Four-Port Multi-Function Bidirectional Converter for V2V, V2H, V2G, and G2G Applications

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ABSTRACT- Portable charging devices for electric vehicle owners are among the key solutions for efficient, safe, continuous, and emergency energy use, enabling electric vehicles to function as both continuous power sources and loads. This paper discusses a four-port converter that performs energy conversion for loads, distributed power sources for EVs, and AC and DC microgrids for household distribution. The converter is designed with a structure aimed at connecting energy between main EV devices and distributed sources in the distribution grid using bidirectional energy conversion principles and voltage step-up/step-down for each independent operating mode. The converter performs with high efficiency of over 96% with a conversion capacity of 5kW and with simple control as described in the laboratory simulation results.

Keywords: DC-DC Converter, DC-AC Converter, Bidirectional Power, Discontinuous Pulse Width Modulation (DPWM) Converter, Electric Vehicle.

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1. INTRODUCTION

In recent years, the use of electric vehicles (electric vehicles) to replace fossil fuel vehicles has been increasing, especially in densely populated urban areas. This replacement brings some benefits to electric vehicle owners such as reducing emissions during traffic to the environment [1] saving costs of using electric vehicles compared to fossil fuel vehicles [2-4], flexible use of electric energy for home and building loads as well as suitable loads such as electric vehicles with each other, with microgrids [5, 6]. Electric vehicles are currently charged mainly through fixed charging stations (FCSs); however, most research and development efforts focus on FCS-based charging infrastructures, which cannot fully meet the rapidly increasing demand for electric vehicles. Therefore, auxiliary support tools for electric vehicles are required as required, such as portable chargers that come with electric vehicles. Vehicle owners need the best features for using a vehicle and benefit the vehicle owner in terms of personal finances, as well as ensuring the environment around them. Portable chargers for electric vehicles are remote charging devices that do not depend on standard fixed charging stations in fixed areas [7-9], the portable charger increases the mobility of electric vehicle owners. As a means of transportation, electric vehicles benefit from portable chargers by reducing dependence on fixed charging infrastructure, alleviating concerns about locating charging sources, and increasing operational flexibility, thereby enabling proactive operation independent of grid infrastructure and electrical systems [10]. Besides, there is also the ability to charge emergencies, and this charging method helps increase EV adoption by reducing charging time and range anxiety [11].

Chargers come in different levels from 1 to 3 [12] demonstrate unidirectional electric vehicle charging, in the charger that is a study propose to only convert energy between two electric vehicles effectively [13] to perform the bidirectional conversion function, which essentially only requires one-way conversion to fulfill the requirement. There is a study that performs bidirectional energy conversion between electric vehicles and the grid [14], an isolated conversion form to increase the voltage on the EV side. A converter combining G2V, V2H and V2G functions for electric motorbikes is proposed in the study [15, 17] to perform operations for the power grid and related electrical systems in a house. These functions do not yet meet the necessary situations of flexible power supply for electric vehicles, home loads and the grid. Fixed wireless charging station solutions using solar energy have been proposed in [16]. In addition, direct energy conversion–based chargers have been shown to improve battery lifetime and power factor for electric vehicles [18].

This paper presents the design and performance evaluation of a four-port multi-functional bidirectional converter specifically designed for Vehicle-to-Vehicle (V2V), Vehicle-to-Home (V2H), Vehicle-to-Microgrid (V2G), and Microgrid-to-Microgrid (G2G) applications. Unlike the previously analyzed solution converters, the proposed topology integrates four operating ports with independent or combined control of other ports for power exchange, enabling seamless energy exchange between EV vehicles, local loads, and microgrids.

2. METHODS

Energy conversion technology is promoted from power electronics such as studies [14, 19] to exchange energy between two G2G grids in two directions in microgrids with renewable energy sources and connected to the main grid, [20] to form a direct-type bidirectional converter connecting DC microgrids with flexible distributed energy storage and power sources. Studies [21] propose a high-efficiency bidirectional converter connecting two electric vehicles together, [14, 22] to combine V2G energy exchange to adapt flexible operations to actual needs to reduce energy waste in the usual way of operating in the power system in general and mobile loads of electric vehicles in particular.

