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Integration Of A DC Battery With A Solar Inverter For Enhanced Power Sustainability In Electrical Workstations

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ABSTRACT
Reliable power supply is essential for effective practical training in electrical and electronics workshops within technical and vocational education institutions. However, frequent power outages and unstable grid electricity often disrupt instructional activities, resulting in reduced productivity and compromised skill acquisition (Akinwale et al., 2021). This paper presents the design and implementation of an integrated DC battery–solar inverter system for enhanced power sustainability in an electrical workstation. The system comprises three major sections: power generation, energy storage, and power conversion. The power generation unit consists of two 600 W photovoltaic (PV) solar panels, while the energy storage unit is made up of eight lithium iron phosphate ($LiFePO_4$) batteries rated at 6.2 V, 200 Ah (640 Wh) each, connected in series to form a 24.8 V, 2.56 kWh battery bank. The power conversion unit employs a 3 kVA solar inverter, supported by a battery management system (BMS) and an active cell balancer to ensure safe and efficient operation. Performance evaluation carried out at the Federal College of Education (Technical), Ekiadolor, Benin City, demonstrated improved power reliability, extended runtime of workstation equipment, and reduced dependence on grid electricity. The developed system provides a cost-effective and sustainable power solution suitable for electrical workstations in technical institutions.
Keywords: Solar inverter, DC battery, $LiFePO_4$, power sustainability, electrical workstation.

INTRODUCTION

The availability of stable and uninterrupted electrical power is a fundamental requirement for effective teaching and learning in technical and vocational education. Electrical workstations are designed to support hands-on practical activities that enable students to acquire relevant skills in electrical installation, maintenance, and electronics (UNESCO, 2018). However, irregular grid electricity supply in Nigeria has continued to undermine the effectiveness of practical-based instruction in technical institutions (Oladipo & Yusuf, 2020).

Conventionally, petrol and diesel generators have been adopted as alternative power sources in workshops. Although these generators provide temporary relief, they are associated with high fuel costs, noise pollution, environmental degradation, and frequent maintenance challenges (Akinwale et al., 2021). These limitations make them unsuitable for sustained instructional use in academic environments.

Recent advancements in renewable energy technologies have provided viable alternatives for sustainable power generation. Solar photovoltaic systems have gained prominence due to their environmental friendliness, modularity, and suitability for decentralized applications, particularly in developing countries with high solar irradiance such as Nigeria (IRENA, 2022). When integrated with energy storage systems and power electronic converters, solar energy can provide reliable power for workshop applications (Adetoye et al., 2019).

The integration of DC battery systems with solar inverters enhances power availability by storing excess solar energy for use during periods of low irradiance or grid failure. Lithium iron phosphate ($LiFePO_4$) batteries are increasingly preferred due to their superior safety characteristics, long cycle life, and high depth-of-discharge capability (Linden & Reddy, 2011). This study therefore focuses on the design and implementation of an integrated DC battery–solar inverter system to enhance power sustainability in an electrical workstation.

MATERIALS AND METHODS

The developed system consists of two major parts: the hardware system and the system configuration and installation procedure**.**

System Hardware Components

The major components used include photovoltaic (PV) solar panels, lithium iron phosphate ($LiFePO_4$) battery bank, battery management system (BMS), active cell balancer, solar charge controller, 3 kVA solar inverter, protective devices, and electrical workstation loads. Each component performs a specific function to ensure efficient power generation, storage, and utilization (Messenger & Ventre, 2015).

Photovoltaic Solar Panel

The power generation unit consists of two 600 W photovoltaic solar panels**,** providing a total installed capacity of 1.2 kW. The panels convert solar radiation into DC electrical energy supplied to the charge controller for battery charging and load support. The selected panel size ensures adequate charging of the battery bank while supporting daytime workshop operations (IRENA, 2022).

Battery Storage System

The energy storage unit comprises eight lithium iron phosphate ($LiFePO_4$) batteries**,** each rated at 6.2 V, 200 Ah (640 Wh). The batteries are connected in series and parallel to form a 24.8V battery bank with a total energy storage capacity of approximately 2.56 kWh**.** $LiFePO_4$ batteries were selected due to their high thermal stability, improved safety, long service life, and suitability for stationary energy storage applications (Linden & Reddy, 2011).

Figure 1: $LiFePO_4$ batteries Connected in series and parallel

Battery Management System and Active Balancer

A Battery Management System (BMS) was integrated to protect the battery bank against over-voltage, under-voltage, over-current, short-circuit, and temperature extremes. An active cell balancer was included to maintain voltage uniformity across the battery cells by redistributing charge from higher-voltage cells to lower-voltage cells. This approach enhances battery efficiency, lifespan, and operational reliability (Zhang et al., 2018).

Figure 2: Integration of Battery Management Components and Active balancer

Solar Inverter

A **3** kVA solar inverter was used as the power conversion unit. The inverter converts DC power from the battery bank into 230 V AC, suitable for powering electrical workstation equipment. The inverter also provides automatic changeover between solar, battery, and grid supply, ensuring uninterrupted power delivery during grid outages (Kalogirou, 2014).

RESULTS AND DISCUSSION

The system was installed and tested at the Electrical Workshop of the Federal College of Education (Technical), Ekiadolor, Edo State. The inverter successfully powered lighting units, soldering stations, testing instruments, and desktop training systems during grid outages. The battery bank provided extended runtime, while the solar panels ensured effective recharging during daylight hours. The integration of the BMS and active balancer ensured safe battery operation and prevented cell imbalance, consistent with findings reported in similar renewable energy studies (Zhang et al., 2018).

Figure 3: Final output stage demonstrating stable power supply from the integrated DC Battery and Solar Inverter System .

CONCLUSION

This study demonstrates that integrating a DC battery system with a solar inverter provides a reliable and sustainable power solution for electrical workstations in technical institutions. The use of a 1.2 kW solar PV array, a 2.56kWh $LiFePO_4$ battery bank with BMS and active balancing, and a 3 kVA inverter significantly enhances power reliability and reduces dependence on grid electricity. The system supports uninterrupted practical training and promotes sustainable energy adoption in technical education.

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