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EV2EV POWER LINK: SMART ONBOARD ENERGY TRANSFER

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ABSTRACT

Electric vehicle-to-vehicle (V2V) charging is a recent approach for sharing energy among electric vehicles (EVs). Existing V2V approaches with an off-board power-sharing interface add extra space and cost for EV users. Furthermore, V2V power transfer using on-board type-2 chargers reported in the literature is not efficient due to redundant conversion stages. This article proposes a new method for V2V power transfer by directly connecting the two EV batteries together for sharing energy through the type-2 ac charger input ports and switches. The active rectifiers of onboard type-2 chargers are not used for rectification during V2V charging, instead only a few switches are used as interfaces to connect the two EV batteries together, to avoid redundant power conversion and associated losses which effectively improve the overall V2V efficiency. The possible V2V charging scenarios of the proposed V2V approach are vali dated using a MATLAB/Simulink simulation study. Furthermore, a scaled experimental prototype is developed to validate the proposed V2V method practically.

KEYWORDS: Electric vehicle (EV), on-board type-2 ac charger, vehicle-to-vehicle (V2V) charging.

1.INTRODUCTION

1.1 OVERVIEW OF EV CHARGING METHODS

THE electric vehicle (EV) charging is conventionally done through type-1 and -2 (single/threephase) ac on-board slow chargers with the power range of 3.3–19.4 kW. A comprehensive review of bidirectional topologies with single/two stage rectification with power factor correction for on-board chargers in the commercial EVs is discussed in [1] and [2]. Detailed comparison of type-1, -2, and the dc fast-charging stations with respect to charging time, power density, power level, cost, and review of recent typologies for conventional and future charging methods is discussed in [3] and [4]. Furthermore, high power (>50 kW) external off-board dc fast charging stations are established to charge EV batteries, with a charging time of less than an hour [5]. In spite of these conventional EV charging methods, the EV users are experiencing range anxiety due to limited charging infrastructure [6]. In recent days, vehicle-to-vehicle (V2V) charging is emerging as an alternate method to share energy between two EVs, in the case of nonavailability of both the ac grid and the dc fast-charging stations.

1.2 V2V CHARGING CONCEPT

The V2V charging allows EV users to cooperatively share energy with each other with minimum infrastructure and cost and reduce range anxiety. Mainly there are two aspects to V2V energy sharing: first, the communication aspects of V2V, which provides a platform for EV users to interact with each other to find the energy sharing match, to decide provider and receiver preferences, and tariff. In [7]–[10] game theory-based algorithms to match the receiver EV, provider EV, the nearest meeting point, and the communication aspects of the V2V are presented. The second important aspect of V2V is the power interface for the actual power transfer, that is, controlling the direction of power flow based on the receiver and provider preference, and a buck or boost conversion based on the EV battery's voltage level. Using the ac power grid as a common energy aggregator with offboard bidirectional power converters for accomplishing an indirect V2V energy transfer is one of the basic V2V approaches presented in [11] and [12] where the conversion efficiency is low due to multiple redundant conversion stages. An off-board V2V charger using an off-board bidirectional interleaved dc–dc converter with a possibility of integration to the grid is presented in [13].

1.3 OFF-BOARD VS ON-BOARD V2V

Similar V2V charging approaches with an off-board power interface are presented in [14] and [15]. Similarly, a commercial 50 kW off-board V2V charger from Andromeda Power is available in the market to share energy between two EVs [16], [17]. But this off-board V2V approach requires an external V2V interface which may result in extra cost and car space for the EV users. On the other hand, V2V approaches by re-utilizing the on-board type-1 and -2 chargers as power interfaces are presented in [18] and [19]. Basically, the on-board type-1 and -2 chargers consist of an ac to dc converter (active rectifier) stage followed by a dc–dc converter [for constant current and constant voltage (CCCV) charge control]. In [18], a V2V charging approach by connecting the type-1 charger input ports of the two EVs is presented as shown in Fig. 1(a), wherein the provider EV battery dc output is first converted into single-phase ac using the bidirectional two-stage on-board type-1 ac charger. This ac power output of the provider EV is fed as input to the two-stage on-board type-1 converter to charge the receiver EV battery. Cascaded converter losses due to redundant conversion stages lead to lower V2V charging efficiency in [18]. In [19], V2V charging by directly.