A mobile charger can provide several benefits and conveniences for electric vehicle users and other related loads, such as at home or in microgrids. The development of a mobile charging converter is a proposal for the electric vehicle management network and supports or replaces mobile electric vehicle charging stations in situations such as the absence of grid power, charging stations, household power, electric vehicle power, or distributed power from the grid. The research team proposed a portable multi-purpose converter with an electric vehicle with full cases of converting energy from real ports in the grid, modern power system. Specifically, as shown in Figure 1. In Figure 1, the converter uses a direct energy conversion method. The proposed converter employs bidirectional buck–boost converters for the EV1 and EV2 ports interfaced with the AC microgrid (assuming the AC microgrid is either connected to the distribution grid or operates independently), instead of using a bidirectional H-bridge DC/AC converter. Between the EV1 and EV2 ports, a bidirectional basic switched-pulse DC–DC converter is implemented. Energy conversion between the two DC ports linked (like DC microgrid) to EV1, EV2 uses a bidirectional buck-boost converter to ensure the parameter requirements between the ports.

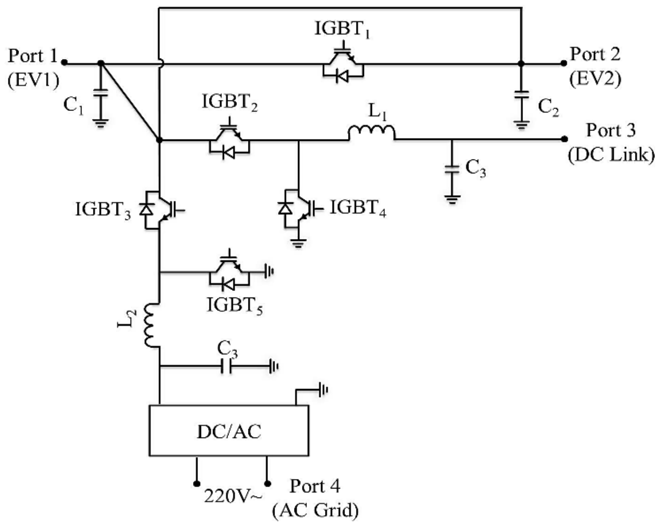

Figure 1. Schematic diagram of the proposed converter for electric vehicle charger

In the proposed converter employs five main switches, this converter combines DC-DC and DC-AC conversion forms performed with four independent ports to implement flexible operating modes according to basic requirements to special cases when occurring for components in the power grid where the core component in the converter is simple, few components, ensuring good performance and power quality.

The proposed converter is given specific operating modes described in *figure 2*. The conversion processes at the 4 ports are specifically performed as modes: Operating mode 1 (V2V) of the charger is the energy exchange between the two ports EV1 and EV2 by a pulse hash converter using a two-way switch IGBT1 as in *figure 1*, when the energy wants to be transferred from the EV1 electric vehicle to EV2, that is, the EV1 vehicle discharges energy, sells electric energy, the IGBT1 switch opens, the output voltage at the EV2 vehicle will be determined as *equation (1)*. The output voltage depends mainly on the opening and closing frequency of the IGBT1 switch and the value of the capacitor C2. Similarly, when wanting to transfer energy from the EV2 vehicle to the EV1 vehicle, that is, the EV1 electric vehicle needs to charge energy, in this case chúng ta chỉ cần đảo đầu cổng là thực hiện được. The voltage and current are determined as *equation (1)* because of the value of *C1 = C2*. Furthermore, in this mode, this portable charger can connect to and draw supplemental power from both the AC (alternating current) and DC (direct current) power sources in the system if available at that location. With this converter circuit condition, the pulse width value needs to be large for the switching of IGBT1.

