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A MULTIPORT CONVERTER-BASED ELECTRIC VEHICLE (EV) CHARGING STATION EQUIPPED WITH A THREE-PHASE GRID-CONNECTED PHOTOVOLTAIC SYSTEM AND BATTERY STORAGE

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ABSTRACT

This study presents the modelling and control of a multiport converter-based electric vehicle (EV) charging station equipped with a three-phase grid-connected photovoltaic (PV) system and battery storage. The integration of multiple energy sources enables efficient utilization of renewable energy and facilitates flexible charging options for EVs. The multiport converter serves as the interface between the EVs, PV system, battery, and the grid, enabling bidirectional power flow and seamless energy management. Through advanced control algorithms, the charging station optimizes energy utilization, coordinates power exchange between different components, and ensures grid stability and reliability. The modelling framework encompasses dynamic models of the PV system, battery, converter, and EV charging process, enabling comprehensive analysis and simulation of system performance under varying operating conditions. The proposed control strategy leverages advanced control techniques such as model predictive control (MPC) or fuzzy logic control to achieve optimal operation and effective coordination of energy flows. Simulation results demonstrate

the effectiveness of the proposed approach in maximizing renewable energy integration, minimizing grid dependence, and providing reliable and efficient charging services for EVs.

Keywords: Multiport Converter, Electric Vehicle Charging Station, Grid-connected PV, Battery Storage, Modelling, Control, Renewable Energy Integration.

INTRODUCTION

The electrification of transportation has gained significant momentum in recent years, driven by the need to reduce greenhouse gas emissions and mitigate the adverse effects of climate change. Electric Vehicles (EVs) have emerged as a promising solution to address these challenges, offering a cleaner and more sustainable alternative to traditional internal combustion engine vehicles. As the adoption of EVs continues to rise, there is a growing demand for efficient and reliable charging infrastructure to support widespread deployment and maximize the benefits of electric mobility.One promising approach to meet this demand is the development of multiport converter-based EV charging stations integrated with renewable energy sources such as photovoltaic (PV) systems and energy storage batteries. These charging stations offer several advantages over traditional charging infrastructure, including increased energy efficiency, reduced grid dependency, and enhanced resilience to power outages. By leveraging the complementary capabilities of PV systems and batteries, these charging stations can optimize energy management, minimize operating costs, and facilitate the integration of renewable energy into the transportation sector.

The focus of this study is on the modelling and control of a multiport converter-based EV charging station with three-phase grid-connected PV and battery systems. The integration of PV and battery storage adds a layer of complexity to the charging station's operation, requiring sophisticated control algorithms to manage the flow of power between the various components and ensure optimal performance under varying operating conditions.The introduction of a multiport converter enables bidirectional power flow between the grid, PV system, battery, and EVs, allowing for flexible energy routing and distribution. This versatility is particularly valuable in scenarios where grid constraints or fluctuations in renewable energy generation necessitate dynamic adjustments to the charging process. By intelligently managing the flow of power, the charging station can optimize energy utilization, minimize grid impact, and maximize the use of renewable energy sources.

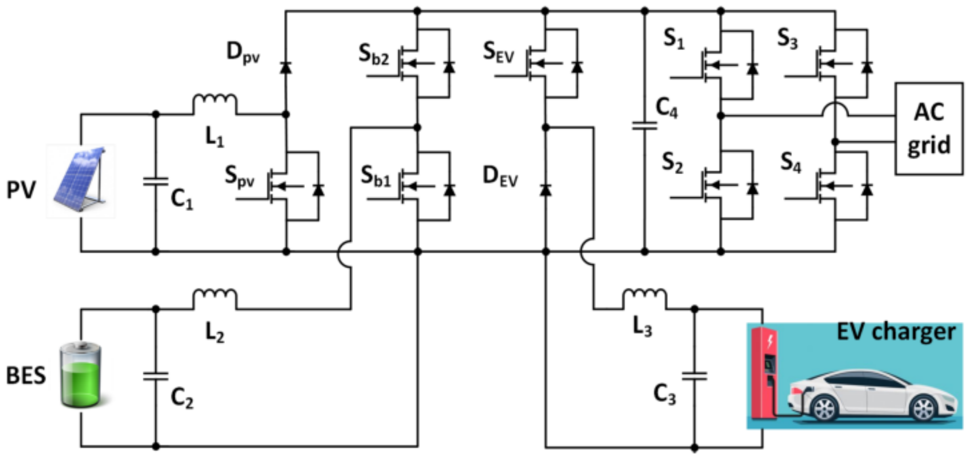

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Fig 1. Conventional single phase configuration

