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Development of Portable Automatic Dual Power Backup System for Continuous Operation in Kalinga Colleges of Science and Technology Incorporated

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ABSTRACT

This study presents the design, development, and implementation of a Portable Automatic Dual Power Backup System with WIFI Controller for the Registrar or Cashier Office of Kalinga Colleges of Science and Technology, Inc. (KCSTI). Frequent power interruptions disrupt critical operations such as record management, enrollment processing, and financial transactions, while increasing the risk of data loss and equipment damage.

To address this problem, the system integrates grid electricity, solar energy, and battery storage to ensure a continuous and reliable power supply. If features an Automatic Transfer Switch (ATS) That detects outages and automatically transfers the load to an available power source, ensuring seamless operation and protecting sensitive devices. The battery backup can sustain essential operations for up to two hours when other sources are unavailable.

The system also incorporates a WIFI controller for real-time monitoring and remote control, allowing users to track power usage, battery status, and operating mode via mobile devices. Overall, the system enhances reliability, energy efficiency, and sustainability, providing a cost-effective solution to maintain uninterrupted office operations and improve productivity.

Keywords: *Portable power backup system; Automatic transfer switch (ATS); Wi-Fi-based monitoring; Hybrid energy system; Battery energy storage; Solar power integration; IoT-enabled control.*

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INTRODUCTION

Electricity is one of the most essential resources in educational institutions because it supports both academic and administrative operations. Modern schools rely heavily on electrical devices such as computers, printers, internet routers, lighting systems, projectors, and office equipment to facilitate communication, record management, enrollment processing, and financial transactions. Without a stable power supply, these operations become vulnerable to interruptions that may lead to delays, data loss, reduced productivity, and equipment damage. In many areas of the Philippines, especially in provinces experiencing unstable electricity supply, frequent power interruptions continue to affect the efficiency of institutional operations.

At Kalinga Colleges of Science and Technology Incorporated (KCSTI), the Registrar and Cashier Offices depend significantly on computers and electronic systems for handling student records, enrollment transactions, accounting processes, and financial documentation. Unexpected power interruptions disrupt these operations and may result in incomplete transactions, unsaved files, system errors, and delays in administrative services. Such interruptions not only affect office personnel but also inconvenience students, teachers, and visitors who rely on continuous and efficient services from these offices.

To address these challenges, the development of a Portable Automatic Dual Power Backup System with Wi-Fi Controller offers a practical and innovative solution. The proposed system is designed to provide continuous and reliable electricity by integrating grid power, solar energy, and battery storage into a single backup system. Through the use of an Automatic Transfer Switch (ATS), the system can automatically switch between available power sources whenever interruptions occur, ensuring uninterrupted operation of essential office equipment. This automatic switching mechanism minimizes downtime and protects sensitive devices from sudden power loss and voltage fluctuations.

The system also incorporates a Wi-Fi controller that allows real-time monitoring and remote management of the backup system. Through internet-enabled devices such as smartphones or computers, users can monitor battery levels, voltage status, power consumption, and active power sources. The Wi-Fi controller also enables users to receive alerts and monitor system performance remotely, improving convenience, safety, and operational efficiency. This feature makes the system more intelligent and adaptable compared to traditional backup power systems.

Renewable energy technologies, particularly solar power systems, have become increasingly important due to rising electricity costs and the growing demand for sustainable energy solutions. Solar-powered backup systems provide clean and renewable energy while reducing dependence on conventional grid electricity. Hybrid systems that combine solar energy, battery storage, and automatic switching technologies have been recognized for their ability to maintain stable electricity supply during outages. These systems are especially beneficial in educational institutions and small-scale offices where uninterrupted power is necessary for continuous operation.

Previous studies have highlighted the effectiveness of hybrid renewable energy systems in providing reliable power supply. Research on portable solar-powered backup systems emphasized the importance of combining renewable energy with battery storage to ensure continuity during emergencies and unexpected outages. Other studies also stressed that automatic transfer switching mechanisms improve operational efficiency by seamlessly transferring loads between power sources without manual intervention. Furthermore, the integration of remote monitoring technologies enhances system management and allows users to monitor energy consumption and system performance more efficiently.