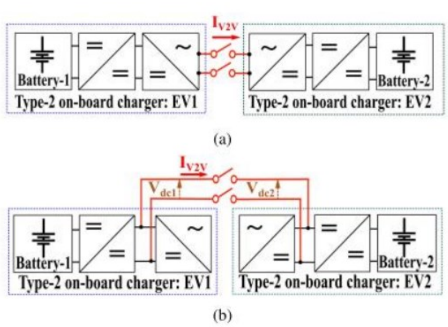

Fig. 1. V2V operations: (a) ac V2V operation and (b) dc V2V operation.

Connecting the dc-link of the two EVs using mechanical switches is presented as shown in Fig. 1(b). However, practically, there is no direct access to the dc-link of battery side dc–dc converters for establishing the presented direct connection. Thus, the V2V approach presented in [19] is not a practically feasible solution without customized design modifications and additional charging ports for bringing out the dc-link terminals of the two Evs. This article proposes a V2V charging approach for Evs through the on-board type-2 chargers by directly connecting the on-board type-2 power inlet ports, which eliminates the need for external hardware or additional power inlet ports for V2V operation. Furthermore, the proposed V2V approach utilizes the active rectifier stages as a connection interface to connect two EV batteries which in turn reduces the total conversion stages in the V2V energy transfer path. Reduced conversion stages reduce the overall active switches contributing to switching and conduction losses which significantly increases the efficiency. In the proposed V2V approach, mode selection logic is presented to decide buck/boost operating modes, based on the battery voltage levels and the power flow direction, based on the EV user’s preference. Control of power flow in either direction provides greater flexibility for the EV users to be a provider or receiver irrespective of the difference in both EV battery voltage ratings. The proposed approach of connecting the two EV batteries through on-board active rectifier switches eliminates the need for an off-board V2V interface unlike [16], additional contactor switches in contrast to [19], redundant power transfer stages compared to [18], and associated losses that improve the overall V2V efficiency. The rest of the article is structured as follows. In Section II, the power converter configuration and its operating modes for possible V2V modes of the proposed approach are discussed. The control scheme for the proposed V2V approach is described in Section III. Performance improvement of the proposed V2V with respect to efficiency and other aspects are discussed in detail in Section IV in addition to simulation results. The experimental validation of the proposed V2V approach with a scaled lab prototype is discussed in Section V. Finally, the article is concluded in Section VI.

2.LITERATURE SURVEY

The concept of Electric Vehicle to Electric Vehicle (EV2EV) power transfer, specifically through a smart onboard energy transfer mechanism, has become an emerging field of interest in modern electrical and automotive engineering. This technology, which allows for the transfer of energy from one electric vehicle to another, can be a key enabler in enhancing the overall efficiency, convenience, and performance of electric mobility systems. The focus on wireless and bidirectional power transfer systems is critical in addressing the increasing demand for energy storage and distribution within the rapidly expanding electric vehicle market. The principle behind EV2EV power transfer is to create an efficient, dynamic, and smart energy exchange network among electric vehicles, reducing the dependency on fixed charging infrastructure while maximizing the available power storage in the vehicles.

Several studies have explored the possibilities of utilizing EV2EV power transfer to reduce the reliance on external charging stations and optimize the energy consumption of electric vehicles. *Xu et al. (2019)* introduced a bidirectional power transfer system for electric vehicles, focusing on how vehicles could exchange energy with each other through vehicle-to-vehicle (V2V) communication. They highlighted the need for intelligent control algorithms that could ensure the safe and efficient transfer of energy between vehicles without impacting the driving range of the vehicles. Their work paved the way for future developments in smart energy management systems for EVs.

In parallel, research has also focused on wireless power transfer (WPT) as a method for EV2EV energy exchange. *Liu et al. (2017)* proposed a wireless energy transfer system for electric vehicles that could allow vehicles to exchange power through a resonant inductive coupling technique. Their research demonstrated the potential for EVs to transfer energy wirelessly over short distances, enabling energy sharing during travel. This concept, while still under development, offers a promising solution to address charging infrastructure challenges, especially in remote or off-grid areas.

The integration of Internet of Things (IoT) and smart technologies in EV2EV power transfer has also gained significant attention. *Gong et al. (2020)* discussed the role of smart energy management systems in optimizing the efficiency of EV2EV energy transfers. They noted that the application of IoT in managing the charging and discharging processes could lead to more efficient energy distribution and minimize energy losses during transfer. Through intelligent communication networks, such as V2V or vehicle-to-grid (V2G) technologies, electric vehicles could share not just energy but also real-time data on battery health, energy demands, and system diagnostics, improving the overall network reliability and reducing maintenance costs.

