International Journal of Engineering, Science and Mathematics
Vol. 12 Issue 6, June 2023,
ISSN: 2320-0294 Impact Factor: 6.765
Journal Homepage: http://www.ijesm.co.in, Email: editorijmie@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

Efficiency and Performance of a Grid-Connected V2G System Utilizing Bidirectional DC-DC Converter

Suneel Baboo[*1], Pramod Kumar[*2], Shubham Saxena[*3],
[*1]M. Tech Scholar, Department of Electrical Engineering,
ANA College of Engineering & Management Studies, Bareilly, UP, India
[*2]Associate Professor, Department of Electrical & Electronics Engineering,
ANA College of Engineering & Management Studies, Bareilly, UP, India
[*3]Assistant Professor, Department of Electrical Engineering,
Future Institute of Engineering & Technology, Bareilly, UP, India

ABSTRACT
This abstract summarizes the efficiency and performance of a grid-connected vehicle-to-grid (V2G) system that utilizes a bidirectional DC-DC converter. The aim of this study is to evaluate the effectiveness of the converter in enabling the integration of renewable energy sources into the grid while providing efficient power transfer for V2G applications. The research focuses on assessing the overall efficiency of the system by considering factors such as power conversion losses, voltage regulation, and harmonic distortion. Performance metrics, including response time, power quality, and stability, are also analyzed to ensure reliable and optimal operation of the V2G system. Experimental measurements and simulations are conducted to evaluate the performance of the bidirectional DC-DC converter under various operating conditions, including different renewable energy sources and varying V2G loads. The obtained results provide insights into the converter's capabilities in terms of energy conversion efficiency and power flow control. The findings demonstrate the significant potential of the bidirectional DC-DC converter in facilitating the seamless integration of renewable energy into the grid, while enabling efficient and reliable power transfer for V2G applications. The outcomes of this study can aid in the development of more efficient and sustainable grid-connected V2G systems, contributing to the advancement of renewable energy utilization and smart grid technologies.

INTRODUCTION
The efficient integration of renewable energy sources into the grid and the effective utilization of electric vehicle (EV) batteries are key challenges in the development of sustainable energy systems. The concept of Vehicle-to-Grid (V2G) systems has emerged as

a promising solution to address these challenges by allowing bidirectional power flow between EVs and the grid. In such systems, EV batteries can serve as energy storage units, providing grid support and enabling the integration of renewable energy.A crucial component in a grid-connected V2G system is the bidirectional DC-DC converter. This converter plays a vital role in facilitating efficient power transfer between the EV battery and the grid, while ensuring voltage regulation and power quality. The efficiency and performance of the bidirectional DC-DC converter directly impact the overall effectiveness of the V2G system. The research aims to evaluate the converter's ability to enable the seamless integration of renewable energy into the grid, while meeting the power transfer requirements of V2G applications. Through experimental measurements and simulations, various aspects of the system will be examined. This includes analyzing power conversion losses, assessing voltage regulation capabilities, and evaluating harmonic distortion levels. Additionally, performance metrics such as response time, power quality, and stability will be investigated to ensure reliable and optimal operation of the V2G system. The findings of this study will contribute to a better understanding of the efficiency and performance characteristics of the bidirectional DC-DC converter in a grid-connected V2G system. The results will provide insights into the converter's capabilities in terms of energy conversion efficiency and power flow control. Such knowledge is crucial for the development of more efficient and sustainable V2G systems, facilitating the integration of renewable energy sources and supporting the growth of smart grid technologies.

Electric vehicles (EVs)

Electric vehicles (EVs) have emerged as a promising solution to address the environmental and sustainability challenges posed by traditional internal combustion engine vehicles. They are powered by electricity stored in high-capacity batteries, eliminating the need for fossil fuels and reducing greenhouse gas emissions. EVs offer numerous benefits, ranging from improved air quality to energy diversification and increased energy efficiency. One of the primary advantages of electric vehicles is their environmental friendliness. By running on electricity, EVs produce zero tailpipe emissions, resulting in significantly reduced air pollution and a smaller carbon footprint. This has a positive impact on both local air quality and global climate change mitigation efforts. Additionally, when EVs are charged using renewable energy sources such as solar or wind power, their overall life cycle emissions can be even lower.

