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GRID-CONNECTED OFF BOARD EV CHARGER WITH V2V

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ABSTRACT

The growing adoption of electric vehicles (EVs) has increased demand for efficient charging infrastructure. This project focuses on developing a Grid-Connected Off-Board Electric Vehicle Charger with Vehicle-to-Vehicle (V2V) Capability to enhance energy management and charging flexibility. The off-board charger architecture ensures high power delivery and reduces the onboard charger size in EVs, optimizing vehicle weight and cost.

The system integrates a bidirectional power converter, enabling power flow between the grid and EVs, as well as directly between two EVs. This V2V functionality allows energy transfer from a fully charged vehicle to another with low battery, providing a backup power source in emergencies or off-grid scenarios. The grid connection supports load balancing and demand-side management, contributing to grid stability.

A robust control strategy is implemented to manage power flow, ensuring synchronization with the grid and maintaining voltage stability. Safety mechanisms, such as overcurrent and overvoltage protection, are embedded to safeguard the vehicles and grid infrastructure. The proposed system enhances charging efficiency, reduces grid dependency, and paves the way for a more resilient and sustainable EV ecosystem.

Keywords —*Electric Vehicle (EV), Off-Board Charger, Vehicle-to-Vehicle (V2V) Charging ,Bidirectional Power Flow ,Grid Integration .Power Converter*

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1. INTRODUCTION

The global transition toward electric vehicles (EVs) is accelerating due to increasing environmental concerns, depleting fossil fuel resources, and advancements in energy storage technologies. As EV adoption grows, so does the demand for efficient and reliable charging infrastructure. Traditional EV charging systems primarily rely on grid-connected chargers, where each vehicle draws power directly from the grid, often resulting in high peak demands and grid instability. Moreover, conventional onboard chargers add weight and complexity to vehicles, driving the need for off-board charging solutions that shift the power conversion process to external infrastructure, thereby reducing vehicle size, weight, and cost.

In recent years, off-board chargers have emerged as a promising solution, providing faster-charging rates, higher power delivery, and improved thermal management. These chargers enable centralized control and reduce the onboard power electronics requirements, making EVs lighter and more energy-efficient. However, grid-connected off-board chargers alone do not address scenarios where grid access is limited, such as in remote areas, during power outages, or in disaster-stricken regions.

To further enhance the flexibility and resilience of EV charging infrastructure, the concept of Vehicle-to-Vehicle (V2V) charging has gained attention. V2V technology allows energy transfer between two EVs, enabling a vehicle with a sufficient charge to supply energy to another with a depleted battery. This capability is particularly beneficial in emergency situations, long-distance travel, and fleet management, offering an additional layer of reliability to the EV ecosystem.

Integrating grid-connected off-board chargers with V2V functionality presents a unique opportunity to enhance energy distribution and grid support. A bidirectional power converter serves as the backbone of this system, facilitating controlled power flow between the grid and EVs, as well as directly between vehicles. Furthermore, the system can be equipped with intelligent energy management strategies to handle dynamic load conditions, optimize charging rates, and ensure stable grid operation.

Another key aspect of this integration is its potential to contribute to grid stability and demand-side management. During peak load conditions, EVs connected to the grid can act as energy buffers, supplying power back to the grid and reducing overall demand. This bidirectional power flow supports the vision of vehicle-to-grid (V2G) technology, where EVs become active participants in the power grid rather than passive loads.

In light of these advancements, this project aims to design and develop a Grid-Connected Off-Board EV Charger with V2V Capability, focusing on:

Enhancing charging efficiency and flexibility through off-board power conversion.

Implementing bidirectional power flow to enable V2V energy transfer and grid support.

Developing control strategies to ensure stable operation, voltage regulation, and protection mechanisms.