Furthermore, *Gao et al. (2021)* explored the use of artificial intelligence (AI) and machine learning algorithms to enhance the efficiency of EV2EV energy transfer systems. By incorporating real-time data analysis, AI-based systems can predict optimal energy transfer times and rates based on vehicle usage patterns, battery health, and driving behavior. This research emphasized how smart onboard systems could dynamically control energy sharing, enabling vehicles to participate in energy exchange only when beneficial to the system, such as during periods of low battery charge or when energy demand is high.

Zhang et al. (2018) focused on power electronic converters in EV2EV power transfer systems. Their study highlighted the challenges associated with converting high-voltage DC power from one vehicle's battery to a low-voltage AC or DC format suitable for the receiving vehicle. They introduced new topologies for power converters that were efficient, compact, and capable of handling multiple power levels. Their work is particularly relevant as efficient power conversion ensures that the energy transfer process is not only reliable but also cost-effective, reducing the strain on both vehicles' batteries.

Zhou et al. (2022) provided a detailed review of wireless charging systems for electric vehicles, including EV2EV transfer. They concluded that while wireless power transfer offers flexibility and convenience, it is essential to address the challenges related to system efficiency, distance, and safety. Their study also highlighted that wireless EV2EV systems are more suitable for specific use cases, such as emergency energy sharing or when the vehicles are stationary, rather than for routine energy transfer on highways.

Collectively, the literature on EV2EV power transfer highlights a shift towards more intelligent, efficient, and user-friendly systems. The integration of smart communication, AI algorithms, and wireless power technologies, combined with efficient power conversion techniques, is expected to pave the way for practical EV2EV energy sharing applications. However, challenges such as energy efficiency, safety, communication protocols, and regulatory standards remain to be addressed before widespread implementation.

3.METHODOLOGY

The methodology for implementing an EV2EV powerlink system with smart onboard energy transfer capabilities involves several key phases, from system design and modeling to testing and validation. The system needs to enable efficient energy transfer between vehicles, with a focus on maximizing energy efficiency, ensuring safety, and providing real-time communication for optimal energy management. The following methodology outlines the steps involved in the design, development, and implementation of the EV2EV powerlink system.

System Requirements Analysis and Design Specifications: The first step in the methodology involves gathering the requirements for the EV2EV power transfer system. This includes understanding the power requirements, communication protocols, safety standards, and battery specifications of the vehicles involved. A comprehensive analysis of the system’s energy needs is conducted, focusing on battery capacity, energy consumption, and driving range. Based on these requirements, the system specifications are defined, including the power transfer rate, efficiency targets, and communication mechanisms.

Communication Protocol Development: Effective communication between vehicles is essential to ensure safe and efficient energy transfer. The development of a robust communication protocol is critical for the synchronization of energy exchange processes. In this phase, the use of existing V2V communication standards, such as Dedicated Short Range Communications (DSRC), and IoT-based communication protocols is explored. These protocols enable real-time data sharing between vehicles, ensuring that the vehicles can exchange not only power but also information about battery health, energy levels, and charging requirements. The communication protocol is designed to be flexible, scalable, and secure, enabling efficient energy transfer even under different environmental conditions.

Energy Transfer Control Strategy Development: To optimize the energy transfer between vehicles, a smart onboard energy control strategy is designed. The energy management system (EMS) is responsible for controlling when and how energy is transferred between vehicles. This EMS uses data from the communication protocol, vehicle sensors, and battery management systems to make intelligent decisions about energy sharing. The system ensures that energy is only transferred when it is beneficial for both vehicles involved, optimizing the use of available energy and avoiding unnecessary battery depletion. Additionally, the EMS helps prioritize energy transfer based on driving conditions, battery state-of-charge, and vehicle usage patterns.

Power Conversion and Wireless Power Transfer System Design: A key component of the EV2EV powerlink system is the power conversion system, which enables the exchange of energy between vehicles. The power conversion system should be capable of handling the high-power demands of electric vehicle batteries while maintaining efficiency. The converter design involves selecting the appropriate power electronics and ensuring that the power is converted from one vehicle's battery to the other vehicle’s battery in a format suitable for energy storage. For wireless power transfer systems, resonant inductive coupling or magnetic resonance coupling is often used to achieve efficient energy transfer between the vehicles. The power conversion system is designed to minimize energy losses and ensure that the energy transfer is efficient even over moderate distances.