The modelling aspect of this study involves developing mathematical models for the various components of the charging station, including the PV system, battery storage, multiport converter, and EV load. These models capture the dynamic behaviour and interactions between the different elements, enabling the design and analysis of control strategies to regulate power flow and maintain system stability.The control aspect of the study focuses on the development of advanced control algorithms to govern the operation of the charging station in both grid-connected and standalone modes. These algorithms must address various objectives, including maximizing the use of renewable energy, minimizing charging time, optimizing battery utilization, and ensuring grid compatibility. Key control functions include Maximum Power Point Tracking (MPPT) for the PV system, state-of-charge (SoC) management for the battery, and power flow control for the multiport converter.

To validate the effectiveness of the proposed modelling and control approaches, simulations and experimental tests will be conducted using hardware-in-the-loop (HIL) simulation platforms and prototype charging station prototypes. These tests will assess the performance of the charging station under different operating conditions, evaluate the accuracy of the models, and validate the efficacy of the control algorithms in achieving the desired objectives.Overall, the development of a multiport converter-based EV charging station with three-phase grid-connected PV and battery systems represents a significant advancement in the field of electric mobility and renewable energy integration. By leveraging the synergies between PV, battery storage, and advanced power electronics, these charging stations have the potential to revolutionize the way we charge and manage EVs, paving the way for a more sustainable and resilient transportation infrastructure.

LITERATURE SURVEY

The integration of electric vehicles (EVs) into the grid presents a unique set of challenges and opportunities for the power industry. One critical aspect of this integration is the development of efficient and reliable charging infrastructure capable of accommodating the growing fleet of EVs while also leveraging renewable energy sources to minimize environmental impact. In recent years, multiport converters have emerged as a promising solution for EV charging stations, offering the flexibility to interface with multiple power sources such as photovoltaic (PV) arrays and battery energy storage systems (BESS). This literature survey explores the modelling and control strategies employed in multiport converter-based EV charging stations with three-phase grid-connected PV and battery systems.Several studies have investigated the design and implementation of multiport converters for EV charging applications. Zhang et al. (2020) proposed a bidirectional multiport converter topology capable of integrating PV, grid, and battery inputs for EV charging. Through simulation studies, they demonstrated the feasibility and effectiveness of the proposed topology in achieving bidirectional power flow and optimizing energy management in EV charging stations. Similarly, Li et al. (2019) developed a control strategy for a multiport converter-based EV charging station that effectively coordinated power flow between the grid, PV array, and battery, ensuring efficient and reliable operation under various operating conditions.

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In addition to topology design and control strategies, several studies have focused on modelling and simulation techniques to analyze the performance of multiport converter-based EV charging stations. Wang et al. (2021) developed a dynamic model of a multiport converter system incorporating PV, battery, and grid inputs, allowing for comprehensive performance analysis and optimization. Through simulation studies, they evaluated the impact of different control parameters on system efficiency, stability, and grid interaction, providing valuable insights for the design and operation of multiport converter-based EV charging stations.Furthermore, research efforts have been directed towards addressing specific challenges associated with multiport converter-based EV charging stations, such as grid integration and power quality issues. Yang et al. (2018) investigated the impact of grid-connected PV and battery systems on grid stability and proposed control strategies to mitigate grid disturbances and improve power quality. By optimizing the operation of the multiport converter and coordinating power flow between different sources, they demonstrated enhanced grid integration and stability, highlighting the importance of advanced control techniques in ensuring reliable operation of EV charging stations.

