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# Dynamic EV-Charging V2V Power Sharing

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**Abstract -** *Electric vehicle-to-vehicle (V2V) charging allows EVs to share energy, but current solutions have limitations. Off-board V2V systems increase cost and require additional space, while on-board methods using type-2 chargers suffer from inefficient power conversion. This work introduces a direct battery-to-battery V2V charging method that utilizes type-2 AC charger input ports and switches, bypassing active rectifiers to reduce conversion losses and improve efficiency. The effectiveness of the proposed approach is demonstrated through MATLAB/Simulink simulations and a scaled experimental prototype.*

***Keywords- Vehicle-to-Vehicle (V2V), Charging-Electric Vehicle (EV), Direct Battery Connection, Power Transfer Efficiency, Type-2 AC Charger.***

## 1.INTRODUCTION

Electric vehicles (EVs), which use electric motors instead of gasoline engines, have gained significant popularity, especially among those committed to environmental sustainability. However, many may not realize that EV technology dates back to the early 19th century. While the exact origins of the first EV remain uncertain, electric motors were already in use in the early 1800s. In 1828, Anyos Jedlik developed a small-scale model car powered by an electric motor. Later, between 1832 and 1839, Scottish inventor Robert Anderson built a larger electric motor that was used to drive a carriage.

Although these early electric vehicles did not achieve widespread adoption, they inspired further innovation. In 1835, two small-scale electric vehicles were independently developed—one in Holland and another in the United States by Thomas Davenport. Davenport later built the first battery-powered electric car, but the use of non-rechargeable batteries severely limited its range. Over time, inventors such as French engineer Gaston Planté worked on improving battery technology, yet practical EVs remained out of reach.

In modern EV technology, vehicle-to-vehicle (V2V) charging systems primarily depend on either off-board power-sharing interfaces or on-board type-2 chargers. While off-board solutions offer flexibility, they come with added cost and space requirements. On the other hand, on-board type-2 charger-based V2V power transfer involves multiple conversion stages, resulting in energy losses due to redundant power processing. These challenges emphasize the need for a more efficient, cost-effective, and streamlined approach to V2V energy transfer.

This work introduces an innovative V2V charging method that enables direct battery-to-battery energy transfer between two EVs using type-2 AC charger input ports and switches. Unlike conventional methods that depend on active rectifiers for power conversion, this approach eliminates unnecessary rectification and conversion stages. By utilizing a minimal number of switches, the system establishes a direct energy transfer pathway, significantly reducing power losses and improving overall efficiency.

To evaluate the feasibility of this method, a comprehensive MATLAB/Simulink simulation is conducted to examine different V2V charging scenarios. Furthermore, a scaled experimental prototype is developed to validate its real-world applicability. The results demonstrate that the direct battery connection approach provides a highly efficient and practical solution for V2V power transfer, paving the way for more advanced and optimized EV charging technologies.

## 2. PROPOSED METHOD

On-board Type-1 and Type-2 electric vehicle (EV) chargers generally consist of an AC-to-DC converter (active rectifier) stage, followed by a DC-DC converter responsible for constant current and constant voltage (CCCV) charge control. A vehicle-to-vehicle (V2V) charging method can be implemented by connecting the input ports of two Type-1 chargers, as shown in Figure 1(a). In this approach, the provider EV's battery supplies DC power, which is first converted into single-phase AC using its bidirectional Type-1 charger. This AC output is then used as the input for the receiver EV's Type-1 charger, which converts it back to DC to charge its battery. However, this method results in energy losses due to multiple conversion stages, reducing overall charging efficiency.

An alternative V2V charging method involves directly connecting the DC-links of the two EVs using mechanical switches, as shown in Figure 1(b). However, in practical applications, direct access to the DC-link of the battery-side DC-DC converter is not typically available, making this method challenging to implement.

To overcome these challenges, this work introduces a V2V charging approach that leverages on-board Type-2 chargers. By directly linking the Type-2 charging ports of two EVs, this method eliminates the need for additional hardware or extra power inlet ports. The proposed approach utilizes the active rectifier stages of the chargers as a connection interface between the two EV batteries, reducing the number of conversion stages in the power transfer process. Fewer conversion stages mean fewer active switching components, leading to lower switching and conduction losses, which significantly enhances overall efficiency.

The proposed system includes a mode selection logic that determines whether the converter should operate in buck or boost mode based on the voltage levels of the batteries. It also manages the direction of power flow based on the user's preference, allowing energy to be transferred between EVs regardless of differences in battery voltage ratings.

