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SIMULATION OF AN INTELLIGENT ANN-BASED THREE-PHASE MULTILEVEL ISOLATED CONVERTER FOR CONCURRENT CHARGING OF DUAL EV BATTERIES

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ABSTRACT

This paper presents an intelligent EV charging system based on a two-stage converter architecture designed for simultaneous charging of dual electric vehicle batteries. The proposed system integrates a three-phase multilevel boost power factor correction (PFC) AC–DC converter with a bidirectional isolated dual-output DC–DC converter employing zero-voltage switching (ZVS). The two stages operate independently, allowing effective control without mutual interference and ensuring stable operation in continuous conduction mode. To enhance system performance, an Artificial Neural Network (ANN)-based controller is implemented, replacing conventional control techniques. The ANN controller is trained to dynamically regulate output voltage, minimize total harmonic distortion (THD), and maintain a high power factor under varying load and grid conditions. Additionally, it enables balanced power distribution between the two batteries and improves transient response and system stability. The proposed architecture supports efficient energy conversion, reduced switching losses, and reliable dual battery management. Simulation results carried out in the MATLAB/Simulink environment demonstrate the effectiveness of the system in achieving high efficiency, improved power quality, and intelligent control performance. Therefore, the proposed ANN-based multilevel isolated converter provides a promising solution for next-generation fast and smart EV charging infrastructure.

Keywords: EV charging, multilevel converter, ANN controller, power factor correction, dual battery charging, zero-voltage switching, total harmonic distortion

INTRODUCTION

The rapid growth of electric vehicles (EVs) has become a defining trend in modern transportation, driven by the urgent need to reduce greenhouse gas emissions, minimize dependence on fossil fuels, and improve overall energy efficiency. Governments and industries worldwide are actively promoting EV adoption through policy incentives, technological advancements, and infrastructure development. However, the increasing penetration of EVs poses significant challenges to existing power systems, particularly in terms of charging infrastructure, grid stability, and power quality. Conventional charging systems, especially single-phase chargers, are often limited in power handling capability and exhibit poor power quality characteristics such as high total harmonic distortion (THD) and low power factor, making them unsuitable for fast and large-scale charging applications [1]. Furthermore, the growing demand for simultaneous charging of multiple EVs necessitates the development of advanced charging architectures that are efficient, scalable, and capable of handling dynamic load conditions [2].

To address these limitations, three-phase AC–DC converter systems have emerged as a preferred solution for high-power EV charging applications. These systems offer advantages such as higher power transfer capability, reduced current stress on components, and improved grid interaction. However, conventional two-level converters used in such systems suffer from issues like high switching losses, increased voltage stress, and poor harmonic performance at higher voltage levels [3]. Multilevel converter topologies, including neutral point clamped (NPC), flying capacitor (FC), and cascaded H-bridge (CHB) configurations, provide an effective alternative by producing stepped voltage waveforms that closely approximate sinusoidal outputs. This results in reduced THD, lower electromagnetic

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interference (EMI), and improved efficiency [4]. Additionally, multilevel converters enable operation at higher voltage levels without increasing device stress, making them highly suitable for fast-charging infrastructure [5].

Another important aspect of modern EV charging systems is the need for isolation and bidirectional power flow. Isolated DC–DC converters, particularly those based on high-frequency transformers, play a crucial role in ensuring safety, voltage matching, and flexibility in multi-port charging applications. Among these, dual-active bridge (DAB) converters and multiport DC–DC converters have gained significant attention due to their capability for bidirectional power transfer and high efficiency through soft-switching techniques such as zero-voltage switching (ZVS) [6]. These converters enable independent control of multiple output ports, facilitating simultaneous charging of multiple EV batteries with different voltage and capacity requirements [7]. Moreover, the integration of such converters supports advanced functionalities like vehicle-to-grid (V2G) operation, energy storage management, and renewable energy integration [8].

Despite these advancements, the control of multilevel and multiport converter systems remains a complex challenge due to their nonlinear behaviour, parameter variations, and dynamic operating conditions. Traditional control methods, such as proportional-integral (PI) controllers, are widely used but often fail to provide optimal performance under varying load and grid disturbances. In recent years, intelligent control techniques, particularly Artificial Neural Networks (ANN), have been explored to overcome these limitations. ANN-based controllers are capable of learning system behaviour from data, adapting to nonlinearities, and providing faster dynamic response compared to conventional methods [9]. They can effectively regulate output voltage, minimize THD, maintain unity power factor, and ensure balanced power sharing among multiple charging ports [10]. This makes ANN-based control a promising approach for next-generation EV charging systems [11].

In this context, the present work focuses on the development of an intelligent EV charging architecture that integrates a three-phase multilevel boost PFC converter with an isolated multiport DC–DC converter for simultaneous dual battery charging. The system is designed to operate efficiently under varying load conditions while maintaining high power quality and reliability. The incorporation of an ANN-based control strategy enhances system performance by providing adaptive and precise control over key parameters such as voltage regulation, harmonic reduction, and power distribution [12]. Simulation studies carried out in the MATLAB/Simulink environment validate the effectiveness of the proposed system in achieving improved efficiency, reduced THD, and stable operation [13]. The proposed approach not only addresses the limitations of conventional charging systems but also contributes to the development of intelligent, scalable, and sustainable EV charging infrastructure suitable for future smart grid applications [14], [15].

