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Efficient Vehicle-to-Vehicle Energy Transfer with Fuzzy Logic Optimization

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Abstract: An emerging approach for enhancing charging efficiency and extending EV usable range is vehicle-to-vehicle (V2V) energy transfer. In this research, we propose a smart energy-sharing architecture that enables adaptive power exchange between EVs by controlling onboard converters using fuzzy logic. In response to variables such as load demand, grid availability, and battery charge level, the suggested system adapts energy flow in real time. Fuzzy logic optimization is used by the system to improve the efficiency of energy transfer, reduce power losses, and ensure the exchange process is stable and dependable. The results of the simulation show that the suggested method improves energy usage while keeping the vehicle's batteries healthy. More sustainable and decentralized charging options are on the horizon, driven by the advancements in smart energy management within EV networks presented in this study.

Keywords: Electric vehicle (EV), Fuzzy logic controller, vehicle-to-vehicle (V2V) charging

I. INTRODUCTION

Typically, on-board slow chargers for electric vehicles (EVs) whether are type-1 or type-2 (single/three-phase) AC have a power range of 3.3-19.4 kW. The references [1] and [2] provide a detailed analysis of bidirectional topologies, including power factor correction, on-board chargers for commercial electric vehicles, and single- or two-stage rectification. Referring to references [3] and [4], we can find a comprehensive analysis of type-1, type-2, and DC fast-charging stations evaluating based on charging duration, power density, Output power, and cost. Additionally, we can analyse existing and upcoming charging technologies. Furthermore, off-board DC fast-charging stations with a power output of more than 50 kW allow electric vehicles batteries to be charged in less than an hour [5]. However, even with these charging options, many users still experience range anxiety because of insufficient charging infrastructure [6].

When traditional power sources like the grid or DC fast-charging stations are inconvenient or non-existent, Despite the unavailable solution, a newer option for transferring energy between EVs is vehicle-to-vehicle (V2V) charging. By helping to reduce range anxiety, vehicle-to-vehicle charging enables electric vehicle users to share energy with minimum infrastructure and cost. In vehicle-to-vehicle energy exchange, the two main components are: Firstly, there's the communication part, which lets EV drivers and riders meet one other for energy-sharing, determine who gets what, and negotiate prices. The sources [7]-[10] provide algorithms based on game theory that match the receiver EV, supplier EV, closest meeting place, and communication characteristics of vehicle-to-vehicle (V2V) systems. Secondly, critical component of vehicle-to-vehicle (V2V) communication is the power interface, which allows for the transmission of power according to the preferences of the supplier and receiver and, in response to the voltage level of the electric vehicle's battery, makes use of either a buck or boost converter.

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Indirect V2V energy transfer using off-board bidirectional power converters is one fundamental V2V strategy, as described in references [11] and [12]. This approach utilises AC power grid as a common energy aggregator. However, multiple redundant conversion processes in this system results in lower energy conversion efficiency. The possibility for grid integration is discussed in [13], which presents an off-board V2V using a bidirectional interleaved DC-DC converter. For further information on off-board V2V charging solutions, refer to [14] and [15]. Andromeda Power offers a commercial 50 kW off-board V2V charger capable of charging two electric vehicles simultaneously [16], [17]. However, this off-board V2V method, requires an external connection, which EV drivers may find inconvenient and expensive.

On the other hand, V2V techniques, as described in [18] and [19] that make use of the type-1 and type-2 chargers as power interfaces. These on-board chargers, typically consists of an active rectifier stage that converts AC voltage to DC voltage, followed by a DC-DC converter that enables CCCV charge management. The V2V charging technique, described in [18] and illustrated in Fig. 1.1(a), involves connecting the type-1 charger input ports of two electric vehicles. This procedure begins with the supplier EV's bidirectional two-stage type-1 AC charger converting the DC output of the battery to single-phase AC.

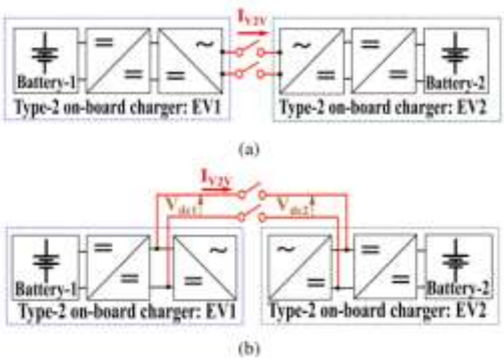

Fig 1 V2V operations: (a) ac V2V operation and (b) dc V2V operation.

In order to charge the battery of the receiving EV, the AC power output from the source EV is fed into the two-stage type-1 converter that is on-board. Nevertheless, as shown in [18], the V2V charging efficiency is reduced due to cascaded converter losses caused by unnecessary conversion steps. The DC-link of both electric vehicles is directly linked using mechanical switches, as shown in Figure 1(b), according to a V2V charging approach suggested in [19]. Unfortunately, in reality, it is not possible to directly connect to the DC-link of the DC-DC converters on the battery side. As a result, getting the two EVs' DC-link terminals to work with the V2V method in [19] would require significant design modifications and additional charging ports.