Despite the increasing development of renewable energy systems, there is still limited research focusing specifically on portable automatic dual power backup systems with integrated Wi-Fi monitoring for educational institutions in local settings such as Kalinga. Most existing studies focus on large-scale renewable energy projects or stationary backup systems that lack portability and remote management capabilities. This research gap highlights the need for a compact, portable, and intelligent backup system capable of ensuring continuous operation in offices and institutions affected by unstable power supply.

In response to this need, the present study aims to design and develop a Portable Automatic Dual Power Backup System with Wi-Fi Controller for Kalinga Colleges of Science and Technology Incorporated. Specifically, the system seeks to provide uninterrupted power supply to the Registrar and Cashier Offices during outages, improve energy efficiency, protect electronic devices, and enhance operational reliability through automatic switching and remote monitoring technologies.

Ultimately, the study contributes to the advancement of sustainable and technology-driven energy solutions for educational institutions. By integrating renewable energy, battery storage, automatic switching, and Wi-Fi-based monitoring, the proposed system promotes operational continuity, energy efficiency, and environmental sustainability while addressing the challenges caused by unstable electricity supply.

REVIEW OF RELATED LITERATURE

Power Interruptions and Institutional Operations

Electricity is a critical component of institutional productivity and operational efficiency. Educational institutions heavily rely on electrical systems to support administrative tasks, communication, information management, and financial transactions. Frequent power interruptions negatively affect office operations by causing delays, system shutdowns, and potential data loss. According to Hall and Khan (2021), unstable electricity supply disrupts institutional workflows and reduces the efficiency of digital systems used in schools and offices. In educational settings, prolonged outages may interrupt enrollment processes, financial transactions, and database management, resulting in inconvenience for both staff and students.

Power interruptions also increase the risk of equipment damage caused by sudden voltage fluctuations and abrupt system shutdowns. Sensitive devices such as computers, servers, and network equipment are particularly vulnerable to electrical instability. Kumar and Singh (2022) emphasized that unstable power supply can shorten the lifespan of electronic devices and increase maintenance costs in institutions that heavily depend on information technology systems.

Backup Power Systems

Backup power systems are designed to provide alternative electricity sources during outages to ensure continuous operation of essential equipment. Traditional backup systems commonly use generators and uninterruptible power supply (UPS) devices. However, these systems often involve high operational costs, fuel dependency, noise pollution, and limited portability.

Recent advancements in renewable energy technologies have encouraged the development of hybrid backup systems that integrate solar power, battery storage, and automatic switching mechanisms. According to Ahmed et al. (2023), hybrid backup systems are more sustainable and cost-efficient because they reduce dependence on conventional fuel-powered generators while ensuring stable electricity supply during emergencies.

Portable backup systems have also gained popularity due to their flexibility and ease of deployment. Portable systems can be transferred to different locations depending on operational needs, making them suitable for schools, offices, and small establishments affected by unstable electricity supply.

Solar Energy as a Renewable Power Source

Solar energy is one of the most widely used renewable energy sources due to its availability, sustainability, and environmental benefits. Solar photovoltaic (PV) systems convert sunlight into electricity and are commonly integrated into hybrid energy systems. According to the International Energy Agency (2023), solar energy adoption has significantly increased worldwide as governments and institutions seek cleaner and more sustainable energy alternatives.

In the Philippines, solar energy has become an effective solution for addressing unstable electricity supply, particularly in remote and rural areas. Reyes and Mendoza (2022) stated that solar-powered systems help reduce electricity expenses and improve energy accessibility in educational institutions and small-scale facilities.

Solar-powered backup systems are beneficial because they continue to operate even during grid failures, provided that sufficient battery storage is available. The integration of solar panels into backup systems also contributes to environmental sustainability by reducing greenhouse gas emissions and dependence on fossil fuels.

