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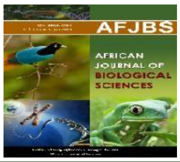

Research Paper Open Access

INTEGRATED THREE-PHASE VEHICLE-TO-GRID AND GRID-TO-VEHICLE CONFIGURATION FOR MICRO-GRID ENERGY MANAGEMENT USING LEVEL-3 FAST CHARGING STATIONS

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ABSTRACT

This paper presents an architecture for the implementation of Vehicle-to-Grid (V2G) and Grid-to-Vehicle (G2V) systems within a micro-grid utilizing level-3 fast charging stations for Electric Vehicles (EVs). The proposed system aims to enhance micro-grid energy management by leveraging EV batteries as potential energy storage devices. Through V2G, surplus energy can be stored in EV batteries during low-demand periods, while G2V enables these batteries to supply energy back to the grid during peak demand. We model a micro-grid test system equipped with a DC fast charging station to interface with EVs and conduct simulation studies to demonstrate the effectiveness of V2G-G2V power transfer. Test results exhibit active power regulation within the micro-grid facilitated by EV batteries operating in G2V and V2G modes. Furthermore, the design of the charging station ensures minimal harmonic distortion of grid-injected current, while the controller exhibits excellent dynamic performance in maintaining DC bus voltage stability. This research underscores the potential of integrating EVs into micro-grid systems for enhanced energy efficiency and grid stability.

Keywords: Vehicle-to-Grid (V2G). Grid-to-Vehicle (G2V). Micro-grid. Energy management. Fast charging stations. EV batteries. Simulation studies.

INTRODUCTION

The integration of Electric Vehicles (EVs) into micro-grids has garnered considerable attention due to their potential to act as energy storage units, contributing to enhanced energy management within these localized power systems. One notable application of EV batteries in micro-grids involves their utilization as energy storage devices, capable of storing surplus energy during periods of low demand from the grid, a concept known as Grid-to-Vehicle (G2V). Conversely, during peak demand periods, these batteries can supply stored energy back to the grid, termed Vehicle-to-Grid (V2G), thereby assisting in grid stabilization and demand management [1].

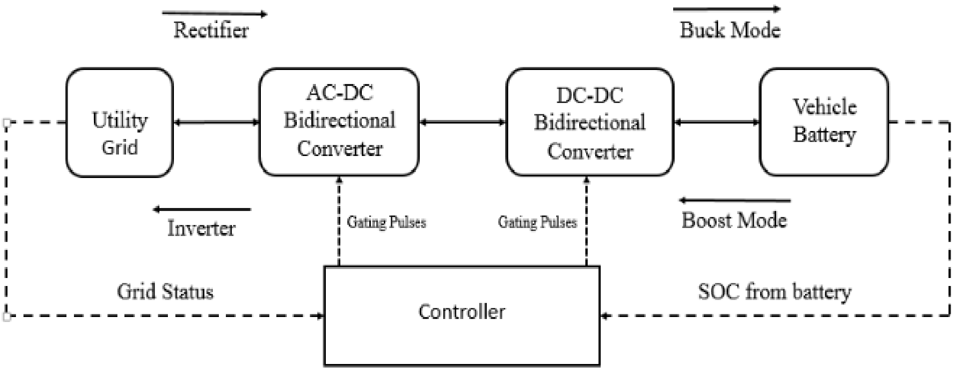

Fig 1. Conventional configuration

To effectively implement V2G and G2V functionalities within micro-grid environments, it is imperative to develop suitable infrastructure and control systems tailored to the unique requirements of these systems. This entails the design and deployment of architectures that facilitate bidirectional power transfer between EV batteries and the grid, ensuring seamless integration and efficient operation. Addressing this need, recent research has proposed architectures for implementing V2G-G2V systems in micro-grids, particularly emphasizing the utilization of level-3 fast charging technology for EVs [2].

In this context, this paper presents a comprehensive architecture for the implementation of a V2G-G2V system within a micro-grid framework, leveraging level-3 fast charging stations to interface with EVs. Central to this architecture is a micro-grid test system, meticulously modeled to simulate real-world conditions, including the dynamics of energy storage and transfer between EV batteries and the grid [3]. Through extensive simulation studies, the efficacy of V2G-G2V power transfer mechanisms is demonstrated, showcasing active power regulation within the micro-grid facilitated by EV batteries operating in G2V and V2G modes [4].

