

Research Paper

ELECTRIC VEHICLE TO VEHICLE ENERGY TRANSFER USING ON BOARD CONVERTERS

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Abstract

Electric Vehicle-to-Vehicle (V2V) energy transfer is an emerging solution for optimizing charging efficiency and extending the operational range of electric vehicles (EVs). This paper explores an intelligent energy-sharing framework utilizing fuzzy logic-based control for onboard converters to enable seamless and adaptive power exchange between EVs. The proposed system dynamically adjusts energy flow based on real-time vehicle parameters such as battery state-of-charge, load demand, and grid availability. By leveraging fuzzy logic optimization, the system enhances energy transfer efficiency, minimizes power losses, and ensures a stable and reliable exchange process. Simulation results demonstrate the effectiveness of the proposed approach in

improving energy utilization while maintaining vehicle battery health. This study contributes to the advancement of smart energy management in EV networks, paving the way for more sustainable and decentralized charging solutions.

Keywords

Electric Vehicles (EV), fuzzy logic control (FLC), Power Management, On board converters.

1. INTRODUCTION

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/twostage 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. 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 off-board 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]. 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 reutilizing 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. 1.1(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

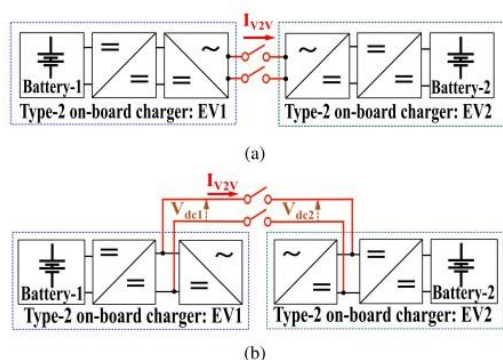


Fig 1. V2V operations: (a) ac V2V operation and (b) dc V2V operation.

2. LITERATURE REVIEW

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.

This paper presents a comprehensive overview and investigation on the state-of-the-art solutions of bidirectional OBCs. It reviews the current status, including architectures and configurations, smart operation modes, industry standards, major components, and commercially available

products. A detailed overview of the promising topologies for bidirectional OBCs, including two-stage and single-stage structures, is provided. Future trends and challenges for topologies, wide bandgap technologies, thermal management, system integration, and wireless charging systems are also discussed in this paper.

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.

his paper starts with surveying the main topologies introduced in the recent literature employing either induction or permanent magnet motors to realize fully integrated slow (single-phase) and fast (three-phase) on-board EV battery charging systems, with emphasis on topologies that entail no or minimum hardware reconfiguration. Although, permanent magnet (PM) motors with conventional double-layer distributed winding layouts have been deployed in most commercial EV motors, the non-overlapped fractional slot concentrated winding (FSCW) has been the prevailing choice in the most recent permanent magnet motor designs due to its

outstanding operational merits. Hence, a thorough investigation of the impact different FSCW stator winding designs have on machine performance under the charging process is presented in this paper.

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.

This paper provides a comprehensive review and analyses on the state-of-the-art and future trends for high-power conductive on-board chargers (OBCs) for electric vehicles. To provide a global context, a summary of global charging standards and electric vehicle (EV) related trends are presented, which demonstrates momentum toward the OBCs with higher power rating. High-power OBCs are either unidirectional or bidirectional, and they have either an integrated or non-integrated system architecture. Non-integrated high-power OBCs are studied both from industry and academia, and the former are used to illustrate the current state of the art. The latter are classified on the basis of the converter design approach, studied for their principle of operation, and compared over power density, weight, efficiency, and other metrics. In addition to non-integrated OBCs, recent advancements in propulsion-machine integrated OBC solutions are also

presented. Other integrated OBC techniques, such as system integration with the EV's auxiliary power module and wireless charging systems, are also discussed.

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.

This paper reviews the status quo of EV battery (EVB) chargers in term of converter topologies, operation modes, and power control strategies for EVs. EVB Chargers are classified based on their power levels and power flow direction. Referring to power ratings, EV chargers can be divided into Level 1, Level 2 and Level 3. Level 1 and Level 2 are normally compatible with on-board chargers while Level 3 is used for an off-board charger. Unidirectional/bidirectional power flow can be obtained at all power levels. However, bidirectional power flow is usually designed for Level 3 chargers as it can provide the huge benefit of transferring power back to grid when needed. Moreover, the different operation modes of an EVB charger are also presented. There are two main modes: Grid-to-Vehicle (V1G or G2V) and Vehicle-to-Grid (V2G). The V2G mode helps bring EV

batteries to become active distributed sources in smart grids and is the crucial solution for a high EV penetration.