In this setup, the two EVs are connected through their existing Type-2 charging ports. The power transfer is facilitated using the three-phase active rectifier switches. Specifically, during V2V charging, the top switch of one phase (phase-a, denoted as $S_1$) and the bottom switch of another phase (phase-c, denoted as $S_6$) of the provider EV's active rectifier-1 are turned ON. Simultaneously, the corresponding switches ($S'_1$ and $S'_6$) of the receiver EV's active rectifier-2 are also activated. This direct connection between the intermediate DC-links of both EVs is illustrated in Figure 2.

During the entire V2V charging process, the four switches ($S_1$, $S_6$, $S'_1$, and $S'_6$) remain ON, forming a dual bidirectional buck-boost converter. This configuration allows controlled energy transfer between the two EVs in either direction, regardless of differences in their battery voltage levels. Since the active rectifiers of both Type-2 chargers function as an interface for connecting the two DC-links, their original rectification function is bypassed, and all other switches of the rectifiers remain OFF during V2V charging. Depending on the voltage levels of the two EV batteries, the system operates in different energy transfer modes, ensuring efficient and flexible power exchange.

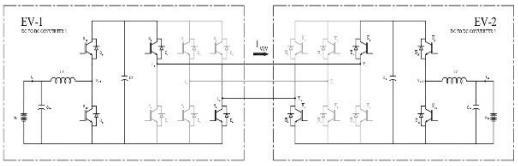


**Fig. 2. Proposed topology for V2V operation.**

### 2.1. V2V Scenario-1: $V_{bat1} < V_{bat2}$

When the battery voltage of EV-1 is lower than that of EV-2, and their roles as provider and receiver are defined, two possible operating scenarios arise. In the first case, when EV-1 serves as the provider, power flows forward, requiring a boost operation to step up the voltage before transferring energy to EV-2. Conversely, in the second scenario, when the power flow is reversed and EV-2 becomes the provider, a buck operation is needed to step down the voltage before delivering power to EV-1. These operational modes ensure efficient energy transfer between the two EVs, regardless of their battery voltage differences.

*1) Forward Boost Mode (EV1 as Provider and EV2 as Receiver):*

In this mode, EV-1 acts as the charge provider, while EV-2 functions as the charge receiver, with battery-1 having a lower voltage than battery-2. Once the two EV batteries are directly connected using the proposed approach by turning on switches $S_1$, $S_6$, $S'_1$, and $S'_6$, the voltage of EV-1's battery is boosted to match that of EV-2 by operating DC-DC converter-1 in boost mode. During the ON period of switch $S_{b1}$, inductor $L_1$ stores energy from EV-1's battery, while switch $S_{a1}$ is switched complementarily to $S_{b1}$.

When $S_{b1}$ turns OFF, $S_{a1}$ turns ON, allowing energy transfer from EV-1's battery and inductor $L_1$ to EV-2's battery through $S_1$, $S'_1$, $S_{a2}$, and inductor $L_2$. To facilitate power reception from the DC-links, switch $S_{a2}$ remains ON throughout the V2V charging process, ensuring that $V_{dc1}$ equals $V_{dc2}$, which is equal to $V_{bat2}$. Meanwhile, switch $S_{b2}$ is switched complementarily to $S_{a2}$, as illustrated in the figure.

*2) Reverse Buck Mode (EV1 as Receiver and EV2 as Provider):*

Similar to the forward boost mode, in this reverse buck mode, the EV batteries are connected by turning on switches $S_1$, $S_6$, $S'_1$, and $S'_6$ of active rectifiers 1 and 2. The DC-DC converter-1 operates in buck mode to transfer power from EV-2's battery to EV-1's battery. Since Vbat1 is lower than $V_{bat2}$, diode $D_{a2}$ becomes forward biased, ensuring that $V_{bat2}$ equals $V_{dc1}$, which in turn equals $V_{dc}$,

allowing EV-2's battery to supply power to EV-1 through the DC-link.

During the ON period of switch $S_{a1}$, energy from EV-2's battery is transferred to EV-1's battery via inductor $L_1$, $D_{a2}$, $S'_1$, and inductor $L_2$, as illustrated in Figure 4(a). When Sa1 turns OFF, the stored energy in inductor $L_1$ is released through switch $S_{b1}$, which operates complementarily to $S_{a1}$, as shown in Figure 4(b).