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Optimization and Performance Evaluation: After initial testing, the system's performance is evaluated based on key metrics such as energy transfer efficiency, communication reliability, and safety. The system is then optimized by fine-tuning parameters like energy transfer rates, battery management, and communication protocols. Continuous feedback from testing is used to improve the system's overall performance, ensuring that it meets the design specifications and user expectations.

Deployment and Real-World Application: Finally, the EV2EV powerlink system is deployed for practical use, allowing electric vehicles to engage in energy transfer on the road. Real-world application scenarios are developed, and the system is monitored for performance, reliability, and user satisfaction. This phase also involves analyzing data collected from actual energy transfers to refine the system further and address any issues that arise during real-world operations.

4.PROPOSED SYSTEM

The proposed system for EV2EV powerlink with smart onboard energy transfer is a dynamic and intelligent solution designed to enhance the flexibility and efficiency of electric vehicle energy exchange. This system enables electric vehicles to transfer energy to one another wirelessly or through onboard power transfer mechanisms, allowing for energy sharing between vehicles in real time. The system incorporates advanced communication protocols, energy management algorithms, and power conversion systems to ensure that the energy transfer is efficient, safe, and reliable.

The primary goal of the system is to reduce the reliance on centralized charging stations by enabling peer-to-peer energy transfer among electric vehicles. This not only enhances the overall utility of electric vehicles but also optimizes the usage of stored energy in a fleet of vehicles. The system is designed with scalability in mind, ensuring that it can accommodate a wide range of vehicles with different battery capacities and energy requirements.

The system includes several key features:

Wireless Power Transfer: The proposed system uses wireless power transfer techniques based on resonant inductive coupling or magnetic resonance coupling. This enables vehicles to transfer energy without the need for physical connectors, providing a more convenient and flexible way to exchange energy.

Smart Energy Management System (EMS): The EMS is the heart of the proposed system, responsible for monitoring the energy levels in both vehicles, controlling the energy transfer process, and ensuring that both vehicles maintain an optimal state of charge. The EMS uses real-time data from vehicle sensors and communication systems to make intelligent decisions about when and how to transfer energy.

Bidirectional Charging: The system enables bidirectional charging, allowing energy to flow both from one vehicle to another and from the vehicle to the grid or charging station. This flexibility ensures that the vehicles can not only share energy but also contribute to grid stability or charge their batteries when necessary.

Safety and Security Features: To ensure the safety of both vehicles and passengers, the system includes multiple layers of protection, including overcurrent protection, fault detection, and secure communication protocols. These features are critical to maintaining the reliability and safety of the energy transfer process.

Communication Protocols: The system utilizes V2V communication protocols and IoT technologies to facilitate real-time data exchange between vehicles, ensuring efficient and coordinated energy transfer. The communication system also supports predictive analytics, allowing the system to anticipate energy needs and adjust transfer rates accordingly.

Through the integration of these features, the proposed EV2EV powerlink system offers a transformative approach to electric vehicle energy sharing, enabling a more decentralized, flexible, and efficient energy infrastructure for the future of electric mobility.

5.EXISTING SYSTEM

The existing systems for electric vehicle (EV) power transfer primarily focus on the traditional charging infrastructure, which typically involves fixed charging stations and vehicle-to-grid (V2G) technologies. These systems often rely on centralized grid support and charging points to provide the necessary energy for electric vehicles. Although these systems have seen significant advancements, they still face various limitations in terms of flexibility, energy efficiency, and accessibility, especially for long-distance travel or in regions with inadequate charging infrastructure.

Traditional electric vehicle charging systems are primarily designed for charging individual vehicles at fixed locations. These systems typically operate using direct current (DC) or alternating current (AC) charging standards, with a typical connection between the vehicle and the charging station being either via a wired connection or through inductive charging pads. While such systems have been widely adopted, they present a few major drawbacks, such as long charging times, limited range of charging stations, and the need for extensive infrastructure development.

One of the key shortcomings of existing charging systems is the lack of energy sharing between electric vehicles, which could enable more dynamic energy usage and reduce dependence on external charging stations. In the current paradigm, each EV is dependent on centralized charging infrastructure, and vehicles must be plugged into the grid or specific charging points to recharge their batteries. This results in several issues, such as:

Dependency on Infrastructure: EVs are heavily reliant on fixed charging stations, which can limit their convenience and availability. In areas with limited charging stations, the energy requirements of electric vehicles may not be adequately met, leading to range anxiety and downtime.