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.

This paper provides a comprehensive review of EV technology that mainly includes electric vehicle supply equipment (EVSE), ESS, and EV chargers. A detailed discussion is presented on the state-of-the-art of EV chargers that include on-/off-board chargers. Different topologies are discussed with low-/high-frequency transformers. The different available power levels for charging are discussed. To reduce the range anxiety the EV chargers based on inductive power transfer (IPT) are discussed. The international standards decided by different institutions and adopted universally are discussed in the latter part of this paper and finally, this paper concludes with the near to future advancement in EV technology.

3. SYSTEM DESCRIPTION

The proposed V2V configuration is realized by connecting the existing type-2 charging

ports of the provider-EV and the receiver-EV. The two EVs are connected by utilizing the three phase active rectifier switches. Turning ON the top switch of one of the phases (phase-a, S1 here) and bottom switch of the other phase (phase-c, S6 here) of the active rectifier-1 and the respective phase switches S'1 and S'6 of the active rectifier-2 directly connects the two EV batteries through the intermediate dc-link of provider and receiver EVs as shown in Fig. 4.1 The four switches S1, S6, S'1, and S'6 are kept ON throughout the V2V power transfer duration. The proposed way of connecting the two EVs realizes a dual bidirectional buck-boost converter that can be controlled to transfer energy between two EVs in either direction regardless of their battery voltage levels. As the active rectifiers of both the type-2 chargers are used as an interface to connect two dc-links instead of their actual purpose of rectification, other switches of both the active rectifiers are kept OFF throughout the V2V operation. Based on the battery voltage of two EVs, the configuration may operate in one of the possible energy transfer modes as discussed below.

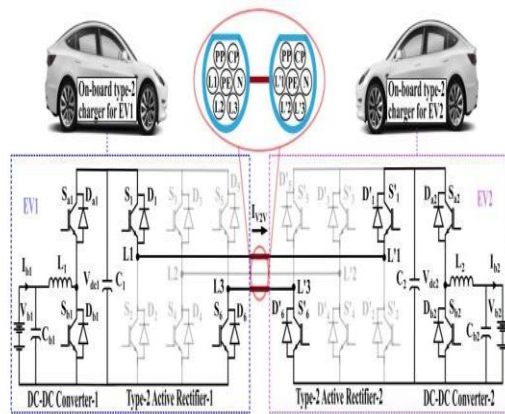


Fig 2. Proposed topology for V2V operation.

3.1 Proposed V2V Architecture

The system consists of:

- Donor EV (energy supplying vehicle)
- Receiver EV (energy receiving vehicle)
- On-board bidirectional DC–DC converters
- Battery Management Systems (BMS)
- Fuzzy Logic Controller

3.2 Operation Principle

- Energy flows from donor EV battery to receiver EV battery.
- Converter regulates voltage and current during transfer.
- FLC adjusts switching to maintain optimal power flow.

3.2 . Converter Design

A bidirectional DC–DC converter is used to enable power flow in both directions.

Modes of Operation:

- **Buck Mode:** Step-down voltage for charging receiver EV
- **Boost Mode:** Step-up voltage when required

3.3 . Mathematical Modeling

3.3.1 Converter Voltage Relationship (Buck Mode)

$$V_o = D \cdot V_{in}$$

Where:

D = duty cycle

3.3.2 Converter Voltage Relationship (Boost Mode)

$$V_o = \frac{V_{in}}{1 - D}$$

3.3.3 Battery State of Charge (SOC)

$$SOC = SOC_{initial} + \frac{1}{C} \int i(t) dt$$

3.3.4 Power Transfer Equation

$$P = V \times I$$

4. FUZZY LOGIC CONTROLLER DESIGN

4.1 Inputs and Outputs

- Inputs:
 - Voltage error (e)
 - Change in error (Δe)
- Output:
 - Duty cycle control signal

- Robust under varying conditions

5. CONTROL STRATEGY

The FLC-based control ensures:

- Stable voltage regulation
- Controlled charging current
- Prevention of battery overcharging
- Smooth bidirectional power flow

4.2 Fuzzy Rule Base

The controller uses linguistic variables such as:

- Negative Big (NB), Negative Small (NS), Zero (Z), Positive Small (PS), Positive Big (PB)

Example rules:

- IF error is NB AND Δe is NS THEN output is NB
- IF error is Z THEN output is Z
- IF error is PB THEN output is PB

4.3 Membership Functions

Triangular and trapezoidal membership functions are used for fuzzification.