$$V_{EV2} = (V_{EV1} - V_{DS-IGBT1})d1 \qquad (1)$$

Where: *d1* is the duty cycle for IGBT1 = t1/T

$V_{DS-IGBT1}$ voltage when the switch S1 is open for current to pass through, determine the voltage as follows:

$$i_{EV2} = I_o e^{\frac{t1}{T_d}} + I_x(1 - e^{\frac{t_1}{T_d}}) \qquad (2)$$

Where:
I_o initial current when considering switch S1 closed or open
I_x steady-state current of the cycle
Td time constant of R-L-C load in the form of load
t_1 is the time interval with pulse

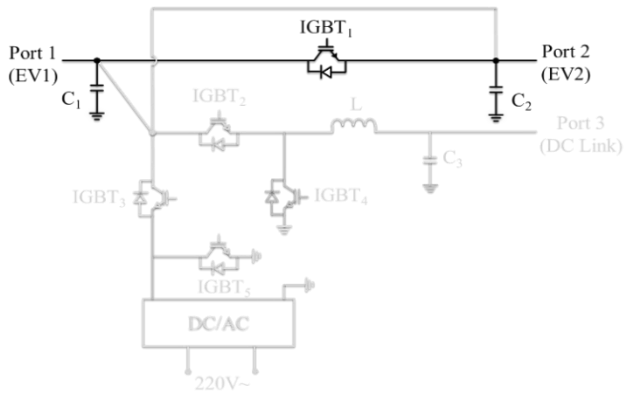

Figure 2. V2V mode of converter

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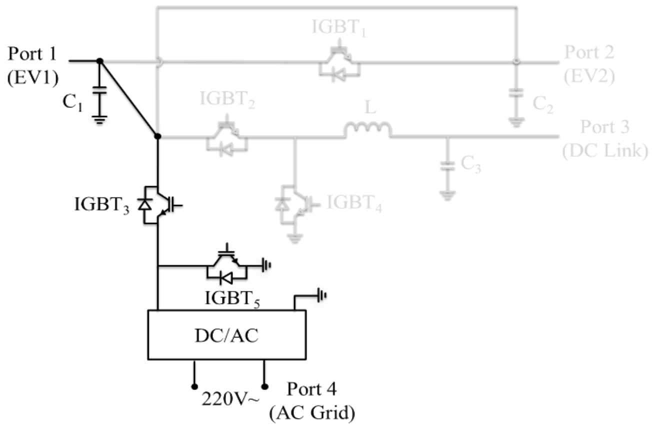

Figure 3. V2G mode (AC microgrid) of converter

Figure 3 shows mode 2 (V2G or V2H) operating from two basic main ports from the owner's homes (same grid), or a home located elsewhere with an electric vehicle charging port, the energy is exchanged in two directions. The basic converter operates on the step-up AC-DC principle. In the case when the EV energy is charged, the converter operates on the boost principle from 220VAC to 860VDC, the H-bridge converter operates to convert from AC to DC, the switch IGBT5 operates in which D of the IGBT5 isn't open, Diode D of the IGBT3 is operates to boost the converter with a switching frequency different from the operating mode 1, the current and voltage are determined according to *equation (3)*. In this mode, the pulse width of the IGBT5 is adjusted to a value suitable for the output voltage to reach V_{EV1}.

Output voltage at capacitor C1 and voltage at EV1:

$$V_{EV1} = V_{rms-AC} \cdot \frac{1}{1-d2} \tag{3}$$

Where: $V_{rms-AC} = V_{max}/\sqrt{2}$

d2 is the duty cycle of IGBT5

Where V_{max} is maximum amplitude of the AC voltage source in the distribution grid.

In this mode (V2G or V2H) when energy from the electric vehicle supplies loads in the household or loads from the microgrid connected to the distribution grid as assumed above. In this mode of this case, the converter operates in a step-down manner with IGBT3 operating and diode *D* of IGBT5 operating. The calculation expression of voltage is as described in *equation (4)*. Additionally, in this case, power can be supplied from a DC gateway link or from another electric vehicle that also supplies power to the distribution grid or to the household. In this mode, the pulse width value of IGBT3 is small, about *d3*=20-50%.