LITERATURE SURVEY

The development of efficient and high-performance EV charging systems has attracted significant research attention in recent years, particularly with the increasing demand for fast and multi-vehicle charging infrastructure. Early studies focused on improving AC–DC converter performance for EV applications, emphasizing power factor correction (PFC) and harmonic reduction. Researchers have explored various three-phase bidirectional AC–DC converter topologies to enhance grid interaction and enable high-power charging capabilities. These works highlight the limitations of conventional converters, such as increased switching losses and poor harmonic performance, especially under high-voltage operation [1], [3]. To overcome these issues, multilevel converter topologies have been introduced, offering improved output waveform quality, reduced total harmonic distortion (THD), and lower voltage stress on switching devices [2], [4]. These advancements make multilevel converters a suitable candidate for modern EV charging stations requiring high efficiency and scalability [5].

Further research has concentrated on integrating isolated DC–DC converter stages with multilevel AC–DC front ends to enhance system safety, flexibility, and performance. Dual-active bridge (DAB) converters and multiport isolated converters have been widely investigated for their ability to support bidirectional power flow and multiple output ports. These converters employ high-frequency transformers to provide galvanic isolation and enable independent control of charging ports, making them ideal for simultaneous charging of multiple EV batteries [6], [7]. Additionally,

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soft-switching techniques such as zero-voltage switching (ZVS) have been incorporated to minimize switching losses and improve overall system efficiency [8]. Modular multilevel converter (MMC)-based architectures have also been proposed to achieve better scalability and dynamic power sharing among multiple charging ports, addressing the growing demand for multi-EV charging systems [9], [10].

Another important area of research focuses on advanced control strategies for managing power flow and maintaining system stability in EV charging systems. Conventional control methods, such as proportional-integral (PI) controllers, have been widely used due to their simplicity and ease of implementation. However, these controllers often exhibit limited performance under nonlinear conditions and dynamic load variations [11]. To address these challenges, robust control techniques such as sliding mode control and model predictive control have been proposed, offering improved dynamic response and disturbance rejection capabilities [4], [12]. Moreover, power sharing control strategies have been developed to ensure balanced distribution of energy among multiple charging ports, which is essential for efficient operation in dual or multi-EV charging scenarios [8], [13].

In recent years, intelligent control approaches based on artificial intelligence have gained significant attention for EV charging applications. Artificial Neural Network (ANN)-based controllers, in particular, have been widely explored due to their ability to learn complex system dynamics and adapt to varying operating conditions. These controllers provide enhanced voltage regulation, reduced THD, and improved power factor compared to traditional control techniques [14]. ANN-based strategies also enable real-time optimization of power distribution between multiple EV batteries, ensuring efficient and balanced charging performance [15]. The integration of intelligent control with advanced multilevel and multiport converter topologies represents a promising direction for future EV charging systems, offering improved efficiency, reliability, and adaptability in smart grid environments.

METHODOLOGY

The proposed methodology begins with the design of a two-stage EV charging architecture capable of supporting simultaneous dual battery charging with high efficiency and improved power quality. A three-phase AC supply is considered as the input source, which is interfaced with a multilevel boost power factor correction (PFC) converter. The purpose of this front-end converter is to convert AC power into a regulated DC output while ensuring near-unity power factor and reduced harmonic distortion. Input side inductors and switching devices are configured to shape the source current into a sinusoidal waveform synchronized with the grid voltage. This configuration enables the system to operate in continuous conduction mode, thereby minimizing current ripple and improving overall efficiency.

The generated DC link voltage is then fed into an isolated multiport DC–DC converter designed to charge two EV batteries simultaneously. The DC–DC stage incorporates high-frequency transformers to provide galvanic isolation and voltage matching between the input and output sides. The converter is structured with one primary port and two secondary ports, each dedicated to an individual battery. By controlling the phase shift between primary and secondary switching signals, power flow to each battery is regulated independently. The presence of leakage inductances and proper switching coordination allows the converter to achieve zero-voltage switching (ZVS), which significantly reduces switching losses and enhances system efficiency.

To maintain stable operation and high power quality, a closed-loop control mechanism is implemented for both the AC–DC and DC–DC stages. In the front-end converter, a voltage control loop is used to regulate the DC link voltage, while a current control loop ensures that the input current follows the reference sinusoidal waveform. A phase-locked loop (PLL) is employed to synchronize the system with the grid voltage, enabling accurate reference signal generation. Additionally, a hysteresis-based current control technique is utilized to generate switching pulses, allowing fast dynamic response and effective tracking of the reference current under varying load conditions.

In the DC–DC stage, control is achieved by adjusting phase shift parameters corresponding to each output port. These parameters determine the amount of power transferred from the primary side to each battery, ensuring balanced and controlled charging. The system is designed to handle variations in battery voltage and state of charge, allowing

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independent regulation of each output. The control strategy also ensures that the DC link voltage remains stable despite fluctuations in load demand, thereby maintaining consistent system performance during transient conditions.

To further enhance the performance of the overall system, an Artificial Neural Network (ANN)-based controller is incorporated in place of conventional controllers. The ANN is trained using input-output data obtained under different operating conditions, enabling it to learn the nonlinear characteristics of the system. The inputs to the ANN include error signals and their variations, while the output generates appropriate control signals for switching devices. This approach improves voltage regulation, reduces total harmonic distortion, and ensures faster dynamic response compared to traditional methods. The entire system is modeled and simulated in the MATLAB/Simulink environment to validate its effectiveness, demonstrating improved efficiency, stable operation, and reliable dual battery charging performance.

