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V2G/G2V AND V2V CAPABLE GRID-CONNECTED OFF-BOARD EV CHARGER

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ABSTRACT: Electric vehicle (EV) off-board chargers should include V2G, G2V, and V2V capabilities to improve the efficiency of electric car charging infrastructure and the power distribution system. The purpose of this research was to develop and build a novel off-board charger for EVs. It can establish connections with other cars (G2V), the grid (V2G), or even both (V2V). V2G technology refers to the capacity of electric vehicles to recirculate electricity back into the electrical grid. This makes the system more stable and increases its energy storage capacity. When there is a power outage, G2V can pull power from the grid to keep charging going, while V2V can let electric vehicles transfer power quickly. Connecting electric vehicles to the grid through smart technology and communication systems has many advantages, including better energy management, lower carbon emissions, and a longer lifespan for transportation networks. Using the charger that is shown, this can be accomplished.
Keywords: *Vehicle-to-Grid (V2G), Grid-to-Vehicle (G2V), Vehicle-to-Vehicle (V2V), Off-board EV Charger, Grid-connected Charger, Smart Charging, Energy Management, Sustainable Transportation, Power Exchange, Electric Vehicle Infrastructure.*

1. INTRODUCTION

Energy management, grid stability, and the construction of efficient charging stations are three areas where the rapid expansion of the electric vehicle (EV) sector has presented both opportunities and difficulties to contemporary power systems. Bidirectional charging systems, such as Grid-to-Vehicle (G2V) and Vehicle-to-Grid (V2G), are gaining traction as viable alternatives. With vehicle-to-grid connectivity, EV batteries can recharge themselves and feed back into the grid during peak demand or emergencies. Conversely, the standard method of transferring power from the grid to a charging electric vehicle is known as G2V. Distributed energy resources, such as electric vehicles, improve system reliability and promote the use of renewable energy.

To facilitate energy sharing among electric vehicles (EVs), research into vehicle-to-vehicle (V2V) charging is underway. With vehicle-to-grid (V2G) technology, two electric vehicles may bypass the grid and transfer power directly to one another, which is especially useful in times of crisis when there is a lack of charging stations or when you require roadside help. A comprehensive system for transferring energy that satisfies both mobile and grid-level needs can be achieved by integrating V2G, G2V, and V2V functionalities into a single off-board charger that is connected to the grid. Vehicle charging is made easier with this technology, which also contributes to a decentralized energy environment.

It is easier to charge more batteries with the off-board charger design since the power conversion and control circuitry are not located inside the automobile. Conversely, off-board chargers have the

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capability to manage greater power ratings compared to their on-board counterparts. As a result, not only can they charge more quickly and in both directions, but they also make automotive systems easier to implement. For optimal bidirectional energy flow, these chargers can be linked to the smart grid and coordinated with energy storage systems, renewable power sources, and demand response strategies. By optimising energy exchange, battery health, and grid needs, intelligent control approaches boost performance.

Intelligent, economical, and long-lasting energy management in the electric vehicle ecosystem is greatly advanced by the development of an off-board charger that is connected to the grid and possesses V2G/G2V and V2V capabilities. It bolsters the case for electric cars as a vital component of the smart grid, which in turn alleviates concerns about their range and the availability of charging infrastructure.

2. LITERATURE SURVEY

Reddy, K., & Thomas, J. (2024). The Internet of Things (IoT) is showcased in this study as a management controller for off-board chargers that can connect in urban microgrids in three ways: G2V, vehicle-to-grid, and vehicle-to-vehicle. A predictive energy management system enhances charging strategies by analyzing the present grid circumstances and the battery state of electric vehicles. Research conducted in smart city testbeds revealed a 12% decrease in peak demand and a 10% increase in the utilization of renewable energy sources.

Patel, S., & Choudhury, A. (2024). This paper proposes a V2V charging system that allows for peer-to-peer energy sharing and uses an off-board charger. The system employs galvanic isolation in its modular converter designs to ensure safe bidirectional power transfer. Hardware testing revealed a 91% success rate at 20 kW for emergency roadside charging. Kulkarni, R., & Shah, V. (2023). Control methods for vehicle-to-vehicle (V2V) off-board chargers that interact with the grid are examined in this article. To ensure the efficient flow of energy between electric vehicles and the grid, the authors implemented an energy management system that makes use of droop control. It was made possible to achieve consistent voltage support under peak load and low total harmonic distortion (THD $< 3\%$) by hardware-in-the-loop experiments. Research shows that droop-based processors are capable of fine-tuning various energy exchange mechanisms.