$$V_{rms} = V_{EV1}.d3 \tag{4}$$

Where *d3* is the duty cycle of IGBT3

In mode 3 (V2G DC distribution grid), energy can be converted in both directions: from the electric vehicle to the DC link using the step-down principle of the converter, and conversely, from the DC link to the EV using the step-up principle of the converter. The operation is described in *figure 4* through two main gates EV1 and DC link. The converter works in two main cases: Case 1, when energy is converted in the direction from EV1 to DC link, the IGBT2 switch and the diode *D* of the IGBT4 switch operate with the voltage calculation expression as *equation (5)*, assuming the pulse width d4 for the IGBT2 switch is smaller than the pulse width d3 because the voltage on the DC link is 400VDC, which is greater than the single-phase AC voltage.

$$V_{DC-link} = V_{EV1}.d4 \tag{5}$$

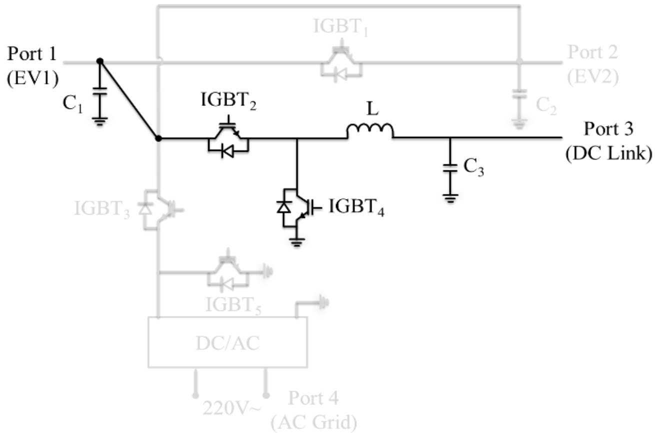

Figure 4. V2G mode (DC link) of converter

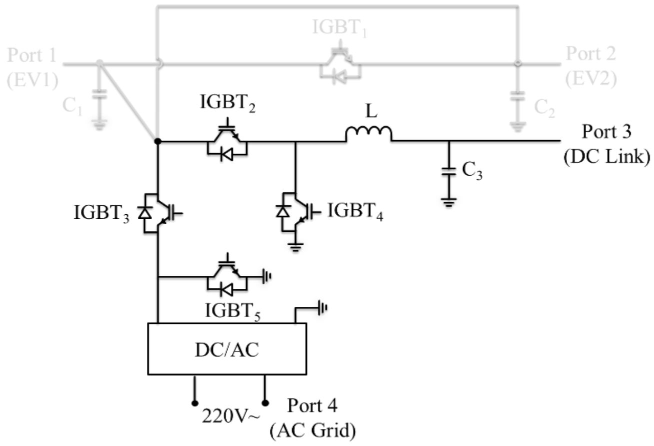

Figure 5. G2G mode of converter

Case 2 of the mode 3, when the energy is converted in the direction from the DC link to EV1, the IGBT4 switch and the diode *D* of the IGBT2 switch operate with the voltage calculation expression as in *equation (6)*, assuming the pulse width d5 for the IGBT4 switch is smaller than the pulse width d2 because the voltage on the DC link is 400VDC, which is greater than the single-phase AC voltage.

$$V_{EV1} = V_{DC-link} \cdot \frac{1}{1-d5} \tag{6}$$

Mode 4 (G2G) operates with two main ports as in *figure 5*, and energy can be exchanged between the AC microgrid and the DC link. This mode is not recommended in this proposed converter.

Due to the converters connecting the two grids, in case of necessity, the converter (mobile charger) can still be used. But this is also a necessary mode for actual power exchange to ensure continuity for the load. This is an issue that needs to be improved for this charger. The load of the two DC link ports and the AC microgrid are also supplemented by the energy from the EV in this mode.

The charger's control technology is implemented independently in separate operating modes using DPWM (Discontinuous Pulse Width Modulation). Each mode of the mobile charger will adjust to the appropriate control mode. *Figure 6* shows the independent control methods of each mode of the charger.

