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Optimized Bidirectional Totem-Pole AC-DC Converter for Efficient Electric Vehicle Charging using Artificial Neural Networks

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KEYWORDS

Bidirectional Converter, Totem-Pole AC/DC Converter, Artificial Neural Network (ANN), Dual Active Bridge (DAB), Electric Vehicle (EV) Charging, Power Factor Correction (PFC), Total Harmonic Distortion (THD).

ABSTRACT

This paper presents a high-efficiency bidirectional AC/DC converter for rapid EV charging that uses a totem-pole topology in conjunction with an ANN-based control method. An isolated bidirectional Dual Active Bridge (DAB) DC-DC converter, which is also controlled by ANN, is added to the system to make it even better. The suggested design minimizes the changing DC-link voltage, allows high-frequency soft switching, and uses an integrated magnetic-linked converter to provide higher performance. When contrasted with traditional PI-controlled converters, the resulting system is both small and efficient. The totem-pole arrangement is a great way to increase power quality, decrease total harmonic distortion (THD), and power factor correction (PFC). It does this by using active switches instead of standard full-bridge diode rectifiers. The converter enables accurate control of voltage and current with decreased switching losses because to its construction employing high-frequency gallium nitride (GaN) switches. The MATLAB simulation results show that the ANN-controlled bidirectional converter is effective for advanced EV charging infrastructures and UPS applications due to its reduced transient harmonic distortion (THD), increased system efficiency, and improved dynamic response

1. INTRODUCTION

The world is moving faster away from internal combustion engine (ICE) vehicles and toward electric ones due to rising demand for sustainable transportation and renewable energy [1]. The global community is putting a lot of money into electric vehicle technologies to fight climate change, fossil fuel depletion, and increasing carbon emissions [2]. In theory, fewer people driving electric vehicles would cut down on pollution in cities and the need to import fossil fuels [3]. Constructing a high-performance charging infrastructure that satisfies current standards for efficiency, safety, and intelligence is a significant technological and infrastructural hurdle to widespread EV adoption. For electric car adoption on a broad scale, there must be a rapid and intelligent charging infrastructure that can adapt to the changing demands of both the power grid and the vehicles using it [4]. Power density, efficiency, bidirectionality, compactness, and thermal optimization are key features of fast chargers. In vehicle-to-grid (V2G) operations, electric converters convert alternating current (AC) from the grid into direct current (DC) that may be controlled in order to charge batteries, and vice versa [5]. At charging stations for electric vehicles, a power converter regulates the flow of electricity from the grid to the battery. Powerful, high-quality, and space-efficient fast-charging converters are essential. Possible AC-to-DC conversion is the bidirectional totem-pole converter, which eschews diode bridges in favor of actively controlled switches [6]. Power factor adjustment, current shaping, and conversion efficiency are all enhanced. A 40 kHz totem-pole converter with a 95% efficiency rating is suggested in this study. Its small size and good performance make it a great choice for electric vehicle charging stations [7]. The DC-link power from the batteries is controlled by a separate DC-to-DC stage. Because of its symmetrical construction, bidirectional capabilities, and soft-switching behavior, the Dual Active Bridge (DAB) converter is often used in such applications. The size and energy losses of transformers are minimized using high-frequency DAB. The data-to-analog converter runs on 85-120 kHz. When operating at high frequencies, power density, dynamic responsiveness, and interference from electromagnetic fields are all improved. The DAB is perfect for charging and discharging EVs because of its soft-switching technology, which enables efficient power transmission regardless of the load [8]. System performance is determined by the design of the controller, not the topology. PI controllers are well-liked due to their effectiveness and simplicity in linear situations. In electric car charging systems, PI controllers are ill-equipped to deal with nonlinearities, dynamic disturbances, and unforeseen operational conditions. Control that does not rely on parameters is required in real time because to fluctuations in grid power, battery status, and load demand. Intelligent control systems, such as ANNs, deal with these constraints. Controllers based on ANNs are able to adapt to new operating circumstances, learn the system's behavior from data, and react appropriately to nonlinear inputs [9]. The absence of the need for precise mathematical models makes ANN systems applicable in the real world both adaptable and resilient [10]. When it comes to power electronics, ANN control improves stability under complicated load patterns, reduces transient harmonic distortion (THD), boosts dynamic performance, and enhances voltage and current regulation [11]. For the purpose of rapid EV charging, this research reproduces in detail an ANN-controlled bidirectional power converter system. An 85-120 kHz high-frequency isolated DAB DC/DC converter and a 95% efficient 40 kHz totem-pole AC/DC converter are included in the proposed system [12]. Using control algorithms based on artificial neural networks, both converters optimize stage performance in real time [13]. Using MATLAB to model and evaluate a system for electric car charging infrastructure. In terms of voltage, current, dynamic responsiveness, power factor, and harmonic content, systems controlled by ANNs perform better than those based on PIs. Because of its small size and decreased passive components, the system is ideal for smart grid-connected devices, electric vehicle charging stations, and uninterruptible power supplies. In order to facilitate hardware prototypes and real-time applications, the research lays a scalable groundwork for the electric car charging infrastructure of the future.