4.4 Advantages of FLC

- No need for precise mathematical model
- Handles nonlinearities effectively
- Fast dynamic response

6. Simulation and Results

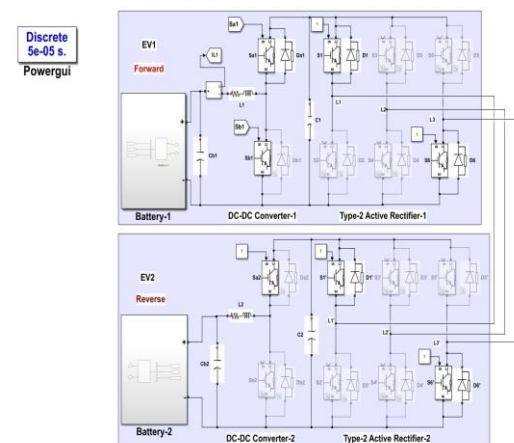
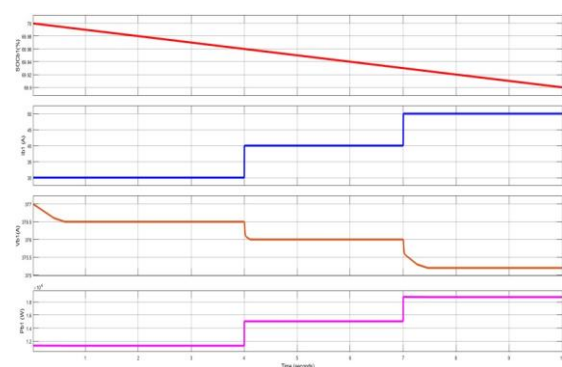
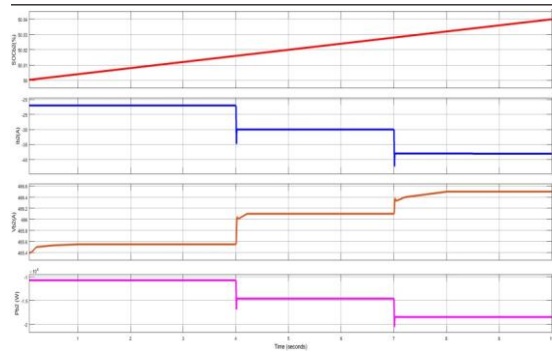


Fig.6.1 simulation circuit

6.1 EXISTING RESULTS (WITH PI CONTROLLER)

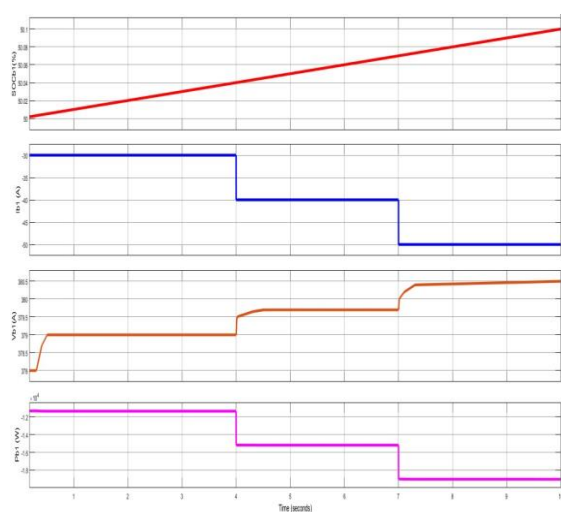


(a)

