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Research Paper

ANN BASED THREE-PHASE ISOLATED MULTILEVEL AC-DC CONVERTER FOR DUAL ELECTRIC VEHICLE BATTERY CHARGING

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Abstract The rapid growth of electric vehicles (EVs) has intensified the need for efficient, reliable, and intelligent charging infrastructures capable of simultaneously charging multiple vehicles. This paper presents an Artificial Neural Network (ANN)-based control strategy for a three-phase isolated multilevel AC–DC converter designed for dual electric vehicle battery charging applications. The proposed topology employs a multilevel converter integrated with a high-frequency isolation transformer to achieve galvanic isolation, enhanced power quality, and reduced voltage stress across switching devices. The ANN controller is implemented to regulate the DC output voltage and charging current under varying grid conditions and battery state-of-charge levels. The intelligent controller provides superior dynamic response, reduced steady-state error, and improved robustness compared with conventional proportional–integral (PI) controllers. Furthermore, the dual-output architecture enables independent charging of two EV batteries with effective power sharing and minimal circulating current. Simulation studies carried out in MATLAB/Simulink demonstrate that the proposed ANN-controlled system achieves low total harmonic distortion (THD), near-unity power factor, fast transient performance, and improved charging efficiency. The results validate the suitability of the proposed converter for future smart EV charging stations.

Keywords: Electric Vehicle Charging, Artificial Neural Network, Multilevel Converter, Isolated AC–DC Converter, Dual EV Charging, Intelligent Control, Power Quality.

I. INTRODUCTION

The increasing penetration of electric vehicles has created significant challenges for power distribution systems due to the rising demand for fast and efficient charging technologies. Conventional single-output chargers are often associated with limited charging capability, lower efficiency, and inadequate adaptability to varying charging conditions. Consequently, advanced charging architectures capable of servicing multiple EVs simultaneously are receiving considerable attention.

Three-phase isolated multilevel AC–DC converters have emerged as promising candidates for EV charging applications owing to their superior efficiency, lower switching losses, reduced electromagnetic interference, and improved output voltage quality. The incorporation of galvanic isolation enhances operational safety and enables compliance with international charging standards. Moreover, multilevel structures distribute voltage stress among semiconductor devices, allowing operation at higher voltage levels.

Traditional control techniques such as PI controllers exhibit performance degradation under parameter variations and nonlinear operating conditions. Artificial Neural Networks offer adaptive learning capabilities and excellent approximation characteristics, making them suitable for complex power electronic systems. By employing ANN-based control, the converter can effectively handle grid disturbances, battery nonlinearities, and load uncertainties while maintaining optimal charging performance.

This paper proposes an ANN-based control strategy for a three-phase isolated multilevel AC–DC converter intended for dual EV battery charging. The proposed system provides independent charging control for two batteries while maintaining high efficiency and superior power quality.

II. LITERATURE REVIEW

Recent advancements in EV charging systems have focused on improving converter efficiency, charging speed, and power quality. Multilevel converters have been extensively investigated due to their ability to generate staircase voltage waveforms with reduced harmonic content. Isolated AC–DC converter topologies have further enhanced safety and bidirectional power flow capability.

Several researchers have employed intelligent control techniques such as fuzzy logic controllers and adaptive control methods for battery charging applications. However, fuzzy controllers require extensive rule bases, and conventional controllers lack adaptability under varying operating conditions. ANN controllers possess self-learning capabilities and can effectively model nonlinear relationships without requiring precise mathematical formulations.

Although previous studies have addressed multilevel converter control and dual-output charging systems independently, limited work has been reported on ANN-assisted isolated multilevel converters for simultaneous charging of multiple EV batteries. This research aims to bridge this gap by integrating ANN control with an isolated multilevel converter architecture for dual EV charging applications.

III. EXISTING SYSTEM

Existing dual EV charging systems commonly utilize conventional two-level converters controlled by PI regulators. These systems suffer from several limitations:

- High switching losses and reduced efficiency.
- Increased output current ripple.
- Limited adaptability to varying battery conditions.
- Poor transient response during sudden load variations.
- Higher total harmonic distortion in grid current.
- Difficulty in maintaining independent charging profiles for multiple EVs.