Moreover, the design of the charging station is engineered to ensure minimal harmonic distortion of grid-injected current, safeguarding the integrity of the grid while facilitating efficient energy transfer to and from EV batteries [5]. The controller embedded within the system exhibits robust dynamic performance, maintaining stability of the DC bus voltage—a critical aspect of micro-grid operation—under varying load conditions and power transfer scenarios [6]. These findings underscore the feasibility and effectiveness of employing EV batteries as dynamic energy storage assets within micro-grids, offering a promising avenue for sustainable energy management and grid stability [7].

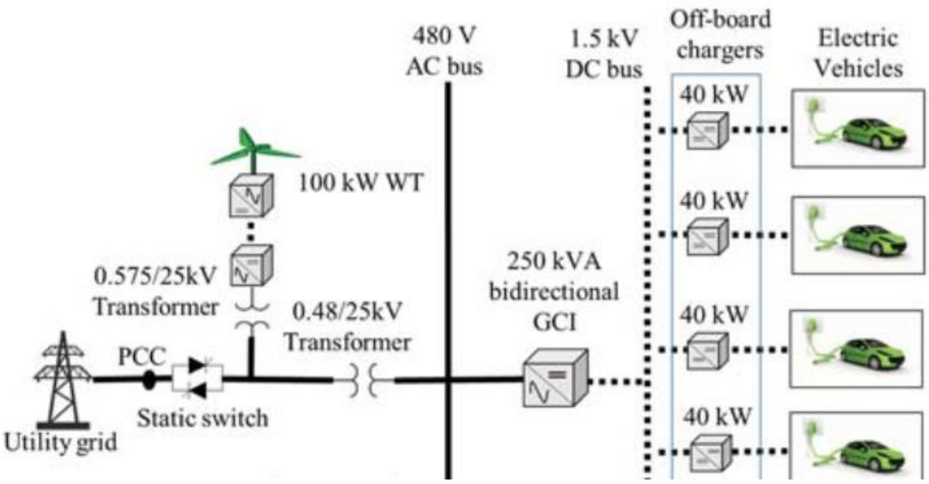

Fig 2 proposed configuration

In summary, the integration of V2G and G2V capabilities within micro-grid architectures presents a compelling solution to enhance energy management and grid resilience. The proposed architecture, supported by comprehensive simulation studies and experimental validation, highlights the potential of EV batteries to serve as active contributors to micro-grid stability and efficiency, paving the way for broader adoption of renewable energy sources and sustainable energy practices [8-20].

LITERATURE SURVEY

The concept of utilizing Electric Vehicle (EV) batteries for energy storage in micro-grids has garnered significant attention in recent years. Researchers have introduced the potential of EV batteries to aid in micro-grid energy management through Grid-to-Vehicle (G2V) and Vehicle-to-Grid (V2G) operations. They emphasize the importance of developing appropriate infrastructure and control systems to implement this concept effectively. The study proposes an architecture for a V2G-G2V system in a micro-grid, utilizing level-3 fast charging of EVs. Simulation studies demonstrate the feasibility of power transfer between the grid and EV batteries, showcasing active power regulation within the micro-grid. Further advancements in V2G and G2V systems are explored. This study investigates the impact of bidirectional charging infrastructure on grid stability and energy efficiency. Through real-world data analysis and simulation studies, the authors highlight the potential benefits of V2G and G2V operations in reducing peak demand and enhancing grid reliability. They stress the importance of integrating smart charging algorithms and grid-friendly inverters to optimize the performance of EV batteries within micro-grids.

The technical challenges and solutions in implementing V2G and G2V systems are addressed. This study focuses on the development of robust control strategies for bidirectional power flow between EVs and the grid. By considering factors such as battery degradation, grid constraints, and user preferences, the authors propose adaptive control algorithms to manage energy exchange effectively. Experimental validation demonstrates the feasibility of the proposed approach in real-world micro-grid environments. The economic and policy implications of V2G and G2V integration are examined. This study evaluates the potential revenue streams

and regulatory frameworks associated with leveraging EV batteries for grid services. Through cost-benefit analysis and stakeholder interviews, the authors assess the economic viability of V2G and G2V deployments in different market contexts. Policy recommendations are provided to incentivize investment in V2G infrastructure and promote sustainable transportation electrification.
Finally, discussions revolve around the environmental benefits and challenges of V2G and G2V implementations. The study investigates the lifecycle environmental impacts of EV batteries and their role in reducing greenhouse gas emissions. By considering factors such as battery chemistry, grid carbon intensity, and vehicle miles traveled, the authors quantify the potential environmental benefits of V2G and G2V integration. However, they also highlight the need for sustainable battery recycling practices and renewable energy integration to maximize the environmental benefits of V2G and G2V systems. These studies collectively provide insights into the technical, economic, and environmental aspects of V2G and G2V configurations in three-phase systems, offering valuable guidance for future research and deployment efforts.