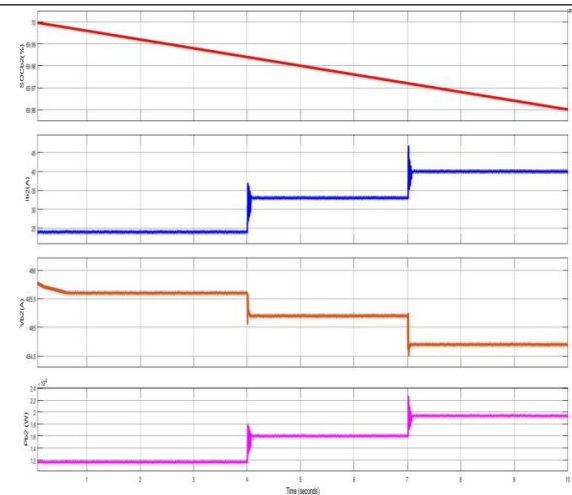


(b)

Fig. 6.2 Simulation results of the proposed V2V operation in forward boost mode with $V_{bat1} < V_{bat2}$. (a) SOC, voltage, current, and power waveforms of EV-1 battery. (b) SOC, voltage, current, and power waveforms of EV-2 battery



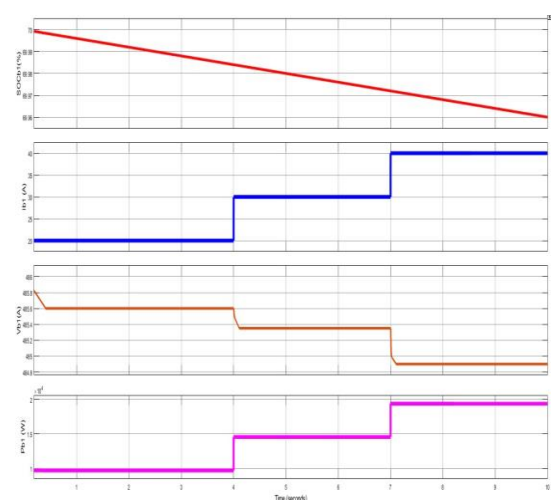
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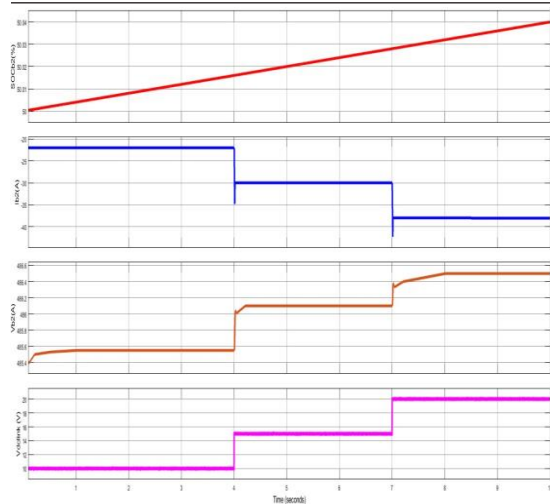
(b)

Fig. 6.3 Simulation results of the proposed V2V operation in the reverse buck mode with $V_{bat1} < V_{bat2}$. (a) SOC, voltage, current, and power waveforms of the EV-1 battery. (b) SOC, voltage, current, and power waveforms of the EV-2 battery

SOC, voltage, current, and power waveforms of the EV-2 battery



(a)



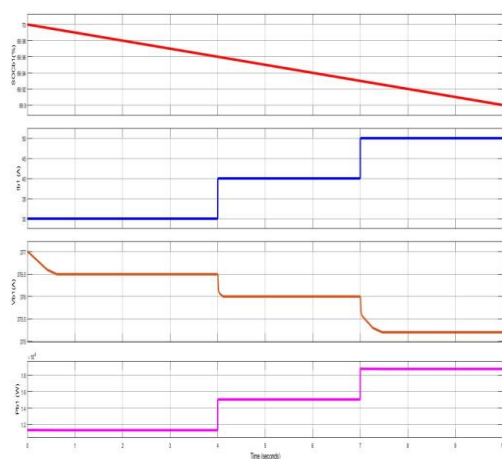
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Fig. 6.4 Simulation results of the proposed V2V operation in the forward boost mode with