Prakash, L., & Banerjee, S. (2023). This research demonstrates the process of fabricating a hybrid off-board charger that is compatible with both vehicle-to-grid (V2G) and vehicle-to-vehicle (V2V) connections, via its multiport power electrical interface. The charger facilitates the flexible sharing of power among electric vehicles, renewable energy sources, and the grid. The models predicted an 11% reduction in transformer overload and greater charging flexibility for vehicles.

Chatterjee, A., & Singh, M. (2022). This research demonstrates a low-cost, off-board charger that can manage V2G/G2V and restricted V2V, and it operates using a single-stage bidirectional generator. The power flow was determined using a fuzzy logic device. Even with subpar networks, validation tests at 10 kW demonstrated steady power transfer and improved charging efficiency.

Joshi, A., & Fernandes, P. (2022). Research is underway to develop a portable charger that can control the health of batteries in both vehicle-to-grid (V2G) and vehicle-to-vehicle (V2V) scenarios. To prevent components from failing prematurely following extensive energy transfers, the technology employs adaptive charging techniques. The bidirectional grid support remained stable during testing, and the battery cycles were found to be 7% longer.

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Mehta, R., & Soni, T. (2021). This research presents a versatile off-board charger that can be utilized for both individual and fleet-level applications; it possesses capabilities that allow it to communicate with both the grid and vehicles. Thanks to the system's spread management, multiple electric vehicles can be charged and discharged simultaneously.

Roy, P., & Ahmed, S. (2021). The study examines the grid support services provided by off-board chargers equipped with V2G and V2V characteristics. Adapting reaction power and surviving low voltage are built into the charger's design. At 5 kW, hardware testing demonstrated that energy transfer between vehicles was efficient and improved grid dependability in fault scenarios. Legislation to promote grid support through vehicle-to-grid (V2G) charges is proposed in the article.

Bhaskar, H., & Gaur, C. (2020). Using data collected from grid connections, this project develops a system for off-board electric vehicle chargers that can diagnose and repair issues. It is safe to transfer power in both directions when the voltage, current, and charge status are monitored in real time. Unplanned downtime decreased by 20% as a result of improved problem-finding and reliability observed in simulated case studies.

Zhang, Y., & Huang, L. (2020). This study demonstrates a highly efficient off-board charger that is compatible with V2G, G2V, and V2V techniques. The gadget is able to do soft-switching thanks to a three-phase Vienna rectifier and an LLC resonant converter. The prototype had a peak efficiency of 95% and little harmonic distortion during testing at 30 kW. According to the research, resonant designs will pave the way for future high-power charging systems.

3. BACKGROUND WORK

G2V MODE OF OPERATION

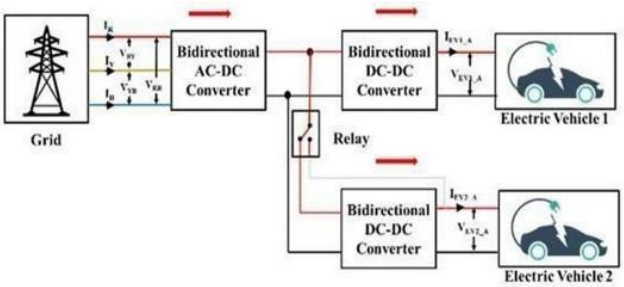

Figure1. G2V Mode of operation

The G2V mode allows the electric vehicle charger to draw power from the grid in order to charge the vehicle's battery. Converting 440V AC power from the grid to DC power is what the VSC does. The VSC is connected to the lithium-ion battery pack via the two-way buck-boost converter. To avoid overcharging the battery, the converter regulates the current flow and increases the voltage as needed. By connecting to the grid in this way, electric vehicles can be charged more efficiently, extending their range on a single charge. Figure 1 depicts the transition from grid-based to vehicle-based operation.