Figure 6 shows the coordination process of the control method for the proposed converter. The input parameters are compared with their reference values using feedback signals from each port based on voltage and current measurements. These signals are used to determine the appropriate pulse width and switching frequency to ensure maximum efficiency and a stable output voltage under different load conditions at the ports. At the EV load ports, where the load is an energy storage battery, the converter operates in a constant-current region and gradually increases the voltage during the charging process. At the DC port, a resistive load is used, for example for lighting. The load at the gate of the house or the AC microgrid is the R-L load for fans, electric stoves, lighting.

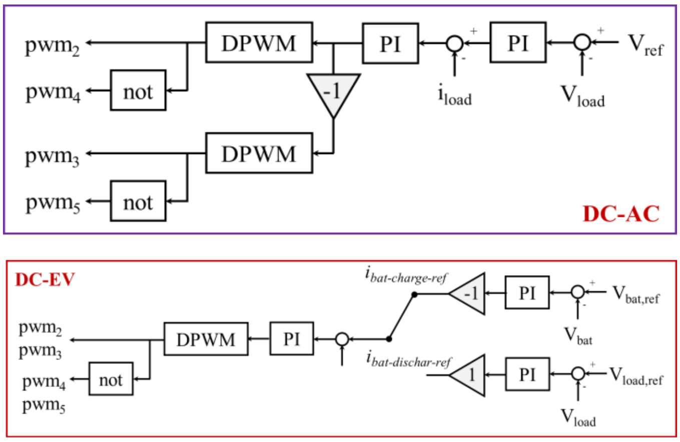

Figure 6. Proposed converter control diagram

The state variable of the converter is represented by *equation (7)*.

$$x = [i_{L1}\ i_{L2}\ v_{C1}\ v_{C2}\ v_{C3}]^T \qquad (7)$$

In which: the inductor current of port 3 and port 4

v_C: DC-link voltage for port 1, port 2, port 3, and port 4 General equation of state.

$$\dot{x} = A(d)x + B(d)u \qquad (8)$$

with: $u = [V_{EV1}, V_{EV2},\ V_{DC-link}, V_{AC}, V_{ESS}]^T$

Voltage at the gates and stored in DC and AC microgrids.
$d = [d1, d2, d3, d4, d5]^T$, Duty cycle vector

Inductor current equation (port *i*) port 3, 4.

$$\frac{di_{Li}}{dt} = \frac{1}{L_i}(diV_i - (1-di)v_C) \qquad (9)$$

DC-link port 1, 2, 3, and 4 voltage equations.

$$C\frac{dv_C}{dt} = \sum_{i=1}^{4}(1-d_i)i_{Li} - i_{load} \qquad (10)$$

Duty cycle – power relationship

Power at each port: $P_i = V_i . i_{Li}$ (11)

Average control relationship:

$$I_{Li} \approx \frac{1}{1-di} . \frac{v_{Ci}}{R_{eq,i}} \qquad (12)$$

$R_{eq,i}$ is the equivalent resistance viewed from port i of the converter at the average operating point.

The sign of the current determines the direction of power:
$P_i > 0$: power supply port
$P_i < 0$: energy receiving gate

The work cycle is determined independently:

$$di = \frac{v_{Ci}}{v_{Ci}+V_i} + \Delta di \qquad (13)$$

where v_{Ci} is the desired voltage that needs to be kept stable, Δd_i is generated by the PI controller.

Inner loop controller:

$$di = K_{pi}(\dot{i}_{Li} - i_{Li}) + K_{ii}\int(\dot{i}_{Li} - i_{Li})\,dt$$

$\dot{i}_{Li}$: desired current (generated by the upper control layer)
DC-link (outer loop) voltage controller.

$$\dot{i}_{Lk} = K_{pv}(\dot{v}_C - v_C) + K_{iv}\int(\dot{v}_C - v_C)\,dt$$

In this case: Port k is selected as the master port; the remaining ports control the power.

When the energy is converted into the form of two-way V2V controlled with DPWM, this control method is given to control the hash pulse form to bring the output voltage within the allowable vehicle charging range of 400-860VDC. The feedback signal is performed at the two ends of the two EV ports in the form of DC voltage. The control frequency is adjusted within the range with the best value shown in *figure 6*.

