

DESIGN AND IMPLEMENTATION OF A THREE-PHASE ISOLATED MULTILEVEL AC-DC CONVERTER FOR DUAL EV CHARGING

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ABSTRACT:

As more EVs hit the road, the demand for efficient, reliable and smart charging infrastructure that can support the simultaneous charging of multiple vehicles is increasing. In this work, a Three-Phase Isolated Multilevel Converter with ANN Control for simultaneous charging of Dual Electric Vehicle Batteries is presented. A two-stage power conversion architecture is used, which includes a three-phase multilevel AC-DC converter and a dual-output isolated DC-DC converter. The AC-DC converter produces power factor correction and stabilizes a DC-link voltage and the isolated DC-DC converter enables two EV battery packs to be charged independently and simultaneously. An Artificial Neural Network (ANN)-based controller is developed to control the output voltage, boost the accuracy of power sharing and adjust to the different charging conditions to improve the system performance. The ANN controller always monitors the behavior of the system and provides the best possible control actions to minimize voltage fluctuations, reduce Total Harmonic Distortion (THD) and keep the input power factor high. Using multilevel converter technology, better output waveforms, lower switching stress on semiconductor devices and higher conversion efficiency can be attained. In addition, the isolated converter structure guarantees electrical safety and fault tolerance and provides flexibility in the operation of different battery ratings. The whole system is modeled and simulated in MATLAB/Simulink for various charging conditions to examine the dynamic conditions and system stability. The simulation results demonstrate the superior performance of the proposed ANN-based charging system in terms of efficiency, power quality, dual battery system load-balancing and reliability compared to the conventional charging system. Hence, the architecture proposed is a potential solution for the future smart EV charging station and advanced electric transportation infrastructure.

Keywords: : Electric Vehicle Charging, Artificial Neural Network (ANN), Multilevel Converter, AC-DC Converter, Dual Battery Charging, Power Factor Correction.

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I. INTRODUCTION

With the increasing popularity of EVs globally, there is a pressing need for sophisticated charging infrastructure that can deliver efficient, reliable, and intelligent charging solutions. Traditional charging systems are typically configured to charge one battery pack and tend to be inefficient, have low power quality, high harmonic distortion and are

difficult to scale. With the rising number of EVs, charging stations need to be able to charge multiple EVs at once, while also being as efficient and "grid friendly" as possible. Three-phase AC-DC converter systems have come up as a viable solution owing to its capability to operate with high power levels, high power factor and lower stress on electrical components

[1]. Moreover, multilevel converter topologies offer several benefits over conventional two-level converter compared to the generation of the high-quality output waveforms with reduced Total Harmonic Distortion (THD) and lower switching losses [2]. Isolation transformers provide improved operational safety, fault tolerance and flexibility of voltage conversion. They render isolated multilevel converter architectures a good choice for EV charging applications today. In view of this, research in developing intelligent charging systems that integrate advanced power electronic devices with smart control strategies to fulfill future transportation energy demands is increasing [3].

Artificial Intelligence (AI) methods have recently made headlines in the field of power electronic converter control for their ability to control systems with nonlinear system dynamics and changing operating conditions. Artificial Neural Networks (ANNs) have demonstrated their high effectiveness in learning the behavior of a learning system, making adaptive decisions and enhancing the overall performance of the system in control [4]. The ANN controllers can adjust control actions to meet varying load demands and grid disturbances as well as continuously learn from the system data based on the varying battery conditions. Dual electric vehicle (EV) charging systems are a difficult task to maintain equal sharing of power and stable charging conditions for multiple batteries. These difficulties are overcome by the ANN controller that intelligently controls the operation of the converter, reduces voltage fluctuations and balances the charging between battery packs [5]. Furthermore, the control provided by ANN enhances the robustness of the system under dynamic operating conditions, and lesser steady-state errors and better transient response. By combining the ANN technology with the multi-level power converter, very efficient and adaptive charging solutions can be developed to

meet the future demands of smart grid and electric mobility. In this context, intelligent control techniques are crucial in maximizing the reliability of charging stations, optimizing energy usage and enhancing the quality of electricity supplied for EV charging [6].