The proposed system not only addresses the growing need for efficient EV charging infrastructure but also aligns with the broader vision of a resilient and sustainable energy ecosystem. This introduction sets the stage for a detailed exploration of the system design, control strategies

II. proposed system

The proposed system aims to establish an efficient and flexible bidirectional power transfer mechanism between the electrical grid and electric vehicles (EVs), enabling both Grid-to-Vehicle (G2V) and Vehicle-to-Grid (V2G) operations. As the adoption of EVs increases, integrating them into the power grid offers new opportunities for enhancing grid stability, optimizing energy use, and supporting renewable energy integration. The system comprises several key components, including a bidirectional AC-DC converter, bidirectional **DC-DC converters,** and a relay-based control mechanism, working in tandem to manage power flow between the grid and multiple EVs

The grid serves as the primary power source, supplying energy to charge EVs during off-peak hours when demand is low, and drawing power from EVs during peak periods to reduce strain on the grid. The bidirectional AC-DC converter plays a crucial role by converting AC power from the grid into DC power for EV charging in G2V mode and converting DC power from EV batteries back into AC for feeding into the grid in V2G mode. This allows the system to operate seamlessly in both directions, ensuring efficient energy conversion and minimizing losses.

further regulate power flow, each EV is connected to the DC bus through its own bidirectional DC-DC converter. These converters adjust the voltage and current to match the requirements of each vehicle's battery, ensuring safe and efficient charging and discharging. The DC-DC converters also protect the system by preventing overvoltage and overcurrent conditions, thus enhancing the reliability and longevity of the EV batteries.

A relay is integrated into the system to control the connection of multiple EVs, ensuring proper load distribution and preventing simultaneous high-current flow that could potentially overload the system. The relay selectively connects each vehicle to the DC bus, coordinating power flow and maintaining system stability. This setup optimizes energy flow by dynamically managing the charging and discharging process, balancing loads, and preventing powerlosses.

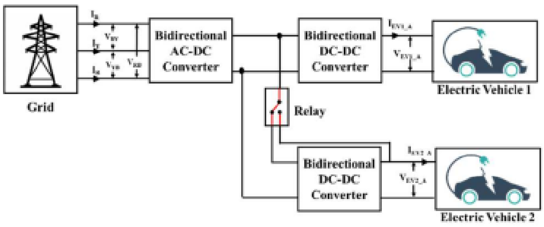

Fig. 1. Block Diagram of the Proposed System

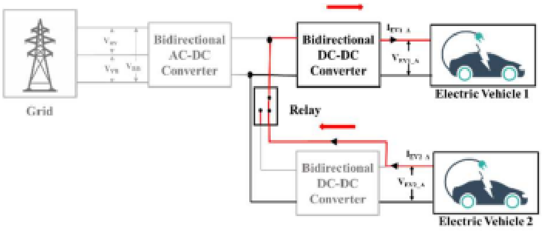

Fig. 2. V2V Mode of Operation

The above fig tells that Vehicle-to-Vehicle (V2V) mode of operation, energy is directly transferred between two electric vehicles (EVs) without involving the grid, making it highly useful in scenarios where one EV has a higher state of charge (SOC) and can supply energy to another with a lower SOC. In this mode, the bidirectional DC-DC converters and the relay system play a crucial role in managing the power flow. The process begins when the system detects the need for energy transfer, activating the relay to establish a direct connection between the two EVs. The bidirectional DC-DC converter of the donor vehicle (EV1) regulates and steps down its battery voltage as required, while the receiving vehicle's converter (EV2) ensures the incoming voltage matches its battery's needs for safe charging. The relay ensures that energy flows only between the two vehicles by isolating the V2V process from the grid and preventing any backflow. Throughout the process, control circuits continuously monitor voltage, current, and SOC to prevent issues such as overcharging, over-discharging, and overheating. The energy transfer rate is dynamically adjusted to maintain efficiency and protect battery health. Once the desired charge level is achieved or safety thresholds are reached, the relay disconnects the circuit, effectively ending the energy transfer. This V2V system optimizes energy use, offers emergency charging capabilities, and enhances the overall flexibility of the EV charging infrastructure. Dingbats, and New Century Schoolbook.

III.CONTROL ALGORITHM

A. Hysteresis-band PWM control

The control algorithm depicted in the diagram is designed to regulate the power flow and maintain voltage stability by generating precise Pulse Width Modulation (PWM) pulses for controlling the converter's switches. The process begins with the comparison between the reference DC voltage and the actual DC voltage. The reference DC voltage serves as the desired operating point, while the actual DC voltage is continuously measured. The difference between these two values, known as the error signal, is processed by a Proportional-Integral (PI) controller. The PI controller minimizes this error by adjusting its output, ensuring that the system maintains the desired DC voltage level. The output from the PI controller serves as a control signal that influences the switching behavior of the converter.