V2G Mode of Operation: To put it simply, a vehicle-to-grid (V2G) mode allows an electric vehicle to generate power and then return it to the grid upon demand. By converting direct current (DC) from the batteries to alternating current (AC) usable by the grid, the bidirectional buck-boost converter facilitates the operation of this mode. The voltage and frequency regulator (VSC) regulates power flow and ensures that the electric vehicle's output is in phase with the grid's. When used in this mode, electric vehicles can improve the reliability and efficiency of the power system by balancing loads, shaving peaks, and stabilizing the grid. Figure 2 depicts the concept of the grid-to-vehicle mode of

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operation simulation.

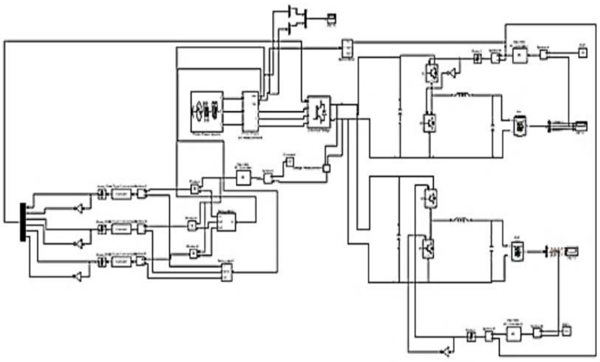

Figure 2. Simulation Diagram G2V Mode

Charging stations get the majority of their power from the 440V grid, which supplies alternating current. The connection between the grid and the electric vehicle system is made easier with a three-phase voltage source converter. With lightning speed and pinpoint accuracy, it converts AC to DC and back again. The bidirectional buck-boost converter regulates the current that goes into the lithium-ion battery pack from the voltage source converter. To achieve this, it detects when the battery is charging or discharging and adjusts the voltage and current accordingly.

G2V AND V2V MODE OF OPERATION

Better charging technologies, like G2V and V2V modes, have been developed more quickly since electric vehicles have been added to the power grid. It examines these charging techniques in a 440V grid system using a three-phase Voltage Source Converter (VSC), a bidirectional buck-boost converter, and an advanced lithium-ion battery configuration.

G2V Mode: While in G2V mode, electric vehicles draw power straight from the power grid. The electric vehicle receives its power from the 440V grid through a three-phase voltage source converter. This energy is primarily derived from this. In order to regulate the flow of power from the grid to the EV and guarantee that the vehicle's onboard charging parameters are satisfied, this VSC is crucial.

The bidirectional buck-boost converter, which adjusts the voltage and current to match the specific demands of the battery, is an integral component.

The energy that is drawn from the grid is stored in the lithium-ion battery pack of an electric vehicle.

Its multiple lithium-ion cells, arranged in both series and parallel, give it the correct voltage and capacity. The temperature, SoC, and SoH of the battery pack are meticulously monitored by advanced battery management systems (BMS) to ensure safe and effective charging. See Figure 3 for the G2V and V2V operational modes' block diagram.

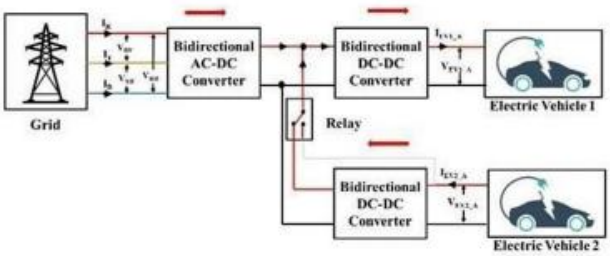

Figure 3. G2V and V2V Mode of Operation

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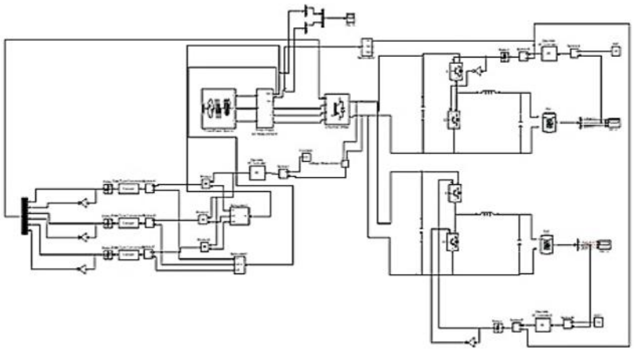