II. CONVERTER DESIGN AND ANALYSIS

Figure 1 shows the proposed electric vehicle charging system, which makes use of a bidirectional totem-pole AC/DC converter controlled by an Intelligent Neural Network (ANN) and an isolated Dual Active Bridge (DAB) DC-DC converter to facilitate efficient bidirectional power flow from the AC grid to the electric vehicle battery for V2G charging and discharging. The converter enhances power factor correction and overall harmonic distortion by substituting high-frequency GaN-based active switches for diode rectifiers. By analyzing the system's actions and making real-time adjustments to the control signals, the ANN controller achieves better results than traditional PI controllers.

This method is perfect for the next generation of rapid electric vehicle chargers since it enhances dynamic performance, overshoot, and settling time.

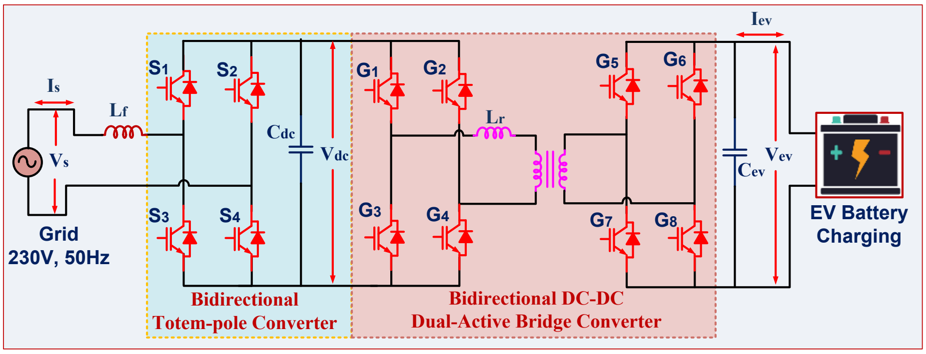


Fig.1 Designing of Bidirectional Totem-pole converter for High-Efficiency EV Charging

A. Bidirectional Totem-Pole Converter

In a totem pole arrangement, four active switches typically high-frequency GaN transistors make up an advanced bridgeless boost converter. Pulse width modulation operates switches throughout the 10-100 kilohertz frequency range in this system. To manage the positive and negative half cycles of the AC input voltage, the converter changes the conduction routes between the switches. The boost inductor and output capacitor are charged during the positive half cycle by the conductance of switches S1 and S2. Keeping power transmission constant requires identical behavior from switches S3 and S4 throughout the negative half cycle. By substituting fast-switching transistors for the diode bridge, the totem pole converter increases efficiency while decreasing conduction losses. Figure 2 shows that with precise input current regulation, the power factor is almost one and the overall harmonic distortion is minimal. This bidirectional converter is used as an inverter to return electricity to the AC grid, which is useful for modern electric car chargers and grid-connected energy systems. The equation for the AC grid input voltage readout is $V_{in}(t) = V_{in\_peak}\sin(\omega t)$, where V_{in_peak} is the line voltage peak and ω=2πf is the angular frequency. In boost mode, the converter increases the regulated DC output voltage to a higher level, which is achieved when $V_{out} > V_{in\_peak}$. The relationship between the input and output voltages of a steady-state boost converter is determined by the duty ratio D:

$$D(t) = 1 - \frac{V_{in}}{V_{out}} \qquad (1)$$

To model the inductor current i_L, we use the basic boost converter differential equation during the switch-on period:

$$\frac{di_L}{dt} = \frac{V_{in}(t)}{L} \qquad (2)$$

And during the off-time (when the switch is open), the inductor current flows through the output diode (or synchronous switch), and the voltage across the inductor becomes:

$$\frac{di_L}{dt} = \frac{V_{in}(t) - V_{out}}{L} \qquad (3)$$

The inductor value L is selected based on the desired current ripple Δi_L and switching frequency:

$$L = \frac{V_{in}(1-D)}{f_s \Delta i_L} \qquad (4)$$

Here, Δi_L is typically 20%–40% of the peak inductor current for optimal performance.

