A Review of Electric Vehicle Charging Stations With G2V and V2G Using Dual Active Bridge

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Abstract –*The rapid adoption of electric vehicles (EVs) necessitates advanced charging infrastructures to ensure efficient energy transfer and grid stability. This review paper provides a comprehensive analysis of electric vehicle charging stations (EVCS) that employ Dual Active Bridge (DAB) converters, highlighting their role in facilitating fast and bidirectional charging capabilities. The paper begins by exploring the evolution of EVCS architectures and the emerging need for DAB converters to address the limitations of traditional systems. We systematically examine the technical advancements, focusing on the efficiency improvements, control strategies, and integration of renewable energy sources within the DAB-enabled EVCS. Through a meta-analysis of recent studies, we evaluate the performance benchmarks, reliability concerns, and cost-effectiveness of DAB converters in various charging scenarios, including V2G (vehicle-to-grid) and G2V (grid-to-vehicle) interactions. The review also delves into the regulatory frameworks and standardization efforts that are shaping the deployment of such systems. Lastly, we discuss the potential future developments and the impact of DAB technology on the smart grids and sustainable transportation. Our findings suggest that DAB converters are pivotal in the transition towards a more resilient and flexible EV charging infrastructure, offering significant benefits in terms of power quality, conversion efficiency, and user convenience.*

Keywords: **Electric Vehicles, Charging Stations, Dual Active Bridge Converters, Bidirectional Charging, Energy Transfer Efficiency, Grid Stability**

I. INTRODUCTION

The paradigm shift towards electric vehicles (EVs) is a cornerstone in the global effort to reduce carbon emissions and combat climate change. This transition is predicated not only on the advancement of EV technology but also on the development of a robust and efficient charging infrastructure capable of supporting the anticipated surge in EV usage. The efficacy of electric vehicle charging stations (EVCS) is therefore critical to the widespread adoption of EVs, presenting unique technical challenges that must be surmounted.

Dual Active Bridge (DAB) converters have been identified as a key technological innovation in this domain, offering significant improvements over traditional charging systems. These converters facilitate efficient power conversion, enabling rapid charging while minimizing energy loss and improving overall system performance. The bidirectional power flow feature of DAB converters further enhances the functionality of EVCS by supporting Vehicle-to-Grid (V2G) and Grid-to-Vehicle (G2V) services, which are essential for the dynamic balancing of the power grid.

As the integration of renewable energy sources becomes increasingly important, DAB converters stand out for their ability to seamlessly incorporate solar and wind energy into the EV charging process, promoting a greener charging cycle. The potential of DAB technology to revolutionize EVCS extends beyond mere energy transfer; it encompasses aspects of grid stability, energy storage, and the future of smart cities.

This paper aims to provide a comprehensive review of the current state of DAB converter application in EVCS. It will cover the technical aspects and design considerations of DAB converters, their operational challenges, and the strategies developed to optimize their performance in various charging environments. It will also discuss the impact of DAB converters on the grid infrastructure, regulatory issues, and the potential for future innovation.

In surveying the landscape of DAB-enabled EVCS, this review synthesizes findings from a wide array of studies, providing a critical assessment of the technology's capabilities and outlining the roadmap for future research and development. By elucidating the nuances of DAB converter technology and its pivotal role in the electrification of transportation, this paper aims to contribute to the field's knowledge base and guide further advancements in sustainable EV charging solutions.

This expanded introduction offers a more detailed look at the motivations for the review, the technological underpinnings of DAB converters, and the broader implications for energy systems and smart grid developments. It sets the stage for a thorough examination of the topic, outlining the breadth and depth of the analysis that will follow in the main body of the paper.A. Power Quality

International Journal of Advancement in Electronics and Computer Engineering (IJAECE)
Volume 12, Issue10, OCT. 2023, pp.322-326, ISSN 2278 -1412

Problems

II. LITERATURE REVIEW

Several authors work for making EVs and conversion management of power grid to vehicle and vehicle to grid. In this chapter literature survey conducted in this study has highlighted the existing research gaps in the field of Vehicle-to-Grid (V2G) and Grid-to-Vehicle (G2V) conversion. These gaps include scalability and flexibility, PE and control, standardization and interoperability, economic and regulatory considerations.

This review is details analaysis of the imperative requirement for additional research aimed at bridging existing gaps and propelling the domain of V2G and G2V conversion forward. To facilitate this advancement, it is essential to focus on several key areas, including the development of TS that are both scalable and adaptable, the establishment of standards and interoperability, a thorough assessment of economic feasibility, the resolution of regulatory complexities, and the reinforcement of grid resilience and cybersecurity measures. Through these concerted efforts, V2G and G2V technologies can be propelled toward broader acceptance and integration.