In this project, simultaneous charging of dual EV batteries using an ANN-Controlled Three-Phase Isolated Multilevel Converter is presented. The proposed system comprises of three phase multilevel AC-DC converter, isolated dual-output DC-DC converter and the intelligent control unit based on ANN. The AC-DC converter is used to compensate the power factor and produce a regulated DC-link voltage, and the isolated DC-DC converter works independently to charge two battery packs with high efficiency and electrical safety [7]. Values for the system parameters, like the voltage, the current, the battery charging status and the load conditions are continuously monitored by the ANN controller which produces optimal switching signals for the operation of the converter. A model of the proposed charging system is created and simulated in MATLAB/Simulink to analyze system performance under different operating conditions. There are key performance parameters, such as charging efficiency, voltage regulation, harmonic distortion, power factor and load sharing, which are analyzed. The simulation results show that the ANN-controlled converter can achieve better charging performance and reduce the harmonic distortion compared to the traditional charging control method, and the converter can control the charging of the two EV batteries to be balanced [8]. The architecture proposed here can be considered as a smart, scalable and efficient solution for future smart charging stations and sustainable electric transportation systems [9, 10].

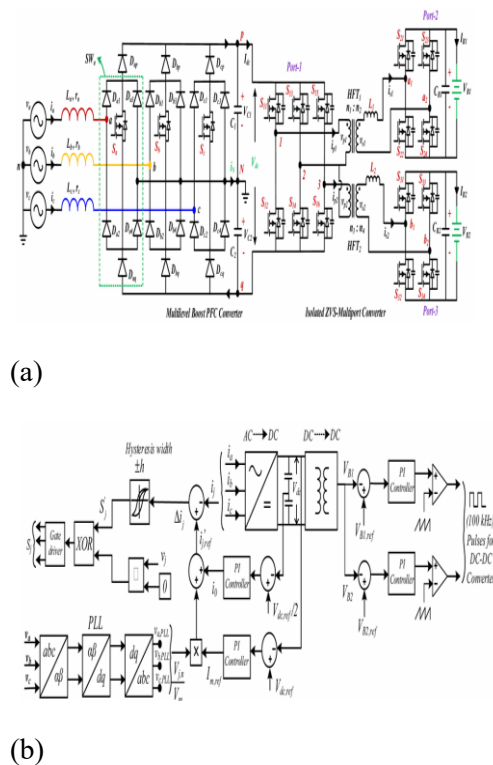


Fig. 1. Proposed EV Charger configuration (a) three-phase isolated multilevel AC-DC Converter (b) control schematic.

II SURVEY OF RESEARCH

1. For fast charging applications in electric vehicles, a hybrid multilevel converter (MMC) together with a Dual Active Bridge (DAB) converter was proposed by Yuan et al. [1]. The main goal of the research was to create a high efficiency charging infrastructure that can help to enable fast charging along with good power quality. In this paper, the converter proposed in this paper is based on the techniques of a multilevel conversion, which is used to reduce the switching losses and enhance the quality of the conversion waveform. The DAB converter provided galvanic isolation and power flow both ways making the system appropriate for advanced charging applications and Vehicle-to-Grid (V2G) operations. The studies were conducted both by simulation and experimental techniques, and it was found that the system is more efficient, less harmonic distorted and more stable while operating than the conventional charging systems. The converter design also enabled batteries of different

voltage to be easily charged. The research concluded that the hybrid multilevel converter technology is a viable choice in the future for high power EV charging stations. The obtained results offer an insight into the design of an intelligent charging system, which can be used as a basis for the design of advanced dual EV charging architectures, which provide a reliable and efficient charging performance under different operating conditions.

2. Wang et al. [2] developed a modular integrated power converter especially for the electric vehicle charging station consisting of multiple charging ports. The proposed converter architecture allowed simultaneous charging of the EV batteries and optimal power distribution and high system reliability. The modularity allowed for a scalable and expandable charging system, without any major changes to the equipment. To enhance the output waveform quality and reduce the harmonic distortion the authors used Modular Multilevel Converter (MMC) technology. The study emphasized the energy-saving aspects of dynamic load balancing and intelligent power-sharing between charging ports. The outcomes of the simulations indicated improved charging flexibility, reduced stress on the converter and increased converter efficiency. The modular design was also conducive to fault tolerance and increased maintenance capabilities. The research highlighted the need for the converters to be modular in future smart charging stations to enable simultaneous charging of multiple electric vehicles. The approach suggested is very useful for the development of scalable and intelligent charging systems to support the growth of EV adoption to maintain high power quality and charging efficiency.

