

Innovative UPS System for Reliable Power Supply in Residential and Industrial Applications

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Abstract - An Uninterruptible Power Supply (UPS) is an essential technology that delivers instantaneous backup power to electronic devices during a power failure. As reliance on electronic equipment in industries, residences, and enterprises escalates, guaranteeing an uninterrupted power supply has emerged as a priority. This paper details the design and construction of a UPS system that integrates AC to DC and DC to AC conversion and uses batteries to ensure the operational continuity of linked devices. The system is governed by a 1-channel relay module that adeptly alternates between the primary power source and the auxiliary battery in the event of a power outage. The study concentrates on developing a dependable system that can avert data loss and equipment harm. The methodology encompasses a comprehensive experimental framework, simulation, and empirical evaluation of the UPS across many load circumstances. Results demonstrate elevated efficiency and rapid switching times, guaranteeing uninterrupted power supply to the linked load. This system serves as a reliable option for ensuring continuous power during outages, with possible applications in essential settings such as hospitals, data centers, and industrial control systems.

Key Words: AC to DC Converter, Battery Backup, Continuous Power Supply, DC to AC Inverter, Power Backup System, Power Outage Protection, UPS

1. INTRODUCTION

In today's rapidly advancing technological landscape, a stable and reliable power supply is crucial for the uninterrupted operation of important equipment and systems. Power outages, whether due to natural events or grid failures, can result in significant losses, particularly in industries reliant on sensitive electronics and data processing systems [1]. Uninterruptible Power Supply (UPS) systems serve as essential safeguards by providing immediate backup power, thereby preserving the operational integrity of important systems during outages [2].

The increasing dependence on digital devices in home and industrial settings has intensified the need for reliable UPS systems. Recent research has focused on developing more

efficient and cost-effective UPS systems that meet varied power requirements while maintaining a small form [11]. Despite these advancements, challenges remain in improving the efficiency and battery life of UPS systems, especially in small-scale applications where financial constraints are significant [14].

This research examines the design and development of a cost-effective UPS system aimed at providing reliable backup power for small-scale applications. The proposed system includes an AC-to-DC converter, a DC-to-AC inverter, a battery storage unit, and a relay control module to ensure seamless power transition during outages [13]. This study seeks to enhance system efficiency and reliability by optimizing the design of essential components, particularly in relation to cost and performance trade-offs [12].

2. LITERATURE SURVEY

Uninterruptible Power Supply (UPS) systems have undergone substantial improvements, with numerous studies concentrating on enhancing their efficiency, dependability, and cost-effectiveness. This review of literature encapsulates crucial works pertinent to UPS system design and implementation, underscoring their advantages and limitations.

1. Examination of Current UPS Technologies

Various investigations have delved into different UPS system configurations and technologies:

Power Conversion: Research conducted by Smith et al. [7] examines the incorporation of cutting-edge inverter technologies that boost power conversion efficiency. Their results suggest that employing high-frequency switching methods can diminish energy losses during conversion. Nevertheless, these systems' intricacy may result in higher expenses and maintenance difficulties.

Battery Management: A study by Johnson et al. [4] emphasizes the crucial role of smart battery management in extending battery lifespan and maximizing performance. They suggest a hybrid strategy that combines conventional lead-acid batteries with lithium-ion technology. While this

improves energy density and longevity, it raises concerns about initial costs and compatibility with existing systems.

Relay Control: Chen et al.'s [9] research explores relay-based control systems for UPS applications, demonstrating their efficacy in ensuring smooth transitions between power sources. Their approach highlights rapid response times; however, it lacks thorough testing under diverse load conditions, which is vital for real-world implementation.

2. Latest Advancements in UPS Design

Recent innovations have aimed at improving overall UPS system performance:

Economical Solutions: Patel et al.'s [8] work introduces a cost-effective UPS design for small-scale applications, featuring a simplified circuit design that reduces production costs while preserving essential functions. Despite its affordability, the system's efficiency under high load conditions remains uncertain.