A more feasible method for V2V charging, using on-board type-2 chargers, is suggested in this article. In this approach, there is no need for additional hardware or power intake ports for vehicle-to-vehicle (V2V) operation when both EVs' on-board type-2 ports are directly linked. In order to reduce the overall number of conversion stages in the V2V energy transfer route, the suggested method employs the active rectifier stages to serve as the connecting interface between the two EV batteries. By reducing the number of conversion steps improves overall efficiency by reducing switching and conduction losses. The new vehicle-to-grid (V2G) method also incorporates mode selection logic, which considers the EV driver's preferences and the current battery voltage and current flow direction to decide whether the system should operate in boost or buck mode. Because of this, the system can control the flow of electricity in either way, giving EV drivers more options when it comes to how they operate, regardless of whether their batteries have different voltage ratings.
This method gets around the necessity for an off-board V2V interface (as shown in [16]) and additional contactor switches (needed in [19]) by connecting the two EV batteries via on-board active rectifier switches. Overall V2V efficiency is improved, and related losses are minimized, since the method removes redundant power transfer steps compared to [18]. Intelligent control techniques are crucial for managing dynamic power flow, which is necessary for effective energy transfer between electric vehicles. An adaptable and resilient approach to maximizing energy transfer is fuzzy logic-based control, which considers many real-time characteristics such as battery state-of-charge (SoC), power demand, and vehicle energy availability. For practical electric vehicle (EV) energy-sharing applications, fuzzy logic is superior to conventional

control approaches because it can handle with non-linearities and uncertainties. The proposed fuzzy logic-based approach optimizes energy transfer between EVs using on-board converters. The system enhances energy efficiency, minimizes losses, and ensures a stable power exchange process. Through simulation and analysis, the effectiveness of this method is demonstrated, contributing to the development of more intelligent and sustainable EV energy networks.

II. PROPOSED SYSTEM

The proposed V2V arrangement is implemented by directly connecting the two EVs' existing type-2 charging connectors. The three-phase active rectifier switches connect the two electric vehicles. The two EV batteries are linked through the intermediate DC-link of both the provider and receiver EVs by activating the upper switch of one phase (phase-a, S1) and the lower switch of another phase (phase-c, S6) of active rectifier-1, as well as the corresponding phase switches (S'1 and S'6) of active rectifier-2. This is illustrated in Figure 2. All four switches—S1, S6, S'1, and S'6 will remain active throughout the voltage-to-current (V2V) transformation process.

By linking the two EVs in this way, a dual bidirectional buck-boost converter is formed; this converter can be adjusted so that power can be transferred in either direction between the two EVs, independent of the voltage levels of their batteries. During the entire V2V operation, the other switches in both active rectifiers remains OFF because the type-2 chargers' rectifiers are used as an interface to connect the two DC-links instead of their original function of rectification.

Depending on the battery voltage levels of the two EVs, the configuration can operate in one of several energy transfer modes, as outlined below.

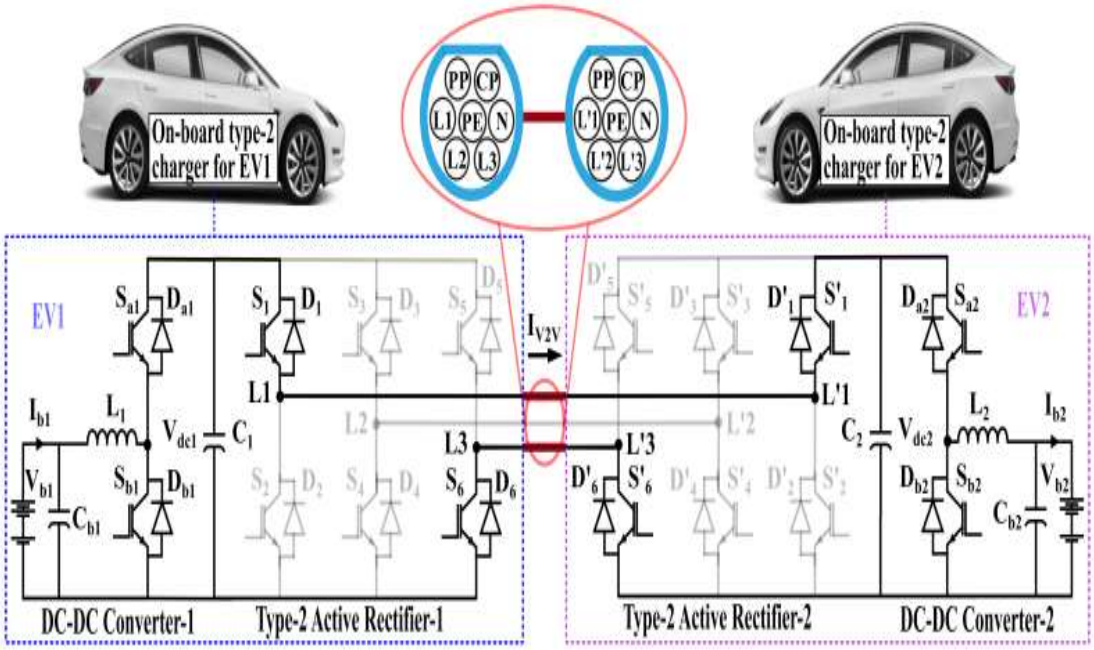

Fig.2 Proposed System for V2V operation.