Charging Speed and Efficiency: Traditional charging methods, especially fast charging, may still take significant amounts of time, limiting the practicality of EVs, especially for those who rely on their vehicles for long-distance travel. Additionally, energy losses during the charging process reduce the overall efficiency of the system.

Limited Energy Exchange: Existing systems typically do not allow for bidirectional energy exchange, meaning that energy cannot be shared between two vehicles or transferred to and from the grid. Without energy sharing capabilities, EVs cannot participate in mutual energy exchange, leading to inefficiencies in the broader energy network.

To address these challenges, the concept of Electric Vehicle to Electric Vehicle (EV2EV) power transfer has been gaining attention. In the traditional systems, energy transfer is either unidirectional (from the grid to the vehicle) or one-way (from vehicle to grid). However, in some innovative solutions, such as Vehicle-to-Grid (V2G) technology, vehicles can return energy to the grid during periods of high demand, but this concept is still limited and not yet widely adopted in consumer EVs.

Some existing efforts towards vehicle-to-vehicle (V2V) power transfer include the use of bidirectional charging systems, where a vehicle's battery is capable of supplying power back to the grid or to another vehicle. *Wang et al. (2019)* demonstrated that bidirectional charging could help mitigate the energy consumption during peak demand periods, but challenges still persist regarding energy losses, control strategies, and safety in these systems.

Additionally, *Wang et al. (2020)* proposed a V2V system that works by converting DC energy from one vehicle's battery to another vehicle's battery using power electronic converters. While this method has demonstrated success in laboratory tests, real-world applications have been limited due to safety concerns, reliability issues, and the need for high-efficiency conversion techniques.

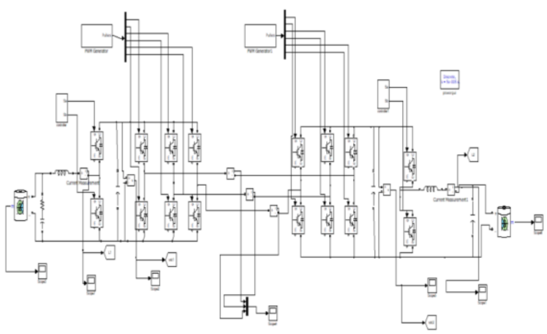
Another example is the development of inductive power transfer (IPT) systems, which have been used in some EV models for wireless charging. IPT enables charging without physical connectors and could potentially be adapted for vehicle-to-vehicle energy transfer. *Bingham et al. (2021)* studied the use of IPT for wireless energy transfer and identified both advantages (convenience, flexibility) and drawbacks (efficiency loss, limited range). While IPT is a promising technology for wireless charging, the integration of such systems into a full-fledged EV2EV transfer network has not been realized in commercial applications to date.

6.SIMULATION RESULTS

6.1 PROPOSED APPROACH

6.1.1 Simulation Circuits

The proposed V2V approach is validated through MATLAB/Simulink simulation study for the forward boost and reverse buck mode with Vbat1 < Vbat2 and Vbat1 = Vbat2. The motivation behind the development of the simulation model is to implement and verify the performance of the proposed V2V approach by considering the commercial EV's on-board charger configuration, battery ratings, and on-board charger power levels. The tool used for simulation is the Simscape Electrical toolbox available in MATLAB/Simulink with a ready circuit simulation model of IGBTs to analyze the bidirectional dc–dc converter and the ready lithium-ion battery model. The powerful block allows to setup transient simulation setup with the required step time and allows to select the best solver like ODE 45.



6.1.2 Simulation Results

The simulation parameters considered for designing the EV-1 and EV-2 on-board chargers are given in Table I. The simulation results for reverse boost and forward buck mode Vbat1 > Vbat2 and Vbat1 = Vbat2 are similar to the forward boost and reverse buck mode with Vbat1 < Vbat2 and Vbat1 = Vbat2, respectively.