The findings derived from the comprehensive literature review underscore the necessity for continued research in these domains to fully harness the capabilities of V2G and G2V conversion. These technologies, enabling the bidirectional exchange of energy between electric vehicles (EVs) and the power grid, play a pivotal role in sustainable energy management. The identification of these research gaps serves as invaluable guidance for future research and development endeavors. It is through these efforts that advancements in the field can be achieved, consequently leaving a positive imprint on the transportation sector, the power grid, and environmental sustainability.

In their study, Evode and colleagues introduced an innovative model designed to simulate the behavior of the electric grid in response to the random charging and discharging activities of Electric Vehicles (EVs). This research not only affirmed the viability of bi-directional operations but also provided a comprehensive exploration of the controls governing the charging and discharging of EV batteries. The investigation delved into the electric grid's behavior with a specific focus on active power generation and reception. Furthermore, the utilization of Simulink topology unveiled the effectiveness of implementing various modes such as Grid-to-Vehicle (G2V), Vehicle-to-Grid (V2G), and supplementary auxiliary modes like Vehicle-to-Vehicle (V2V), Vehicle-to-Load (V2L), and Grid-to-Load (G2L)[18].

Bidirectional power conversion stands as a pivotal technology in both Vehicle-to-Grid (V2G) and Grid-to-Vehicle (G2V) applications. In V2G scenarios, bidirectional conversion empowers electric vehicles (EVs) to contribute power back to the grid during peak demand periods, while in G2V applications, it facilitates the process of EVs drawing power from the grid. Extensive literature examination has revealed a variety of bidirectional conversion topologies designed to cater to the needs of V2G and G2V applications.

One of the most widely adopted bidirectional conversion topologies is the AC/DC bi-directional converter. In a noteworthy work by [19], a bidirectional converter was put forth for V2G applications, enabling the EV battery to feed power into the grid via an AC/DC converter during periods of peak demand. Similarly, in a separate study by [20], a bidirectional AC/DC converter was proposed for G2V applications, facilitating the charging of EVs from the grid.

Another frequently employed topology for bidirectional conversion is the DC/DC converter. In a publication by [3], a bi-directional DC/DC converter was introduced for V2G applications, allowing the EV battery to supply power to the grid during peak demand. Similarly, in [4], a bidirectional DC/DC converter was presented for G2V applications, enabling EVs to draw power from the grid.

Apart from the AC/DC and DC/DC converters, alternative bidirectional conversion topologies have also been suggested. For instance, in a study outlined in [5], a hybrid converter was proposed for V2G applications, merging the functionalities of an AC/DC converter and a DC/DC converter. This hybrid converter provides the flexibility for EV batteries to contribute power to the grid during peak demand periods while also permitting the charging of EVs from the grid.

Vehicle-to-Grid (V2G) represents an innovative technology that facilitates the bidirectional exchange of energy between EVs and the electrical grid. This pioneering approach possesses the potential to reshape the energy landscape by harnessing EVs as dynamic mobile energy storage units, allowing them to feed power energy to back in grid during periods of high demand or when renewable energy generation is limited. This time, alternate approach have been dedicated to research and development within the V2G domain, delving into numerous facets of its implementation, as well as the challenges and opportunities it presents. The subsequent literature review offers an encapsulated summary of the principal discoveries extracted from prevailing V2G research, replete with pertinent references.

Scalability and Flexibility of V2G Systems:

A central point of emphasis within the domain of Vehicle-to-Grid (V2G) research pertains to the scalability and adaptability of V2G systems. This principle encompasses the systems' ability to efficiently handle diverse charging and discharging rates, accommodate a wide spectrum of electric vehicle (EV) models, and seamlessly integrate with a range of grid infrastructures. Researchers have diligently pursued the development of optimized solutions aimed at augmenting the performance and efficiency of V2G systems. To achieve this objective, innovative algorithms and control strategies have been introduced to facilitate dynamic energy management within V2G systems. These strategies take into account multiple variables, including EV charging and discharging rates, battery state of charge (SOC), and grid conditions [1]. Furthermore, extensive investigation has been conducted to evaluate the impact of various charging and discharging scenarios on V2G system performance, encompassing aspects such as peak load reduction, load equilibrium, and frequency regulation, all of which contribute to the maximization of the benefits derived from bidirectional energy transfer [2]. This body of research underscores the pivotal role played by scalability and adaptability in the seamless integration of V2G systems with the electrical grid.