III. CONTROL SCHEME FOR THE PROPOSED V2V APPROACH

In the proposed V2V method, the on-board converters regulate the charging rate and the total energy delivered. Based on the provided receiver information and the EV-1 and EV-2 battery levels, the mode selection flow shown in Fig.6 determines the V2V mode. In addition, as mentioned earlier, the on-board charger converters can be regulated to achieve the desired V2V depending on the mode of operation.

A) **Control of the Active Rectifiers as V2V Interface**

To convert three-phase ac to dc with unity power factor operating at the grid terminals, the active rectifier is typically regulated in d-q control mode. During, regular three-phase ac charging with a type-2 charger. The active rectifier is reproposed as a connector to access and link the two EV batteries for the planned V2V charging. During all modes of V2V charging, once the type-2 charger ports have been connected, the gating pulse for the active rectifier-1 switches S1 and S6 and the active rectifier-2 switches S'1 and S'6 remains high. This applies to both the EV-1 and the active rectifier-2.

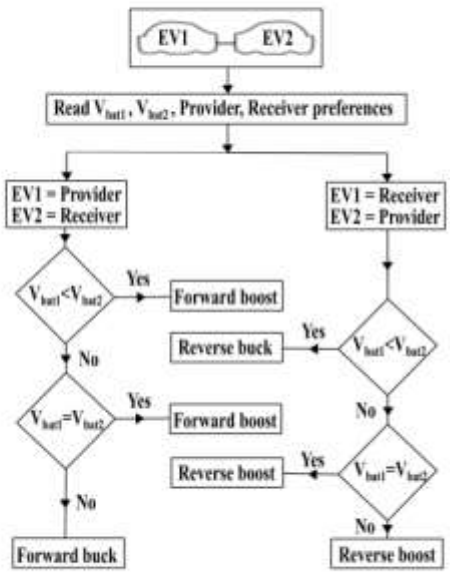

Fig.3 Proposed V2V power transfer control flow.

B) Control of DC–DC Converters

The type-2 chargers, dc-dc converters are closed-loop current-controlled, which is ideal for the proposed V2V charging method that utilizes the on-board chargers. Figure 4 shows the control circuit for the converter, but instead of a PI controller, an expansion employs a fuzzy logic controller.

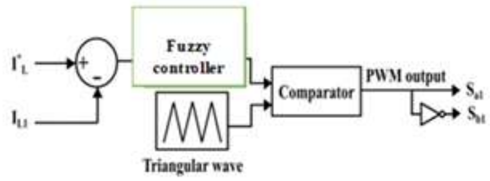

Fig.4 Current control structure with fuzzy controller

The mode maintains a high level of activity in the gating signal to the switch Sa2. Equation [20] gives the current-to-control transfer function for the dc-dc converter-1 fuzzy controller, where D is the duty ratio and R2 is the load resistance which corresponds to the charging current of the EV-2 battery.

$$\frac{\widehat{I_{L1}}(s)}{\widehat{d}(s)} = \frac{(C_1 V_{b1})s + 2(1-D)L_1}{(L_1 C_1)s^2 + \frac{L_1}{R_2}s + (1-D)^2}. \quad (1)$$

The equation that determines I*L takes into account the intended charging time (Tc), the kWh ratings of the EV-1 and EV-2 batteries (Ebat1 and Ebat2, respectively), and the system operation. A reference current is determined by selecting the lowest possible value from the two possible battery ratings and voltage levels.

$$I_L^* = \frac{\min(E_{\mathrm{bat1}}, E_{\mathrm{bat2}})}{\min(V_{\mathrm{bat1}}, V_{\mathrm{bat2}}) * T_c}. \quad (2)$$

The on-board active rectifier IGBTs' current ratings (S1, S6, S'1, and S'6) determine the maximum value of I*L. If the calculated value of I*L is more than Is1r, the current reference will be limited to Is1r. To control the IL2 in forward or reverse direction in the forward buck or reverse boost mode with (Vbat1 > Vbat2), the same control structure is employed. The duty ratio for the switch Sb2 is generated, and switch Sa2 is complimentarily switched to Sb2. Throughout this mode, the gating signal is set to high to switch Sa1. In addition, while operating in forward boost mode with (Vbat1 = Vbat2), the current control mode is used by both dc-dc converters to regulate IL1 and IL2 in the forward direction. In order to keep the power balanced between the two EV batteries, it is necessary that the current reference I*L should be same for both dc-dc converters, given that in this scenario, the voltages of the two batteries are equal. One way to control this mode is to operate the dc-dc converter-2 in current controlled buck mode and the