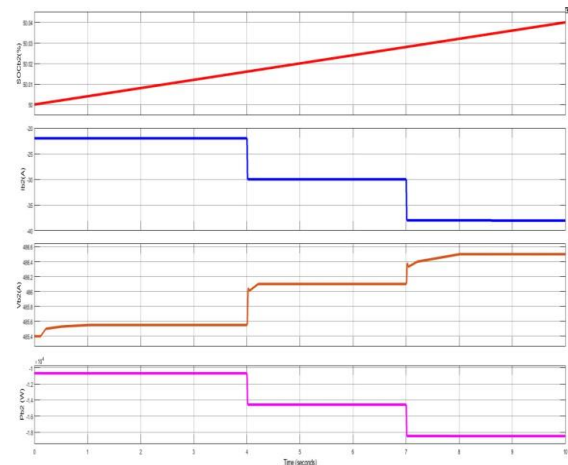
$V_{bat1} = V_{bat2}$. (a) SOC, voltage, current, and power waveforms of EV-1 battery. (b) SOC,

voltage, current of EV-2 battery, and dc-link voltage.

6.2 EXTENSION RESULTS (WITH FLC CONTROLLER)



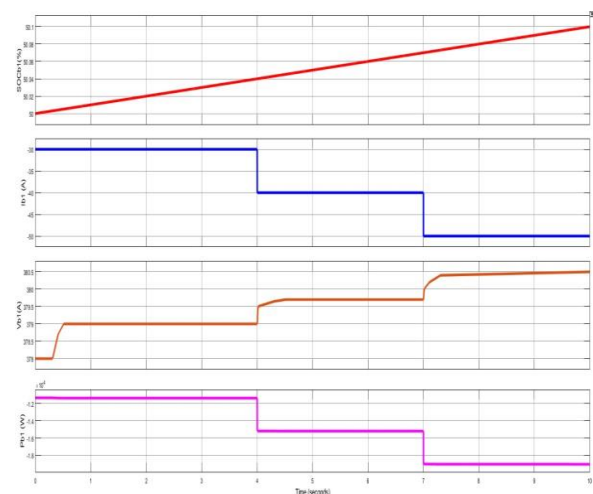
(a)



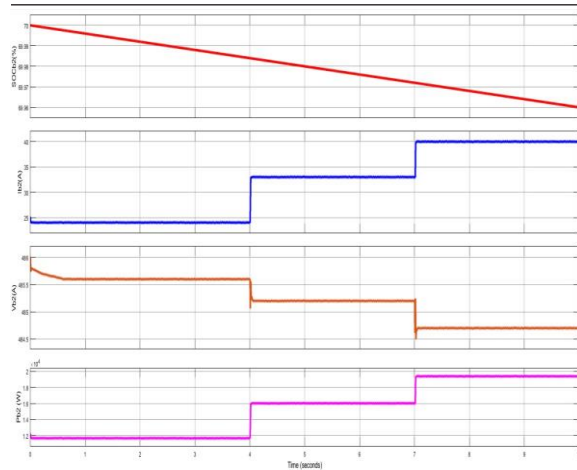
(b)

Fig. 6.5 Simulation results of the proposed V2V operation in forward boost mode with $V_{bat1} < V_{bat2}$. (a) SOC, voltage, current, and power waveforms of EV-1 battery. (b) SOC, voltage,

current, and power waveforms of EV-2 battery



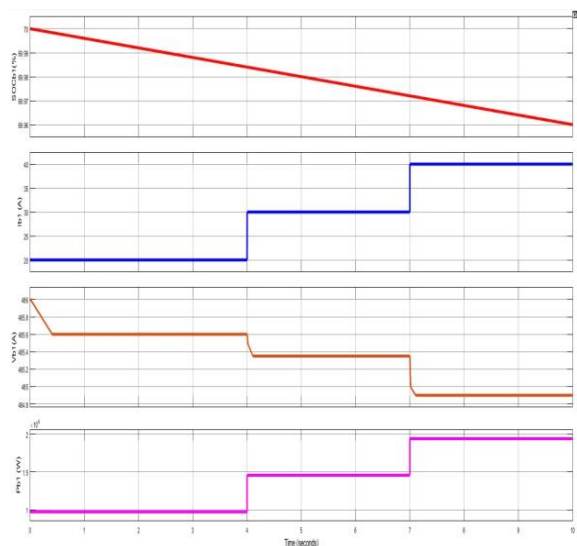
(a)