IV. PROPOSED SYSTEM

The proposed system employs a three-phase isolated multilevel AC–DC converter integrated with an ANN-based controller for dual EV battery charging. The converter consists of:

- Three-phase diode rectifier stage.
- Multilevel power conversion stage.
- High-frequency isolation transformer.
- Dual-output DC charging ports.
- ANN-based voltage and current control loops.

The ANN controller is trained using system operating data to generate appropriate control signals for maintaining desired charging conditions. The intelligent controller regulates output voltage, controls charging current, and ensures balanced power distribution between the two charging channels.

Advantages of the Proposed System

- Simultaneous charging of two EV batteries.
- Improved charging efficiency.
- Reduced grid current THD.
- Near-unity power factor operation.
- Enhanced dynamic response.
- Robust performance under parameter variations.
- Independent charging control for different battery requirements.

V. SYSTEM CONFIGURATION AND OPERATING PRINCIPLE

The three-phase AC supply is converted into DC through an input rectification stage. The multilevel converter processes the power and transfers it through a high-frequency isolation transformer, ensuring electrical isolation between the grid and EV batteries.

The dual-output structure enables separate charging of two EV batteries. Voltage and current sensors continuously monitor system parameters. These measurements serve as inputs to the ANN controller, which generates gating pulses for the converter switches.

During operation, the ANN controller minimizes the error between reference and actual charging variables, thereby achieving precise regulation and efficient power transfer.

EV CHARGER CONFIGURATION & CONTROL STRATEGY

A. Dual Battery Charger Configuration

The proposed charger configuration comprises of a threephase multilevel boost PFC (MBPFC) converter with an isolated ZVS-multiport DC-DC converter (ZVS-MPC) to charge the two equally rated EV batteries. The proposed EV battery charger configuration along with its control strategy is shown in Fig. 1. As shown in Fig. 1(a), the front-end MBPFC configures three source side filtering inductors Lj with an internal resistance rj where j represents the phases a, b and c. Further, three bipolar bidirectional switches (SWj), is connected to upper group of a fast recovery diodes Djp at the positive terminal of p. In the similar way the lower group of fast recovery diodes Djq are connected at the negative terminal of q. Output DC link voltage is obtained at the two midpoint capacitors (C1 and C2). To implement a single bipolar bidirectional switch (SWa) for phase- a, a single controlled switch Sa is integrated with a diode bridge Da1, Da2, Da3 and Da4. Also, it is connected at terminal p and q using diodes Dap and Daq respectively. Moreover, to achieve balanced DC output voltage one leg of the switch SWa is connected to the midpoint "N" and another leg connected to the source.

The MBPFC is interfaced to an ZVS-MPC for simultaneous charging of EV batteries. The ZVS-MPC has three leg full bridge converter (port 1) at the primary side and two leg full bridge converter at the secondary sides (port 2 and port 3) are connected to two DC outputs. It consists of two identical transformers HFT1 and HFT2 with turns ratio n1 : n2 and n3 : n4 respectively, to provide galvanic isolation among the ports. The presence of leakage inductances L1 and L2 significantly influences the power handling capacity. Therefore, there is no direct leakage inductance across the secondary side ports, which helps in minimizing the leakage power between the outputs. Moreover, ZVS is attained across all the switches, resulting in increased efficiency for the entire system while minimizing losses. It is capable of providing bidirectional operation and enabling precise control over power distribution from port 1 to the ports 2 and 3, essential for the simultaneous and individualized management of each battery's charging.