Industrial Engineering Journal
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dc-dc converter-1 in voltage-controlled boost mode, both of which regulate the dc-link at a higher voltage. Electric vehicle owners are more likely to accept the suggested V2V method due to its greater efficiency, reduced losses, and the ease of connecting two EVs using the already on-board type-2 charging connections. In order to set up a communication link between two EVs and get the necessary parameters for V2V, it is often necessary to have access to the on-board instrumentation sensors and BMS controllers of the sending and receiving EVs. This is essential for the actual execution of any V2V strategy. Under the premise that the bidirectional power converter interface for V2V is present, these V2V features have been previously covered in [10]-[12], along with specifics of algorithms based on game theory that match the receiver and supplier EVs. As described in [10]-[12], the proposed V2V method for commercial EVs requires a robust interface for the on-board type-2 charger hardware component to facilitate the actual V2V power transfer, and it also assumes that communication between EVs and access to controllers and instrumentation sensors are readily available. For vehicle-to-vehicle (V2V) energy sharing, the two EVs may be linked directly using the type-2 charging ports that are already installed on the vehicles. As seen in Figure 4.2, the decision about the V2V mode is made based on the battery voltage levels, provider preferences, and EV user inputs, which are obtained from the on-board instrumentation sensors. By utilizing on-board DSP controllers, the desired mode of operation (such as forward boost) determines the direction of power flow and the quantity of energy transfer that is necessary. By activating the top and bottom switches on either leg, the active rectifiers of the on-board chargers may be regulated to function as an interface. Following the connection of the dc-links of the two on-board chargers, the current-controlled battery side dc-dc converter of the chargers can provide the necessary charge to the receiving electric vehicle (EV), as mentioned earlier in this section, depending on the selected V2V mode.

IV. PROPOSED FUZZY LOGIC CONTROLLER

Fuzzy logic enhances traditional device design when used in conjunction with a design expert. Fuzzy logic allows for a significant reduction in the need for rigorous mathematical modelling in control operations. A controller based on sophisticated analytical methods cannot match the efficiency of a human operator when it comes to process monitoring.

Fluid set theory, as implemented by FLC, has recently gained popularity. The membership function (MF) values imply just two distinct values, 0 and 1, creating a fuzzy collection. Fuzzy packages are shown below.

In the discourse universe U, a fuzzy set A is defined by a member function A(x) that determines the number associated with each element x of U on the interval of A that measures the member status [0, 1].

Physical structure and logic are considered as essential components of fuzzy logic regulation. 1. Fuzzy source code; 2. knowledge base; 3. engine inference; and 4. defuzzification are the four primary components.

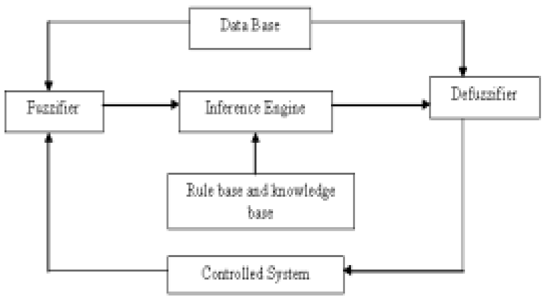

Fig.5 Structure of Fuzzy Logic controller

1. Fuzzification:

Diagrams span several domains of discussion, from the basic semantic to a more fluid set. The membership intensity in subcategory A is shown for a certain value x. (x). (x). The following procedures make up flushing. Evaluates the impact of the factors.

For each of the input variables, the computer maps new range into its corresponding discourse universe and adjusts the range accordingly.

Activates the fluctuation function, which takes in data and outputs language variables that may be understood as labels for fuzzy logic sets.

2. Knowledge Base (KB):

Fuzzy MFs for input and output variables, together with their meanings and control rules that explain when, how, and why to apply them, make up the foundation of knowledge.

Industrial Engineering Journal
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Volume : 54, Issue 4, April : 2025

The system incorporates a database and a language rules basis.

1. Principles of language control and irrelevant data processing may be found in the database.
2. A series of language rules is used to organize the fundamental rule, which is to specify control objectives and controls for domain experts.

3. Inference Mechanism:

Using a series of fluid if-then rules, such as:

IF X = A = Y = B = B = C, to make decisions on paper.

The linguistic values of x, y, and z, as well as a, b, and c, stand for two input variables and one power variable, respectively. It provides the foundation for a fuzzy logic computer (FLC) that can mimic human behaviour, down to the principles of inference and decision-making.

Two outputs, representing the rules between the two systems, are often associated with fuzzy sets.