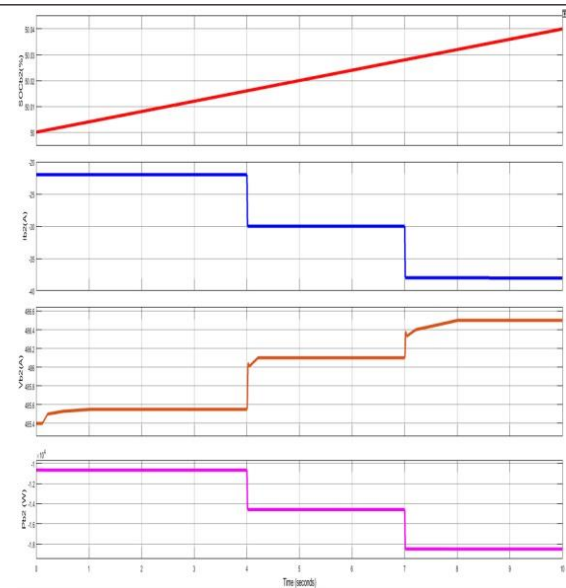
(b)

Fig. 6.6 Simulation results of the proposed V2V operation in the reverse buck mode with $V_{bat1} < V_{bat2}$. (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. 6.7 Simulation results of the proposed V2V operation in the forward boost mode with

$V_{bat1} = V_{bat2}$. (a) SOC, voltage, current, and power waveforms of EV-1 battery. (b)

SOC, voltage, current of EV-2 battery, and dc-link voltage.

Performance Comparison

Parameter	Existing System (PI Controller)	Extended System (FLC Controller)	Improvement
Controller Used	PI (Proportional-Integral)	FLC (Fuzzy Logic Controller)	✓ Advanced nonlinear control
Dynamic Response	Slower response; more overshoot	Fast dynamic response; minimal overshoot	✓ Faster & smoother
Steady-State Error	Noticeable error under load changes	Almost zero ~~steady-state~~ error	✓ Improved accuracy
Voltage Regulation	Moderate; ripple present	Very stable; reduced voltage ripple	✓ High stability
Current Ripple	Higher current ripple in boost/buck	Significantly reduced ripple	✓ Smooth current flow
Power Transfer Efficiency	Lower due to tuning limitations	Higher due to adaptive control	✓ Better efficiency
Performance Under Battery Mismatch ($V_{bat1} < V_{bat2}$)	Slow balancing; fluctuations	Fast, smooth, stable energy transfer	✓ Improved V2V balancing
Performance at Equal Voltage Condition ($V_{bat1} = V_{bat2}$)	Delay in power sharing	Immediate stabilization	✓ Better transition handling
Robustness to Parameter Variations	Low (needs constant tuning)	High (rule-based adaptation)	✓ Strong robustness
Overall System Stability	Moderate	Highly stable	✓ Enhanced system stability
Suitability for Nonlinear Systems	Poor	Excellent	✓ Best for EV V2V conditions

7. CONCLUSION

This paper presented a Fuzzy Logic Control (FLC) strategy for efficient Vehicle-to-Vehicle (V2V) energy transfer using on-board converters in electric vehicles (EVs). The proposed control method ensures fast dynamic response, precise current tracking, and robustness against system uncertainties, making it well-suited for real-time energy-sharing applications. By maintaining the current within a predefined hysteresis band, the FLC strategy effectively mitigates voltage fluctuations and improves power transfer stability. Simulation results validate the effectiveness of the proposed approach,

demonstrating enhanced energy transfer efficiency, reduced switching losses, and improved system stability under various load and state-of-charge (SOC) conditions. Compared to conventional control methods, FLC provides superior transient performance and adaptability to dynamic changes in energy demand. The findings of this research contribute to the advancement of intelligent and decentralized EV charging infrastructures, reducing dependency on fixed charging stations and promoting energy-sharing networks. Future work will focus on integrating predictive control techniques, optimizing hysteresis band selection, and exploring real-world implementations in large-scale V2V energy transfer systems.

Future scope

In the future, this system will be further integrated with Neural network technology to increase the efficiency of the system and also the proposed system will be implemented in real time

8. 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.
- [11] 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.
- [12] E. Ucer et al., “A flexible V2V charger as a new layer of vehicle-grid integration framework,” in Proc. IEEE Transp. Electrification Conf. Expo (ITEC), Jun. 2019, pp. 1–7.
- [13] 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.
- [14] 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.