PROPOSED SYSTEM

The proposed system presents an advanced electric vehicle (EV) charging architecture designed to enable simultaneous charging of two EV batteries with high efficiency, improved power quality, and intelligent control. The system is structured as a two-stage power conversion unit consisting of a three-phase multilevel boost power factor correction (PFC) AC–DC converter followed by an isolated multiport DC–DC converter. The front-end converter is responsible for converting the three-phase AC input into a regulated DC output while maintaining near-unity power factor and minimizing total harmonic distortion (THD). By employing a multilevel topology, the converter produces stepped voltage waveforms that closely approximate sinusoidal signals, thereby reducing switching losses, electromagnetic interference, and stress on power electronic components. This makes the system highly suitable for high-power EV charging applications where efficiency and reliability are critical.

The second stage of the proposed system is an isolated multiport DC–DC converter designed to facilitate dual battery charging. This converter utilizes high-frequency transformers to provide galvanic isolation and ensure safe operation between the input and output sides. It consists of a primary full-bridge converter connected to the DC link and two secondary full-bridge converters connected to individual EV batteries. The use of identical transformer configurations ensures equal voltage distribution and consistent performance across both charging ports. The converter operates based on phase-shift control, where the amount of power transferred to each battery is determined by adjusting the phase shift between the primary and corresponding secondary switching signals. This configuration allows independent and precise control of charging power for each battery, enabling flexible operation even when the batteries have different voltage levels or states of charge.

A key feature of the proposed system is the implementation of zero-voltage switching (ZVS) in the DC–DC stage, which significantly enhances efficiency by reducing switching losses. The presence of leakage inductances in the transformer and proper synchronization of switching signals enable soft-switching operation across all power devices. This not only improves efficiency but also reduces thermal stress and extends the lifespan of the components. Additionally, the system supports bidirectional power flow, making it compatible with advanced functionalities such as vehicle-to-grid (V2G) operation and energy storage integration. The multilevel PFC converter and isolated DC–DC converter operate independently, ensuring that variations in one stage do not adversely affect the performance of the other, thereby improving overall system stability.

To further enhance system performance, an Artificial Neural Network (ANN)-based controller is integrated into the control architecture. The ANN controller replaces conventional control methods and is trained using system data under various operating conditions to capture nonlinear characteristics and dynamic behaviour. It receives inputs such as voltage and current errors and generates optimal control signals for switching devices. This intelligent control approach enables precise voltage regulation, reduced THD, and improved power factor, even under fluctuating load and grid conditions. Moreover, the ANN ensures balanced power sharing between the two batteries and provides faster dynamic response compared to traditional controllers. The entire system is modeled and validated using MATLAB/Simulink simulations, demonstrating its capability to achieve efficient, stable, and intelligent dual EV charging, making it a promising solution for future smart charging infrastructure.

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RESULTS AND DISCUSSION

The performance of the proposed intelligent EV charging system is evaluated using detailed simulations carried out in the MATLAB/Simulink environment. The system is analyzed under various operating conditions, including changes in load demand, variations in input voltage, and simultaneous charging of two EV batteries. The results demonstrate that the three-phase multilevel boost PFC converter effectively converts the AC input into a stable DC output while maintaining near-unity power factor. The input current waveform is observed to be highly sinusoidal and in phase with the supply voltage, indicating successful power factor correction. Compared to conventional two-level converters, the multilevel configuration significantly reduces harmonic distortion, thereby improving overall power quality and ensuring compliance with grid standards.