Power Electronics and Control for V2G Systems:

The pivotal role of power electronics and control in V2G systems cannot be overstated. These elements are instrumental in ensuring efficient and reliable advanced power electronics converters and control algorithms, designed to optimize the energy conversion process, enhance power quality, and guarantee the safety and reliability of V2G systems. Notable contributions in this domain include the introduction of novel converter topologies, such as bi-directional AC/DC and DC/DC converters, CACS for V2G applications. These strategies account for factors like power factor correction, harmonic mitigation, and grid synchronization [3]. Additionally, researchers have delved into the utilization of advanced control algorithms, such as model predictive control, fuzzy logic control, and artificial intelligence-based control, to achieve optimal energy management within V2G systems. These approaches factor in considerations such as grid constraints, battery degradation, and user preferences [4]. This body of research underscores the significance of power electronics and control in enabling the efficient and dependable bidirectional flow of energy within V2G systems.

Standardization and Interoperability in V2G Systems:

The importance of standardization and interoperability cannot be overstated when it comes to the widespread adoption and integration of V2G systems into existing power grid infrastructure. Author is focused in the formulation of standards and protocols for V2G communication, interoperability, and grid integration. After this they are proposed communication protocols, such as ISO/IEC 15118 and CHAdeMO, that is activate communication in between EVs and the grid, ensuring interoperability across different EV models and grid infrastructures [5]. Furthermore, research has encompassed an evaluation of the impact of V2G systems on grid stability, power quality, and grid management. It has also put forward strategies for grid integration to guarantee the reliable and efficient operation of V2G systems within the existing grid infrastructure [6]. This body of research underscores the essential need for standardization and interoperability in V2G systems to award integration with power grid.

III. METHOD

Electric vehicles (EVs) have emerged as a dual-purpose solution, serving not only as an eco-friendly mode of transportation but also as a valuable energy storage resource for grid management. Their role in grid energy management is pivotal. Although most EVs are primarily employed for personal transport, they spend a substantial amount of time parked, often more than 20 hours per day. This inherent characteristic positions them as an ideal resource for storing surplus electricity (Grid-to-Vehicle, G2V) and returning it to the grid during peak demand periods (Vehicle-to-Grid, V2G).

However, it's important to note that, while some electrical grids in various countries can be adapted to accommodate EV charging, they have not yet evolved to efficiently handle the electricity generated by EVs. Nonetheless, as the market share of EVs is expected to experience significant growth, the management of EV battery charging is vital for maintaining grid stability in both G2V and V2G processes. As EVs become more commonplace, a substantial amount of energy will be stored within their batteries, enabling the possibility of an energy flow in the reverse direction, V2G.

Furthermore, EVs can function as a voltage source in Grid-to-Vehicle (G2V) and Vehicle-to-Grid (V2G) systems, capable of supplying electrical loads, particularly at EV charging stations. This concept has been referred to as "Vehicle-to-Load" (V2L) in the literature. A notable example is Nissan's "LEAF-to-Home" technology, which employs an "EV Power Station" unit to provide energy from the car batteries to power household loads [5]. Consequently, the expansion of the smart grid will initiate with smart households equipped with energy management and efficiency technologies.

Incorporating an on-board battery charger, as suggested in this study, allows for the V2L system to function at the location where the electric vehicle is parked. This bidirectional battery charger enables the receipt of power from the grid in Grid-to-Vehicle (G2V) operations and the discharge of stored energy back to the grid in Vehicle-to-Grid (V2G) operations. This flexibility allows for the operation of EVs in off-grid locations and provides energy to loads connected to the EV in a Vehicle-to-Load (V2L) manner.

In V2G, the energy stored in the EV battery bank can be exported back to the grid, potentially generating income. Grid-to-Vehicle (G2V) charging methods are employed, with the utility taking on the responsibility of meeting the energy requirements of the parking area. These innovative concepts enable electric vehicles to contribute to residential energy conservation, especially during blackouts and emergencies. From a grid perspective, electric vehicles can enhance auxiliary services and compensate for the intermittent nature of renewable energy sources.

IV. CONCLUSION

In this paper review, The transition to electric vehicles (EVs) is an irreversible trend with profound implications for our energy systems. This review has illuminated the pivotal role that G2V and V2G technologies can play in harmonizing the influx of EVs with the existing electric grid infrastructure. Through intelligent charging strategies and bidirectional energy flows, these technologies empower EVs to become dynamic participants in grid management, contributing to load balancing, peak shaving, and frequency regulation.

Our analysis revealed that the successful deployment of bidirectional battery chargers in EVs is critical to the actualization of these technologies. By enabling EVs to charge with high efficiency and return energy to the grid or home when necessary, these chargers can significantly enhance grid stability and resilience. Moreover, the integration of V2H capabilities presents a promising avenue for providing households with a degree of energy independence, particularly valuable during outages or periods of high demand.

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