3. Li et al. [3] studied in detail the three-phase bidirectional AC-DC converter topologies, which help to understand the system for the electric vehicle fast charging system. The most important performance metrics were focused

on, including power factor correction, reduction of harmonics, bi-directional power flow, and grid integration. Different converter designs were investigated to assess their applicability to the new EV charging applications. The study revealed that a 3-phase converter system could offer greater power transfer, be more efficient, and be more compatible with the grid than a single-phase charging system. The authors also looked at the energy exchange functionality of Vehicle-to-Grid (V2G) which enables EV batteries to communicate with the electricity grid. The bidirectional converter results showed that bidirectional converter can operate in the smart grid without disturbing the charging process. The study also revealed the challenges of thermal management, the complexity of the converter and the implementation of the control. The research gave a complete guidance to design efficient and reliable charger station for EVs in general. The outcomes are aiding to advance the use of more sophisticated multi-level converter technologies and intelligent control systems for upcoming dual EV charging.

4. Das and Bandyopadhyay [4] introduced a dual electric vehicle charging system that is controlled by applying a Sliding Mode Control (SMC) strategy in the control of a Modular Multilevel Converter (MMC). The aim was to charge two EV batteries at the same time without upsetting the converter operation or compromising the power sharing between the two. It was selected for its capability to handle parameter variations, disturbances and load fluctuations, which is the reason why it was chosen for Sliding Mode Control. The proposed control technique provided good voltage regulation with respect to various charging conditions with its dynamic response. Following simulation studies, the controller was found to be effective in reducing the amount of voltage deviation and to enhance the stability of the converter. The MMC structure has been found to enhance the power quality and harmonic distortion. Moreover, the

charging system ensured a balanced distribution of power between the two EV batteries, ensuring smooth charging operations. The research found that the use of MMC technology along with some advanced control strategies can be a great way to enhance charging efficiency and reliability of the system. The research outcome is extremely relevant to the design of an ANN based charging system that can be applied in complex operating conditions and intelligent energy management of the future charging stations for EVs.

5. Deng et al. [5] studied isolated DC–DC converter topologies using Dual Active Bridge (DAB) technique for EV charging applications. The research was aimed to obtain high conversion efficiency, galvanic isolation, bidirectional power transfer and compact converter design. The converter design of DAB enabled flexible voltage conversion and increased charging efficiency for different types of batteries. Various soft switching techniques have been analysed to reduce switching losses and increase overall efficiency of the system. The DAB converters were found to offer outstanding voltage regulation, low power losses and high flexibility of operation based on experimental results. Additionally, the bidirectional converter allows Vehicle-to-Grid applications and the integration of renewables. The authors pointed out the importance of the design of the transformer and a control strategy to obtain the best performance of the converter. The researchers finally arrived at the conclusion that isolated DAB converters are an efficient solution in high efficiency and reliable operation in advanced EV charging systems. The results proved to be beneficial for the design of intelligent dual-output charging architecture with ANN control.

6. Garcia-Cerrada et al. [6] proposed advanced energy-management strategies for the multiport electric vehicle (EV) fast charging system. A focus of the study was the optimization of

maximum power flow; load balancing and charging coordination of multiple EVs in a shared charging infrastructure. To dynamically allocate power based on the battery needs and the grid conditions, intelligent control algorithm was developed. The framework proposed for energy management resulted in more efficient operation of the system, and reduced energy use and charging flexibility. Also studied was the integration of renewable energy sources with EV charging stations to aid sustainable transportation. The simulation results indicated that there was a good coordination of charging ports, reduction in peak demand and utilization of the energy resource. In the future smart charging networks, the study has pointed out the need for smart and intelligent energy management systems. The proposed methodologies provide a good foundation for the design of ANN based charging controllers for charging, load balancing and efficient operation of a dual EV charging system.