Battery Storage Systems

Battery storage systems are essential components of backup power systems because they store excess electrical energy for future use. During power interruptions, stored energy from batteries supplies electricity to connected devices and equipment. Lithium-ion batteries and deep-cycle batteries are among the most commonly used storage technologies due to their efficiency, reliability, and long operational lifespan.

According to Zhang et al. (2021), battery storage systems improve energy reliability and help stabilize power supply in hybrid renewable energy systems. These systems ensure uninterrupted operation during outages and minimize downtime in institutions and offices.

Battery management is also important in maintaining system efficiency and safety. Advanced battery monitoring technologies allow users to track battery levels, charging conditions, and power consumption in real time. Proper battery management extends battery lifespan and improves overall system performance.

Automatic Transfer Switch (ATS) Technology

An Automatic Transfer Switch (ATS) is a device that automatically transfers electrical loads from the primary power source to a backup source whenever a power interruption occurs. ATS technology is widely used in critical facilities such as hospitals, schools, offices, and communication centers where uninterrupted electricity is essential.

According to Lee and Park (2022), ATS systems improve operational continuity by minimizing transition delays during power interruptions. Automatic switching mechanisms eliminate the need for manual intervention, reducing downtime and preventing operational disruptions.

In hybrid backup systems, ATS technology enables seamless integration between grid electricity, solar energy, and battery storage systems. This automatic switching capability enhances reliability and ensures continuous power supply to connected devices.

Wi-Fi Controllers and Remote Monitoring Systems

The integration of Wi-Fi controllers and Internet of Things (IoT) technologies has improved the functionality and efficiency of modern power systems. Wi-Fi controllers allow users to monitor and control electrical systems remotely using smartphones, tablets, or computers connected to the internet.

Remote monitoring systems provide real-time information regarding battery levels, voltage conditions, power consumption, and active energy sources. According to Santos and Cruz (2023), remote monitoring technologies improve energy management by enabling users to identify system issues early and respond immediately to abnormal conditions.

Wi-Fi-enabled systems also enhance convenience and operational efficiency because users can monitor system performance without physically inspecting the equipment. These technologies are increasingly used in smart homes, renewable energy systems, and institutional power management applications.

Hybrid Renewable Energy Systems

Hybrid renewable energy systems combine multiple energy sources such as solar panels, batteries, and conventional grid electricity to improve reliability and efficiency. These systems are designed to maximize energy availability while minimizing operational costs and environmental impact.

According to Sharma et al. (2022), hybrid systems are more effective than standalone renewable energy systems because they provide stable electricity even when one energy source becomes unavailable. In educational institutions, hybrid systems help maintain continuous operation during outages while reducing electricity expenses.

The integration of automatic switching mechanisms and battery storage further enhances the efficiency of hybrid systems by ensuring uninterrupted power supply. These features make hybrid renewable energy systems suitable for offices, schools, and institutions requiring reliable backup power solutions.

Sustainable Energy Solutions in Educational Institutions

Educational institutions are increasingly adopting sustainable energy technologies to reduce operational costs and promote environmental responsibility. Renewable energy systems such as solar-powered backup solutions help schools minimize electricity expenses while supporting sustainability initiatives.

According to the Department of Energy Philippines (2023), integrating renewable energy systems into schools contributes to long-term energy security and environmental conservation. Sustainable power systems also serve as educational tools that promote awareness of clean energy technologies among students and staff.

The implementation of renewable energy-based backup systems aligns with global sustainability goals by reducing carbon emissions and encouraging efficient energy utilization.

Research Gap

Several studies have explored solar-powered systems, hybrid renewable energy technologies, and automatic transfer switching mechanisms. However, limited research focuses specifically on portable automatic dual power backup systems with integrated Wi-Fi monitoring designed for educational institutions in local settings such as Kalinga.

Most existing studies emphasize large-scale renewable energy systems or stationary backup technologies that lack portability and remote management capabilities. Furthermore, few studies examine the application of intelligent backup systems in school administrative offices where uninterrupted electricity is critical for daily operations.

This study addresses these gaps by developing a portable, intelligent, and renewable energy-based backup system capable of automatically switching between power sources while providing real-time monitoring and remote-control features.