The output capacitor C_{out} must be chosen to handle the output voltage ripple ΔV_{out} and support the load during switching cycles. Its value can be calculated as:

$$C_{out} = \frac{I_{out} \cdot D}{f_s \cdot \Delta V_{out}} \qquad (5)$$

Where I_{out} is the output current, D is the duty cycle, and ΔV_{out} is the allowed output ripple voltage, often limited to 1–2% of V_{out}.

B. Bidirectional dual Active Bridge converter

Electric vehicle charging systems use the bidirectional isolated DC-to-DC Dual Active Bridge converter to transfer energy between the high-voltage DC link and the battery. It has two galvanically isolated full-bridge inverters connected by a high-frequency transformer. Both bridges switch at ω (similar to 80-150 kHz) and generate square-wave voltages V_1 and V_2 on their sides. Incorporating a phase shift φ between the voltage waveforms modulates instantaneous power transfer. For ideal square waves and no losses, the average power P is given by

$$P = \frac{V_1 V_2}{nL\omega}\,\phi\left(1 - \frac{|\phi|}{\pi}\right) \qquad (6)$$

where n is the transformer turns ratio and L is the total series inductance (including transformer leakage). To ensure soft-switching and limit current ripple, L is chosen according to the maximum power P_{max} and desired ripple, for example by

$$L = \frac{V_1 V_2}{n\omega P_{max}} \quad (7)$$

During charging, φ is positive and energy flows from the DC link to the battery; in vehicle-to-grid mode φ becomes negative and energy reverses direction. The transformer must be designed for high-frequency operation with low core and copper losses and sufficient insulation. A control scheme dynamically adjusts φ based on feedback of battery voltage and current demand, thereby maintaining regulated charging current and high efficiency across a wide operating range as shown in Fig.3.

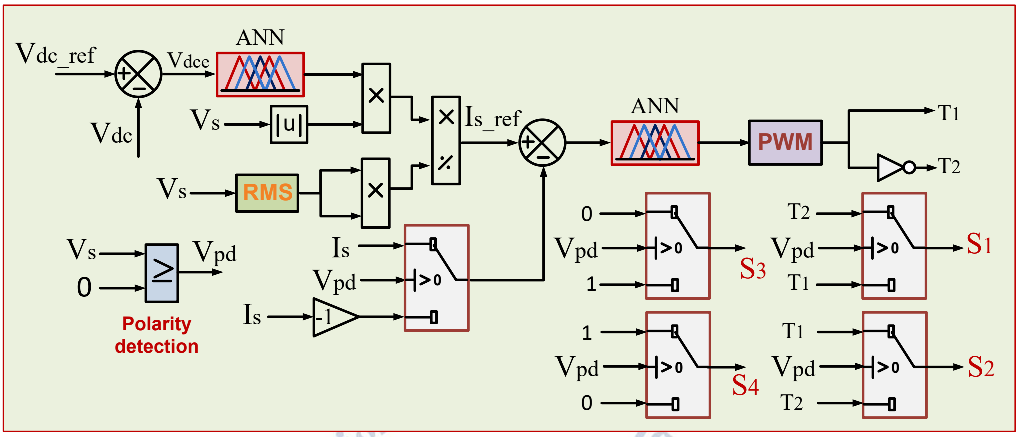


Fig.2 Controller of AC/DC Totem pole converter

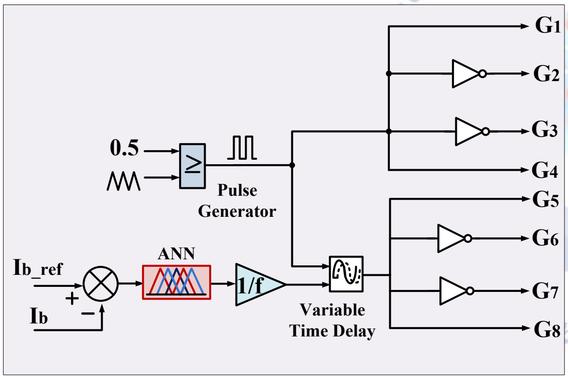


Fig.3 Controller of bidirectional DAB converter

III. DESIGNING OF ANN CONTROLLER

In a bidirectional electric vehicle charging system, the Artificial Neural Network controller is applied to both the Totem-Pole converter and the Dual Active Bridge converter to enhance accuracy, adaptability, and dynamic response. The ANN controller uses system measurements and learned nonlinear relationships to generate control signals in real time. For the Totem-Pole AC-DC converter, the ANN controller regulates the DC-link voltage and ensures power factor correction. It uses the voltage error as input, defined by

