar charge controller, provides a backup power during outages. An automatic switch will be functioning as an automatic selector based on the available source.

3.3 Prototype Development

This section describes the physical development and configuration of the hybrid static UPS prototype that was constructed to validate the proposed system design. The prototype integrates dual power sources, main grid supply and backup solar-battery supply, together with Wi-Fi-enabled smart breakers to demonstrate uninterrupted power delivery and remote monitoring capability. Figure 3 shows the complete prototype of the UPS system, which is physically divided into three main sections Main Power Supply, the Backup Power Supply, and the Load Section.

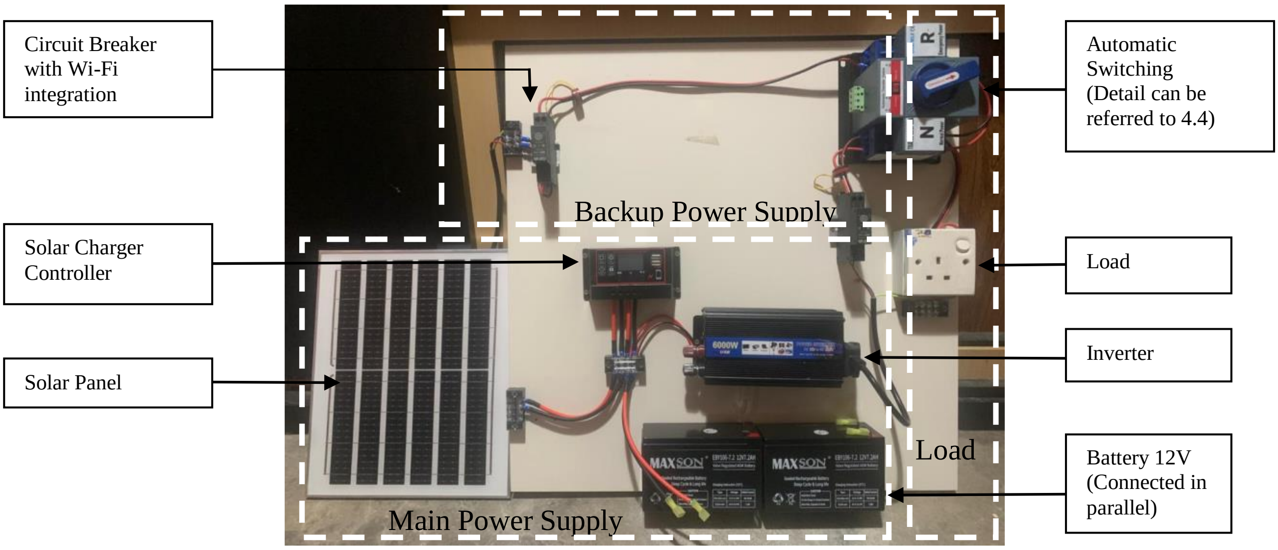

Fig.3: Prototype of the UPS System

4. Results and Discussion

This chapter presents the results and analysis of the developed hybrid static UPS system using dual power sources and wireless control. The system performance is evaluated through prototype testing, battery state-of-charge (SoC) behavior, discharge characteristics, Wi-Fi smart breaker operation, and power source switching functionality

4.1 SoC Data and Analysis

This section presents the analysis of battery SoC performance. The objective of this analysis is to evaluate the contribution of the solar PV system and to assess its impact on the overall reliability of the hybrid static UPS system. The UPS system utilizes a 100 W solar panel installed at a tilt angle of 10° to 15° facing south. During system operation, three different operating conditions were observed. The corresponding solar irradiance, voltage, current, and power output were recorded and analyzed to determine their influence on battery charging and SoC behavior. Table 2 presents the SoC parameters recorded

Table 2: System Operating Conditions: SoC

Parameter	Dataset 1	Dataset 2	Dataset 3
Solar irradiance (W/m^2)	500	400	200
PV operating voltage, V_{pv}, (V)	18.0	17.5	16.5
PV operating current, I_{pv} (A)	2.8	2.2	1.1
PV output power, P_{pv} (W)	50.4	38.5	18.2

Figure 4 shows higher irradiance levels, the photovoltaic system delivered greater charging power, resulting in faster battery recovery and increased SoC. Under moderate irradiance, the reduced PV output was still sufficient to maintain a stable SoC and slow battery discharge during backup operation. At lower irradiance levels, charging power decreased significantly; however, it helped limit battery discharge and prevented rapid depletion during extended operation.

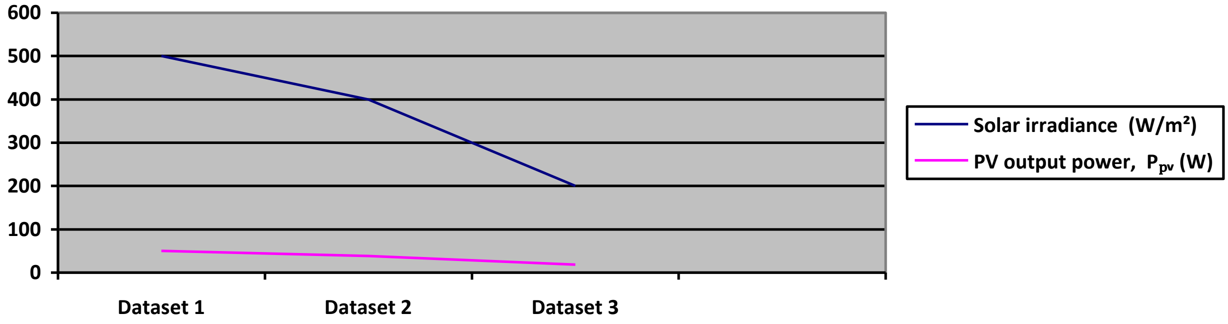

Fig.4: SoC graph

The overall lower battery SoC observed across the datasets is mainly due to reduced solar energy availability during the monsoon period. Persistent cloud cover and rainfall lowered solar irradiance, resulting in reduced charging current and prolonged partial discharge of the battery, leading to lower average SoC levels.