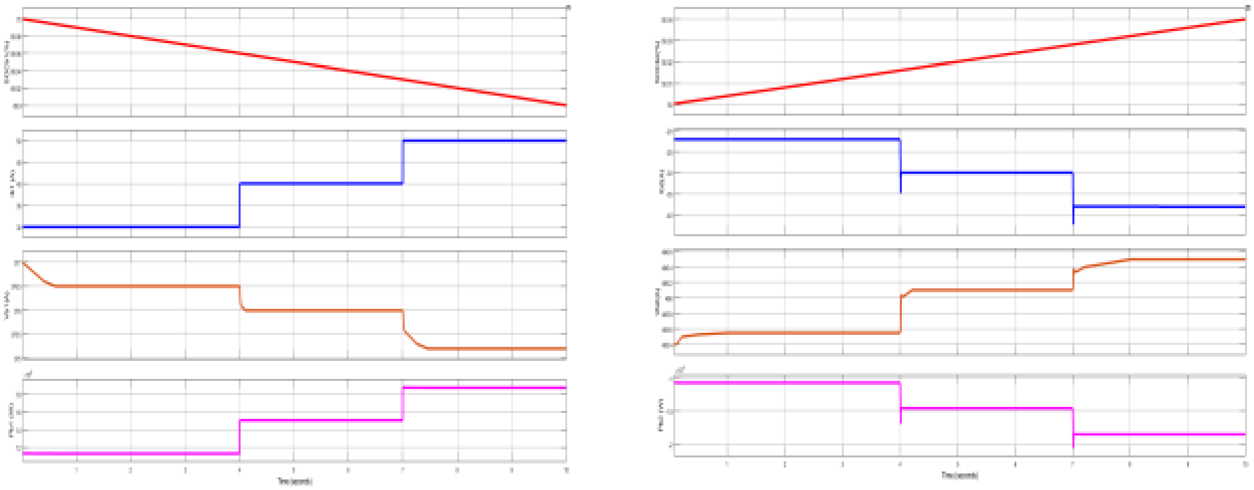
4. Defuzzification:

Numerical quantities that are reliant on language may be measured using defuzzification. The center technique was used in this investigation.

(1) A mapping scale that converts the range of input values to the set of values for the output variable. Separating non-fuzzy control behaviour from a fluctuating control operation is the goal of this method (2).

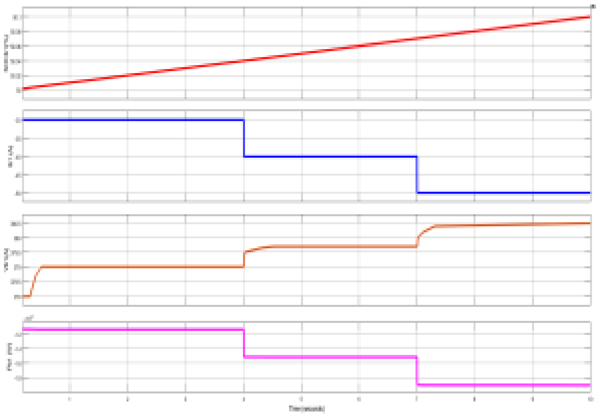
V. SIMULATION RESULTS

A) EXISTING RESULTS

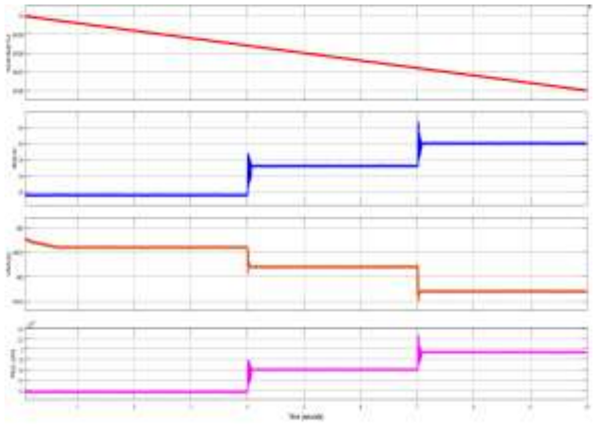


(a) (b)

Fig. 6 Simulation results of the proposed V2V operation in forward boost mode with Vbat1 < Vbat2. (a) SOC, voltage, current, and power waveforms of EV-1 battery. (b) SOC, voltage, current, and power waveforms of EV-2 battery

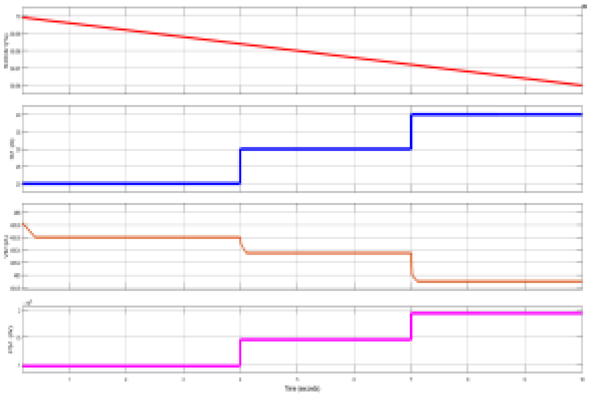


(a)

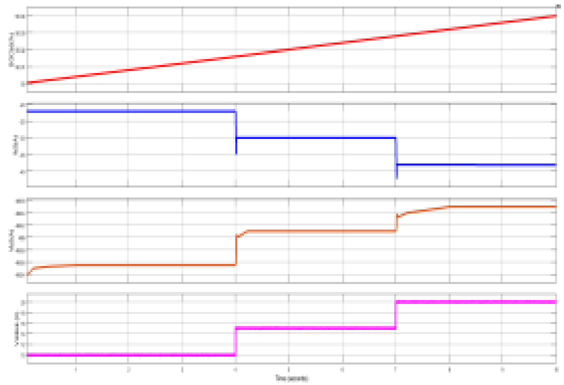


(b)

Fig.7 Simulation results of the proposed V2V operation in the reverse buck mode with Vbat1 < Vbat2. (a) SOC, voltage, current, and power waveforms of the EV-1 battery. (b) SOC, voltage, current, and power waveforms of the EV-2 battery



(a)



(b)

Fig.8 Simulation results of the proposed V2V operation in the forward boost mode with Vbat1 = Vbat2. (a) SOC, voltage, current, and power waveforms of EV-1 battery. (b) SOC, voltage, current of EV-2 battery, and dc-link voltage.