The energy from the renewable energy source at the charging station or from the DC microgrid is performed to increase and decrease the voltage in two directions, the feedback signal is in the form of DC voltage with different values at the EV port with voltage fluctuating up to 860VDC, the port at the DC microgrid 350-400VDC. Energy control for the DPWM type converter. Controlling energy from the AC microgrid or the distribution grid in households, the energy can be carried out in two directions and has voltage values at different ports, at the AC port is about 220VDC so the control technique increases or decreases the voltage according to DPWM.

3. RESULTS

In the converter with the input parameters to perform the simulation are shown in *table 1*. The input voltage value for EV charging is the value reaching level 1-2 charging, the power value of level 1 charging for electric vehicles. The parameters at DC link are shown according to the voltage near the AC distribution grid.

Table 1. Simulated input parameters for the universal charger

Parameters	Value/unit
EV1, EV2 charging voltage	600-860V
EV1, EV2 discharging voltage	600-860V
EV charging/discharging capacity	1-5kW
DC link voltage	400VDC
AC microgrid voltage	220V, 50Hz
AC microgrid load	(R-L)-3kW
DC link load	R-3kW
AC microgrid power	1-5kW
DC link power	1-5kW
L1, L2 coil	2.5mH

The converter is simulated using MATLAB. The internal structure of the gates is shown in detail, as in real-world EV gates, simulating actual battery cells with R_internal and SOC. The AC microgrid is single-phase or three-phase with a typical R+L load, phase-dependent power supply, and fixed-phase load. The DC link has a DC power source and a fixed load R. The converter simulates the main modes in two directions: EV–EV; EV–Home; EV–Grid; Grid–Grid, as specifically described in the figures below.

Figure 7 simulates the converter with 2 different cases. *Figure 7 (a)* SoC process of storage at EV1, *figure 7(b), (c), (d)* depicts the simulation graph of current, voltage and energy conversion capacity between two ports EV1 and EV2. When energy is transferred from EV1 to EV2, the voltage at EV1 is 860VDC, while the voltage at EV2 is lower than the allowable value of 850VDC due to the pulse-cutting circuit principle. The pulse width d1 is 65%. The power received by EV2 is approximately 4kW, and the power delivered from EV1 is 4kW. The current through EV1, as shown in *figure 7 (c)*, is negative due to energy transfer. The current and voltage waveforms on EV2 are as shown in *figure 7*. Similarly, when EV1 is charging, the current, voltage, and stored power are as described in *figure 8*. As shown in the simulations in *figures 7 and 8*, in this mode, energy is converted in a simple structure with a stable voltage and current waveform when transferring energy in two directions EV1-EV2 or EV2-EV1 with the same control principle. The power transmitted and multiplied at the EV gate are approximately equal because the losses in this mode are only the main losses on a single IGBT1 switch, which depends on the switching frequency as described in the working principle in *figure 2*.