METHODOLOGY

Research Design

This study utilized a developmental-descriptive research design in designing and evaluating the Portable Automatic Dual Power Backup System with Wi-Fi Controller for Kalinga Colleges of Science and Technology Incorporated (KCSTI). The developmental aspect of the study focused on the creation, assembly, and integration of the system components, including the solar panel, battery storage, automatic transfer switch, inverter, and Wi-Fi controller. Meanwhile, the descriptive approach was used to evaluate the system’s functionality, efficiency, portability, reliability, and operational performance based on actual testing and observation.

The research design was considered appropriate because the study aimed not only to develop a functional prototype but also to assess its capability in providing continuous electricity supply during power interruptions. Through this design, the researchers were able to analyze the effectiveness of the system in maintaining uninterrupted operations in the Registrar and Cashier Offices of KCSTI.

Research Locale

The study was conducted at Kalinga Colleges of Science and Technology Incorporated (KCSTI) located in Tabuk City, Kalinga, Philippines. Specifically, the system was designed and tested for application in the Registrar and Cashier Offices, which are among the most electricity-dependent administrative offices in the institution.

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These offices were selected because they handle essential institutional operations such as enrollment processing, student records management, accounting, and financial transactions. Frequent power interruptions in these offices significantly affect operational efficiency and service delivery, making them ideal locations for implementing and testing the proposed backup power system.

Materials and Components Used

The development of the Portable Automatic Dual Power Backup System required various electrical and electronic components to ensure efficient and reliable operation. The major components used in the study included:

- Solar panel
- Rechargeable battery storage
- Automatic Transfer Switch (ATS)
- Power inverter
- Wi-Fi controller module
- Voltage regulator
- Circuit breakers and protection devices
- Electrical wires and connectors
- Portable casing and mounting materials

The solar panel served as the renewable energy source that converts sunlight into electrical energy. The rechargeable battery stored excess energy for backup use during outages. The inverter converted direct current (DC) from the battery into alternating current (AC) suitable for office equipment. The ATS enabled automatic switching between power sources, while the Wi-Fi controller provided remote monitoring and control capabilities.

System Development Procedure

The development of the system followed a systematic process consisting of planning, design, assembly, programming, testing, and evaluation.

Planning and Design Phase. During this phase, the researchers identified the electrical requirements of the Registrar and Cashier Offices, including the estimated power consumption of essential devices such as computers, printers, routers, and lighting systems. A schematic diagram of the backup system was prepared to determine the proper arrangement and connection of components. The researchers also determined the appropriate capacity of the solar panel, inverter, and battery storage to ensure that the system could sustain office operations during power interruptions.

Assembly and Installation Phase. After finalizing the design, the components were assembled and integrated into a portable casing for easy transport and installation. Electrical wiring and protective devices were installed carefully to ensure operational safety and reliability. The solar panel was connected to the charge controller and battery storage system, while the inverter and ATS were integrated to enable automatic switching between power sources. The Wi-Fi controller module was installed and configured for remote monitoring functionality.

Programming and Wi-Fi Configuration. The Wi-Fi controller was programmed using compatible software and microcontroller technologies. The configuration process enabled the system to monitor voltage levels, battery conditions, power usage, and active energy sources in real time. The researchers established wireless connectivity between the controller and mobile devices to allow remote monitoring and system management through internet-enabled platforms.

Testing and Evaluation Procedure. The developed system underwent several testing procedures to evaluate its operational performance, reliability, and efficiency.

Functionality Testing

Functionality testing was conducted to determine whether the system operated according to its intended purpose. The researchers tested the capability of the system to:

- Automatically switch between grid power and backup sources
- Supply continuous electricity during outages
- Charge and discharge the battery properly
- Provide remote monitoring through Wi-Fi connectivity
- The functionality of each component was observed and recorded during actual operation.

Performance Testing

Performance testing was performed to evaluate the efficiency and reliability of the system under different operational conditions. The researchers measured:

- Battery backup duration
- Switching response time
- Voltage stability
- Power output performance
- Wi-Fi connectivity reliability

The system was tested during simulated and actual power interruptions to determine its capability in sustaining office operations.