B) EXTENSION RESULTS

This mode allows for the regulation of the inductor current (IL1) to transfer energy from the EV-1 battery to the EV-2 battery. For the forward boost mode, the reference inductor current (I*L) is initially set to 30A and then increased to 50A in 10-amp increments to control the EV-1 battery discharge current (Ib1). Figure 9(a) shows the control of Ib1 and the accompanying drop in the EV-1 battery's state of charge (SoCb1), voltage (Vb1), and discharged power (Pb1) as a result.

Figure 9(b) shows the charging current (Ib2), voltage (Vb2), and charged power (Pb2) of the EV-2 battery, as well as the associated rise in the state of charge (SoCb2) and battery voltage. When the battery current is positive, it means the battery is draining; when it is negative, it means the battery is charging. Both the charging and discharging currents remain within the 45A current rating of the on-board type-2 charger's active rectifier switches (Is1r).

Industrial Engineering Journal
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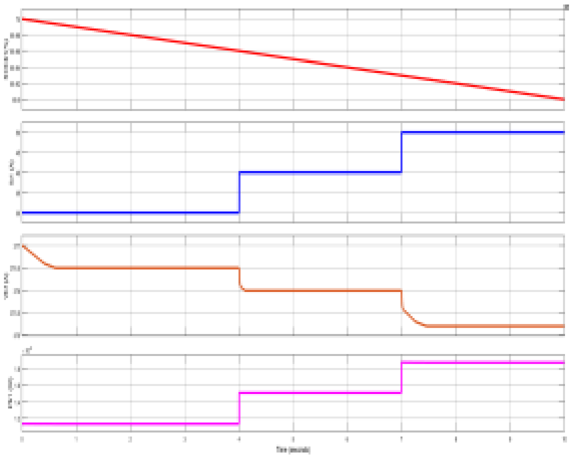
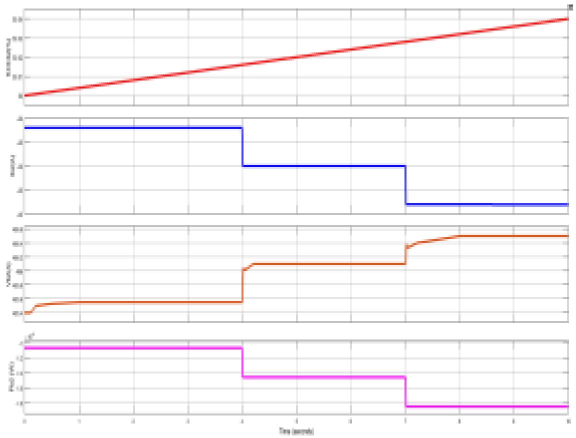


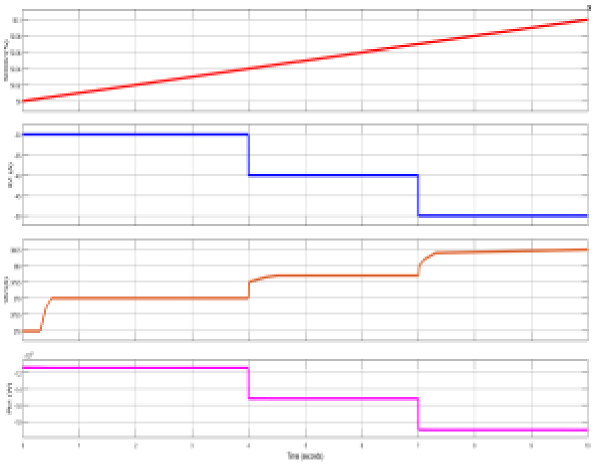
(a)



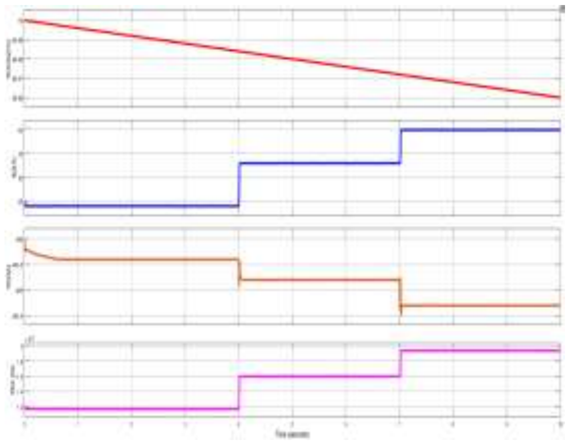
(b)

Fig.9 Simulation results of the proposed V2V operation in forward boost mode with Vbat1 < Vbat2. (a) SOC, voltage, current, and power waveforms of EV-1 battery. (b) SOC, voltage, current, and power waveforms of EV-2 battery

Here, the power goes in the opposite direction compared to forward boost mode, but the EV-1 and EV-2 batteries maintain their original voltage levels. Figure 10(a) shows the charging current (Ib1) going into the EV-1 battery, which causes the SOC, voltage, and charging power level to increase. However, Fig. 10(b) shows the EV-2 battery's discharging current (Ib2) and the related changes in its state of charge (SOC), voltage, and discharging power.