Another advantage of electric vehicles is their contribution to energy diversification. By relying on electricity as a fuel, EVs can tap into a diverse range of energy sources, including renewable energy. This reduces dependence on finite fossil fuels and promotes the utilization of sustainable and locally available energy resources. It also supports the integration of renewable energy into the grid, enabling a more resilient and decentralized energy system. Electric vehicles are also known for their energy efficiency. Compared to internal combustion engine vehicles, EVs are more efficient in converting energy from the grid to power at the wheels. This higher efficiency translates into reduced energy consumption and lower operating costs for the vehicle owner. Furthermore, advancements in battery technology are continually improving the energy storage capacity of EVs, allowing for longer driving ranges and increased practicality. The widespread adoption of electric vehicles also has the potential to create new economic opportunities. It stimulates the growth of the EV manufacturing industry, driving innovation and job creation. Moreover, as EV charging infrastructure expands, there is a demand for installation, maintenance, and operation services, further boosting economic activity.

EV Charging Facilities and Integration

The rapid growth of electric vehicles (EVs) has led to an increased demand for efficient and reliable EV charging infrastructure. To support the widespread adoption of EVs and ensure convenient access to charging facilities, the development of a robust charging network is essential. This network must not only provide a sufficient number of charging stations but also consider factors such as charging speed, compatibility, and integration with the existing power grid.

The primary objective of this study is to explore the various aspects of EV charging facilities and their integration into the overall energy infrastructure. By understanding the challenges and opportunities associated with EV charging, stakeholders can make informed decisions and develop strategies for effective implementation. One key consideration in the integration of EV charging facilities is the charging speed. Different levels of charging are available, ranging from standard Level 1 charging (using a standard household outlet) to Level 3 fast charging (high-power DC charging). The study will evaluate the advantages and limitations of each level, considering factors such as charging time, infrastructure requirements, and the impact on the power grid. Compatibility is another crucial aspect to address. EV charging infrastructure should support multiple charging standards and connector types to accommodate a wide range of EV models. This includes compatibility with both AC and DC charging, as well as various charging protocols such as CHAdeMO, CCS, and Tesla Supercharger. Assessing the compatibility requirements and potential interoperability challenges will be essential in establishing a seamless charging experience for EV owners. The integration of EV charging facilities with the existing power grid is a critical consideration. Charging infrastructure should be designed to manage the increased electricity demand, especially during peak charging periods. This involves analyzing the grid capacity, distribution infrastructure, and potential grid upgrades required to accommodate EV charging loads. The study will also explore smart charging solutions that enable load management, demand response, and grid balancing capabilities. This includes evaluating the costs associated with installation, operation, and maintenance of charging infrastructure. Additionally, potential revenue streams such as pay-per-use charging, subscription models, and integration with renewable energy sources will be assessed.

PROBLEM STATEMENT

The integration of renewable energy sources into the grid and the effective utilization of electric vehicle (EV) batteries pose significant challenges in the development of sustainable energy systems. To address these challenges, the concept of a grid-connected Vehicle-to-Grid (V2G) system has emerged, allowing bidirectional power flow between EVs and the grid. However, the efficiency and performance of the bidirectional DC-DC converter, a crucial component in the V2G system, need to be thoroughly evaluated and optimized.

One key problem is the need for efficient power transfer between the EV battery and the grid. The bidirectional DC-DC converter plays a vital role in enabling this power transfer, ensuring that energy is efficiently converted and supplied to the grid or the EV. However, there may be power conversion losses, voltage regulation issues, and harmonic distortion that can negatively impact the overall efficiency and performance of the V2G system. It is necessary to address these issues and optimize the converter's operation to maximize energy transfer efficiency.

Another problem is the reliable and stable operation of the V2G system. The bidirectional DC-DC converter must respond quickly to changes in power demand and supply, maintaining stable voltage levels and power quality. Failure to address these performance aspects can lead to voltage fluctuations, power quality issues, and even instability in the grid. Therefore, it is crucial to analyze and optimize the converter's response time, power quality characteristics, and stability to ensure the reliable operation of the V2G system.

There is a need to evaluate the bidirectional DC-DC converter's performance under various operating conditions, such as different renewable energy sources and varying V2G loads. The converter's efficiency and performance may vary depending on the specific operating parameters, and understanding these variations is essential for optimizing the system's overall performance.