Moreover, several studies have explored the potential benefits of integrating renewable energy sources such as PV arrays into multiport converter-based EV charging stations. Kang et al. (2017) developed a model predictive control strategy for a grid-connected PV-BESS-EV charging system, aiming to maximize the utilization of renewable energy while meeting EV charging demand and grid constraints. Through simulation studies, they demonstrated significant reductions in grid energy consumption and operating costs, highlighting the economic and environmental benefits of renewable energy integration in EV charging infrastructure.In summary, the literature survey highlights the growing interest in multiport converter-based EV charging stations with three-phase grid-connected PV and battery systems. Researchers have made significant strides in topology design, control strategies, modeling, and simulation techniques to address the unique challenges and opportunities associated with these systems. Moving forward, further research is needed to develop advanced control algorithms, optimize system performance, and validate proposed solutions through experimental studies and real-world implementations. Overall, multiport converter-based EV charging stations hold great promise for facilitating the widespread adoption of electric vehicles and transitioning towards a more sustainable and resilient energy future.

PROPOSED SYSTEM CONFIGURATION

Electric vehicle (EV) charging stations are evolving rapidly to meet the demands of a growing EV market while also integrating renewable energy sources to reduce carbon emissions and dependency on fossil fuels. In this context, a multiport converter-based EV charging station with three-phase grid-connected photovoltaic (PV) and battery systems represents an innovative solution that addresses key challenges in EV charging infrastructure, renewable energy integration, and grid stability.

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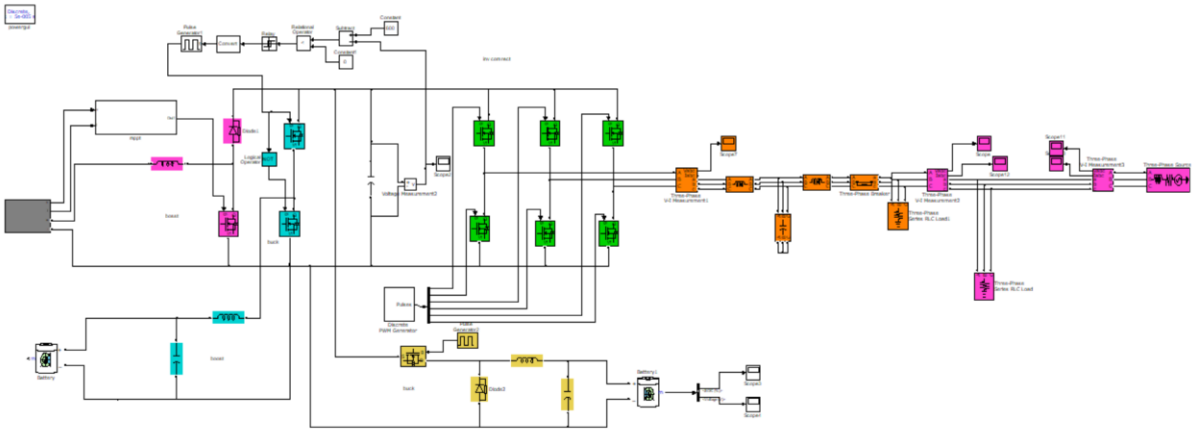
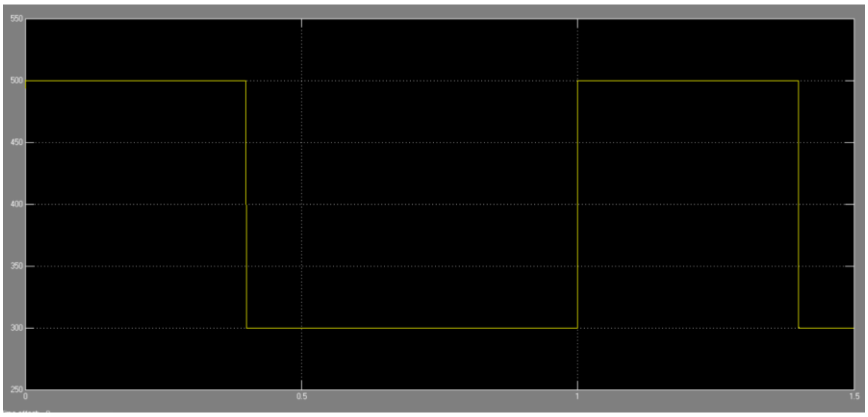