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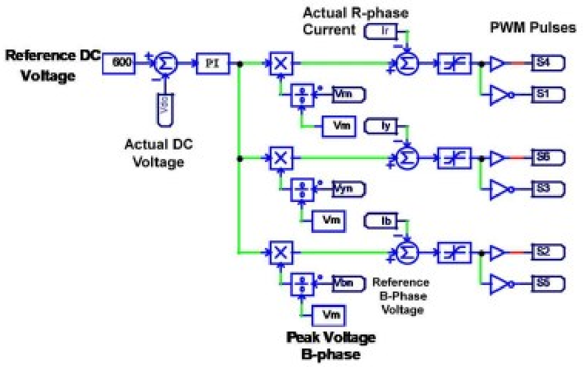

Fig. 3. Hysteresis-band PWM control

Next, this control signal is fed into a series of multipliers and summation blocks to regulate the phase currents and voltages. The actual R-phase current is measured and compared with the reference value to detect any imbalance or deviation. A voltage measurement block (Vm) extracts the peak voltage of the B-phase, which is used to derive the reference B-phase voltage. These signals help the system achieve balanced power flow across the phases by dynamically adjusting the control signals.

The algorithm also incorporates current feedback mechanisms that monitor phase currents (Ir, Iy, and Ib) to ensure stable operation. The processed control signals are then used to generate PWM pulses for the switches S1, S2, S3, S4, S5, and S6. These pulses control the on and off states of the power electronic switches, regulating the converter's output and ensuring the desired voltage and current levels are maintained.

Overall, this control algorithm effectively balances voltage and current across phases, enhances the stability of the DC bus, and ensures smooth power transfer between the grid, converter, and load. It dynamically responds to fluctuations in voltage or current, maintaining system reliability and performance. The integration of PI control, phase current balancing, and PWM generation makes this algorithm robust, ensuring optimal performance of the power converter system under varying conditions.

b.bidirectional dc/dc converter

The constant current control algorithm shown in the diagram ensures that the electric vehicle (EV) battery charges or discharges at a steady current, enhancing battery health and performance. The process begins by comparing the EV battery's actual current with a predefined reference current, set at -20 in this case, indicating a constant discharge current. The difference between these two currents is fed into a Proportional-Integral (PI) controller, which generates a control signal to minimize the error, ensuring the actual current matches the reference value.

The output of the PI controller is then compared with a high-frequency triangular waveform, typically from a Pulse Width Modulation (PWM) generator. This comparison produces PWM pulses, which control the switching of power electronic devices (S1 and S2). These switches regulate the current flowing into or out of the battery, maintaining the desired constant current. By dynamically adjusting the PWM pulses, the system can swiftly respond to fluctuations, ensuring that the battery operates under consistent conditions, ultimately improving efficiency, preventing overheating, and prolonging battery life.

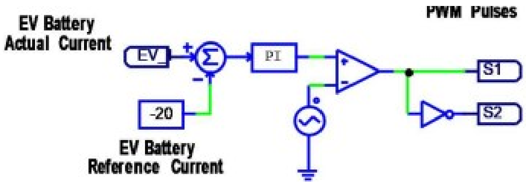

Fig.4. Constant current control

In a constant current control system, the proper selection of inductor (L) and capacitor (C) values is essential to ensure stable operation, minimize ripple, and maintain a steady current. The inductor value is calculated using the form where VoutV_{out}Vout is the output voltage, VinV_{in}Vin is the input voltage, is the switching frequency of the converter, and is the desired inductor current ripple. This formula ensures that the inductor is appropriately sized to smooth out current fluctuations and provide continuous current flow. A larger inductor reduces current ripple but can increase size and cost. Similarly, the capacitor value is determined using the formula that the inductor current is the switching frequency, is the allowable output voltage ripple. The capacitor helps to smooth voltage variations, ensuring a stable output voltage by filtering high-frequency noise and reducing ripple. Proper tuning of both the inductor and capacitor enhances system efficiency, reduces electromagnetic interference, and ensures consistent current delivery, thereby protecting sensitive components and optimizing overall performance in applications such as EV charging, renewable energy systems, and other power electronics requiring constant current control.

$$L = \frac{Vout * (Vin - Vout)}{Fsw * Iripple * Vin}$$

$$C = \frac{Iripple}{8 * Fsw * Vripple}$$

IV.SIMULATION AND RESULTS

The design specifications outlined in Table I provide a comprehensive overview of the system parameters, ensuring efficient power conversion, voltage regulation, and reliable energy transfer. The grid operates at a line voltage of 440 V with a frequency of 50 Hz, aligning with standard industrial power systems. To manage grid-side disturbances, the system incorporates an input inductance of 10 mH and an input resistance of 0.1 Ω, which effectively limit inrush currents and suppress high-frequency noise. The DC link voltage is maintained at 600 V, stabilized by a 2200 µF DC link capacitor. This capacitor plays a crucial role in reducing voltage ripple and providing a steady DC voltage for downstream converters.