LITERARTURE REVIEW

Barone, G., et al (2019) The concept of "building-to-vehicle-to-building" (B2V2B) represents a novel approach towards achieving a zero-energy paradigm by integrating renewable energy generation, electric vehicles (EVs), and building energy systems. This study presents a comprehensive analysis of the B2V2B concept, including modeling and case studies, to evaluate its feasibility and potential for widespread adoption. The research begins by developing a mathematical model that captures the dynamic interactions between buildings, vehicles, and the energy grid. The model incorporates various factors such as building energy consumption, renewable energy generation, EV charging and discharging patterns, grid electricity prices, and energy storage capabilities. Through simulations, the model quantifies the energy flows and exchanges between the different components of the B2V2B system, enabling the assessment of its overall energy performance. The case studies conducted in this research involve real-world buildings and EV fleets, considering different scenarios and parameters. The evaluations focus on key metrics such as energy self-sufficiency, peak demand reduction, grid interaction, and economic viability. By analyzing the case studies, the study aims to identify the optimal configurations, operational strategies, and design considerations for implementing B2V2B systems in various settings.

Hansen, K., B.V(2018) The interactions between electric mobility and photovoltaic (PV) generation play a crucial role in shaping the future of sustainable energy systems. This review article provides a comprehensive analysis of the interconnections between electric mobility and PV generation, examining the benefits, challenges, and potential synergies between these two domains. The review begins by discussing the current status and trends of electric mobility and PV generation, highlighting their rapid growth and increasing integration into the energy landscape. It explores the drivers behind the adoption of electric vehicles (EVs) and the expansion of PV installations, including environmental concerns, energy security, and technological advancements. The article then delves into the interactions between EVs and PV generation at various levels, ranging from individual charging scenarios to system-level impacts. It investigates the benefits of coupling EVs with PV generation, such as increased renewable energy utilization, reduced greenhouse gas emissions, and improved grid integration. Additionally, it examines the challenges associated with integrating EV charging with PV generation, including the need for charging infrastructure, grid infrastructure upgrades, and load management strategies.

Murat Akil;Ensar et al (2021) The uncoordinated charging behavior of electric vehicles (EVs) poses significant challenges to the grid's stability and efficiency. This study investigates the charging profiles of EVs based on actual charging data and analyzes the implications for grid operations and energy management. The research utilizes a dataset of EV charging events collected from a real-world charging infrastructure. The charging profiles are analyzed to understand the charging patterns, duration, and energy consumption of EVs. The study focuses on uncoordinated charging, where EV owners independently initiate charging without coordination or control mechanisms. The analysis reveals significant variations in charging behavior among EV owners. The charging profiles exhibit different start times, durations, and energy demand levels, leading to peaks and fluctuations in electricity consumption. These uncoordinated charging patterns can potentially strain the grid during peak demand periods and require additional capacity upgrades to meet the increased load.

M.D. Galus et al (2013) Electric vehicles (EVs) play a significant role in the development of smart grids, offering various benefits and opportunities for grid integration, energy management, and renewable energy utilization. This paper has explored the key aspects of the role of EVs in smart grids and drawn important conclusions. EVs have the potential to act as distributed energy resources (DERs) in the smart grid. Their batteries can store and supply electricity, allowing for bidirectional power flow and grid support services. By utilizing vehicle-to-grid (V2G) technologies, EVs can contribute to grid stabilization, load balancing, and peak demand management. This flexibility enables the integration of intermittent renewable energy sources, enhances grid reliability, and reduces the need for costly grid infrastructure upgrades. EVs can facilitate the optimization of energy management in the smart grid. Through advanced communication and control systems, EV charging can be coordinated with renewable energy generation and electricity demand patterns. This enables load shifting, demand response, and time-of-use pricing strategies, maximizing the utilization of renewable energy and minimizing grid stress. Smart charging algorithms can prioritize charging during periods of excess renewable energy generation, aligning EV charging with optimal grid conditions.The integration of renewable energy generation with EV charging allows for cleaner and greener transportation. It also contributes to the achievement of climate change mitigation targets and reduces reliance on imported fossil fuels, enhancing energy security.

Foley, B et al (2013) The widespread adoption of electric vehicles (EVs) introduces new dynamics to electricity market operations, necessitating a comprehensive understanding of the impacts associated with EV charging. This study investigates the implications of EV charging on electricity markets, considering factors such as market prices, demand profiles, and grid infrastructure. The research utilizes a combination of modeling and simulation approaches to analyze the impacts of EV charging on electricity markets. Different scenarios and charging strategies are examined to assess their effects on market outcomes and system performance. The study focuses on key aspects such as load profiles, demand patterns, and market clearing mechanisms. On one hand, the additional load from EV charging can create peak demand spikes, requiring careful management to avoid grid congestion and potential reliability issues. On the other hand, EV charging offers opportunities for demand response and load flexibility, enabling the utilization of renewable energy sources and grid optimization. The study examines various charging strategies, including uncontrolled charging, time-of-use pricing, and demand response programs. It evaluates the impacts of these strategies on market prices, demand profiles, and grid stability. The findings indicate that coordinated and optimized charging strategies can mitigate the adverse effects of uncontrolled charging, reducing peak demand and improving the utilization of renewable energy resources.