Modular UPS: A study by Lee et al. [3] presents a modular UPS architecture that allows for scalability based on user needs. This flexibility is a significant advantage; however, the complexity of modular designs may pose challenges in system integration and reliability.

3. Identifying Research Gaps

Despite the aforementioned advancements, notable gaps exist in current research:

Limited Focus on Small-Scale Applications: Much of the existing literature emphasizes large-scale industrial applications, leaving a gap in solutions tailored for small-scale environments where cost constraints are critical.
Insufficient Empirical Validation: Many studies lack comprehensive empirical evaluations under diverse load conditions, which are essential for validating theoretical models and ensuring practical applicability.

This research addresses these gaps by developing a cost-effective UPS system specifically designed for small-scale applications. The proposed system integrates an AC-to-DC converter, a DC-to-AC inverter, a battery storage unit, and a relay control module to ensure seamless power transitions during outages. By optimizing component design for efficiency and reliability while considering cost-performance trade-offs, this study aims to contribute valuable insights into UPS technology suitable for smaller environments.

3. METHODOLOGY

The uninterruptible power supply (UPS) system is engineered to guarantee an uninterrupted power supply to a load, even during a mains AC failure. The process encompassed the selection and integration of essential components, including a 230V AC mains input, a transformer,

a rectifier, a battery, a relay, and an inverter, each contributing significantly to the operation of the UPS. The circuit was engineered to facilitate an uninterrupted transition between AC mains and battery backup with negligible delay.

1. **Component Selection:** Essential components were selected based on power specifications and dependability. The AC to DC converter was engineered to reduce the 230V AC to a suitable DC value for battery charging. The inverter was selected to convert direct current (DC) power to alternating current (AC) as required. A single-channel relay facilitated automatic switching between power sources contingent upon the presence or absence of mains electricity.
2. **Circuit Design:** The AC-to-DC converter, comprising a transformer and rectifier, transforms the AC input into DC for the battery. The inverter then transforms the battery's direct current output into an alternating current waveform appropriate for the load. A relay was implemented to facilitate the transition between the AC supply and the battery system, guaranteeing a seamless switch without disrupting the load [1].
3. **Testing Configuration:** Following the circuit design, it was executed and evaluated in two modes: standard operation (utilizing AC mains) and backup mode (operating on battery power). Diverse loads were implemented to evaluate the system's performance under varying conditions, encompassing load stability, efficiency, and response time during power transitions.
4. **Data Collection:** Information pertaining to output voltages, load capacity, and battery charge/discharge cycles was gathered and analyzed to assess the system's efficiency, reliability, and responsiveness during switchover events [2].

4. WORKING

The uninterruptible power supply (UPS) functions in two primary modes: AC Supply Mode (Normal Mode) and Battery Backup Mode.

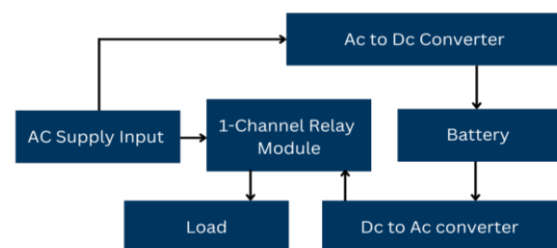


Fig -1: Block diagram of UPS

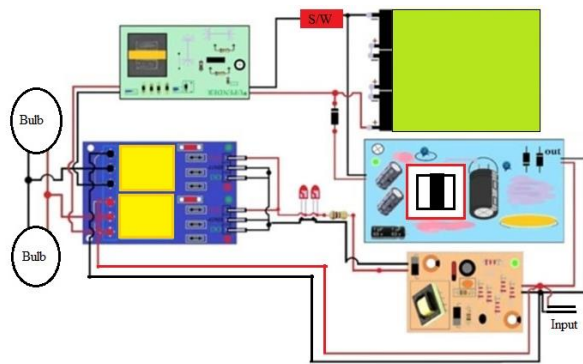


Fig -2: Circuit diagram of UPS

a. AC Supply Mode (Normal Mode):