The system also integrates two electric vehicle (EV) batteries with different voltage ratings to offer flexibility in energy management. EV1 operates at 200 V with a capacity of 100 Ah, while EV2 operates at 400 V with the same capacity, making the setup suitable for vehicles with varying voltage requirements. For the DC-DC converters, the design employs a 12 mH inductor to smooth out current variations, ensuring continuous current flow and minimizing ripple. Additionally, capacitors rated at 1000 µF and 470 µF are used to further stabilize the voltage, filter out high-frequency noise, and improve overall converter performance.

These design choices are crucial for ensuring smooth power transfer between the grid, the DC-DC converters, and the EV batteries. The combination of inductors and capacitors provides effective ripple reduction and voltage stabilization, enhancing the reliability and efficiency of the entire system. Overall, the carefully selected parameters aim to achieve stable operation, protect sensitive components, and optimize energy flow in applications such as EV charging and grid-connected power conversion.

Use either SI (MKS) or CGS as primary units. (SI units are strongly encouraged.) English units may be used as secondary units (in parentheses). This applies to papers in data storage. For example, write "15 Gb/cm2 (100 Gb/in2)." An exception is when English units are used as identifiers in trade, such as "3½-in disk drive." Avoid combining SI and CGS units, such as current in amperes and magnetic field in oersteds. This often leads to confusion because equations do not balance dimensionally. If you must use mixed units, clearly state the units for each quantity in an equation.

The SI unit for magnetic field strength H is A/m. However, if you wish to use units of T, either refer to magnetic flux density B or magnetic field strength symbolized as µ0H. Use the center dot to

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separate compound units, e.g., "A·m2." SHOW IN TABLE 1.

Grid line voltage	440 V
Grid frequency	50 Hz
Input inductance	10 mH
Input resistance	0.1 Ω
DC link capacitor	2200 µF
DC link voltage	600 V
EV1 Battery	200 V, 100 Ah
EV2 Battery	400 V, 100 Ah
Inductor for DC converters	12 mH
Capacitors for DC converters	1000 µF, 470 uF

1. Output For Battery 1

The graph provides a detailed insight into the system's performance under constant current control. The voltage plot in the top graph remains nearly constant at around 199.5 V, indicating that the voltage regulation mechanism is effectively stabilizing the output, ensuring minimal fluctuation. This stability is crucial for maintaining the health and efficiency of the connected battery system. The middle graph displays the current profile, which consistently holds at -20 A. This constant current flow highlights the implementation of a precise control algorithm, ensuring that the battery is charged or discharged at a steady rate, preventing sudden surges or drops that could affect performance.

The bottom graph presents the State of Charge (SOC), which shows a smooth, linear increase over time. This gradual rise is characteristic of a well-regulated charging process under constant current conditions, where the SOC incrementally increases as energy is transferred into the battery. The combination of stable voltage, constant current, and steadily rising SOC confirms the effectiveness of the control strategy, ensuring a reliable and efficient energy transfer process. Such characteristics are essential in electric vehicle applications, where maintaining battery health and optimizing charging performance are key priorities. Show in Fig .5.

