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Modeling and Control of a Multiport Converter based EV Charging Station with PV and Battery

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ABSTRACT

The transition towards electric vehicles (EVs) demands innovative charging solutions that are efficient, sustainable, and adaptable to renewable energy sources. This research paper presents a comprehensive study on the modeling and control of a multiport converter-based EV charging station integrated with photovoltaic (PV) panels and batteries. The proposed system optimally manages the power flow between the grid, PV panels, batteries, and EVs, ensuring reliable charging while maximizing the utilization of renewable energy. A detailed mathematical model of the multiport converter is developed, considering various operating scenarios. Advanced control algorithms are employed to regulate the charging process, prioritize renewable energy utilization, and ensure grid stability. Simulation results and experimental validation demonstrate the effectiveness and feasibility of the proposed system, highlighting its potential to revolutionize the EV charging infrastructure with sustainable energy integration.

INTRODUCTION

The rising demand for electric vehicles (EVs) necessitates a paradigm shift in the design of EV charging stations. To meet this demand sustainably, integrating renewable energy sources like photovoltaic (PV) panels and energy storage systems such as batteries into charging stations is imperative. This paper introduces a novel approach for modeling and controlling a multiport converter-based EV charging station, which seamlessly integrates power from the grid, PV panels, batteries, and EVs.

The heart of the proposed system is a multiport converter that serves as the interface between different energy sources and the EVs. By intelligently managing power flow among these ports, the charging station ensures optimal energy utilization. A detailed mathematical model of the multiport converter is developed, capturing its behavior under varying conditions, including different charging rates and states of charge of the battery. The integration of PV panels and batteries introduces a layer of complexity, requiring sophisticated control strategies. Advanced control algorithms are implemented to address these challenges. These algorithms not only regulate the charging process but also prioritize the use of solar energy and stored energy from the batteries whenever possible. This approach not only reduces the strain on the grid but also enhances the station's reliability, especially during peak demand periods or grid outages.

The research conducts extensive simulations, considering diverse scenarios such as varying solar irradiance, battery state of charge, and EV charging requirements. The simulation results

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demonstrate the system's efficiency, showcasing its ability to adapt to different operating conditions while ensuring fast and reliable charging for EVs. Furthermore, experimental validation in a real-world environment corroborates the simulation findings, confirming the practical feasibility and effectiveness of the proposed multiport converter-based EV charging station. This research marks a significant step toward the development of sustainable and intelligent EV charging infrastructure. By harnessing the power of renewable energy sources and leveraging advanced control techniques, the proposed system not only addresses the challenges of grid integration but also contributes substantially to reducing greenhouse gas emissions and promoting a greener transportation ecosystem.

PROPOSED CONFIGURATION

a PV-BESS powered grid-connected charging station are essential for optimizing performance, ensuring stability, managing costs, complying with regulations, and promoting sustainability. These simulations provide valuable insights into the system's behavior under various conditions, allowing for informed decision-making and successful implementation of renewable energy solutions. To develop a comprehensive simulation model for a PV-BESS powered grid-connected charging station, aiming to optimize energy utilization, enhance grid stability, and promote sustainable transportation. This simulation will facilitate the analysis of the station's energy generation, storage, distribution, and its impact on the grid.