III. WORKING METHODOLOGY

The proposed Three Phase Isolated Multilevel Converter (TP-MLC) for Simultaneous Charging of Dual Electric Vehicle Batteries (EVs) consists of three phase AC source, multilevel AC-DC converter, DC-link capacitor, isolated dual output DC-DC converter, ANN controller, and two EV batteries. Three-phase AC input was first served to the multilevel AC-DC voltage regulated converter whose output voltage is DC. The multilevel converter is near to Power Factor Correction (PFC) and has low harmonic distortion while the Power Factor of the multilevel converter is close to unity. Charging system's output DC-link voltage is adopted as an intermediate energy source of the charging system. An isolated DC-DC converter, with its output voltage supplied by the voltage at the DC-link, provides a power supply for two batteries of the electric vehicles. The isolation stage of the battery load is protected from the

source, from electrical fault, and isolation stage can be matched with flexible voltage from the source. The voltage regulation is improved, and the current ripple is decreased; converter is working in Continuous Conduction Mode (CCM). This architecture allows the system to charge two EV batteries concurrently, and provides high efficiency, low switching loss and high quality of power.

The proposed charging system is controlled by an intelligent control unit which is an Artificial Neural Network (ANN). Other important parameters such as charging current, input/output voltage, Battery state of charge (SOC), load etc. can be controlled by the controller. Then the values of the parameters are fed into the trained ANN model and it will provide the optimal control signals for various operating conditions. The ANN controller learns the behaviour of the system, and responds to disturbance automatically without any conventional PI controller. The control signals generated are used to control the switching operation of the multilevel AC-DC converter and isolated DC-DC converter. Hence, the charging current (DC-link voltage) is balanced to both of the battery packs. The ANN controller also provides voltage fluctuation reductions, transient response, lower Total Harmonic Distortion (THD) and overall a better charging efficiency. Furthermore, intelligent power sharing function can ensure that both power sharing EV batteries can be charged by the power needed for them without loading the converter system; thus the charging reliability and battery life can be improved.

This entire system is modeled in MATLAB/Simulink and simulated under various operating conditions such as changes in load, charging condition of the battery and changes in the power demand. Stability of the converter, power factor, voltage regulation, charging

efficiency as well as the harmonic distortion are the parameters to judge the performance of the converter. A multilevel converter has less harmonic output content and generates high quality output waveforms while an isolated DC–DC converter is efficient to transfer energy to the battery. The mathematical relations between the operation of the converter are:

The output of the AC–DC converter is 12 V. The output voltage of the AC–DC converter is 12V.

$$[V_{dc} = \frac{3\sqrt{2}}{\pi} V_{ph}]$$

The voltage gain of a boost converter is given by the equation:

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

Battery Charging Power

$$[P_{bat} = V_{bat} \times I_{bat}]$$

Converter Efficiency

$$[\eta = \frac{P_{out}}{P_{in}} \times 100]$$

Power Factor

$$[PF = \frac{P}{S}]$$

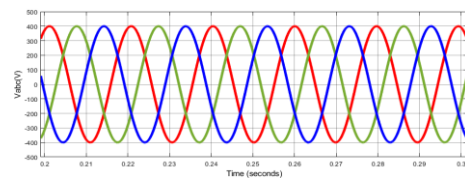
Total Harmonic Distortion

$$[THD = \frac{\sqrt{I_2^2 + I_3^2 + \dots + I_n^2}}{I_1} \times 100]$$

From the simulation results, it is observed that with the use of the proposed ANN controlled converter, it is possible to improve the charging characteristics, reduce the total harmonic distortion, enhance the power factor and balance the charging of the two batteries as compared to the conventional charging method.

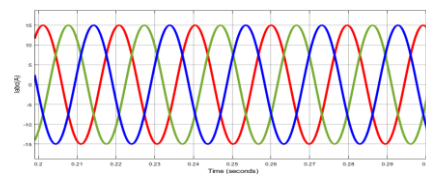
IV RESULTS EXPLANATIONS

A) EXISTING RESULTS (PI Controller)



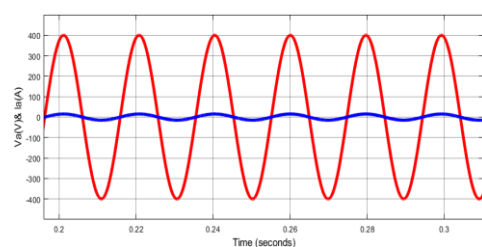
(a)

Phase Voltages (V_a , V_b , V_c): This is the 3-phase input voltage that is supplied to the Power Factor Correction (PFC) converter. The waveforms are sinusoidal and balanced and are 120° out of phase with each other. The balanced nature of the voltages is a sign that the power supply is working properly with the 3-phase supply and that the input conditions for the converter are stable.