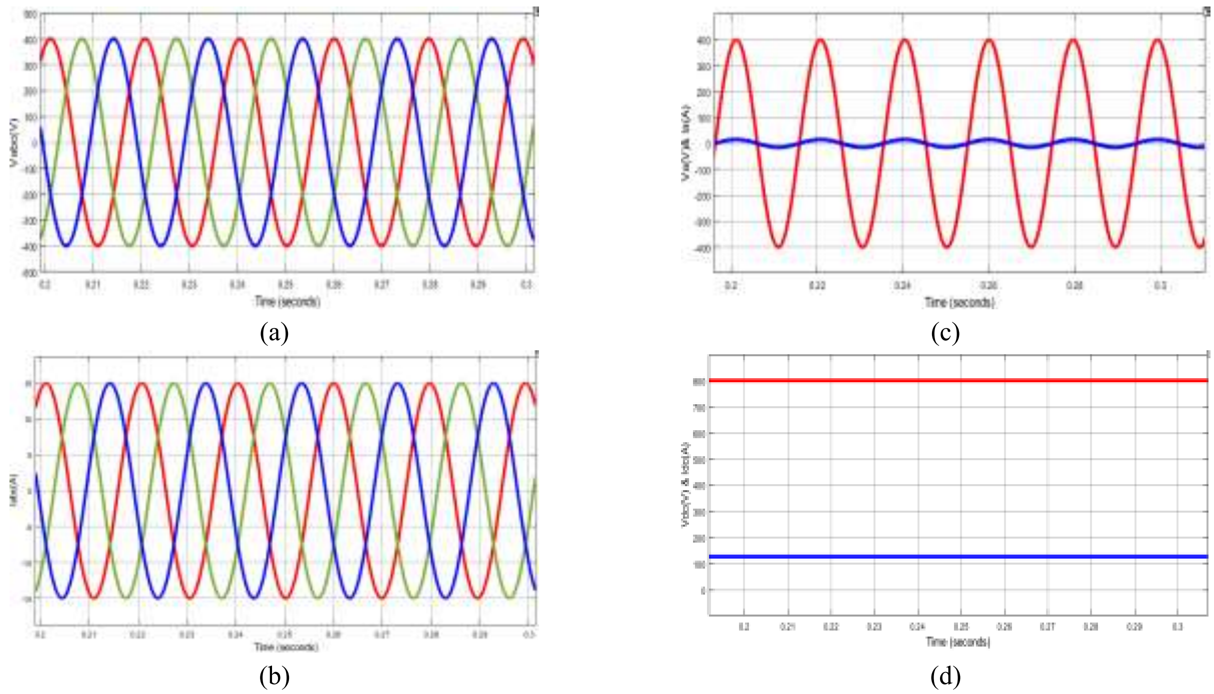

Fig 1. Simulated and test results of PFC converter (a) phase voltages (va,vb,vc) (b) phase currents (ia,ib,ic) (c) phase voltage va, and phase current ia. (d) Rectified voltage (Vdc) and current (Idc).

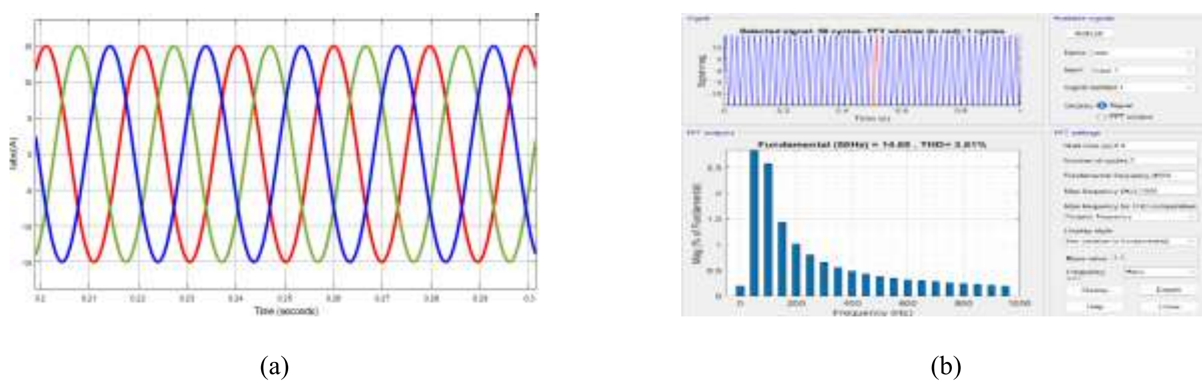

Fig 2. Test results of PFC converter (a) phase currents (b) total current harmonic distortion

The DC link voltage plays a crucial role in maintaining the stability of the entire system. Simulation results show that the proposed control strategy maintains a constant DC link voltage with minimal fluctuations, even under dynamic load conditions. During transient events such as sudden load changes or switching between charging modes, the

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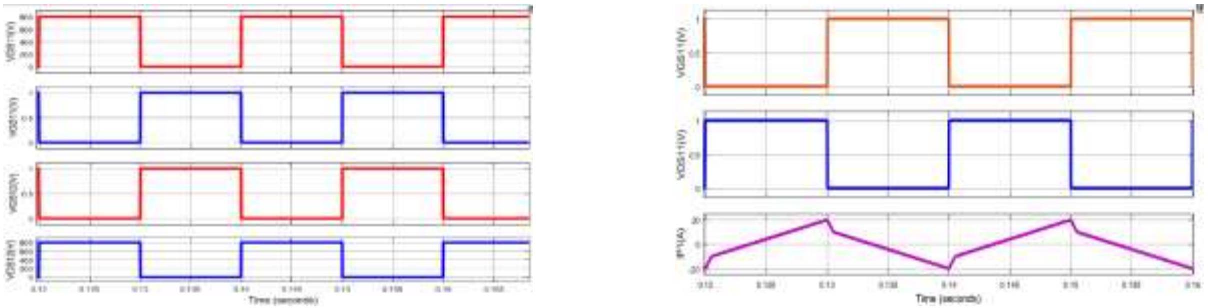
voltage settles quickly without excessive overshoot or oscillations. This improved dynamic response can be attributed to the effective coordination between the AC–DC and DC–DC stages, as well as the implementation of advanced control techniques. The stable DC link ensures consistent power delivery to the DC–DC converter, thereby enhancing the reliability of the dual battery charging process.



(a) (b)

Fig 3. Simulated results of ZVS-MPC(a)&(b)Port1ZVSoperation of switch S11 & S12.

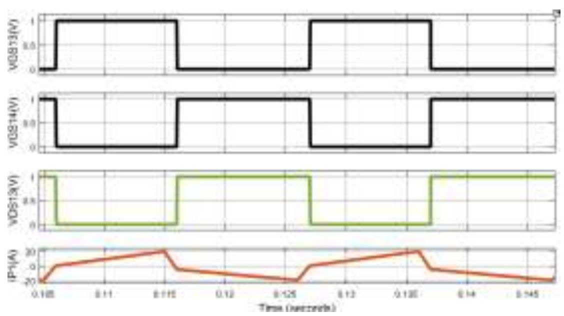


Fig 4. Simulated results of switching pulses for S13, S14 and switch voltage VDS13, current ip1.