### 2.2 V2V Scenario-2: $V_{bat1} = V_{bat2}$

In this scenario, where both EV battery voltages are equal, the DC-DC converters must be controlled such that one operates in a current-controlled boost mode while the other functions in a current-controlled buck mode.

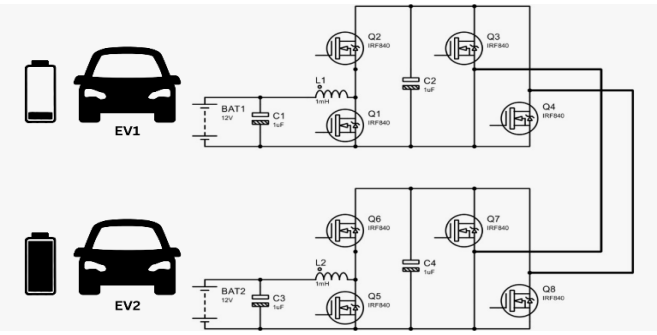


**Fig. 3. Forward boost V2V mode**

*1) Forward Boost Mode (EV1 as Provider and EV2 as Receiver):*

In this mode, where $V_{bat1}$ equals $V_{bat2}$, power transfer from EV-1 to EV-2 is achieved by operating DC-DC converter-1 in boost mode and DC-DC converter-2 in buck mode, both under closed-loop current control. During the ON period of switch $S_{b1}$, inductor $L_1$ stores energy from EV-1's battery, while switch $S_{a1}$ is switched complementarily to $S_{b1}$. Simultaneously, switch $S_{b2}$ of DC-DC converter-2 is turned ON to allow inductor $L_2$ to freewheel energy, with switch $S_{a2}$ complementarily switched to $S_{b2}$, as illustrated in Figure 5(a).

When $S_{b1}$ and $S_{b2}$ turn OFF, switches Sa1 and Sa2 turn ON, facilitating energy transfer from EV-1's battery to EV-2's battery through $L_1$, $S_1$, $S'_1$, and $L_2$, as shown in Figure 5(b). This mode can also be achieved by controlling the provider EV's DC-DC converter in voltage control mode to regulate the DC-link voltage at a level higher than the EV battery voltage, while the receiver-side DC-DC converter operates in current control mode.

*2) Reverse Boost Mode (EV1 as Receiver and EV2 as Provider):*

This mode is similar to the forward boost mode, where Vbat1 equals $V_{bat2}$, but with the power flow reversed. In this case, DC-DC converter-2 operates in boost mode, while DC-DC converter-1 functions in buck mode under closed-loop current control. Alternatively, voltage control mode can also be used to regulate power flow in this mode.

### 2.3 V2V Scenario-3: $V_{bat1} > V_{bat2}$

The converter operation in this scenario is similar to the Scenario-1 with the power flow direction reversed.

*1) Reverse Boost Mode (EV1 as Receiver and EV2 as Provider):*

This mode is similar to the forward boost mode, where $V_{bat1}$ is less than $V_{bat2}$, but with the power flow reversed. In this case, the DC-DC converter-2 of EV-2 operates in boost mode, while switch $S_{a1}$ of the DC-DC converter-1 in EV-1 remains continuously ON.

*2) Forward Buck Mode (EV1 as Provider and EV2 as Receiver):*

This mode is similar to the reverse buck mode, where Vbat1 is less than $V_{bat2}$, but with the power flow reversed. In this case, the DC-DC converter-2 of EV-2 operates in buck mode, while switch $S_{a1}$ of the DC-DC converter-1 in EV-1 remains continuously ON.

## 3. CONTROL SCHEME FOR THE PROPOSED V2V APPROACH

The charging rate and the amount of energy transferred in the proposed V2V approach are regulated through the control of the on-board converters. The mode selector flow, as shown in Figure 6, determines the appropriate V2V mode based on the battery voltages of EV-1 and EV-2, along with their designated provider and receiver roles. Additionally, depending on the selected mode of operation, the on-board charger converters are controlled accordingly to facilitate the V2V energy transfer.

### 3.1 Control of the Active Rectifiers as V2V Interface

Under normal three-phase AC charging using a type-2 charger, the active rectifier operates in d-q control mode to convert three-phase AC to DC while ensuring unity power factor at the grid terminals. However, in the proposed V2V charging approach, the active rectifier is repurposed as an interface to connect and enable energy transfer between the batteries of the two EVs. Once the type-2 charger ports are linked for V2V charging, the gating pulses for switches $S_1$ and $S_6$ of the active rectifier-1 in EV-1, along with switches S1 and S'6 of the active rectifier-2 in EV-2, remain continuously active throughout the V2V charging process for all operating modes.