4.2 Discharge Data and Analysis

This section analyses the battery discharge characteristics of the hybrid static UPS system under different operating conditions. The objective of this analysis is to evaluate battery voltage stability and discharge behavior during load operation. Table 4.2 presents the discharge parameters recorded for three datasets with same energy consumption levels for every 10 minutes.

Table 4.2: System Operating Conditions : Discharge

Parameter	Dataset 1	Dataset 2	Dataset 3
Power Consumed , (kWh)	500	400	200
Input voltage , Vin (V)	12.8	12.8	12.7
Output Voltage , Vo (V)	12.8	12.7	12.7
Current (A)	0.993	0.993	0.993

The measured input and output voltages correspond to the battery DC side of the system. Despite slight variations in battery voltage, the inverter consistently maintained a stable AC output between 220 V and 230 V. Across all datasets, the battery voltage remained stable at approximately 12.7–12.8 V, with only a minor reduction over time, while the discharge current stayed constant at 0.993 A, indicating a steady load condition.

The gradual voltage reduction observed in the second and third datasets reflects normal energy consumption during discharge. This slow decline is mainly due to the parallel battery configuration, which increases total capacity while maintaining the nominal voltage, thereby distributing the load and reducing stress on individual batteries. Overall, the results confirm that the parallel battery arrangement improves system reliability and extends backup duration.

4.3 Wi-Fi Breaker Real-Time Monitoring and Remote Control

This section reviews the performance of the Wi-Fi-enabled smart breakers used for real-time monitoring and remote control in the hybrid static UPS system. The smart breakers were integrated to provide wireless control, operational status indication, and basic electrical parameter monitoring through an IoT platform. Figures 5 collectively demonstrate the operating states and monitoring capability of the smart breaker system.

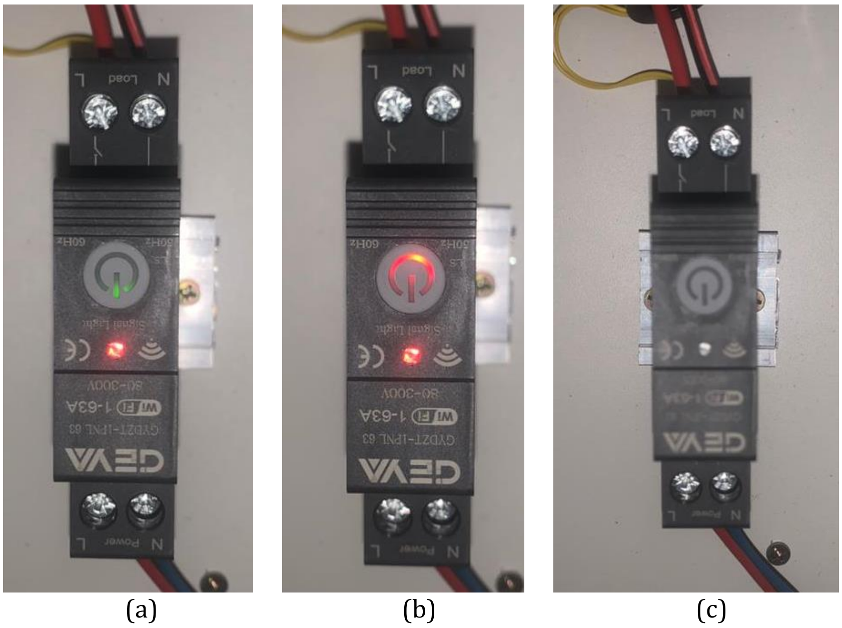

Fig.4: Wi-Fi Breaker (a)closed mode (b) open mode (c) offline

In offline mode, the breaker is not energized, and no power is supplied to the load. In open mode, the breaker successfully disconnects the load, as indicated by the red power symbol, while in closed mode, the green indicator confirms normal power delivery. Figure 5 shows the IoT configuration used in operating the breaker.

Fig.5: System configuration and IoT-monitoring

4.4 Automatic Switching Control

This section reviews the power source switching mechanism of the hybrid static UPS system, which selects between the solar-based backup supply and the grid supply to ensure continuous power delivery. Figures 6 shows the switching operation of the hybrid static UPS under different supply conditions, including emergency mode when the solar source is unavailable and grid power is used, and normal mode when both sources are available and the selected supply powers the load.

(a)

(b)

(c)

Fig.6: Wi-Fi Breaker (a) main power (b) emergency power (c) normal mode

These results confirm that the combined automatic and manual switching ensures reliable and uninterrupted operation of the dual-power-source UPS system. It is also proven in the load area where is a lamp have been used to indicate the availability of supply by observing the lamp light. The lamp does not turn off during the switching operation.

5. Conclusion

A hybrid static UPS using grid and solar-battery sources with Wi-Fi smart breakers was successfully developed. The system provided stable AC output, reliable automatic switching, and effective battery charging from the solar PV. Real-time monitoring and remote-control improved system flexibility and reliability. The proposed UPS offers a simple, low-cost, and energy-efficient solution for small-scale power applications.

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