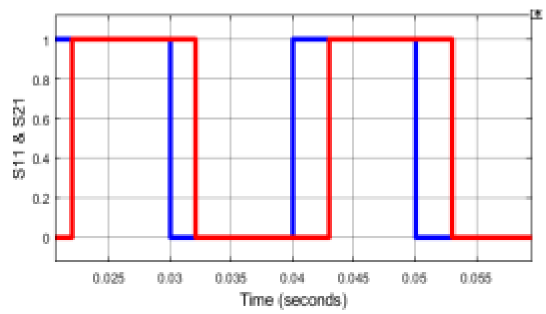
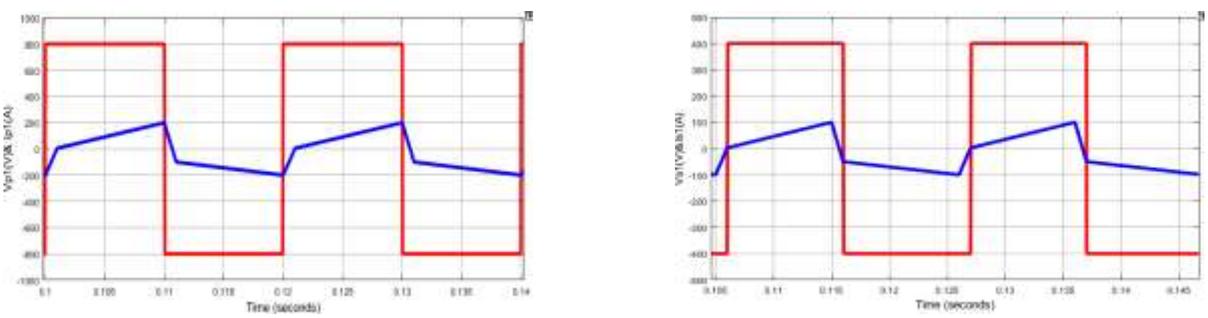


Fig 5. Simulation and test results of Phases hiftd1 between port1 and port2.



(a) (b)

Fig 6. Simulated results of DC-DC converter (a) primary side voltage/current of HFT1, (b) secondary side voltage/current of HFT1**.**

The performance of the isolated multiport DC–DC converter is evaluated based on its ability to deliver controlled and balanced power to two EV batteries. The results indicate that the converter successfully distributes power between the two output ports according to the specified control parameters. Even when the batteries have different initial states of charge or voltage levels, the system maintains independent control over each charging port. The phase-shift control mechanism allows precise regulation of power flow, ensuring that both batteries are charged efficiently without interference. Additionally, the implementation of zero-voltage switching (ZVS) is validated through reduced

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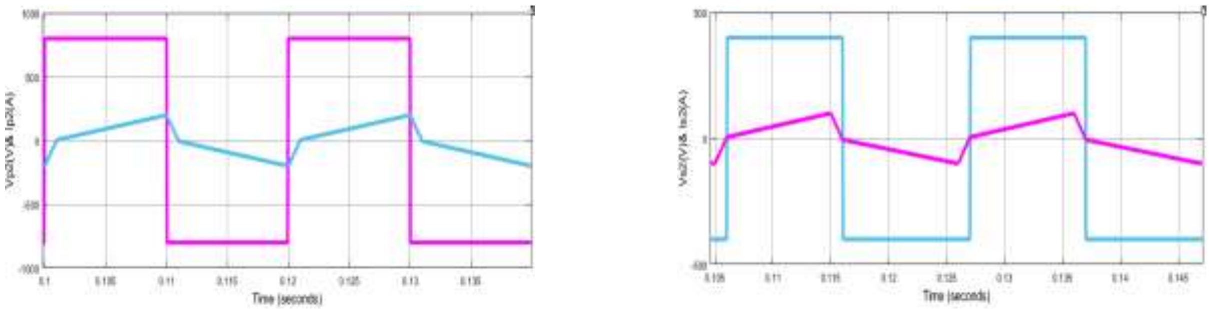
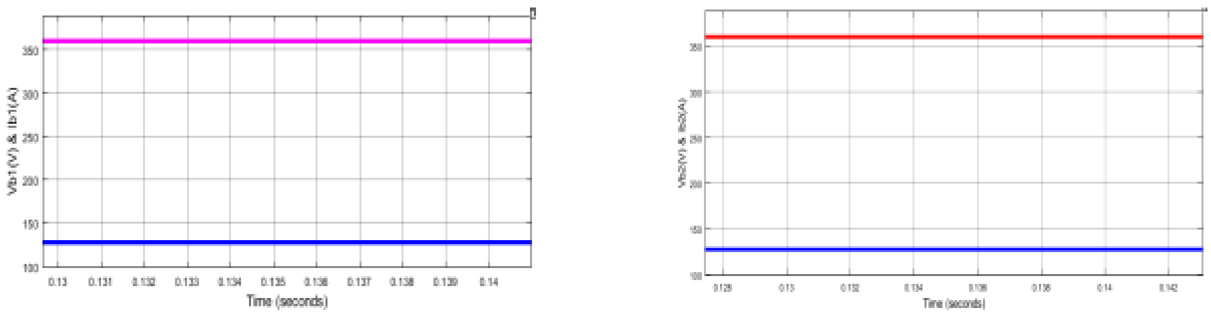
switching losses and smoother voltage transitions across the switching devices, contributing to improved efficiency and reduced thermal stress.