Portability and Safety Evaluation

The portability of the system was evaluated based on its ease of transport, installation, and usability. Safety evaluation was also conducted to ensure that all electrical connections, protective devices, and components complied with safe operational standards.

The researchers observed whether the system generated excessive heat, electrical fluctuations, or operational hazards during usage.

Data Gathering Procedure

Data gathering involved direct observation, actual testing, and recording of system performance during operation. The researchers documented all test results, including switching time, battery performance, power stability, and Wi-Fi monitoring functionality.

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Feedback from office personnel and users was also gathered to assess the practicality, convenience, and effectiveness of the developed system in real-world office operations.

Statistical Treatment of Data

The study used descriptive statistical methods to analyze the collected data. Frequency counts, percentages, and mean values were utilized to summarize the evaluation results regarding system performance, reliability, portability, and effectiveness.

The gathered data were organized into tables and interpreted based on the objectives of the study. These statistical tools helped determine the overall acceptability and operational capability of the Portable Automatic Dual Power Backup System with Wi-Fi Controller.

Ethical Considerations

The researchers ensured that the study complied with ethical standards throughout the conduct of the research. Permission was obtained from the administration of KCSTI before conducting system testing within the institution.

The researchers also ensured that the developed system did not pose risks to office personnel, equipment, or institutional operations during testing and implementation. All gathered information and observations were used strictly for academic and research purposes.

RESULTS AND DISCUSSION

Presentation, Analysis, and Interpretation of Data

This section presents the findings of the study regarding the development and evaluation of the Portable Automatic Dual Power Backup System with Wi-Fi Controller for Kalinga Colleges of Science and Technology Incorporated (KCSTI). The results include the system's functionality, performance, reliability, portability, safety, and effectiveness in providing continuous electricity during power interruptions in the Registrar and Cashier Offices.

The findings were analyzed based on actual testing, observation, and evaluation of the developed system. The discussion also explains how the integrated components such as the solar panel, battery storage, automatic transfer switch, inverter, and Wi-Fi controller contributed to the overall operational capability of the system.

Functionality of the Portable Automatic Dual Power Backup System

The developed system successfully performed its intended functions during testing and evaluation. The system was able to automatically switch between the primary power source and the backup power supply whenever interruptions occurred. During actual power interruption simulations, the Automatic Transfer Switch (ATS) responded immediately and transferred the electrical load from the main power source to the battery backup system without requiring manual intervention.

The automatic switching capability significantly reduced downtime in office operations. Computers, printers, internet routers, and lighting systems connected to the backup system continued operating with minimal interruption. This result demonstrates that the developed system is capable of maintaining continuity in administrative operations during power outages.

The integration of solar energy into the backup system also contributed to its operational effectiveness. The solar panel continuously charged the battery during daytime operation, allowing stored energy to remain available during emergencies. This feature improved the sustainability and efficiency of the system by reducing dependence on conventional electricity sources.

Furthermore, the Wi-Fi controller functioned effectively during testing. Users were able to monitor system status, battery levels, voltage conditions, and active power sources through mobile devices connected to the internet. Real-time monitoring enhanced user convenience and allowed immediate detection of abnormal system conditions.

Performance of the Battery Backup System

The battery backup system demonstrated reliable performance during actual and simulated power interruptions. Based on testing, the battery was capable of supplying electricity to essential office equipment for approximately two hours, depending on the connected load and energy consumption.

The battery maintained stable voltage output throughout the testing period, ensuring safe operation of connected devices. No significant voltage fluctuations were observed during operation, indicating that the inverter and voltage regulation components functioned effectively.

The charging performance of the battery was also evaluated. The solar panel successfully replenished battery power during daylight hours, while grid electricity served as an alternative charging source when solar energy was insufficient. This dual charging capability improved energy reliability and ensured that backup power remained available even during unfavorable weather conditions.

The findings indicate that the battery storage system provides an effective solution for maintaining uninterrupted operations in critical offices during temporary power interruptions.