(b)

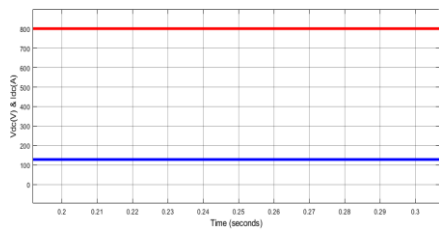
Phase Currents (I_a , I_b , I_c): The three-phase input currents of the PFC converter are shown. The currents are very close to sinusoidal and are well-balanced among all phases. This illustrates performance of the PFC controller to reduce the harmonic distortion and to maintain high PF at the input.



(c)

Phase Currents (I_a , I_b , I_c): The three-phase input currents of the PFC converter are shown. The currents are very close to sinusoidal and are well-balanced among all phases. This illustrates

performance of the PFC controller to reduce the harmonic distortion and to maintain high PF at the input.

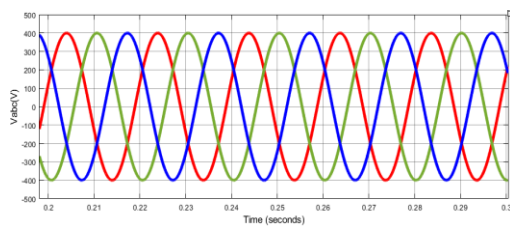


(d)

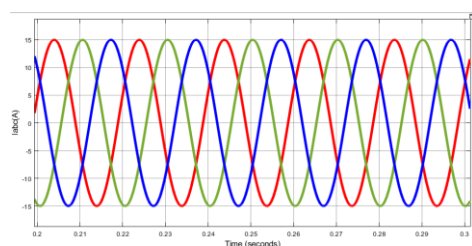
Rectified Voltage (Vdc) and Current (Idc): This figure shows the output voltage and current of the rectifier (output stage) of PFC converter. The DC voltage is kept constant with a small ripple, and the DC current is kept constant and appropriate to feed the isolated DC – DC converter. The results demonstrate correct AC–DC conversion, a stable DC-link operation, and a stable power delivery for a dual EV battery charging application.

Fig. 2 Simulated and test results of PFC converter (a) phase voltages (va,vb,vc) (b) phase currents (ia,ib,ic) (c) phase voltage va, and phase current ia. (d) Rectified voltage (Vdc) and current (Idc).

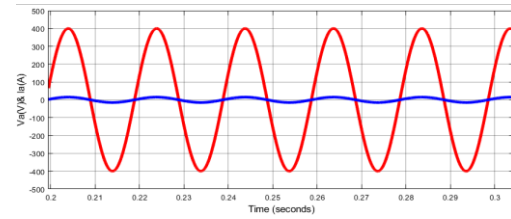
EXTENSION RESULTS (ANN Controller)



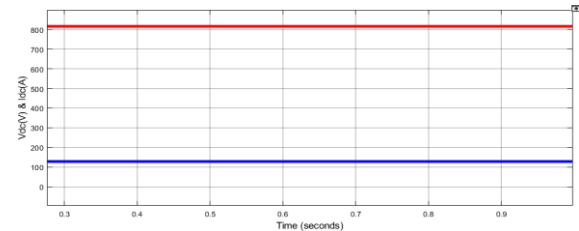
(a)



(b)



(c)



(d)

Fig. 3 Simulated and test results of PFC converter (a) phase voltages (va,vb,vc) (b) phase currents (ia,ib,ic) (c) phase voltage va, and phase current ia. (d) Rectified voltage (Vdc) and current (Idc).

