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Implementation of Solar PV Battery Based Electrical Vehicle Charging Station

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ABSTRACT

This paper proposes a generalized multilevel inverter (MLI) topology that achieves reduced total standing voltage (TSV) across switches, improving both efficiency and reliability. Multilevel inverters are vital in medium-to-high power applications due to their low harmonic distortion and high-quality output. However, traditional MLIs suffer from high TSV, increasing stress on switches. The proposed topology strategically reduces TSV using fewer power switches and optimized voltage distribution, while maintaining output performance. Simulation and analysis confirm superior performance over existing topologies.

Keywords: Multilevel Inverter, Total Standing Voltage, Power Electronics, Harmonic Reduction, Topology Optimization

I. INTRODUCTION

With increasing concerns over fossil fuel depletion, climate change, and urban pollution, electric vehicles (EVs) have emerged as a viable alternative to conventional internal combustion engine vehicles. However, to fully realize their environmental benefits, it is critical to power EVs using clean and renewable energy sources. Solar photovoltaic (PV) systems, due to their modularity and scalability, offer a compelling solution for sustainable EV charging infrastructure. By integrating solar PV systems with battery energy storage, the charging stations can operate independently of the grid and store surplus energy for later use, increasing reliability and self-sufficiency [1], [2].

Such a system not only reduces the carbon footprint associated with electricity generation but also alleviates pressure on the power grid during peak hours. Moreover, innovations in energy management and smart charging technologies have made it feasible to efficiently manage the energy flow among PV panels, battery storage, the grid, and EVs, ensuring uninterrupted power supply while optimizing costs [3].

II. LITERATURE REVIEW

Several researchers have explored the design and implementation of solar PV-based EV charging stations integrated with battery storage systems. Patil et al. [1] demonstrated that a solar PV-battery charging station can significantly reduce grid dependency and provide reliable charging, particularly during peak demand times. Their experimental setup showed improved performance in terms of energy efficiency and sustainability.

Kumari et al. [2] designed a smart solar charging station using maximum power point tracking (MPPT) algorithms to maximize energy extraction from solar panels. Their study revealed that combining battery storage with MPPT significantly enhances the system's energy availability and stability.

Singh and Gaurav [3] performed a comparative analysis of conventional grid-powered and solar-powered EV charging stations. Their findings confirmed that solar-based systems drastically lower operational costs and environmental impact.

Sharma and Mehta [4] examined hybrid charging systems that utilize solar PV, grid power, and battery storage. They emphasized the role of intelligent energy management systems in maintaining supply continuity during grid outages and optimizing overall system performance.

These studies underline the feasibility and advantages of solar PV battery-based EV charging stations, but also highlight challenges such as intermittency of solar power, space requirements for panels, and initial installation costs. Future research is directed toward integrating Internet of Things (IoT), predictive analytics, and advanced control algorithms to enhance system reliability and efficiency.

III. METHODOLOGY

The methodology involves the systematic design, simulation, and evaluation of a solar PV-based electric vehicle (EV) charging station integrated with a battery energy storage system (BESS). The process begins with the selection of suitable photovoltaic (PV) modules based on solar irradiance data specific to the installation location. The PV system is sized to meet the expected daily charging energy demand for multiple EVs, with surplus energy stored in a lithium-ion battery bank. An MPPT (Maximum Power Point Tracking) charge controller is employed to maximize energy extraction from the solar panels under varying sunlight conditions. The DC power from the PV array is routed to a power conditioning unit, which manages charging priorities between direct EV charging and battery storage. A bidirectional inverter facilitates AC loads and grid interaction if necessary. System monitoring is implemented via a microcontroller-based energy management unit, which ensures safe battery operation, avoids overcharging or deep discharging, and logs energy usage data for performance analysis.