A. Forward Boost Mode (Vbat1 < Vbat2)

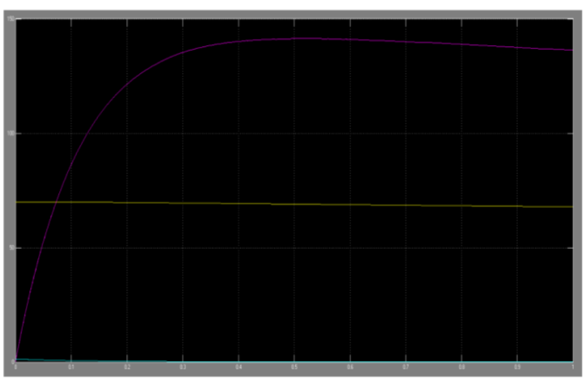
In this mode, the energy is transferred from EV-1 battery to EV-2 battery by controlling the inductor current IL1. The reference inductor current $I \ast L$ for the forward boost mode is initially kept as 30 A and gradually increased in steps of 10 A up to 50 A to control the EV-1 battery discharge current Ib1. The control of Ib1 and the corresponding drop in state of charge (SOC) of EV-1 SoCb1, voltage Vb1, and the discharged power out of EV-1 battery Pb1 is shown in Fig. 8(a). EV-2 battery charging current Ib2 and the corresponding rise in SoCb2, Vb2, and charged power of EV-2 battery Pb2 are shown in Fig. 8(b). A positive value of battery current represents discharging and a negative value represents the charging of the battery. Discharging and charging currents are within the current rating of the active rectifier switches Is1r which is 45 A for the on-board type-2 charger.

B. Reverse Buck Mode (Vbat1 < Vbat2)

In this mode, for the same EV-1 and EV-2 battery voltage levels as the forward boost mode but the power flow is reversed. The receiver EV-1 battery is charged with the charging current Ib1 and the corresponding rise in SOC and voltage with the charging power level is shown in Fig. 9(a). The discharging current of the EV-2 battery Ib2 and the corresponding SOC and voltage with the EV-2 battery discharge power are shown in Fig. 9(b).

C. Forward Boost Mode (Vbat1 = Vbat2)

This mode represents the energy transfer between two same model EVs with equal voltage cases. The currents IL1 and IL2 are controlled with the same current reference in the forward direction. Fig. 10(a) shows the discharging current of the EV-1 battery and the corresponding changes in SOC, voltage, and power. The charging current and respective changes in EV-2 battery SOC and voltage with variations in the dc-link voltages are shown in Fig. 10(b). Depending on the current reference value of the dc–dc converter-2, the dc-link voltage will be slightly higher than the EV-2 battery voltage.



D. Performance Analysis

In this section, the efficiency of the proposed V2V approach and loss calculations at different output power levels are presented. The main losses incurred during V2V power transfer operation are switching and conduction losses of the on-board charger's switches and the ohmic losses in filter inductors. The switching and conduction losses calculations of the diode and the IGBTs are calculated based on the basic equations given in [21]. The power losses and power conversion efficiency in the forward boost mode for the reference inductor current I ∗ L of 30 A are presented. There is no switching loss in dc–dc converter-2 since Sa2 is kept ON and Sb2 is kept OFF throughout this mode. The power conversion efficiency and power losses due to switching and conduction with respect to the output power are shown in Fig. 11. The V2V efficiency and losses are computed for three different output power levels Poutput which are ≈11, ≈14, and ≈18 kW according to the change in reference inductor current I ∗ L as shown in Fig. 8(b). As I ∗ L increases, the corresponding power losses also increase due to higher energy transfer between two EVs and thus, the power conversion efficiency (η) decreases with higher output power. The conduction losses in inductors L1 and L2 are relatively low due to low value of internal resistances R1 and R2. Furthermore, to show the improved performance of the proposed V2V approach, it is quantitatively compared with a similar V2V.

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approach presented in [18] as shown in Table III. The proposed V2V approach connects the two EVs through the type-2 three-phase on-board chargers of 19.4 kW rated power. The V2V approach presented in [18] utilizes type-1

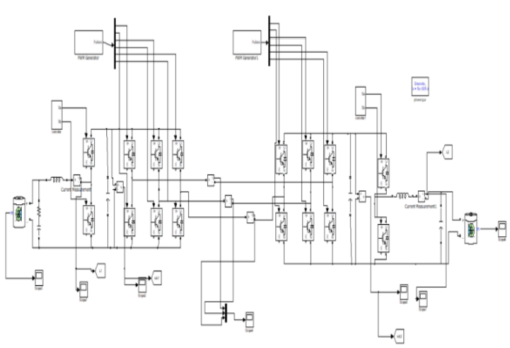
6.1.3 Limitations –

Time consuming

6.2 ENHANCEMENT OF PROPOSED APPROACH

The proposed approach solves the main problems that have been listed earlier, but it is still very slow which is again a limitation for the user. In order to overcome it, we have come up with an enhancement, that is the inclusion of fuzzy controller in the above proposed system. The circuit and the results are shown in the below sections.