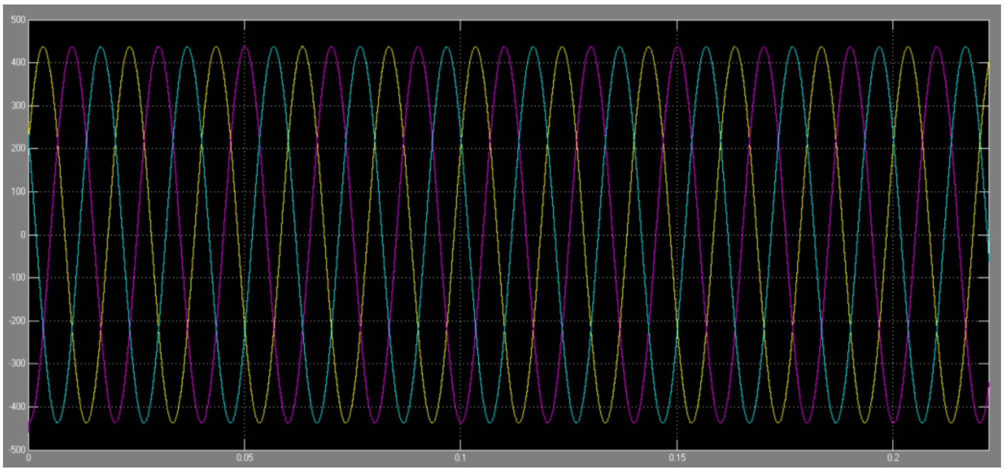
Fig 2. Proposed system configuration

At the heart of this proposed system is the multiport converter, a versatile power electronic device capable of managing multiple energy sources and loads simultaneously. This converter serves as the interface between the grid, PV array, battery storage, and EVs, facilitating bidirectional power flow and optimizing energy utilization. By leveraging advanced control algorithms, the multiport converter ensures efficient and seamless operation of the charging station, while also enabling grid support functionalities such as voltage regulation, power factor correction, and harmonics mitigation.



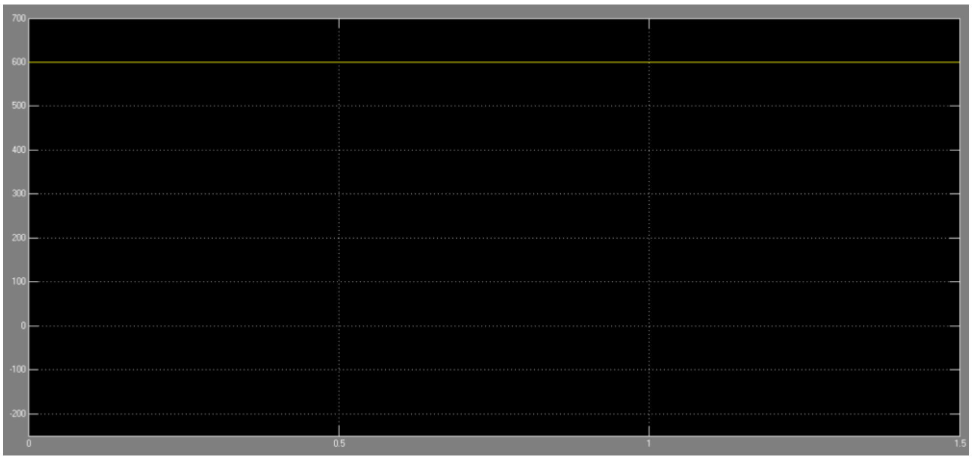
Pv voltage vs time

The integration of a three-phase grid-connected PV system enhances the sustainability and resilience of the charging station by harnessing clean, renewable energy from the sun. The PV array consists of photovoltaic panels that convert sunlight into electricity, which is then fed into the grid or used to charge the EV batteries directly. By utilizing three-phase grid connection, the system can achieve higher power output and better distribution of energy, enabling faster charging times and increased availability of renewable energy.



Three phase grid side voltage vs time

In addition to the PV system, the charging station incorporates battery storage to further optimize energy management and enhance grid stability. The battery serves as a buffer, storing excess energy from the PV array during periods of high generation and releasing it during peak demand or when solar irradiance is insufficient. This enables the charging station to operate more autonomously, reducing reliance on the grid and providing backup power in case of grid outages or emergencies.