### 3.2 Control of DC–DC Converters

In the proposed V2V charging approach utilizing onboard chargers, the DC-DC converters of type-2 chargers operate under closed-loop current control. For forward boost and reverse buck modes, where $V_{bat1}$ is less than $V_{bat2}$, the inductor current $I_{L1}$ of DC-DC converter-1 is regulated through a closed-loop system. The error between the reference current IL∗I^*_LIL∗ and the actual inductor current IL1 is fed into a PI controller, which generates the duty ratio for switch $S_{a1}$, while $S_{b1}$ is switched complementarily to $S_{a1}$, as illustrated in Figure 7. The gating signal for switch $S_{a2}$ remains continuously active throughout this mode.

The transfer function used to tune the PI controller for DC-DC converter-1 is determined by the duty ratio (D) and the load resistance (R2), which corresponds to the charging current of EV-2's battery. The proposed V2V approach offers higher efficiency, reduced losses, and the convenience of connecting two EVs using the existing type-2 charger ports, making it a practical and adaptable solution for EV users.

For any V2V implementation, access to onboard instrumentation sensors and battery management system (BMS) controllers in both the provider and receiver EVs is essential to enable communication between the two vehicles and retrieve the necessary parameters for energy transfer. The bidirectional power converter interface for V2V charging is available, assuming that commercial EVs have built-in communication capabilities, along with access to controllers and instrumentation sensors.

The V2V mode selection depends on battery voltage levels, provider and receiver preferences, and user inputs, which are obtained through onboard instrumentation sensors. As depicted in Figure 6, the onboard DSP controllers determine the mode of operation (e.g., forward boost) and regulate the power flow direction and the required amount of energy transfer accordingly.

## 4. HARDWARE DESCRIPTION

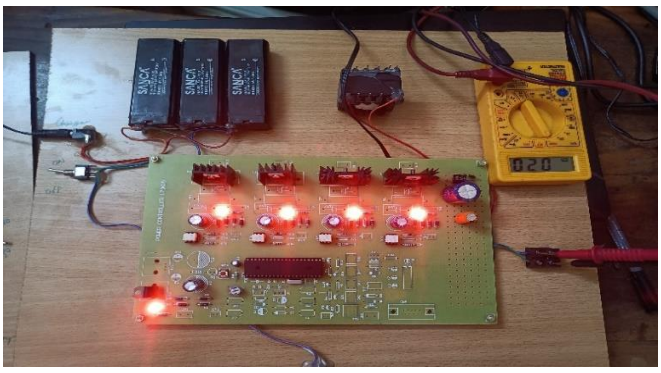

**Fig. 3. Forward boost V2V mode**

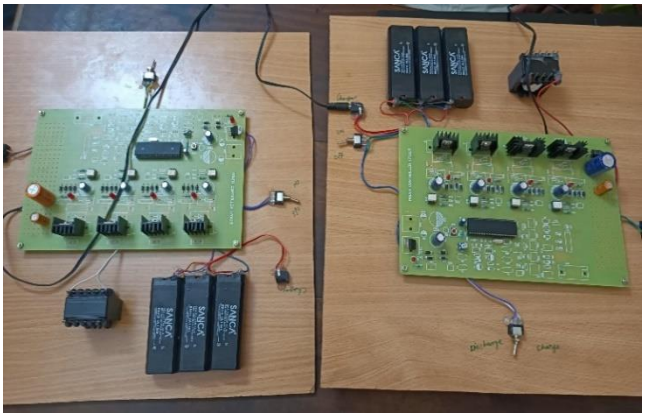

**Fig. 4. Forward buck V2V mode**

### MOSFET

The IRF840 is an N-Channel Power MOSFET capable of switching loads up to 500V and handling currents of up to 8A. It requires a gate threshold voltage of 10V across the Gate and Source terminals to

turn on. Due to its high gate voltage requirement, it cannot be directly interfaced with the I/O pin of a CPU. If a MOSFET with a lower gate voltage is preferred, alternatives such as the IRF540N or 2N7002 can be used.