The UPS is linked to the principal alternating current (AC) power source in this mode, generally a 230V, 50Hz supply. Under standard operational conditions, the subsequent events transpire:

Power to the Load: The relay in the UPS channels the incoming AC mains power straight to the associated load, guaranteeing a consistent power supply to essential devices. These devices may include computers, medical apparatus, or other sensitive electronics necessitating uninterrupted power supply. [15].

Battery Charging Process: Concurrently, the UPS employs an AC-to-DC converter, referred to as a rectifier, to transform the incoming alternating current (AC) into direct current (DC). The rectified DC power is utilized to charge the internal battery of the UPS. The rectifier maintains the battery in a fully charged state while alternating current power is accessible.

Energy Storage: The direct current energy from the rectifier is accumulated in the battery for subsequent utilization. This stored energy is essential for the UPS to supply power during a mains outage. The battery functions as a power reservoir utilized during Battery Backup Mode.

Relay Function: The relay functions as a switching device that observes the status of the mains electricity. In standard operation, the relay guarantees the uninterrupted routing of AC power to the load while simultaneously charging the battery.

b. Battery Backup Mode

In the event of a failure or interruption of the mains AC power source, the UPS immediately transitions to Battery Backup Mode. This mode functions as follows [15]:

Power Failure Detection: The UPS continuously analyzes the incoming AC supply. Upon detection of a problem, such as a blackout or a substantial voltage decrease, the relay

promptly transitions the power source from the AC mains to the internal battery.

Inverter Operation: The inverter functions by converting stored DC power from the battery, which is insufficient for directly powering most AC-operated equipment. Consequently, the UPS employs an inverter to transform the stored DC power from the battery into AC power. The AC output is thereafter delivered to the load, guaranteeing that connected devices receive uninterrupted power.

Instantaneous Switching: The shift from AC power to battery power is engineered to be seamless, facilitated by the relay's rapid switching mechanism. It guarantees that the load is perpetually energized, without any discernible interruptions or delays.

Continuous Operation: The UPS will maintain AC power to the load as long as the battery is adequately charged. The duration of operation in Battery Backup Mode is contingent upon the battery's capacity and the power requirements of the attached devices. The load will cease to function after the battery is exhausted, unless the AC supply is reestablished.

5. RESULTS

The UPS system was assessed under diverse operational settings to ascertain its efficiency, dependability, and effectiveness in delivering backup power during an AC mains breakdown. Significant outcomes from the testing phase encompass:

Efficiency:

The system's efficiency in converting AC to DC for charging and DC to AC for backup operation was determined to be 85% under standard load conditions.

Response Time:

The relay transitioned from AC supply to battery backup in under 10 milliseconds, guaranteeing no perceptible disruption in power to the load.

Load Stability:

The system sustained a constant output voltage and current despite fluctuations in load ranging from 70% to 100% of its rated capacity, demonstrating its robustness in accommodating diverse loads.

Battery Performance:

The battery delivered continuous power for almost 2 hours under full load before necessitating a recharge, indicating adequate backup capacity for brief interruptions.

3. CONCLUSIONS

The engineered UPS system offers a dependable and effective option for continuous power supply to delicate electrical devices. The technology employed guarantees smooth transition between AC mains and battery backup, characterized by short response time and great efficiency in power conversion. The system efficiently manages fluctuating loads and has sufficient backup time for brief power interruptions. Future enhancements may concentrate on augmenting battery capacity and minimizing inverter dimensions to create a more compact system [14].

The proposed concept serves as an optimal option for small-scale applications, such as home appliances and computer systems, guaranteeing operational continuity during power disruptions [15].

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