(a) (b)

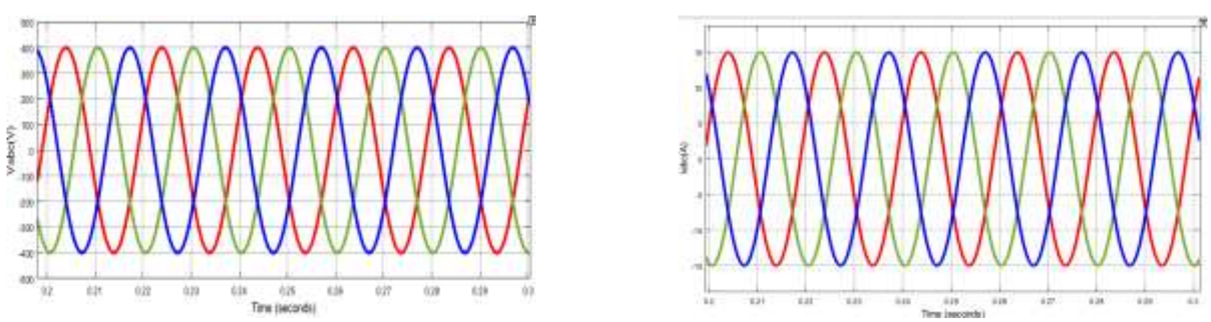
Fig 7. Simulation results of ZVS-MPC (a) voltage/current of secondary winding of HFT2,(b) voltage/current of secondary winding HFT2.



(a) (b)

Fig 8. Simulation results of ZVS-MPC (a) port 2 output volt age/current, (b) Port 3 output voltage /current.

A comparative analysis between conventional PI-based control and the proposed ANN-based control is conducted to highlight the advantages of the intelligent control approach. The results show that the ANN controller provides superior performance in terms of voltage regulation, dynamic response, and harmonic reduction. The output voltage under ANN control exhibits minimal ripple and faster settling time compared to the PI controller. Furthermore, the ANN-based system demonstrates better adaptability to changing operating conditions, such as sudden variations in load or input voltage. This adaptability is achieved through the learning capability of the ANN, which enables it to generate optimal control signals based on system behavior, thereby enhancing overall system stability and performance.



(a) (b)

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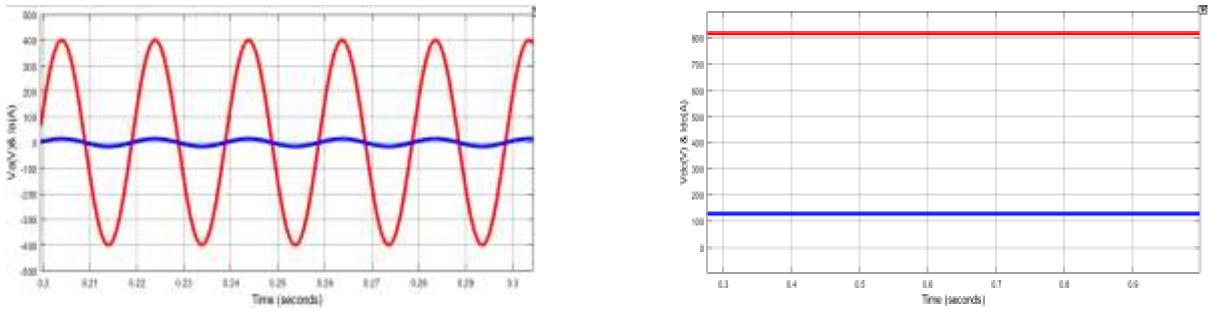
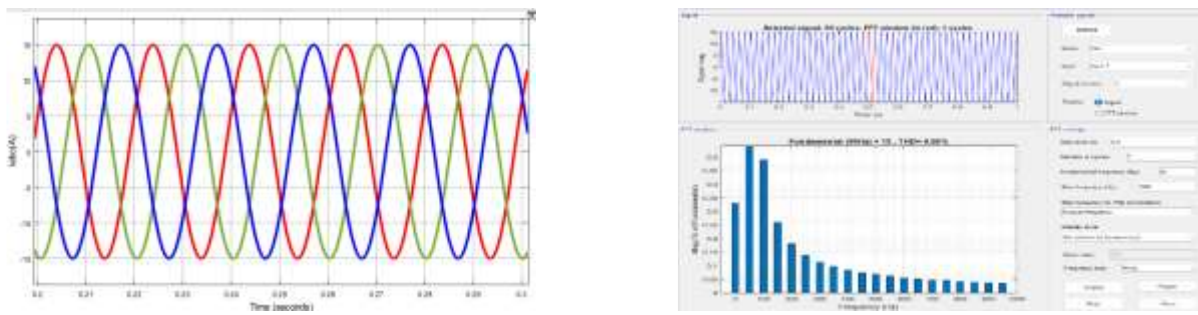


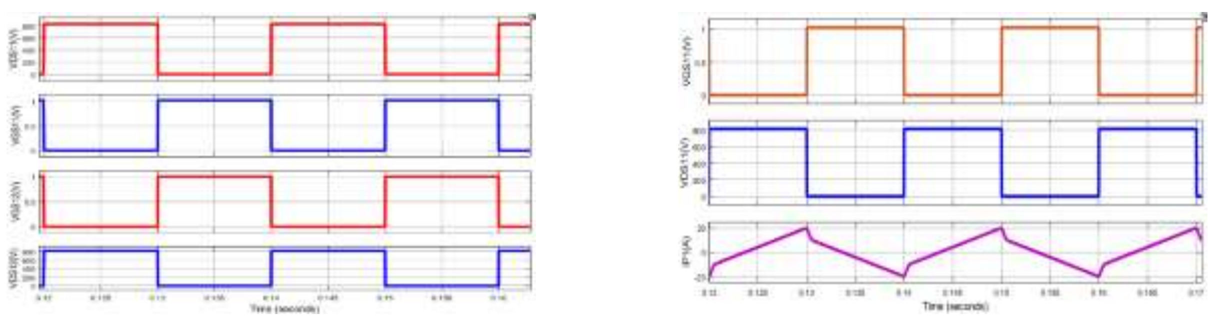
(c) (d)

Fig 9. 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).