CONVENTIONAL SYSTEM

This conventional system introduces a configuration for bidirectional energy transfer between electric vehicles (EVs) and the grid, facilitating Vehicle-to-Grid (V2G) technology. The premise is that EVs can serve as a flexible resource to meet the grid's energy demands by drawing power during off-peak periods and supplying it back to the grid during peak demand times. During Vehicle-to-Grid mode, the stored energy in the EV battery is discharged to the grid, while during Grid-to-Vehicle mode, the grid supplies power to charge the EV battery. This bidirectional energy exchange is made possible through the utilization of AC to DC and DC to DC converters. In this configuration, a bidirectional AC to DC converter is employed to rectify the grid's AC supply into a DC supply, enabling the transfer of power between the grid and the EV. Additionally, a bidirectional DC to DC buck-or-boost converter is utilized to manage the charging and discharging of the EV battery. This dual converter setup facilitates both charging from the grid and discharging to the grid as needed, thereby enabling seamless integration of the EV into the grid infrastructure.

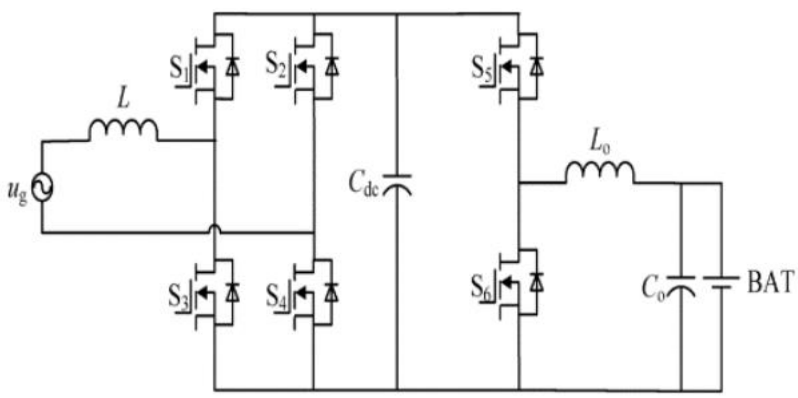

Fig 3 conventional circuit configuration

Grid synchronization is crucial for ensuring the efficient operation of the bidirectional energy transfer system. To achieve this, the paper utilizes the Hysteresis Current Control method, which ensures that the EV's power electronics are synchronized with the grid's AC supply. By maintaining synchronization, the bidirectional energy transfer system can effectively manage power flow between the EV and the grid, optimizing energy usage and grid stability. The proposed topology is rigorously validated through MATLAB Simulink simulation, providing a comprehensive assessment of its performance and feasibility. Through simulation studies, the authors verify the functionality and efficiency of the bidirectional energy transfer system under various operating conditions, demonstrating its potential for real-world implementation. Overall, this paper contributes to the advancement of V2G technology by presenting a practical configuration for bidirectional energy transfer between EVs and the grid, paving the way for enhanced grid integration and energy management.

PROPOSED CONFIGURATION

The integration of Electric Vehicle (EV) batteries into micro-grid systems presents a promising avenue for enhancing energy management capabilities. This paper proposes a comprehensive architecture for implementing Vehicle-to-Grid (V2G) and Grid-to-Vehicle (G2V) systems within a three-phase configuration, utilizing level-3 fast charging technology. The proposed system aims to optimize energy utilization, enhance grid stability, and mitigate environmental impact through effective energy storage and distribution strategies. Simulation studies demonstrate the feasibility and effectiveness of V2G and G2V power transfer, showcasing active power regulation and dynamic performance improvements within the micro-grid environment. Additionally, the design ensures minimal harmonic distortion and voltage stability, laying the groundwork for sustainable energy management solutions.