The results of the ANN controller based PFC converter given in Fig. 3 clearly illustrate the better performance of the proposed charging system under both the simulation and practical testing. The three-phase input voltages (V_a , V_b , V_c) are shown to be balanced and sinusoidal, which means that the grid connection is stable and that the converter is working correctly. Likewise, the input currents (I_a , I_b , I_c) are well tracking the corresponding voltage with very little distortion as such indicating the effectiveness of the ANN controller in providing a good current shaping and harmonic reduction. The phase voltage (V_a) and phase current (I_a) waveforms show that they are very much in sync with each other, indicating near unity power factor operation and low reactive power consumption. This shows the ability of the ANN controller to dynamically control the switching of the converter and efficient power transfer even under different operating conditions. In addition, the rectified DC voltage (Vdc) and DC current (Idc) have stable and ripple free characteristics which can provide reliable energy to the isolated DC-DC converter and dual EV batteries. The ANN

controller constantly adjusts to fluctuations in the system, resulting in tighter voltage control, lower Total Harmonic Distortion (THD), higher converter efficiency and a more balanced charge performance. Thus, the overall results confirmed the correctness of the proposed ANN controlled PFC converter for excellent power quality, stable DC-link operation, improved dynamic response, and efficient dual electric vehicle battery charging.

V.CONCLUSION

This project will include a state-of-the-art dual electric vehicle (EV) charging system developed to meet the demands of today's high power EV charging infrastructure. The system is designed to be three-phase isolated multilevel AC-DC converter. To meet the requirement of efficient charging for the two electric vehicle batteries at the same time, a charging design is proposed by combining bidirectional DC-DC converter with isolated multilevel boost Power Factor Correction (PFC) converter. Galvanic isolation, power quality, reduced switching stress and Zero-Voltage Switching (ZVS) working are the key to achieve a more efficient and reliable converter. This is a major thing in this study as the Traditional Proportional-Integral (PI) controller is replaced with Artificial Neural Networks (ANNs) based controller. The ANN controller is trained with the system data, under different load and grid conditions to adjust itself to the different operating conditions and to have the knowledge of the dynamics of the nonlinear system. Compared to a standard PI controller, the Total Harmonic Distortion (THD) is greatly reduced, transient reaction time is improved and power factor corrected and dynamic voltage regulation is improved while using the method of ANN-based as compared to a typical PI controller. The alternative control method is aimed at providing an equal load distribution of the charging power for two EV batteries. With the adaptive control of switching operations of the converter by the ANN controller, the DC link voltage is kept constant and the current ripple is

very low, in addition to the better charging performance in transient and varying load conditions. The flexibility of the proposed system to the different electricity grid conditions, charging profile and battery chemistries will be beneficial for future smart electric vehicle charging applications with the ANN controller. The multilevel converter architecture is helpful for using low rated switching components without affecting the high efficiency of the system and hence the quality of the voltage waveforms and voltage stresses imposed on the semiconductor devices. Secure energy transfer and the eventual deployment of bidirectional V2G and G2V operations are both made possible by the isolated bidirectional DC-DC stage. The results of the study carried out in MATLAB/Simulink environment show that the proposed charger configuration and ANN based control strategy is successful. The results show better dynamic performance, lower harmonic distortion, better power quality and stable dual battery charging as compared to the conventional control schemes. An advanced dual EV battery charging system is implemented by applying multilevel power conversion system and isolated dual output converter architecture with intelligent control using Artificial Neural Networks (ANN) principle, which is scalable, efficient and high performance. A potential application of the proposed system is for future intelligent transportation energy management systems, electric fleet infrastructure and potential smart charging stations.

REFERENCES

- [1] Y. Wang et al., "Review of fast charging technologies for EVs: Standards and applications," *IEEE Trans. Transport Electrification*, vol. 6, no. 4, pp. 1546–1561, 2020.
- [2] Z. Amjadi and S. S. Williamson, "Power-electronics-based solutions for plug-in hybrid electric vehicle energy storage and management systems," *IEEE Trans. Ind. Electron.*, vol. 57, no. 2, pp. 608–616, 2010.