(a) (b)

Fig 10. Test results of PFC converter (a) phase currents (b) total current harmonic distortion



(a) (b)

Fig 11. Simulated results of ZVS-MPC(a)&(b)Port1ZVSoperation of switch S11 & S12.

The total harmonic distortion (THD) of the input current is a key performance parameter for grid-connected systems. Simulation results reveal that the proposed system achieves significantly lower THD compared to conventional charging systems. The multilevel converter topology, combined with ANN-based control, ensures smooth current waveforms with reduced harmonic content. This improvement not only enhances power quality but also reduces stress on grid infrastructure and minimizes electromagnetic interference. The system also maintains a high power factor close to unity under all operating conditions, which is essential for efficient energy utilization and reduced reactive power consumption.

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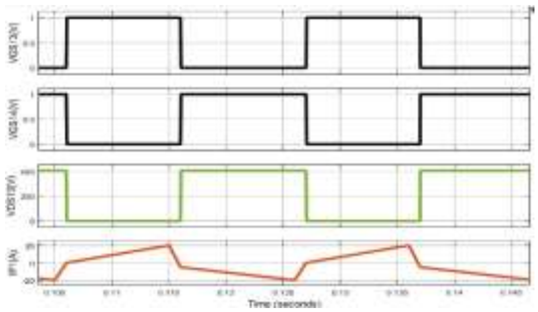


Fig 12. Simulated results of switching pulses for S13, S14 and switch voltage VDS13, current ip1.

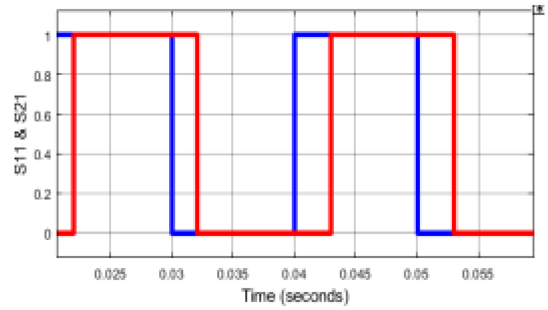
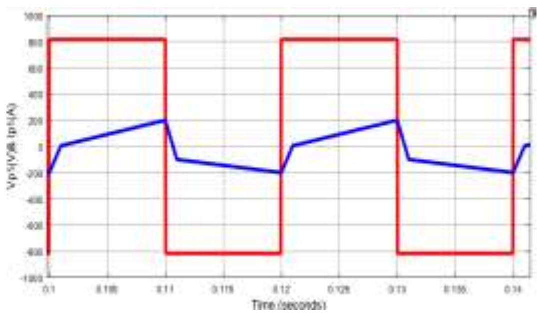
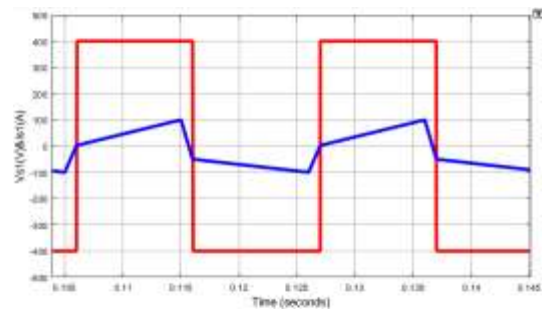


Fig 13. Simulation and test results of Phases hiftd1 between port1 and port2.

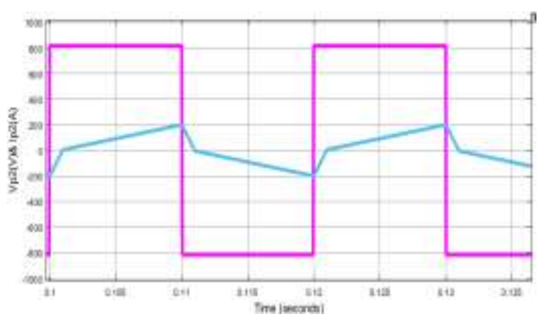


(a)

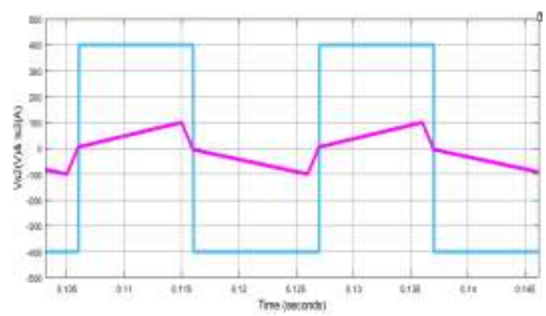


(b)

Fig. 7.15 Simulated results of DC-DC converter (a) primary side voltage/current of HFT1, (b) secondary side voltage/current of HFT1.