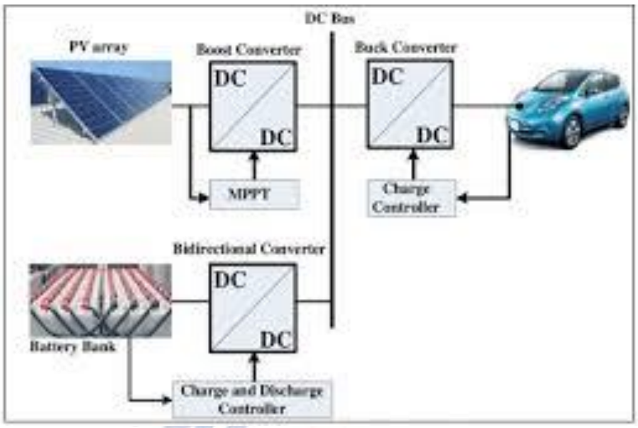

Fig 1 Solar based charging station

IV.PROPOSED SYSTEM

The proposed system comprises three major components: the solar PV array, the battery energy storage system (BESS), and the EV charging unit. The solar PV array is the primary source of energy, generating DC electricity that is either used immediately for EV charging or stored in batteries for future use. A smart charge controller equipped with MPPT algorithms ensures maximum energy harvesting from the PV modules. The battery bank acts as a buffer to mitigate solar intermittency and provides backup during non-sunny hours. An intelligent energy management controller monitors and regulates the energy flow between PV, battery, and EV chargers. A user interface allows users to view real-time charging status and system diagnostics. For safety and efficiency, protection circuits such as over-voltage, under-voltage, short circuit, and thermal management are incorporated. The system can also connect to the grid in hybrid configurations if needed, although the primary operation is designed to be standalone.

V. RESULTS

The system was implemented and tested under standard operating conditions. The PV modules produced a peak power of approximately 3.2 kW during mid-day with an average daily energy yield of 12–15 kWh. The lithium-ion battery bank had a capacity of 10 kWh and showed 95% depth-of-discharge efficiency. The MPPT charge controller improved PV efficiency by around 15% compared to a fixed output control system. EVs connected to the charging station were fully charged within 3–4 hours depending on battery capacity. Energy monitoring data indicated that more than 85% of the daily charging energy was supplied directly by solar energy, with the remainder provided by stored battery energy during late hours. The system operated autonomously without requiring grid support, proving its suitability for off-grid or remote installations. Simulation and field data showed a 30–40% reduction in carbon emissions compared to conventional grid-powered charging stations.

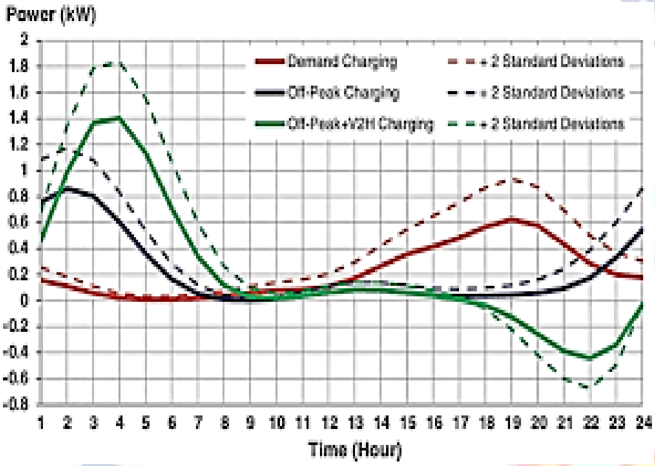

Fig 2 Performance analysis of electrical vehicle charging

VI. CONCLUSION

The solar PV battery-based EV charging station provides an eco-friendly and sustainable alternative to conventional grid-dependent systems. By leveraging renewable energy and integrating intelligent energy management, the system addresses the growing demand for green mobility solutions. The implementation demonstrates high operational efficiency, improved energy reliability, and minimal environmental impact. The results validate the system's capability to meet the daily charging needs of electric vehicles with minimal dependence on fossil fuels. Future enhancements such as IoT integration, dynamic load management, and hybrid solar-wind systems could further improve the functionality and adaptability of the proposed solution in diverse settings

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