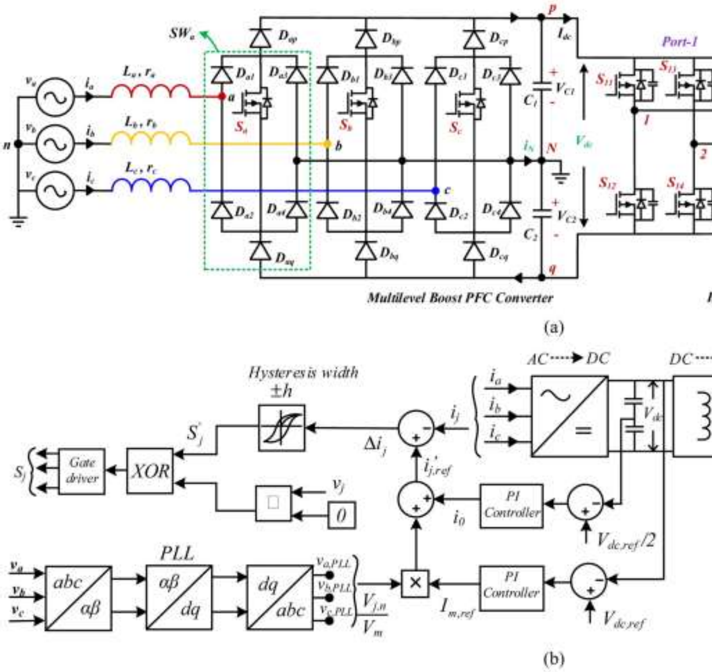

Fig. 1. Proposed EV Charger configuration (a) three-phase isolated multilevel AC-DC Converter (b) control schematic

B. Control Strategy

The implemented control strategy for the proposed charger configuration, as shown in Fig. 1(b), aims to attain a pure sinusoidal source current with Unity Power Factor (UPF), regulating the DC link voltage, and controlling the charging process of EV batteries. To synchronize the source currents ij with the source voltages vj , a phase-locked loop (PLL) is utilized. Control over the switches Sj and the source voltage of PFC converter synthesis is achieved through hysteresis control of the phase currents, facilitated by independent phase current controllers. To employ hysteresis control of source currents, the distribution of power harmonics across a broad frequency spectrum resulting from varying switching frequencies reduces the need for extensive filtering efforts to meet EMI regulations compared to constant switching frequency strategies. The reference for the source current peak amplitude Im, ref is obtained from the DC link voltage controller output, which is integrated into the current control loop. The reference sinusoidal source current ij,ref is achieved by multiplying the peak amplitude of source current Im, ref with the per unit sinusoidal waveform.

$$i_{j,ref} = I_{m,\,ref}\left(\frac{v_j}{V_m}\right)$$

where, Vm and Im, ref is the peak amplitudes of the source voltage and current respectively. The relationship between the polarity of a PFC converter source voltage vj and the direction of the corresponding source current ij has to be considered to obtain the pulses for switches Sjby utilizing the reversal of the switching actions carry out by the corresponding hysteresis controller, accompanied by the sign of the source current reference value ij,ref , observed in Fig. 1(b). Therefore, the generated driving signals for the switches Sa, Sb, Sc is illustrated in Fig. 3.

$$S_j = \begin{cases} S\prime_j; \; i_{j,\,ref} \geq 0 \\ \bar{S}'_j; \; i_{j,\,ref} < 0 \end{cases}$$

$$S\prime_j = \frac{1}{2}\left\{1 + sign\left[\Delta i_j - h * sign\left(\frac{d\Delta i_j}{dt}\right)\right]\right\}$$

where, Δij = ij, ref − ij is the error in the source current, h is the hysteresis band width. Assuming that, the value dΔij/dt remains consistent within the hysteresis band without altering its sign for |Δij | < h and it is independent of the direction of the Δij , for |Δij | > h. Thereafter, (3) can be modified as

$$S'_j = \begin{cases} 0; & i_j > i_{j,ref} + h \\ 1; & i_j < i_{j,ref} - h \end{cases}$$