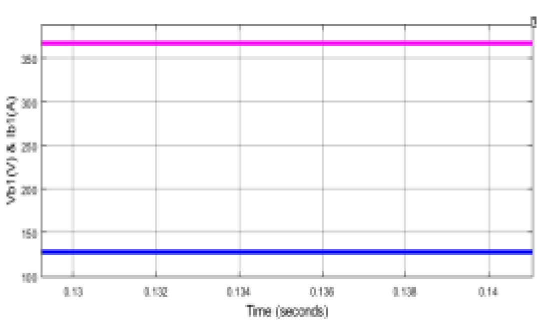


(a)

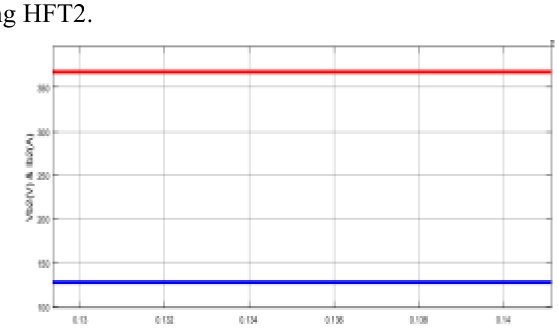


(b)

Fig. 7.16 Simulation results of ZVS-MPC (a) voltage/current of secondary winding of HFT2,(b) voltage/current of secondary winding HFT2.



(a)



(b)

Fig. 7.7 Simulation results of ZVS-MPC (a) port 2 output volt age/current, (b) Port 3 output voltage /current.

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Overall, the results confirm that the proposed ANN-based multilevel isolated converter system offers a highly efficient and reliable solution for dual EV battery charging. The system demonstrates improved performance in terms of efficiency, power quality, dynamic response, and control accuracy. The ability to simultaneously charge two batteries with independent control, while maintaining stable operation and low harmonic distortion, highlights the effectiveness of the proposed design. These findings suggest that the system is well-suited for modern EV charging applications, particularly in smart grid environments where flexibility, scalability, and intelligent control are essential. The integration of advanced converter topologies with artificial intelligence-based control represents a significant step toward the development of next-generation EV charging infrastructure.

CONCLUSION

In conclusion, this work presents an advanced and intelligent EV charging system based on a two-stage multilevel isolated converter architecture integrated with an ANN-based control strategy for simultaneous dual battery charging. The proposed system effectively addresses the limitations of conventional charging methods by improving power quality, enhancing efficiency, and enabling flexible multi-vehicle charging. The three-phase multilevel boost PFC converter ensures near-unity power factor and reduced total harmonic distortion, while the isolated multiport DC–DC converter provides safe, efficient, and independently controlled power delivery to each battery. The incorporation of zero-voltage switching further minimizes switching losses and improves overall system performance. Additionally, the ANN-based controller demonstrates superior capability in handling nonlinearities, dynamic load variations, and grid disturbances compared to traditional control techniques. Simulation results validate the effectiveness of the proposed system in achieving stable operation, fast dynamic response, and balanced power sharing. Therefore, the developed system offers a reliable, efficient, and scalable solution for next-generation EV charging infrastructure, supporting the growing demand for smart and sustainable transportation systems.

REFERENCES

[1] Yuan, X., Li, J., Zhang, Z., & Liu, H. (2021). A hybrid multilevel converter with dual active bridge for fast EV charging stations. IEEE Transactions on Industrial Electronics, 68(12), 12589–12601.

[2] Zhang, Z., Yuan, X., & Wang, Y. (2023). Integrated modular multilevel converter for multiport EV charging applications. IEEE Transactions on Power Electronics, 38(1), 678–690.

[3] Li, C., Dusmez, S., & Khaligh, A. (2021). Three-phase bidirectional AC-DC converters for EV fast chargers: A review. IEEE Transactions on Power Electronics, 36(4), 3642–3664.

[4] Das, T., & Bandyopadhyay, B. (2023). Sliding mode control of modular multilevel converters for dual EV charging. IEEE Transactions on Industrial Informatics, 19(2), 1123–1133.

[5] Deng, Y., Xiao, W., & Wu, J. (2020). A review on dual active bridge-based isolated DC-DC converters for EV charging. IEEE Journal of Emerging and Selected Topics in Power Electronics, 8(2), 951–972.

[6] García, P., Blanco, M., & Garcia-Cerrada, A. (2021). Advanced energy management strategies for EV fast chargers. IEEE Transactions on Transportation Electrification, 7(2), 438–451.

[7] Meng, L., Wu, H., & He, X. (2019). High-frequency isolated multilevel converters for EV chargers. IEEE Transactions on Industrial Electronics, 66(11), 8617–8627.

[8] Jatskevich, J., Lukic, S. M., & Bauer, P. (2018). Power sharing control for modular multilevel multiport EV charging systems. IEEE Transactions on Industrial Electronics, 65(12), 9912–9921.

[9] Narimani, M., Blaabjerg, F., & Barbosa, P. (2020). A review of three-phase AC-DC converters for EV applications. IEEE Transactions on Industrial Applications, 56(3), 2384–2397.

[10] Sabbah, A., Zhang, R., & Ehsani, M. (2020). High-power bidirectional onboard charger using SiC-based multilevel converter. IEEE Transactions on Industrial Electronics, 67(12), 10265–10275.

[11] Erickson, R. W., & Maksimović, D. (2001). Fundamentals of power electronics (2nd ed.). Springer.

10.48047/jocaaa.2024.33.08.497

[12] Mohan, N., Undeland, T. M., & Robbins, W. P. (2003). Power electronics: Converters, applications, and design (3rd ed.). John Wiley & Sons.

[13] Rashid, M. H. (2014). Power electronics: Circuits, devices, and applications (4th ed.). Pearson.

[14] Haykin, S. (2009). Neural networks and learning machines (3rd ed.). Pearson.

[15] Bishop, C. M. (2006). Pattern recognition and machine learning. Springer.