Automatic Transfer Switch (ATS) Performance

The Automatic Transfer Switch played a critical role in ensuring uninterrupted electricity supply. During testing, the ATS transferred electrical loads from the primary power source to the backup source within a few seconds after detecting power interruption.

The transition process was smooth and did not cause significant operational disruption to connected devices. Office equipment continued functioning without experiencing major shutdowns or system errors. The automatic switching mechanism minimized operational downtime and reduced the risk of data loss caused by abrupt power interruptions.

The ATS also functioned effectively when the primary power source was restored. The system automatically shifted the load back to grid electricity while simultaneously recharging the battery system. This automatic restoration process improved operational convenience and eliminated the need for manual

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switching procedures. These findings confirm that the ATS significantly enhances system reliability and operational efficiency.

Wi-Fi Monitoring and Remote-Control Performance

One of the most innovative features of the developed system is the Wi-Fi monitoring capability. During testing, the Wi-Fi controller successfully transmitted real-time system information to connected mobile devices and computers.

Users were able to monitor battery percentage, voltage status, charging condition, active power source, and system activity remotely. The monitoring interface provided accurate and timely updates regarding system performance.

The remote monitoring capability improved user convenience because system status could be checked without physically inspecting the backup unit. This feature is particularly beneficial in institutional settings where immediate response to electrical issues is necessary.

Additionally, the Wi-Fi controller improved preventive maintenance practices by enabling early detection of low battery levels, unstable voltage conditions, and charging problems. Through this feature, users can respond promptly to potential system failures and maintain continuous operation.

Portability and Physical Design Evaluation

The portability of the system was evaluated based on its mobility, compactness, and ease of installation. The developed system was housed in a portable casing that allowed convenient transport between locations.

The compact design minimized space consumption and made the system suitable for office environments with limited available space. Office personnel were able to position and operate the system without difficulty.

The portability feature also increased the versatility of the backup system because it can be transferred to different offices or locations depending on operational requirements. This characteristic distinguishes the developed system from conventional stationary backup systems.

The physical design also contributed to operational safety by properly enclosing electrical components and minimizing exposure to hazardous electrical connections.

Safety and Reliability Evaluation

Safety testing showed that the developed system operated within acceptable electrical safety standards. The installed circuit breakers, voltage regulators, and protective devices effectively protected the system from overload, short circuits, and abnormal voltage conditions.

During prolonged operation, the system did not generate excessive heat or unstable electrical output. The inverter maintained stable power conversion throughout the testing process, preventing damage to connected devices.

The reliability of the system was further demonstrated through repeated testing during multiple simulated power interruptions. The backup system consistently provided stable and uninterrupted electricity without significant operational failure. These findings indicate that the developed system is both safe and reliable for institutional use.

Discussion of Findings

The results of the study demonstrate that the Portable Automatic Dual Power Backup System with Wi-Fi Controller effectively addresses the challenges caused by unstable electricity supply in educational institutions. The integration of solar energy, battery storage, automatic switching technology, and Wi-Fi monitoring enhanced operational continuity, energy efficiency, and user convenience.

The automatic switching mechanism minimized downtime and protected sensitive electronic devices from sudden power interruptions. Meanwhile, the incorporation of renewable energy contributed to sustainability by reducing dependence on conventional electricity.

The Wi-Fi monitoring capability also represents a significant technological improvement over traditional backup systems because it enables real-time monitoring and remote management. This feature improves system maintenance and operational efficiency while increasing user accessibility.

Overall, the developed system proved to be a practical, portable, efficient, and sustainable backup power solution for institutional office operations.

Conclusion

This study successfully designed and developed a Portable Automatic Dual Power Backup System with Wi-Fi Controller intended for the Registrar and Cashier Offices of Kalinga Colleges of Science and Technology Incorporated (KCSTI). The developed system effectively addressed the challenges caused by unstable electricity supply by providing continuous and reliable backup power during outages.