(a)



(b)

Fig.10 Simulation results of the proposed V2V operation in the reverse buck mode with Vbat1 < Vbat2. (a) SOC, voltage, current, and power waveforms of the EV-1 battery. (b) SOC, voltage, current, and power waveforms of the EV-2 battery

This mode depicts the transfer of energy between two identical electric vehicles with the same model and voltage levels. In the forward direction, the current references used to regulate the currents (IL1 and IL2) are identical. Figure 11(a) shows the EV-1 battery's discharging current, voltage, and power changes as a function of the corresponding changes in the state of charge (SOC). Fig. 11(b) displays the EV-2 battery's charging current, changes in SOC and voltage, and variations in DC-link voltages.

Industrial Engineering Journal

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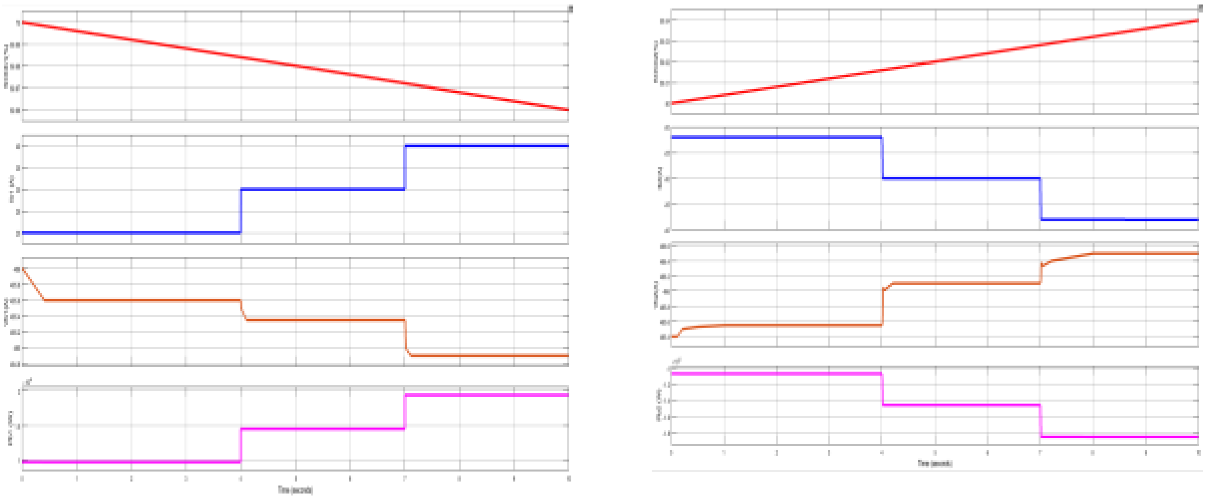
Volume : 54, Issue 4, April : 2025

The DC-link voltage will remain slightly higher than the EV-2 battery voltage, depending on the present reference value of the DC-DC converter-2.



(a) (b)

Fig.11 Simulation results of the proposed V2V operation in the forward boost mode with Vbat1 = Vbat2. (a) SOC, voltage, current, and power waveforms of EV-1 battery. (b) SOC, voltage, current of EV-2 battery, and dc-link voltage

CONCLUSION

In order to improve the efficiency of vehicle-to-vehicle (V2V) energy transfer, this research explores the use of fuzzy logic optimization. The system employs fuzzy logic control to dynamically adjust charging settings depending on factors such as energy demand, ambient conditions, and battery state of charge (SoC). The proposed method enhances overall system stability, precision of energy distribution, and loss minimization. By guaranteeing adaptable, real-time energy allocation, decreasing power waste, and increasing battery longevity, testing and simulation findings show that fuzzy logic optimization beats traditional techniques. Additionally, the method makes energy transmission in EV networks more reliable, paving the way for its potential use in smart transportation systems.

Exploring blockchain for secure energy transactions, including machine learning to dynamically adjust fuzzy logic parameters, and extending real-world pilot studies to test performance under different traffic and environmental situations are all possible directions for future study.

REFERENCES

[1] J. Yuan, L. Dorn-Gomba, A. D. Callegaro, J. Reimers, and A. Emadi, “A review of bidirectional on-board chargers for electric vehicles,” IEEE Access, vol. 9, pp. 51501–51518, 2021.

[2] M. Y. Metwly, M. S. Abdel-Majeed, A. S. Abdel-Khalik, R. A. Hamdy, M. S. Hamad, and S. Ahmed, “A review of integrated on-board EV battery chargers: Advanced topologies, recent developments and optimal selection of FSCW slot/pole combination,” IEEE Access, vol. 8, pp. 85216–85242, 2020.