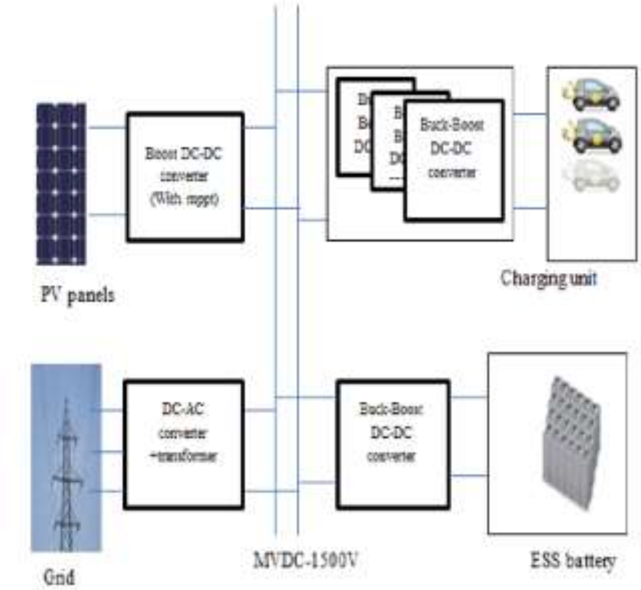

Fig 1 proposed system configuration

The proposed DC bus charging station, consists of one more bi-directional power source BES sharing the same DC bus. The BES is utilized to maintain the DC link voltage and balance power surplus/insufficiency from the PV. With this configuration. Photovoltaic panels generate electricity from sunlight during daylight hours. This DC electricity is produced directly from the sunlight falling on the PV cells. The DC electricity generated by the PV panels is converted into AC (alternating current) electricity by an inverter. This conversion is necessary because most electrical grids and EV chargers operate on AC power. The inverter sends the AC electricity into the grid. The PV system is connected to the local electrical grid, allowing any excess electricity generated by the PV panels to be fed back into the grid. This process is often facilitated through a net metering arrangement, where excess power results in credits or reduced electricity bills for the owner. When an electric vehicle is plugged into the charger, it draws power directly from the grid. The EV charger converts the grid AC electricity to the DC electricity needed to charge the vehicle's battery. The charging rate of the EV charger can be adjusted based on the real-time power output from the PV panels. If the PV system is generating more power than the charging station and other appliances on the grid are using, the surplus power can be utilized for charging the EVs. Conversely, if the PV system's output is lower than the total demand, the grid supplies the additional power required for charging.

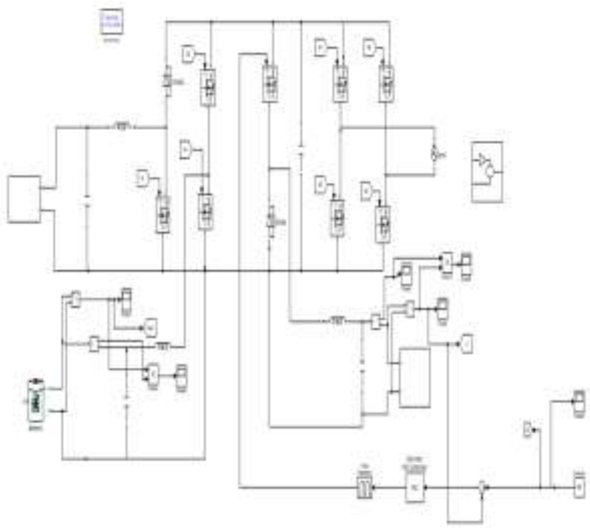

Fig 2 proposed system simulation

The integration of Battery Energy Storage Systems (BESS) with PV powered grid-connected charging stations offers several advantages, making the system more efficient, reliable, and sustainable. Here are the key advantages of this integration. BESS can store excess energy generated by PV panels during peak sunlight hours. This stored energy can be used during periods of low sunlight or high demand, ensuring a stable power supply to the charging station and electric vehicles even when the sun is not shining. BESS integration enables grid stability by smoothing out fluctuations in energy supply. It helps in managing peak demand effectively, reducing stress on the grid during high-demand periods, and preventing grid overloads. This can lead to a more reliable and stable grid operation.