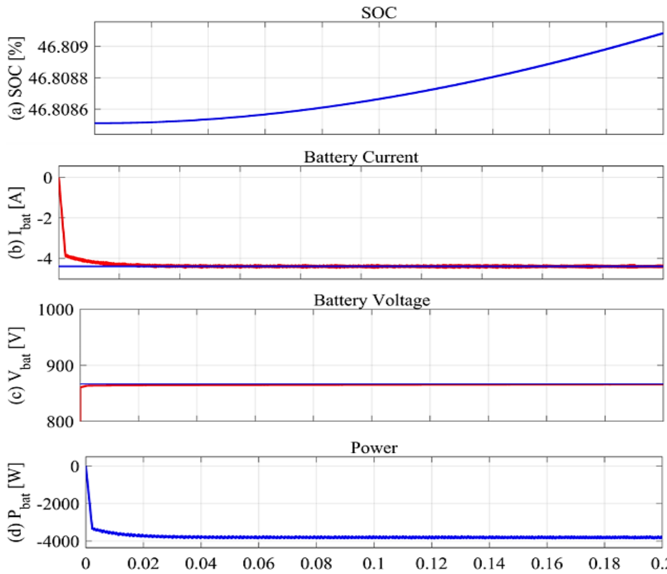

Figure 7. EV SoC graph when charging V2V mode

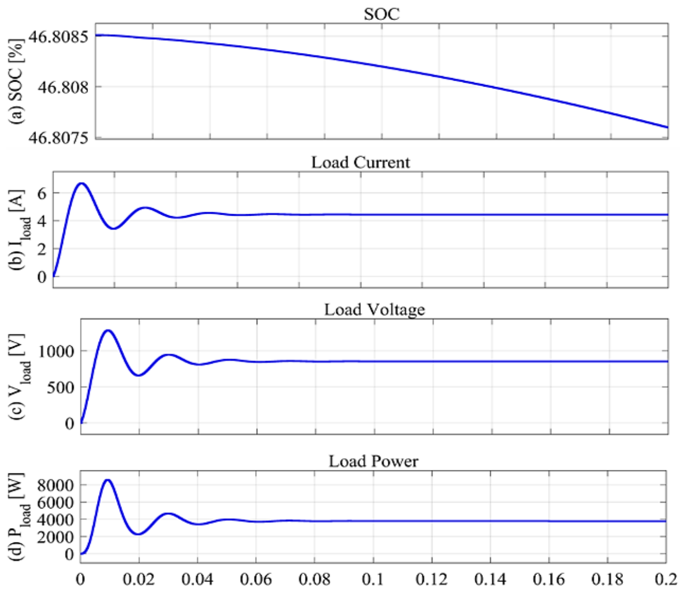

Figure 8. EV SoC graph when discharging electric energy V2V mode

Figure 9 shows mode 2 implementing two ports of the house or microgrid with the electric vehicle. The current signal through IGBT3 represents the charging or discharging process of the electric vehicle EV. The voltage on IGBT3 400VDC represents the selected voltage for the switch IGBT3. The energy exchange between the two ports 5.1kW is shown from the direction from EV1 or EV2 to the AC microgrid (or house load). The switch IGBT5 and IGBT3 are calculated and selected as mode when power is transferred from the AC distribution grid to port EV1 or EV2, the voltage of IGBT5 works in boost mode and the voltage on the switch is close to the voltage on the EV port. In the diagram, we can see that the voltage of the IGBT5 switch changes greatly during the conversion process when the output voltage supplied to the EV changes from 600-800V. *Figure 9* shows the 3-phase power supply from the AC microgrid (V2G).

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In this mode, the converter's performance depends on the IGBT5 switch, which operates to convert energy in the G2V direction using a step-up principle to a value of 600-800VDC. Therefore, the step-up voltage increases the duty cycle of the IGBT5 switch, leading to increased energy loss during the conversion process and consequently reduced efficiency. Alternatively, IGBT3 operates using a step-down principle, converting energy in the V2G direction. In this case, the duty cycle for IGBT3 is smaller, reducing losses during the switching process and increasing efficiency. *Figure 10* shows the simulation results of a single-phase grid power supply for a residential system (V2H) with a current, voltage and power exchange of more than 2.6kW. The simulation results show that the harmonics of the current and voltage have small values, the harmonics of the converter have a value of 0.27% shown in *figure 11*. This mode, the electrical quality guaranteed to meet the IEC-EN 50160 standard with a voltage of <5%.