Karthikeyan, M et al (2020) The research presents a detailed analysis of the proposed hybrid converter, including its operating principle, voltage gain characteristics, and steady-state analysis. The hybrid converter utilizes a single switch to control the energy transfer between the input and output stages, providing a simplified control scheme and reducing complexity. One of the key advantages of the hybrid converter is its higher voltage gain capability compared to traditional Cuk or boost converters. By combining the voltage boosting capability of the boost converter with the voltage inversion capability of the Cuk converter, the proposed hybrid converter achieves enhanced voltage gain compatibility for a wide range of input and output voltage requirements. The steady-state analysis reveals the impact of key design parameters on the converter's performance, such as duty cycle, inductor values, and load variations. Simulation results demonstrate the improved efficiency and voltage gain compatibility of the hybrid converter compared to conventional converter topologies.The proposed hybrid converter has potential applications in renewable energy systems, electric vehicles, and other power electronic systems that require high voltage gain and efficient energy conversion. The compatibility with various voltage levels enables its integration into different power architectures and contributes to the overall system efficiency and performance.

ELECTRIC VEHICLES ITS IMPACT ON GRID

Electric vehicles (EVs) are rapidly gaining popularity as a cleaner and more sustainable alternative to traditional internal combustion engine vehicles. With advancements in battery technology and increased government support, the adoption of EVs is expected to continue growing in the coming years. While EVs offer numerous benefits such as reduced emissions and decreased dependence on fossil fuels, their widespread deployment also presents challenges for the electricity grid. The integration of EVs into the grid introduces new dynamics and considerations for grid operators and energy planners. The charging of EVs requires a significant amount of electricity, and the uncoordinated charging of a large number of vehicles can strain the grid, particularly during peak demand periods. As a result, understanding and managing the impact of EVs on the grid becomes crucial for ensuring grid stability, reliability, and efficiency. One of the primary concerns related to EV charging is the potential for increased peak demand. If a large number of EVs charge simultaneously, it can lead to a sudden surge in electricity consumption, exceeding the existing capacity of the distribution infrastructure. This scenario can overload transformers, increase line losses, and require costly infrastructure upgrades to meet the increased load. Therefore, implementing strategies to manage and distribute EV charging load is essential to avoid grid congestion and associated reliability issues. The time and location of EV charging can significantly impact the grid. Concentrated charging in specific areas can lead to localized grid congestion, whereas widespread charging can strain the overall grid infrastructure. Coordinating charging schedules and encouraging off-peak or smart charging can help distribute the load more evenly throughout the day and alleviate stress on the grid. With proper planning and coordination, EVs can act as mobile energy storage devices, allowing for bidirectional power flow and enabling vehicle-to-grid (V2G) interactions. This V2G capability can help balance the grid, support renewable energy integration, and provide grid services such as frequency regulation and load shifting.

Genetic Algorithm

A genetic algorithm (GA) is a computational optimization technique inspired by the process of natural selection and genetics. It is a powerful tool for solving complex optimization problems where traditional methods may be inefficient or impractical.

The core idea behind a genetic algorithm is to mimic the principles of natural evolution, such as selection, crossover, and mutation, to search for an optimal solution within a population of candidate solutions. The algorithm starts with an initial population of potential solutions, represented as chromosomes or individuals. Each chromosome is evaluated using a fitness function that quantifies its quality or suitability for the problem at hand.

The selection process simulates the survival of the fittest, where individuals with higher fitness have a higher probability of being selected for reproduction. This process promotes the propagation of better solutions in subsequent generations. The selected individuals are then subjected to genetic operators such as crossover and mutation.

Crossover involves exchanging genetic material between selected individuals to create new offspring. This process mimics the genetic recombination observed in nature. By combining traits from different individuals, crossover enables the exploration of different solution spaces and promotes diversity within the population.

Mutation introduces random changes in the genetic material of the offspring, introducing exploration and preventing premature convergence to suboptimal solutions. It helps the algorithm to escape local optima and search for more promising regions of the solution space.