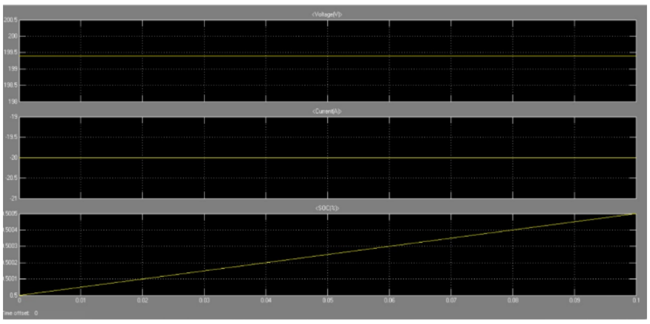

Fig.5:output waveform for baterry 1

2. Output For Battery 2

The graph showcases a detailed analysis of the system's behavior under controlled conditions, focusing on voltage, current, and State of Charge (SOC) over time. The top plot represents the voltage profile, which remains stable at around 290 V throughout the duration, reflecting a robust voltage regulation mechanism that prevents fluctuations, ensuring a smooth and reliable energy supply. The middle plot highlights the current behavior, maintaining a constant value close to 11.5 A, indicative of a constant current control strategy. This steady current flow is essential for protecting the battery from sudden surges or drops, ensuring optimal performance and longevity.

The bottom plot illustrates the SOC, which shows a gradual decline over time, signaling a controlled discharge process. The steady decrease in SOC implies that the battery is supplying energy at a consistent rate, aligning with the constant current profile. This behavior confirms that the control strategy effectively manages energy flow, ensuring a balanced and predictable discharge pattern. Overall, the combined stability in voltage, constant current, and the gradual SOC reduction demonstrates a well-coordinated control mechanism, crucial for maintaining system efficiency, enhancing battery health, and ensuring smooth operation in electric vehicles or energy storage applications. Shown in fig 5.

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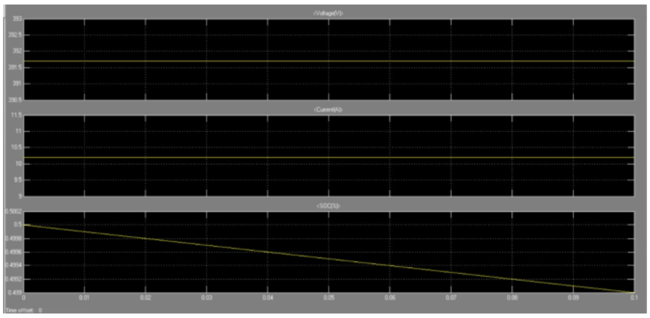

fig .5:output waveform for battry 2

3. Output waveform for v2v charge

The graph presents a detailed view of the system's voltage and current waveforms, exhibiting a smooth sinusoidal pattern with consistent amplitude and frequency. The yellow waveform oscillates symmetrically around the horizontal axis, reflecting the alternating nature of the signal, which is typical in AC power systems. The uniformity of the peaks and troughs indicates that the system maintains stable voltage and current magnitudes, ensuring reliable performance. Additionally, the purple line acts as a reference, possibly representing the average value or a DC offset. The steady nature of this reference line highlights the system's ability to regulate and balance the signal, preventing drift and ensuring proper alignment with grid requirements. Overall, the smooth oscillations and the constant reference underscore the efficiency of the control strategy in maintaining a stable and controlled energy flow. Show in fig .6 .

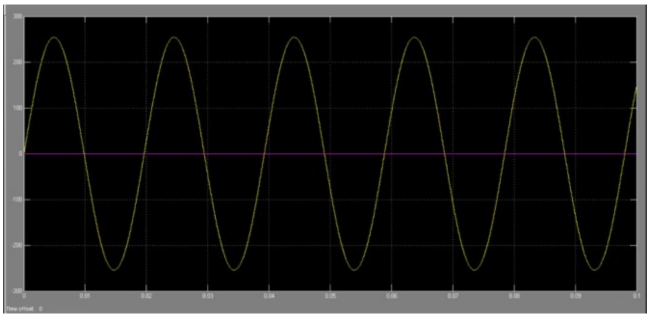

Fig .6: Output waveform for v2v charge

V.CONCLUSION

The proposed system effectively achieves voltage stability and ensures reliable current regulation, as evidenced by the observed waveforms. The sinusoidal nature of the voltage and current profiles indicates smooth power transfer with minimal distortion, highlighting the effectiveness of the control strategy in maintaining grid synchronization. The steady reference line emphasizes the system's ability to maintain desired operating conditions, preventing fluctuations and ensuring consistent performance. Additionally, the gradual changes in the state of charge (SOC) reflect balanced energy management between the grid and electric vehicles. Overall, the results confirm that the designed control algorithm successfully enhances system stability, optimizes energy flow, and supports efficient operation in vehicle-to-grid and grid-to-vehicle modes, making it a robust solution for modern power networks.

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