$$e_V(t) = V_{ref} - V_{dc}(t) \quad (8)$$

where VVref is the reference DC output voltage and Vdc is the measured voltage. Additional inputs include the grid current Iin(t) and the input voltage Vin(t). The ANN learns the mapping

$$D(t) = ANN(e_V(t), I_{in}(t), V_{in}(t)) \quad (9)$$

to generate the optimal duty cycle D(t) for controlling the high-frequency switches. This enables sinusoidal current shaping, near-unity power factor, and reduced THD. For the DAB DC-DC converter, the ANN controls the phase shift ϕ, which regulates bidirectional power flow. The inputs to the ANN include the DC-link voltage V1, battery voltage V2, output current Iout, and the error in current

$$e_i(t) = I_{ref} - I_{out}(t) \quad (10)$$

The ANN determines the appropriate phase shift using the relation

$$\phi(t) = ANN(V_1, V_2, I_{out}(t), e_i(t)) \quad (11)$$

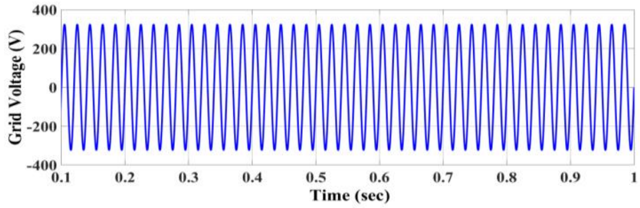
By adjusting the outputs D(t) and ϕ(t), the ANN controller enables precise control of both converters. The unified ANN control approach optimizes power conversion and battery charging/discharging operations by learning from system behavior, maintaining high efficiency under dynamic grid, load, and battery conditions.

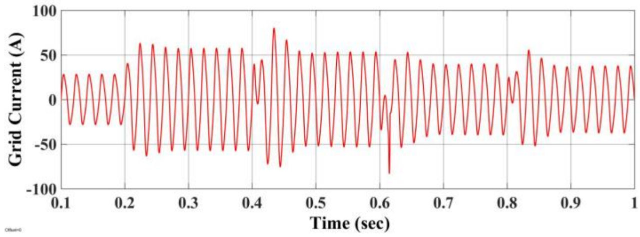
TABLE.1 SIMULATION DESIGN PARAMETERS

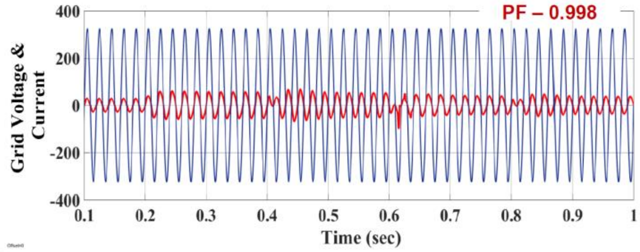
Components	Values	Quantity
AC line Voltage	230 V	/
DC-Link Voltage	400 V	/
IGBTs (S1-S4)	Gan	4
Lf	190 µH	1
Swiching frequency fs	40 KHz	
Cdc	2486 µF	1
IGBTs (G1-G8)	Gan	8
Primary Voltage	400 V	/
Secondary Voltage	280 V	/
HF Transformer	12 KW	1
Lr	120 µH	1
DAB fs	85 KHz	
Cev	30 µF	1
EV Battery Voltage	160 V	/
EV Battery Current	148 Ah	/
EV Battery SOC%	80 %	/