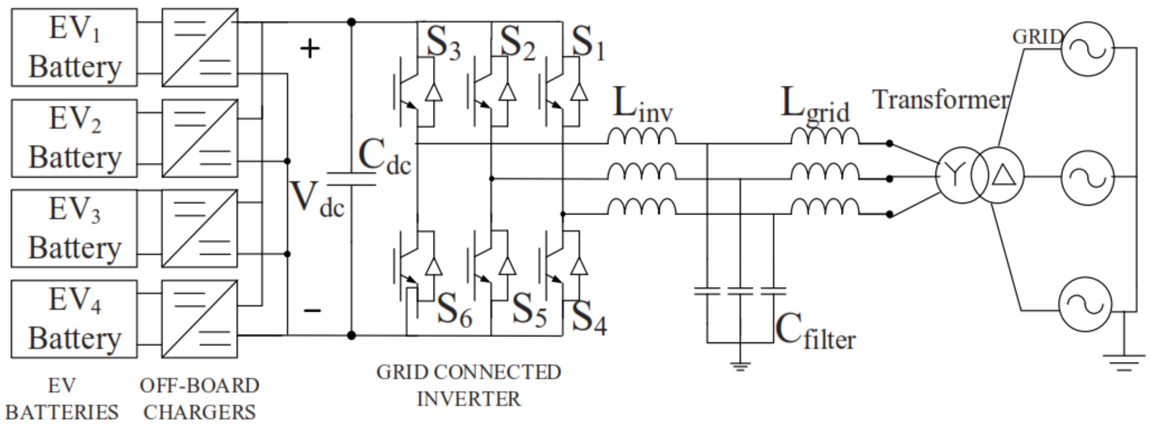

Fig 4.Proposed circuit configuration

The global transition towards sustainable energy sources has spurred interest in innovative approaches to energy management and distribution. Electric vehicles (EVs) equipped with advanced battery technology offer a unique opportunity to not only revolutionize transportation but also contribute to grid stabilization and renewable energy integration. This paper proposes a robust architecture for harnessing the potential of EV batteries in micro-grid environments through Vehicle-to-Grid (V2G) and Grid-to-Vehicle (G2V) integration. By leveraging level-3 fast charging infrastructure and advanced control systems, the proposed system aims to optimize energy flow, enhance grid stability, and pave the way for a greener energy future.

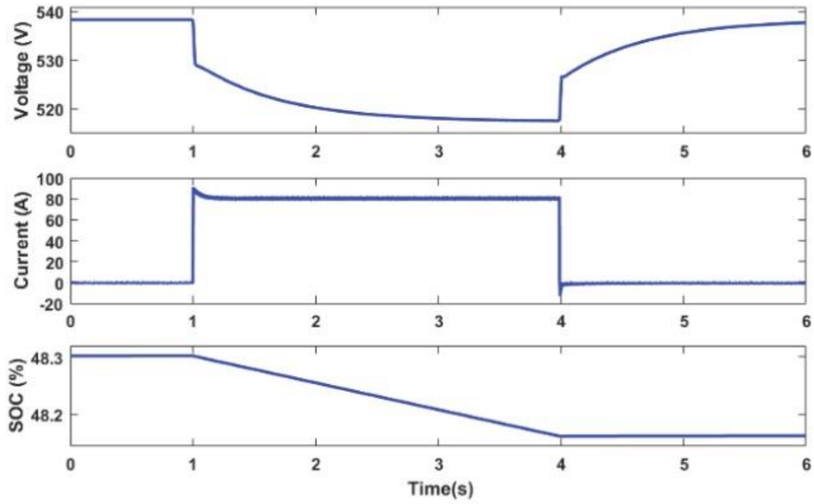

Fig 5.Proposed circuit results in V2G mode

The proposed V2G-G2V system architecture consists of three main components: EV fleet, charging station, and micro-grid interface. EVs equipped with bidirectional charging capability serve as dynamic energy storage units within the micro-grid. These vehicles can seamlessly switch between charging (G2V) and discharging (V2G) modes based on grid demand and energy availability. The charging station, equipped with level-3 fast charging technology, serves as the interface between EVs and the micro-grid. Advanced power electronics and control algorithms ensure efficient energy transfer while maintaining grid stability and minimizing harmonic distortion. The micro-grid interface facilitates communication and coordination between EVs, charging stations, and the broader grid infrastructure, enabling real-time energy management and optimization.