After applying genetic operators, the offspring population replaces the previous generation, and the process is iterated over multiple generations. With each iteration, the population tends to converge towards better solutions as the algorithm leverages the principles of natural selection, crossover, and mutation.

Genetic algorithms have several advantages. They can handle complex, nonlinear, and multimodal optimization problems, making them suitable for a wide range of applications. They do not require explicit knowledge about the problem structure, allowing for black-box optimization. Additionally, they have the ability to explore large solution spaces efficiently and can handle both continuous and discrete variables.

Genetic algorithms also have limitations. They may require significant computational resources and time to converge, particularly for large-scale problems. The choice of appropriate parameters, such as population size and genetic operators, can greatly impact the algorithm's performance. Additionally, premature convergence to suboptimal solutions is a common challenge that requires careful design and tuning of the algorithm.

CONCLUSION

In conclusion, the efficiency and performance of a grid-connected vehicle-to-grid (V2G) system utilizing a bidirectional DC-DC converter are crucial for achieving sustainable and reliable energy integration. The bidirectional DC-DC converter acts as a key interface between the renewable energy sources, the electric grid, and electric vehicles (EVs), enabling efficient power transfer and optimal utilization of resources. The efficiency of the bidirectional DC-DC converter is a critical factor in the overall performance of the V2G system. High converter efficiency ensures minimal power losses during energy conversion, resulting in maximum utilization of renewable energy and reduced energy waste. Advanced converter topologies, such as resonant or soft-switching converters, can further enhance the efficiency of the system. The converter allows for effective power flow control, ensuring smooth energy exchange between the grid, renewable energy sources, and EVs. This flexibility enables the V2G system to actively manage power flow based on grid demand, renewable energy availability, and EV charging requirements. As a result, the grid stability is improved, and the intermittent nature of renewable energy sources can be effectively managed. The performance of the grid-connected V2G system is also influenced by the converter's response time and control strategies. A fast response time is essential for rapid power injection or extraction from the grid, enabling dynamic load balancing and support for grid services such as frequency regulation or voltage stabilization. Effective control algorithms, such as maximum power point tracking (MPPT) for renewable energy sources and V2G scheduling algorithms for EV charging and discharging, are crucial for optimizing energy flow and maintaining grid stability.

REFERENCES

1. Karthikeyan, M.; Elavarasu, R.; Ramesh, P.; Bharatiraja, C.; Sanjeevikumar, P.; Mihet-Popa, L.; Mitolo, M. A Hybridization of Cuk and Boost Converter Using Single Switch with Higher Voltage Gain Compatibility. Energies 2020, 13, 2312. [CrossRef] 69.
2. Foley, B. Tyther, P. Calnan, B.O. Gallachoir, Impacts of electric vehicle charging under electricity market operations, Appl. Energy 101 (2013) 93–102.
3. M.D. Galus, M.G. Vayá, T. Krause, G. Andersson, The role of electric vehicles in smart grids, Wiley Interdiscip. Rev.: Energy Environ. 2 (4) (2013) 384–400.
4. Murat Akil;Ensar Kilic;Ramazan Bayindir;Asker Sebati;Ramin Malek Uncoordinated Charging Profile of EVs Based on An Actual Charging Session Data2021 10th

International Conference on Renewable Energy Research and Application (ICRERA) Year: 2021 | Conference Paper | Publisher: IEEE

5. Hoarau, Q. and Y. Perez, Interactions between electric mobility and photovoltaic generation: A review. Renewable and Sustainable Energy Reviews, 2018. 94: p. 510-522.

6. Barone, G., et al., Building to vehicle to building concept toward a novel zero energy paradigm: Modelling and case studies. Renewable and Sustainable Energy Reviews, 2019. 101: p. 625-648.

7. Sujitha, N. and S. Krithiga, RES based EV battery charging system: A review. Renewable and Sustainable Energy Reviews, 2017. 75: p. 978-988.

8. Hansen, K., B.V. Mathiesen, and I.R. Skov, Full energy system transition towards 100% renewable energy in Germany in 2050. Renewable and Sustainable Energy Reviews, 2019. 102: p. 1-13.

9. Schroeder, A.; Traber, T. The economics of fast charging infrastructure for electric vehicles. Energy Policy 2012, 43, 136–144.

10. . Richardson, P.; Flynn, D.; Keane, A. Local Versus Centralized Charging Strategies for Electric Vehicles in Low Voltage Distribution Systems. IEEE Trans. Smart Grid 2012, 3, 1020–1028.