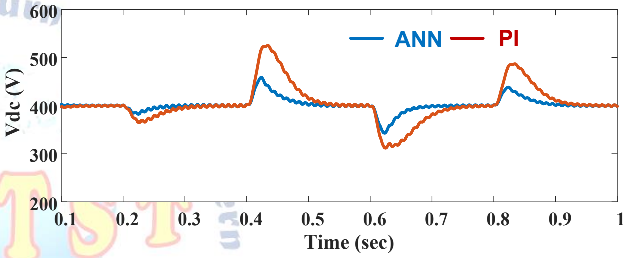
IV.SIMULATION RESULTS AND DISCUSSIONS

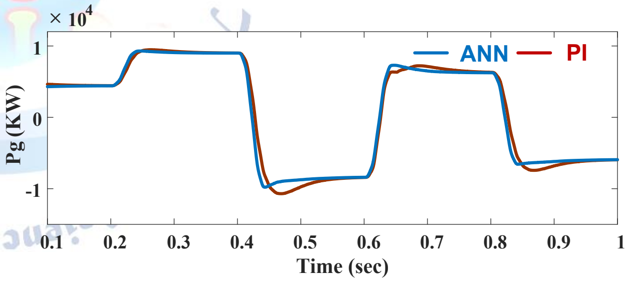
The proposed ANN-controlled bidirectional converter system was simulated in MATLAB Simulink to analyze its performance under dynamic and nonlinear conditions caused by varying electric vehicle (EV) charging loads. The system integrates a totem-pole AC/DC converter and an isolated Dual Active Bridge DC/DC converter, both governed by an Artificial Neural Network (ANN)-based control algorithm. During simulation, the ANN controller effectively maintained the DC-link voltage at a stable 400 V, even when subjected to rapid EV load variations and nonlinearity in system behavior. It demonstrated fast dynamic response and robust tracking of current demand without overshoot or instability. In contrast, the conventional PI controller struggled under the same conditions, showing slower recovery and greater voltage and current fluctuations. The ANN-based system achieved a near-unity power factor of 0.998, indicating efficient grid synchronization with minimal reactive power flow as shown in Fig.4. Furthermore, the grid current Total Harmonic Distortion (THD) was significantly improved by the ANN controller. While the PI controller maintained the THD at 4.17%, the ANN-based control reduced it to 3.45%, resulting in cleaner current waveforms and better compliance with power quality standards as shown in Fig.6. These results confirm that ANN control enhances system efficiency, power quality, and overall stability, making it well-suited for high-performance EV charging infrastructure