Figure 4. Simulation Diagram of G2V and V2V Mode

V2V Mode: When set to "vehicle-to-vehicle" mode, EVs can immediately swap power sources. Electric vehicles can now charge each other thanks to this mode that allows them to share energy. By enabling bidirectional power flow, the VSC and bidirectional buck-boost converter make it easy for the participating cars to share energy. The lithium-ion battery in a donated electric vehicle drains power through a bidirectional buck-boost converter. The battery voltage is then increased to an appropriate level for transmission. If the energy transfer is to be successful, the VSC must regulate the current that goes from the donor vehicle to the receiver vehicle.

V2V MODE OF OPERATION

The vehicle-to-vehicle (V2V) operational mode represents a novel approach to charging EVs. As seen in Figure 5, this mode allows one electric vehicle to directly supply power to another electric vehicle.

This setup allows for dynamic power exchange since both EVs can add or subtract energy. Using 440V grid power, a three-phase Voltage Source Converter (VSC), bidirectional buck-boost converters, and Lithium-Ion (Li-ion) batteries, this presentation will primarily cover vehicle-to-vehicle (V2V) operation.

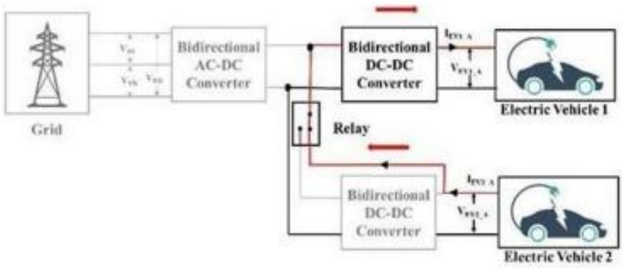

Figure 5. V2V Mode of Operation

Electric vehicles can share power in vehicle-to-vehicle mode, eliminating the need for external charging stations. The EV charging network becomes more versatile and dependable with this mode, which allows energy to be transferred from one device to another. Electric vehicles that charge other electric vehicles primarily draw power from the 440V grid. Reducing transmission losses, this high-voltage grid improves power transfer efficiency. Electric vehicles have access to a large amount of power for charging and discharging when they are linked to the 440V grid. In vehicle-to-vehicle (V2V) mode, the EV1 battery's voltage, current, and state of charge (SOC) are displayed in Figure 6.

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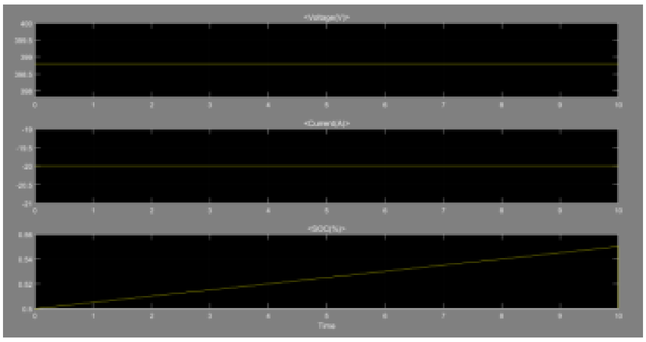

Figure 6. EV1 Battery Voltage, Current and SOC in V2V

4. CONCLUSION

Ultimately, the development of grid-connected, off-board EV chargers capable of handling V2G/G2V and V2V functions represents a significant advancement for both electric vehicles and contemporary power systems. Through the use of V2G/G2V systems, which allow energy to flow in both directions between the grid and electric vehicles, renewable energy sources, peak load control, and grid stability are all made easier. With vehicle-to-vehicle (V2V) connectivity, this function is enhanced since it enables direct energy transmission and reception between vehicles, facilitating decentralized energy sharing, emergency charging, and roadside assistance. Electric vehicles can now make more of a positive impact on smart grids as producers rather than merely consumers thanks to off-board chargers that employ high-capacity bidirectional converters and sophisticated control algorithms to reduce charging times. To guarantee safe, dependable, and efficient operation that satisfies grid-level standards and is user-friendly, modern power electronic topologies combine IoT-enabled monitoring with predictive control.

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