Usually, the switching state of the converter is determined directly by comparing the sinusoidal current reference with the actual source current. Wherein, multilevel PFC converters, to carry out the balanced output voltage across the DC-link capacitors, VC1 = VC2 = Vdc/2, the zero-sequence current i0 is added to the current reference ij,ref

$$i'_{j,ref} = i_{j,ref} + i_0$$

The voltage unbalance in capacitors is happening due to the current iN loading the capacitive midpoint 'N'. Moreover, unbalance capacitor voltages result in voltage stress across the controlled switches, freewheeling diodes, and on individual capacitors of the converter. Also, it introduces uneven current distribution across devices throughout the fundamental period. The absence of a zero-component current cannot be set up by the current controllers due to the floating mains star point (ia + ib + ic = 0). As a result, it does not directly affect the shape of the source current. However, it has an impact on the capacitive midpoint current iN . Hence, i0 plays a prominent role in equalizing the partial voltages at the DC-link output. Furthermore, a PI controller has been implemented to generate the pulses using single phase shift PWM for MPC. Which facilitate simultaneous power sharing between two two secondary side ports 2 and 3. The converter has two control phase shift parameters, d1 and d2, each corresponding to one of the two outputs, VB1 and VB2, which can be controlled independently. The port 2 voltage is regulated by adjusting the phase shift, d1, provided between ports 1 and 2. Similarly, the regulation of port 3 voltage is done by adjusting the control variable, d2, between ports 1 and 3. This ensures a continuous flow of charging across ports.

VI. ARTIFICIAL NEURAL NETWORK CONTROLLER DESIGN

The ANN controller comprises an input layer, hidden layer, and output layer. The network inputs include:

- DC-link voltage error.
- Change in voltage error.
- Output current error.
- State-of-charge information.

The output of the ANN corresponds to the control action required for generating switching pulses.

ANN Training Procedure

1. Collection of training datasets under various operating conditions.
2. Data normalization and preprocessing.
3. Selection of network architecture.
4. Training using backpropagation algorithm.
5. Validation using testing datasets.
6. Implementation within the converter control system.

The ANN learns the nonlinear characteristics of the charging system and provides adaptive control action to maintain desired performance.

VII. SIMULATION RESULTS AND DISCUSSION

The proposed converter is modeled in MATLAB/Simulink under different loading conditions and battery charging scenarios.

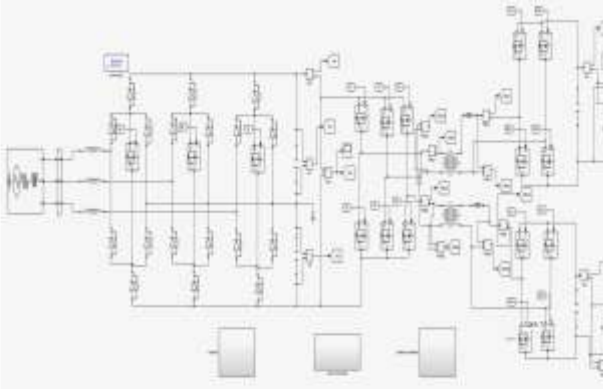

Fig 2. Simulation circuit model

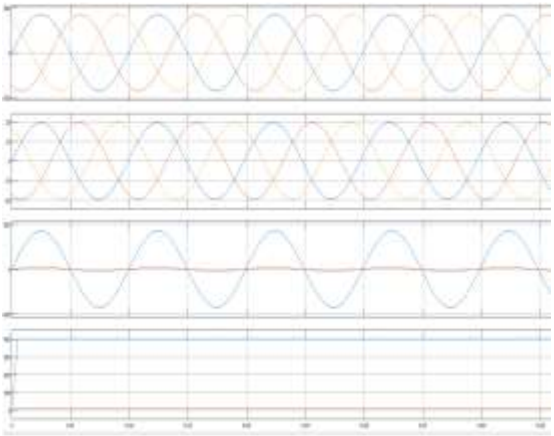

Fig. 3. Simulated and test results of PFC converter (a) phase voltages (va,vb,vc) (b) phase currents (ia,ib,ic) (c) phase voltage va, and phase current ia. (d) Rectified voltage (Vdc) and current (Idc).