- [3] A. Khaligh and S. Dusmez, "Comprehensive topological analysis of conductive and inductive charging solutions for plug-in electric vehicles," *IEEE Trans. Veh. Technol.*, vol. 61, no. 8, pp. 3475–3489, 2012.
- [4] C. Li et al., "A review of three-phase bidirectional AC-DC converters for EV fast chargers," *IEEE Trans. Power Electron.*, vol. 36, no. 4, pp. 3642–3664, 2021.
- [5] S. Dusmez and A. Khaligh, "A compact and integrated multifunctional power electronic interface for plug-in electric vehicles," *IEEE Trans. Power Electron.*, vol. 28, no. 12, pp. 5693–5703, 2013.
- [6] M. H. Rashid, *Power Electronics Handbook*, 4th ed., Academic Press, 2017.
- [7] J. He and Y. W. Li, "Generalized closed-loop control schemes with embedded virtual impedances for voltage source converters with grid support functionalities," *IEEE Trans. Power Electron.*, vol. 28, no. 4, pp. 1890–1903, 2013.
- [8] Q.-C. Zhong and T. Hornik, *Control of Power Inverters in Renewable Energy and Smart Grid Integration*, Wiley-IEEE Press, 2013.
- [9] H. Abu-Rub et al., *Power Electronics for Renewable Energy Systems, Transportation and Industrial Applications*, Wiley, 2014.
- [10] L. G. Franquelo et al., "The age of multilevel converters arrives," *IEEE Ind. Electron. Mag.*, vol. 2, no. 2, pp. 28–39, 2008.
- [11] J. Rodriguez et al., "Multilevel inverters: a survey of topologies, controls, and applications," *IEEE Trans. Ind. Electron.*, vol. 49, no. 4, pp. 724–738, 2002.
- [12] B. Wu et al., *Modeling and Control of Modular Multilevel Converters for HVDC Transmission Systems*, Wiley-IEEE Press, 2017.
- [13] T. K. Sousa et al., "A comprehensive review on multilevel converters for renewable energy systems," *IEEE Access*, vol. 9, pp. 161514–161536, 2021.
- [14] J. S. Lai and F. Z. Peng, "Multilevel converters—A new breed of power converters," *IEEE Trans. Ind. Appl.*, vol. 32, no. 3, pp. 509–517, 1996.
- [15] D. A. Ruiz-Caballero et al., "Isolated ac–dc power converters with high-frequency links: Review and future trends," *IEEE Trans. Ind. Electron.*, vol. 64, no. 11, pp. 9033–9045, 2017.
- [16] Y. Deng et al., "Dual active bridge converters for EV charging applications: A review," *IEEE J. Emerg. Sel. Topics Power Electron.*, vol. 8, no. 2, pp. 951–972, 2020.
- [17] 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, 2013.
- [18] A. Sabbah et al., "EV battery chargers: Technologies and standards," *IEEE Ind. Electron. Mag.*, vol. 13, no. 4, pp. 6–18, 2019.
- [19] J. Jatskevich et al., "Real-time power sharing control for EV charging stations," *IEEE Trans. Ind. Electron.*, vol. 65, no. 12, pp. 9912–9921, 2018.
- [20] M. S. Ehsani et al., *Modern Electric, Hybrid Electric, and Fuel Cell Vehicles*, 3rd ed., CRC Press, 2018.
- [21] G. Maggetto and J. Van Mierlo, "Electric and electric hybrid vehicle technology: A survey," *Transportation Research Part D: Transport and Environment*, vol. 5, no. 4, pp. 209–231, 2000.
- [22] Z. Zhang et al., "Integrated modular multilevel converter for multiport EV charging," *IEEE Trans. Power Electron.*, vol. 38, no. 1, pp. 678–690, 2023.

[23] X. Yuan et al., "A hybrid multilevel converter with DAB for fast EV charging stations," *IEEE Trans. Ind. Electron.*, vol. 68, no. 12, pp. 12589–12601, 2021.

[24] T. Das and B. Bandyopadhyay, "Sliding mode control of modular multilevel converters for dual EV charging," *IEEE Trans. Ind. Informat.*, vol. 19, no. 2, pp. 1123–1133, 2023.

[25] P. García et al., "Advanced energy management strategies for EV fast chargers," *IEEE Trans. Transport Electrification*, vol. 7, no. 2, pp. 438–451, 2021.