[3] A. Khaligh and M. D’Antonio, “Global trends in high-power on-board chargers for electric vehicles,” IEEE Trans. Veh. Technol., vol. 68, no. 4, pp. 3306–3324, Apr. 2019.

[4] V. T. Tran, D. Sutanto, and K. M. Muttaqi, “The state of the art of battery charging infrastructure for electrical vehicles: Topologies, power control strategies, and future trend,” in Proc. Australas. Universities Power Eng. Conf. (AUPEC), Nov. 2017, pp. 1–6.

[5] M. R. Khalid, I. A. Khan, S. Hameed, M. S. J. Asghar, and J.-S. Ro, "A comprehensive review on structural topologies, power levels, energy storage systems, and standards for electric vehicle charging stations and their impacts on grid," IEEE Access, vol. 9, pp. 128069–128094, 2021.

[6] M. Yilmaz and P. T. Krein, "Review of battery charger topologies, charging power levels, and infrastructure for plug-in electric and hybrid vehicles," IEEE Trans. Power Electron., vol. 28, no. 5, pp. 2151–2169, May 2013.

[7] G. Li, L. Boukhatem, L. Zhao, and J. Wu, "Direct vehicle-to-vehicle charging strategy in vehicular Ad-Hoc networks," in Proc. 9th IFIP Int. Conf. New Technol., Mobility Secur. (NTMS), Jan. 2018, pp. 1–5.

[8] R. Q. Zhang, X. Cheng, and L. Q. Yang, "Flexible energy management protocol for cooperative EV-to-EV charging," IEEE Trans. Intell. Transp. Syst., vol. 20, no. 1, pp. 172–184, Jan. 2019

[9] D. M. Mughal, J. S. Kim, H. Lee, and M. Y. Chung, "Performance analysis of V2V communications: A novel scheduling assignment and data transmission scheme," IEEE Trans. Veh. Technol., vol. 68, no. 7, pp. 7045–7056, Jul. 2019.

[10] E. Bulut and M. C. Kisacikoglu, "Mitigating range anxiety via vehicle-to-vehicle social charging system," in Proc. IEEE 85th Veh. Technol. Conf. (VTC Spring), Jun. 2017, pp. 1–5.

[11] P. You and Z. Yang, "Efficient optimal scheduling of charging station with multiple electric vehicles via V2V," in Proc. IEEE Int. Conf. Smart Grid Commun. (SmartGridComm), Nov. 2014, pp. 716–721.

[12] A.-M. Koufakis, E. S. Rigas, N. Bassiliades, and S. D. Ramchurn, "Towards an optimal EV charging scheduling scheme with V2G and V2V energy transfer," in Proc. IEEE Int. Conf. Smart Grid Commun. (SmartGridComm), Nov. 2016, pp. 302–307.

[13] E. Ucer et al., "A flexible V2V charger as a new layer of vehicle-grid integration framework," in Proc. IEEE Transp. Electrific. Conf. Expo (ITEC), Jun. 2019, pp. 1–7.

[14] C. Liu, K. T. Chau, D. Wu, and S. Gao, "Opportunities and challenges of vehicle-to-home, vehicle-to-vehicle, and vehicle-to-grid technologies," Proc. IEEE, vol. 101, no. 11, pp. 2409–2427, Nov. 2013.

[15] P. Mahure, R. K. Keshri, R. Abhyankar, and G. Buja, "Bidirectional conductive charging of electric vehicles for V2V energy exchange," in Proc. 46th Annu. Conf. IEEE Ind. Electron. Soc. (IECON), Oct. 2020, pp. 2011–2016.

[16] Andromeda Power. Accessed: Nov. 2021. [Online]. Available: https:// www.andromedapower.com

[17] Dec. 2019. Hyundai introduces vehicle to vehicle charging facility. Accessed: Nov. 2021. [Online]. Available: https://www.autocarindia. com/car-news/hyundai-introduces-vehicle-to-vehicle-charging-facility 415144

[18] S. Taghizadeh, M. J. Hossain, N. Poursafar, J. Lu, and G. Kon stantinou, "A multifunctional single-phase EV on-board charger with a new V2V charging assistance capability," IEEE Access, vol. 8, pp. 116812–116823, 2020.

[19] T. J. C. Sousa, V. Monteiro, J. C. A. Fernandes, C. Couto, A. A. N. Meléndez, and J. L. Afonso, "New perspectives for vehicle to-vehicle (V2V) power transfer," in Proc. 44th Annu. Conf. IEEE Ind. Electron. Soc., Oct. 2018, pp. 5183–5188.

[20] R. W. Erickson and D. Maksimovic, Fundamentals of Power Electronics, 2nd ed. Norwell, MA, USA: Springer, 2007.

[21] D. Graovac and M. Purschel, "IGBT power losses calculation using the data-sheet parameters-application note," Infineon Technol. AG, Neubiberg, Germany, Appl. Note V 1.1, Jan. 2009