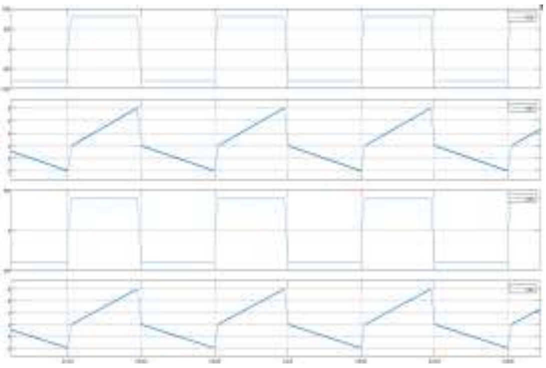

Fig. 4. Simulated and test results of DC-DC converter (a) primary side voltage/current of HFT1, (b) secondary side voltage/current of HFT1.

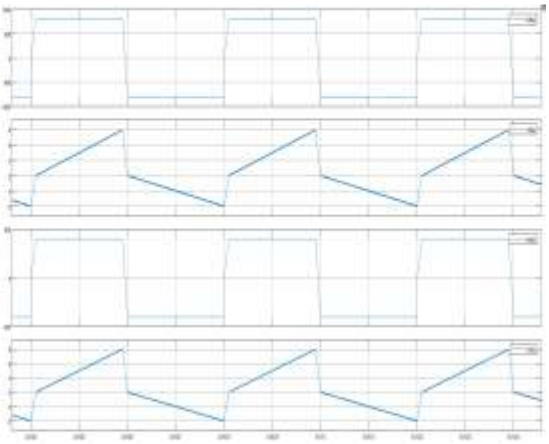

Fig. 5. Simulation and test results of ZVS-MPC (a) voltage/current of secondary winding of HFT2,(b) voltage/current of secondary winding HFT2

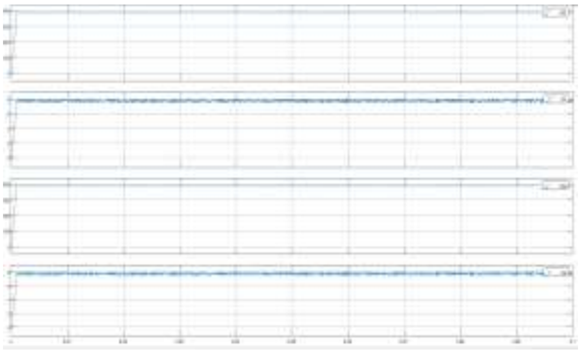

Fig. 6. Simulation and test results of ZVS-MPC (a) port 2 output voltage/current, (b) Port 3 output voltage /current.

Simulation Parameters

Parameter	**Value**
Input Voltage	415 V (Three-phase)
Grid Frequency	50 Hz
DC-Link Voltage	700 V
Switching Frequency	20 kHz
EV Battery 1 Voltage	300 V
EV Battery 2 Voltage	300 V
Transformer Turns Ratio	1:1
ANN Hidden Neurons	10

Performance Analysis

Simulation results demonstrate that:

- The DC output voltage remains stable during load variations.
- Independent charging currents are maintained for both EV batteries.
- Source current exhibits sinusoidal characteristics.
- Grid-side power factor approaches unity.
- Current THD remains within IEEE recommended limits.
- The ANN controller provides faster settling time compared with conventional PI control.

VIII. CONCLUSION

This paper presented an ANN-based control strategy for a three-phase isolated multilevel AC–DC converter intended for dual electric vehicle battery charging applications. The proposed topology offers galvanic isolation, improved power quality, reduced switching stress, and efficient simultaneous charging capability. The ANN controller enhances dynamic performance and adaptability under varying operating conditions. Simulation studies confirm the effectiveness of the proposed approach in achieving stable charging, low harmonic distortion, and high efficiency. Therefore, the proposed system represents a promising solution for future smart charging infrastructures supporting widespread EV adoption.

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