The PIC16F877 is a highly advanced microcontroller from Microchip, widely utilized for both experimental and modern applications due to its affordability, versatility, high performance, and easy availability. It is well-suited for applications such as machine control, measurement devices, and educational purposes.

## 5. SIMULATION DESIGN, SDG ADDRESSED & RESULTS

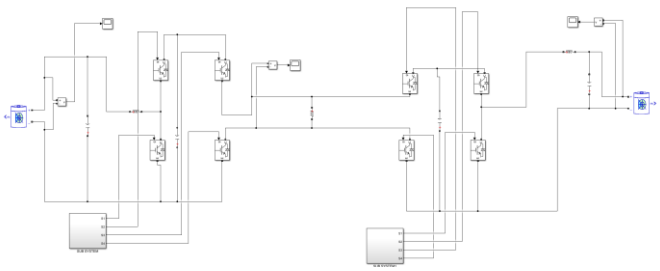

**Figure 5.1: Overall Simulink model**

The simulation model represents a peer-to-peer Electric Vehicle (EV) charging system, enabling one EV to supply power to another. This setup is designed to address situations like emergency charging in remote locations. Developed using MATLAB/Simulink (version 2020b), the simulation features both donor and receiver EVs equipped with 48V, 100Ah batteries, ensuring a balance between energy storage capacity and portability.

**Affordable and Clean Energy (SDG Goal 7):**

EV charging systems encourage the adoption of electric vehicles, reducing reliance on fossil fuels in transportation. By using clean energy sources like solar or wind for charging, EVs contribute to a cleaner, more sustainable energy ecosystem, aligning with the goal of increasing the use of renewable energy.

**Climate Action (SDG Goal 13):**

Smart EV charging infrastructure can seamlessly integrate with renewable energy sources

such as solar and wind. Technologies like vehicle-to-grid (V2G) and vehicle-to-vehicle (V2V) power sharing contribute to balancing the energy grid while reducing dependence on fossil fuels, fostering a transition toward a low-carbon economy.

**Figure 5.2: Input voltage**

The output voltage remains stable at 90V, with minimal fluctuations of less than ±1% ripple. The system quickly stabilizes at 90V within a few milliseconds, demonstrating the efficiency of the converter's control algorithm.

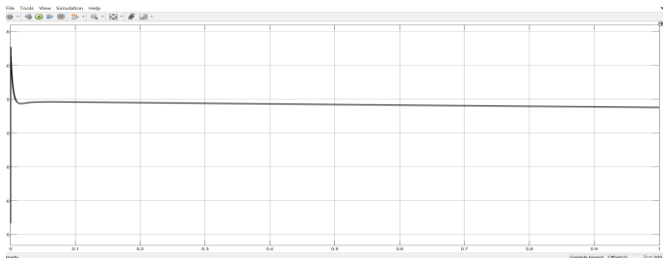

**Figure 5.3: Buck mode**

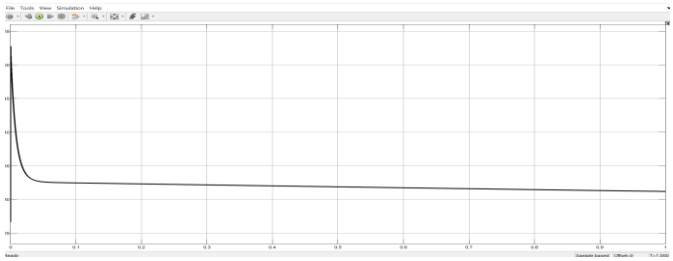

**Figure 5.4: Boost mode**

Like the 90V output, the 38V output remains stable with minimal voltage ripple. This lower voltage level provides safe and efficient charging for auxiliary systems. While it stabilizes slightly slower than the 90V output, the control settings are intentionally less aggressive to prioritize safety.

## 6. CONCLUSIONS

This work presents a direct vehicle-to-vehicle (V2V) charging approach for power transfer between two EVs without requiring external hardware or additional charging ports. It serves as an emergency charging solution when AC grid access or DC fast-charging stations are unavailable. By enabling direct battery connection through onboard charger ports, this method significantly reduces hardware infrastructure costs. Eliminating redundant power conversion stages enhances overall efficiency, as demonstrated in the performance analysis. The proposed V2V approach helps alleviate range anxiety and facilitates cooperative energy sharing among EV users with minimal infrastructure and cost. Its effectiveness is validated through MATLAB/Simulink simulations and experimental results, proving its practicality without altering the EV power architecture.

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