SIMULATION CIRCUIT



The above figure shows how a fuzzy controller can be added to the existing circuit for the enhancement of the performance. This can be further studied by looking into the performance characteristics, which are given in the following section of the simulation results.

6.2.2 Simulation Results

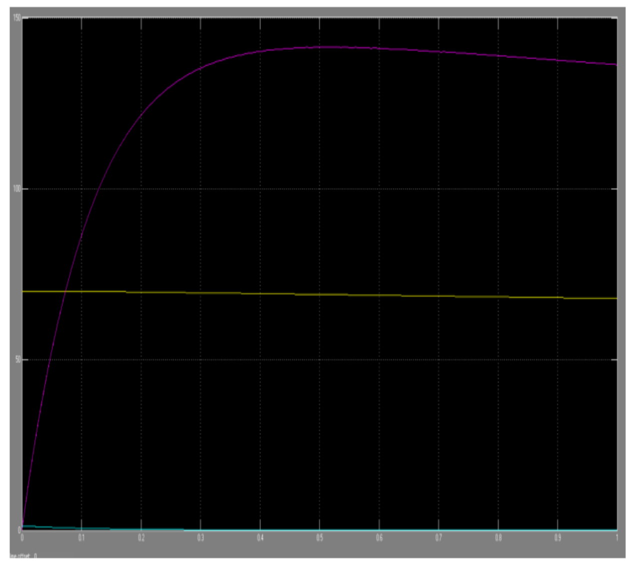


TABLE I POWER LOSSES FOR THE PROPOSED V2V OPERATION IN THE FORWARD BOOST MODE

Parameter	Value
DC-DC converter-1 switching losses ($P_{SW,DC1}$)	132 W
DC-DC converter-1 conduction losses ($P_{cond,DC1}$)	14.1 W
Type-2 active rectifier-1 conduction losses ($P_{cond,AR1}$)	9.6 W
DC-DC converter-2 switching losses ($P_{SW,DC2}$)	0 W
DC-DC converter-2 conduction losses ($P_{cond,DC2}$)	12.77 W
Type-2 active rectifier-2 conduction losses ($P_{cond,AR2}$)	9.6 W
Input power (P_{input})	11.35 kW
Output power (P_{output})	11.172 kW
Power conversion efficiency (η)	98.43 %

single-phase on-board chargers with maximum power limited to 3.3 kW. In [18], V2V power transfer is carried out using four stages (dc to dc, dc to ac, ac to dc, and then back dc–dc). For an adequate comparison, the approach presented in [18] is carried out for 19.4 kW three-phase system and quantitatively compared with the proposed V2V approach. The proposed approach with fewer conversion stages and less number of

TABLE II COMPARISON BETWEEN THE PROPOSED AND PRESENTED V2V APPROACH IN [18]

Parameter	Proposed	[18]
Power conversion stages	2	4
Total conduction losses	0.203 kW	0.56 kW
Total switching losses	0.2 kW	2.284 kW
Switching frequency (f_{sw})	20 kHz	20 kHz
Efficiency (η)	97.92 %	85.34 %
Battery voltage (V_{bat})	450 V	450 V
Battery capacity (E_{bat})	100 kWh	100 kWh
Maximum possible battery charging current (I_{bat})	45 A	45 A
Total charging time for 20 % charging	1 Hr	1 Hr
On-board type-2 charger power rating	19.4 kW	19.4 kW

7.CONCLUSION

This article proposes a direct V2V charging approach for power transfer between two EVs without the need for external hardware or additional charging ports. It is an emergency rescue charging solution in the case of non-availability of ac grid and dc fast-charging stations. Connecting two EV batteries directly through the on-board charger ports leads to significant hardware infrastructure savings. The redundant power conversion stages were avoided, which improved the overall efficiency of the proposed V2V approach which is evident in the performance analysis. The proposed V2V approach mitigates range anxiety and cooperatively shares energy between EV users with minimum infrastructure and cost. The proposed V2V method is validated through simulation in MATLAB/Simulink which prove the practical effectiveness without modifying the EV power architecture.

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