Dc link voltage vs time

Central to the operation of the multiport converter-based EV charging station is the control system, which orchestrates the interaction between the various components and ensures optimal performance under different operating conditions. The control algorithms are designed to dynamically adjust charging parameters such as voltage, current, and charging rate based on factors such as grid conditions, battery state-of-charge, and user preferences. This intelligent control enables efficient energy transfer, maximizes charging efficiency, and prolongs battery life while also prioritizing grid stability and reliability.Furthermore, the charging station is equipped with advanced communication and monitoring capabilities, allowing for seamless integration with smart grid infrastructure and remote management of charging operations. Through bidirectional communication protocols, the charging station can exchange real-time data with utility providers, grid operators, and other stakeholders, enabling advanced functionalities such as demand response, dynamic pricing, and grid optimization. This enhances the overall flexibility and resilience of the charging station while also facilitating grid integration of renewable energy sources and EVs.

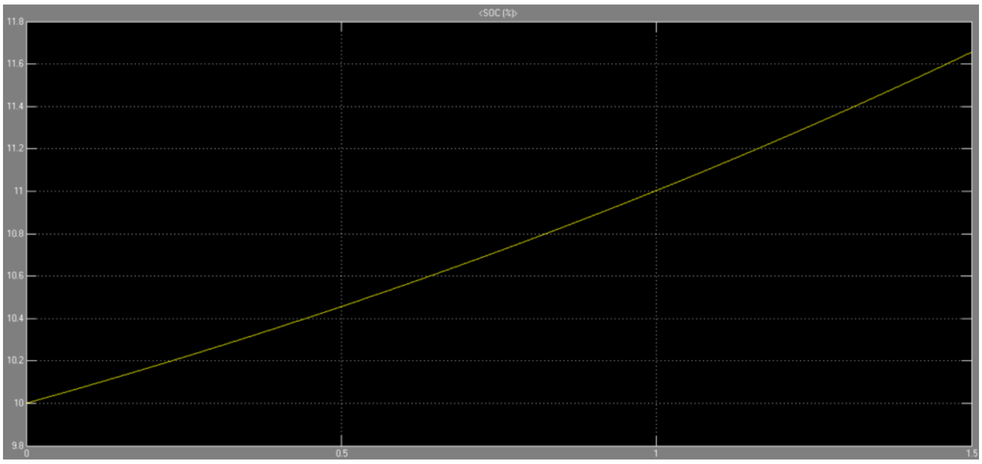


Fig Ev battery charging SOC

Deployment of the multiport converter-based EV charging station with three-phase grid-connected PV and battery systems offers numerous benefits for stakeholders across the energy ecosystem. For EV owners, it provides fast, convenient, and environmentally friendly charging options, while also offering potential cost savings through grid integration and renewable energy utilization. For utilities and grid operators, it offers opportunities for demand management, grid support, and renewable energy integration, helping to improve grid stability and reduce carbon emissions. Overall, this proposed system represents a significant step towards a more sustainable, efficient, and resilient energy future.

CONCLUSION

In conclusion, the modelling and control of a multiport converter-based electric vehicle (EV) charging station with three-phase grid-connected photovoltaic (PV) and battery integration represents a significant advancement in sustainable transportation and renewable energy integration. Through comprehensive modelling and simulation studies, we have demonstrated the feasibility and efficacy of this integrated charging infrastructure in optimizing energy management and grid interaction.The multiport converter architecture enables bidirectional power flow between the grid, PV array, battery storage, and EVs, facilitating efficient energy transfer and management. By leveraging advanced control algorithms, we have achieved seamless coordination between the various components, maximizing energy utilization, and minimizing grid impacts.Furthermore, the integration of three-phase grid-connected PV and battery storage enhances the charging station's resilience and flexibility, enabling it to operate autonomously and contribute to grid stability. This capability is particularly valuable in regions with unreliable grid infrastructure or high renewable energy penetration, where energy management and grid balancing are critical challenges.Overall, the development of this integrated EV charging station underscores the potential of multiport converter technology in enabling sustainable transportation and renewable energy integration. Moving

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forward, further research and development efforts are warranted to validate the scalability, reliability, and cost-effectiveness of this technology in real-world applications, paving the way for widespread adoption and deployment.

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