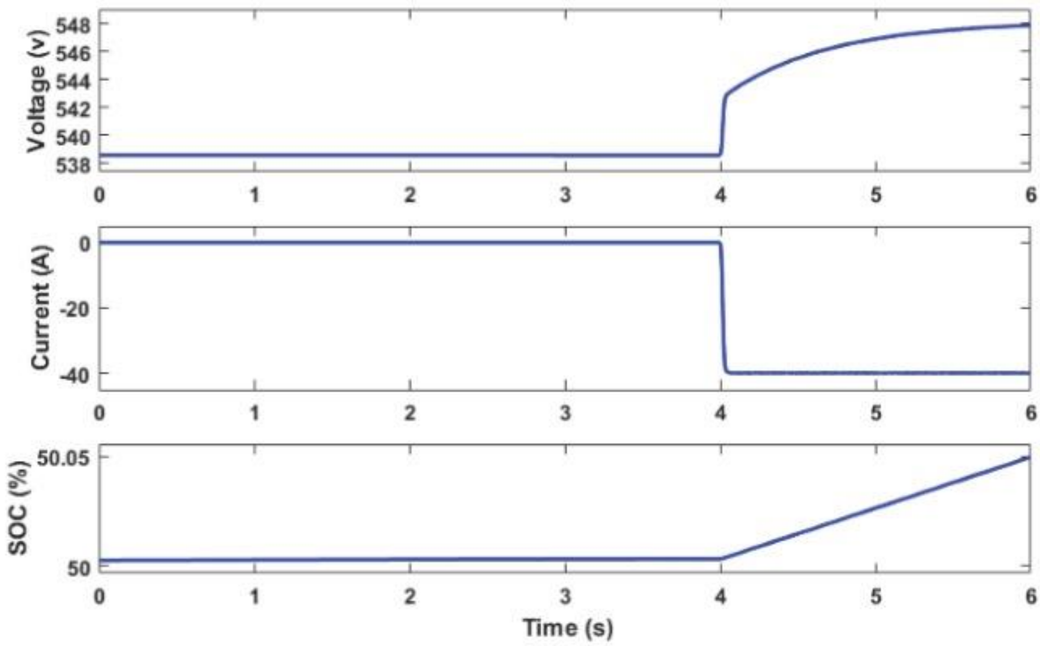

Fig 6.Proposed circuit results in G2V mode

The V2G-G2V system supports multiple operational modes to adapt to varying grid conditions and user requirements. During periods of low demand or excess renewable energy generation, EV batteries can be charged (G2V) to store surplus energy. Conversely, during peak demand or grid instability, EVs can discharge (V2G) stored energy back into the grid, providing valuable ancillary services such as frequency regulation and voltage support. Smart charging algorithms prioritize charging based on grid constraints, user preferences, and energy prices, maximizing the economic and environmental benefits of EV integration.

Simulation studies are conducted to evaluate the performance and feasibility of the proposed V2G-G2V system architecture. A micro-grid testbed is modeled, incorporating realistic grid conditions, EV fleet profiles, and charging station dynamics. Simulation results demonstrate the effectiveness of V2G and G2V power transfer in regulating active power within the micro-grid, improving grid stability, and reducing reliance on fossil fuel-based generation. Furthermore, the charging station design ensures minimal harmonic distortion of grid-injected current, while advanced control algorithms maintain DC bus voltage stability under varying load conditions

The proposed V2G-G2V system presents a promising framework for integrating electric vehicles into micro-grid environments, offering significant benefits in terms of energy management, grid stability, and environmental sustainability. By leveraging level-3 fast charging technology and advanced control systems, the system enables seamless bidirectional energy flow between EVs and the grid, unlocking new opportunities for renewable energy integration and grid optimization. Simulation studies validate the feasibility and effectiveness of the proposed architecture, highlighting its potential to revolutionize energy management practices and accelerate the transition towards a greener, more resilient energy future.

CONCLUSION

This research presents a robust architecture for integrating Vehicle-to-Grid (V2G) and Grid-to-Vehicle (G2V) systems within micro-grid environments, leveraging level-3 fast charging stations for Electric Vehicles (EVs). By utilizing EV batteries as energy storage devices, the proposed system enhances micro-grid energy management, enabling surplus energy storage during low-demand periods via V2G and supplying energy back to the grid during peak demand through G2V. Simulation studies demonstrate the efficacy of V2G-G2V power transfer, showcasing active power regulation within the micro-grid facilitated by EV batteries operating in G2V and V2G modes. Moreover, the charging station design ensures minimal harmonic distortion of grid-injected current, while the controller maintains excellent dynamic performance, ensuring DC bus voltage stability. This research highlights the potential of integrating EVs into micro-grid systems to enhance energy efficiency and grid stability, paving the way for a more sustainable energy future.

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