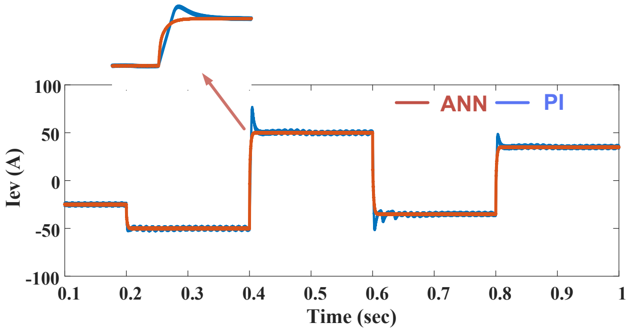


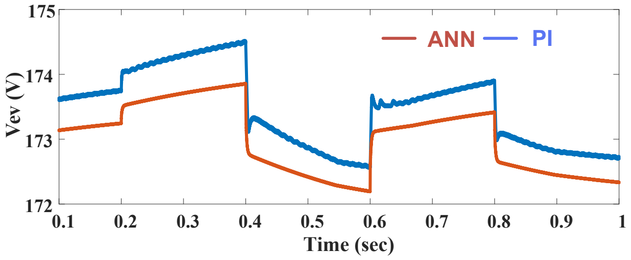












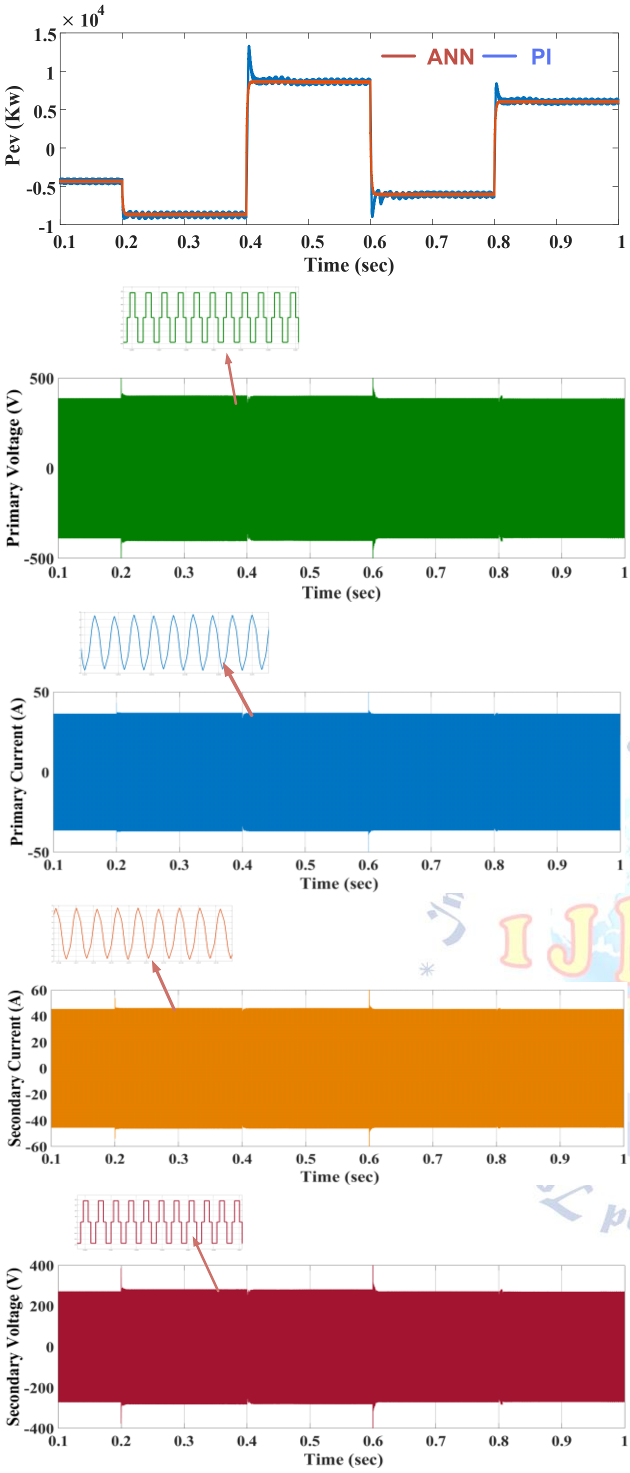
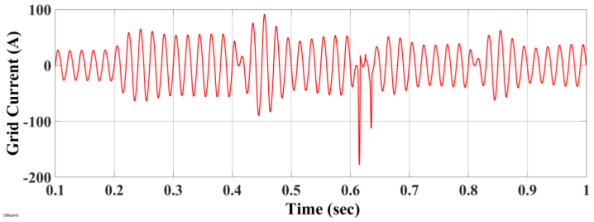
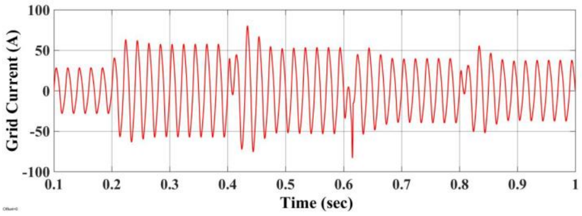


Fig. 4 simulation results of different EV load variations

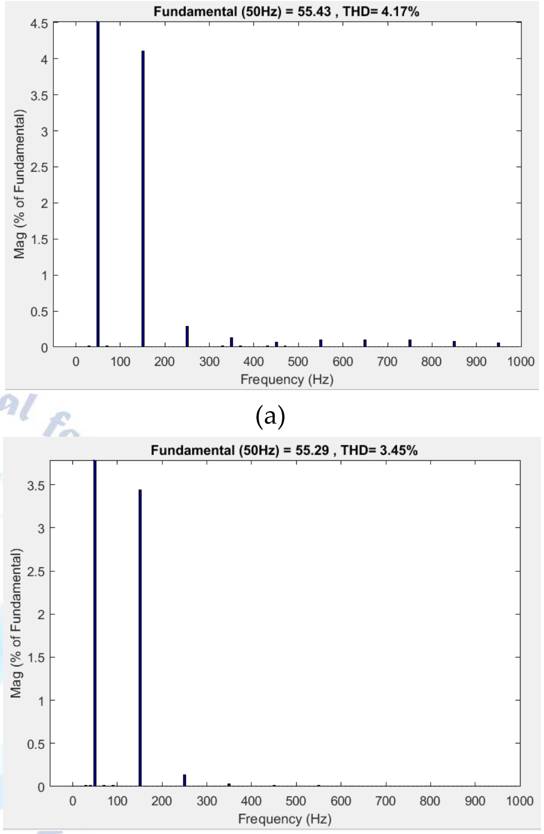


(a)