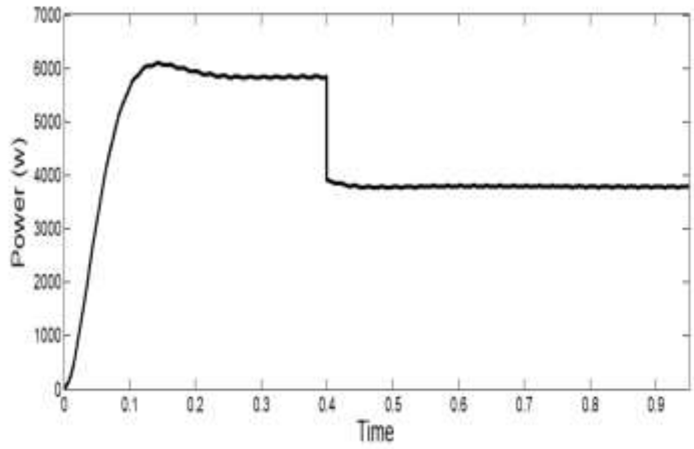

Fig 3 Pv generated power

BESS can be used to optimize energy usage based on time-of-use (TOU) pricing. It can store energy when electricity rates are low and supply power during peak hours when rates are high. This can result in significant cost savings for the charging station operator. By storing excess energy and intelligently managing the usage, the charging station can reduce its dependency on the grid. During emergencies or grid failures, the station can continue operating, providing a reliable charging service to electric vehicle users.

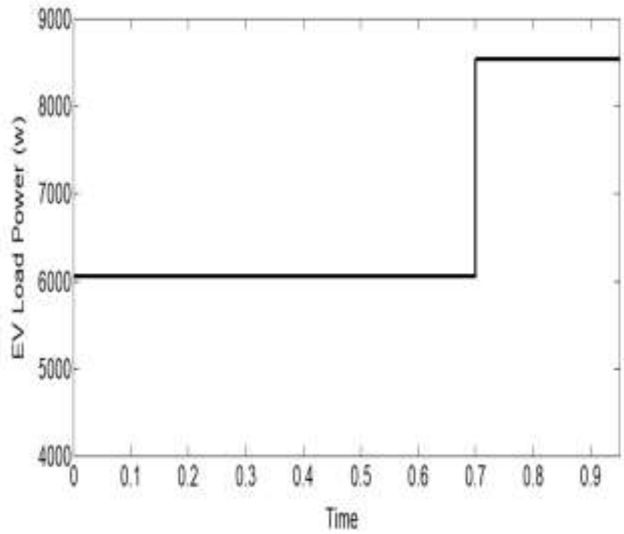

Fig 4 EV Load power

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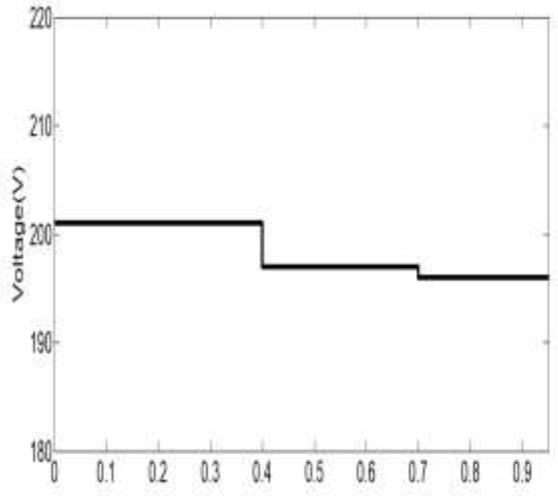

Fig 5 BESS load Power

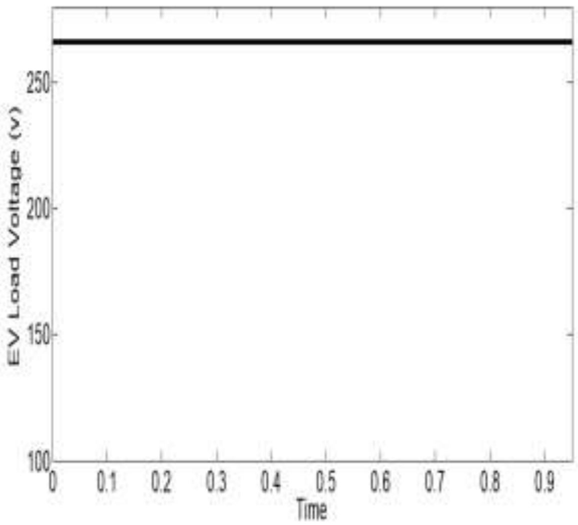

Fig 6 EV Load Voltage

CONCLUSION

The simulation of a PV powered grid-connected charging station with BESS integration represents a pivotal step towards a more sustainable, efficient, and resilient energy and transportation infrastructure. By continuing to refine and implement these integrated systems, society can accelerate the transition towards a greener future, addressing both energy challenges and environmental concerns in a holistic manner.

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