The findings revealed that the integration of solar energy, rechargeable battery storage, automatic transfer switching, and Wi-Fi monitoring technologies significantly improved operational continuity and energy reliability. The Automatic Transfer Switch (ATS) successfully transferred electrical loads between power sources with minimal interruption, ensuring uninterrupted operation of essential office equipment such as computers, printers, routers, and lighting systems.

The battery backup system demonstrated stable performance and was capable of sustaining office operations for approximately two hours during power interruptions. The solar charging capability also enhanced the sustainability of the system by reducing dependence on conventional electricity and supporting renewable energy utilization.

Furthermore, the Wi-Fi controller functioned effectively by providing real-time monitoring of battery levels, voltage conditions, active power sources, and system status. This feature improved user convenience and system management by enabling remote monitoring and early detection of operational issues.

The portability and compact design of the system increased its practicality and versatility for institutional use. Safety testing also confirmed that the system operated within acceptable electrical safety standards, with protective devices effectively preventing overloads, voltage instability, and short circuits.

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Overall, the study concludes that the developed Portable Automatic Dual Power Backup System with Wi-Fi Controller is an effective, reliable, sustainable, and innovative solution for maintaining uninterrupted office operations during power interruptions. The system contributes to institutional efficiency, equipment protection, and sustainable energy management in educational institutions.

Implications of the Study

The findings of this study have significant implications for educational institutions, energy management systems, and renewable energy applications.

For educational institutions, the study demonstrates the importance of backup power systems in maintaining operational continuity during power interruptions. The developed system can help schools and offices minimize disruptions in administrative processes, improve service delivery, and protect important electronic records and equipment.

From a technological perspective, the integration of Wi-Fi monitoring and remote management features highlights the growing role of smart technologies and Internet of Things (IoT) applications in modern energy systems. Real-time monitoring improves operational efficiency, preventive maintenance, and system accessibility.

The study also contributes to sustainable energy initiatives by promoting the use of renewable energy technologies such as solar power. Integrating solar energy into institutional backup systems reduces dependence on conventional electricity and supports environmental sustainability through cleaner energy utilization.

Furthermore, the study provides a practical reference for future researchers, engineers, and developers interested in hybrid backup power systems, smart energy management technologies, and renewable energy integration.

Recommendations

Based on the findings and conclusions of the study, the following recommendations are proposed:

- Educational institutions and offices experiencing unstable electricity supply may adopt the developed Portable Automatic Dual Power Backup System to ensure continuous operation during outages. Implementing such systems can improve operational reliability and minimize service interruptions.
- Future developers may improve the system by increasing battery storage capacity to extend backup duration for larger electrical loads and longer power interruptions. Additional solar panels may also be integrated to enhance charging efficiency and energy availability.
- The Wi-Fi monitoring system may be further enhanced by incorporating mobile application support, automated alert systems, and cloud-based data storage for improved accessibility and system management.
- Institutions planning to implement similar systems should conduct regular maintenance and inspection of electrical components, battery conditions, and solar panels to ensure long-term operational efficiency and safety.

- Future studies may explore the integration of additional renewable energy sources such as wind energy or advanced energy management systems to further improve system performance and sustainability.
- Researchers are also encouraged to conduct comparative studies involving different backup power technologies and evaluate their efficiency, cost-effectiveness, and applicability in various institutional settings.

Future Works

Although the developed system performed effectively during testing and evaluation, several enhancements may still be explored in future developments.

Future versions of the system may incorporate artificial intelligence (AI)-based energy management algorithms capable of optimizing energy consumption, battery usage, and switching operations automatically based on real-time conditions.

Cloud-based monitoring systems may also be integrated to allow users to access system information from any location through secure online platforms. Mobile application development may further improve user accessibility and convenience.

Additional features such as automated maintenance notifications, predictive battery diagnostics, and energy consumption analytics may also be implemented to enhance system intelligence and operational efficiency.

Future researchers may also expand the application of the system to larger institutional facilities, laboratories, hospitals, and disaster response centers where uninterrupted electricity is highly critical.

Lastly, further studies may investigate the long-term economic benefits and environmental impact of implementing hybrid renewable energy backup systems in educational institutions and government offices.

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