(b)

Fig.5 performance variation of Grid Current by EV load changing (a) with PI controller (b) with ANN controller



(a)

(b)

Fig.5 comparison of Grid current THD (a) with PI (b) with ANN controller

V. CONCLUSION

A smart and efficient bidirectional power converter system controlled by artificial neural networks (ANNs) is suggested here for charging electric vehicles quickly and intelligently. High switching frequencies are used by both the totem-pole AC/DC converter and the isolated Dual Active Bridge DC/DC converter in the system to decrease losses and increase power density. In comparison to conventional PI controllers, ANN-based control greatly enhances the system's responsiveness to nonlinear situations, dynamic performance, and flexibility. Better control of voltage and current, lower total harmonic distortion, and greater system stability under fluctuating load and grid circumstances were all achieved by the ANN technique, according to the simulation findings. Smart energy applications and sophisticated EV charging infrastructure are good fits for the suggested system because of its totem-pole architecture, high-frequency DAB, and intelligent control. The research lays a solid foundation for developing small, high-performance bidirectional charging devices in the future and for their real-time implementation.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

REFERENCES

[1] M. A. Abella and F. Chenlo, ''Photovoltaic charging station for electrical vehicles,'' in Proc. 3rdWorld Conf. Photovolt. Energy Convers., May 2003, pp. 2280–2283.

[2] A. Damm, J. Köberl, F. Prettenthaler, N. Rogler, and C. Töglhofer, ''Impacts of +2 ◦C global warming on electricity demand in Europe,'' Climate Services, vol. 7, pp. 12–30, Aug. 2017.

[3] S. Habib, M. M. Khan, F. Abbas, A. Ali, M. T. Faiz, F. Ehsan, and H. Tang, ''Contemporary trends in power electronics converters for charging solutions of electric vehicles,'' CSEE J. Power Energy Syst., vol. 6, no. 4, pp. 911–929, Dec. 2020.

[4] 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.

[5] Z. Huang, Z. Li, C. S. Lai, Z. Zhao, X. Wu, X. Li, N. Tong, and L. L. Lai, ''A novel power market mechanism based on blockchain for electric vehicle charging stations,'' Electronics, vol. 10, no. 3, p. 307, Jan. 2021.

[6] F. Musavi, W. Eberle, and W. G. Dunford, "A high-performance single-phase bridgeless interleaved PFC converter for plug-in hybrid electric vehicle battery chargers," IEEE Trans. on Ind. Appl., vol. 47, no. 4, pp. 1183-1143, 2011.

[7] N. M¨uller, S. Kouro, P. Zanchetta, and P. Wheeler, "Bidirectional partial power converter interface for energy storage systems to provide peak shaving in grid-tied PV plants," in 2018 IEEE International Conference on Industrial Technology (ICIT), pp. 892–897.

[8] S. Srdic and S. Lukic, ''Toward extreme fast charging: Challenges and opportunities in directly connecting to medium-voltage line,'' IEEE Electrific. Mag., vol. 7, no. 1, pp. 22–31, Mar. 2019.

[9] Mohd. Arif Khan, "ANN Based Simulation of PWM Scheme for Seven Phase Voltage Source Inverter using MATLAB/Simulink", Research gate journals 18th International Conference on Wireless Communication 2016.

[10] C. Subramani, A. A. Jimoh, Harish Kiran S, Subhransu Sekhar Dash, "Artificial Neural Network based Voltage Stability Analysis in Power System". International Conference on Circuit, Power and Computing Technologies 2016.

[11] Sayidul Morsalin, Khizir Mahmud and Graham Town "Electric Vehicle Charge Scheduling Using An Artificial Neural Network" IEEE Conference Innovative Smart Grid Technologies – Asia 2016.

[12] F. Musavi, W. Eberle, and W. G. Dunford, "A phase shifted semi-bridgeless boost power factor corrected converter for plug-in hybrid electric vehicle battery chargers," in Proc. IEEE Appl. Power Electron. Conf. and Expo., 2011, pp. 821-828.

[13] Ala A. Hussein, "A Neural Network Based Method for Instantaneous Power Estimation in Electric Vehicles' Li-ion Batteries" IEEE Applied Power Electronics Conference and Exposition 2017.