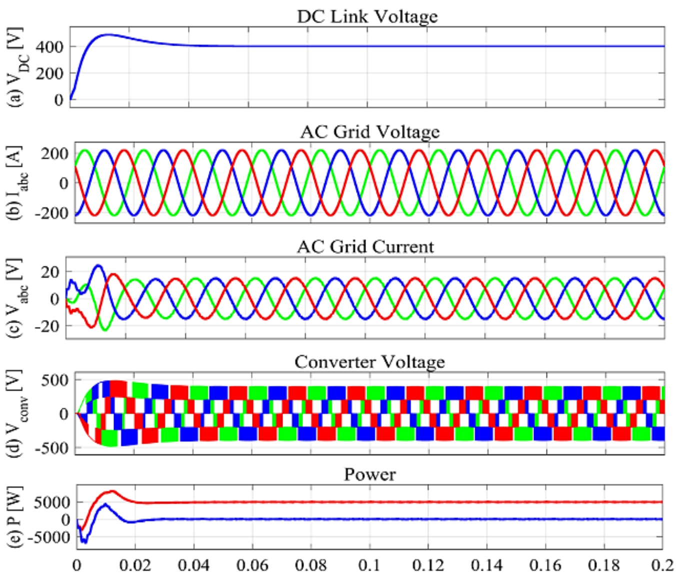

Figure 9. AC microgrid port current, voltage and power (three-phase) graph V2G or V2H mode

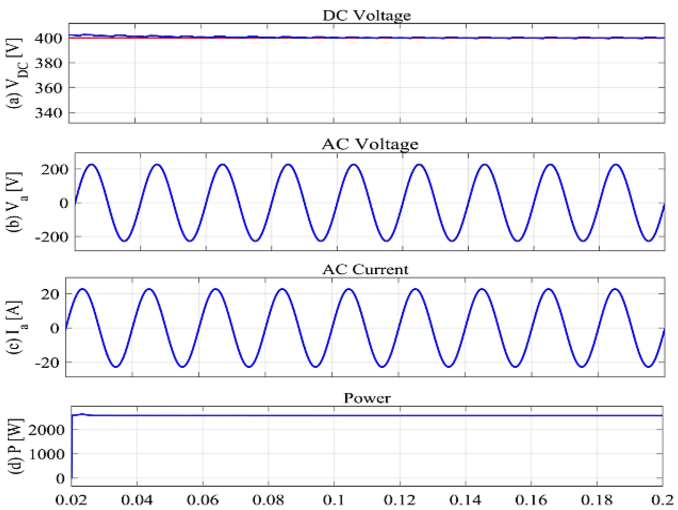

Figure 10. AC microgrid port current, voltage and power (single phase) graph V2G or V2H mode

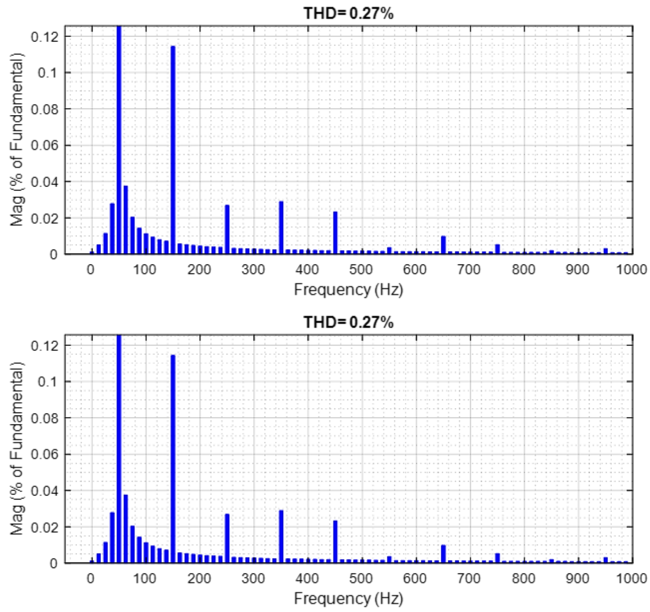

Figure 11. THD% value of energy conversion in converter V2G (three - phase) or V2H (single phase) mode

Figure 12 illustrates the simulation results of the proposed converter's operating mode, showing power transferred from the DC link to EVs 1 and 2, or energy transferred to a separate EV. *Figures 12 (b), (c),* and *(d)* show the current, voltage, and power graphs of the EV when energized, corresponding to the SoC graph in *figure 12 (a)*. The power output received by the EV is over 5kW, fluctuating and gradually decreasing throughout the simulation. The changing load pattern leads to a decrease in the charging current to the EV according to the load value, while the voltage at the EV charging port remains constant. This mode is an example of load change during energy conversion, with the converter operating stably.

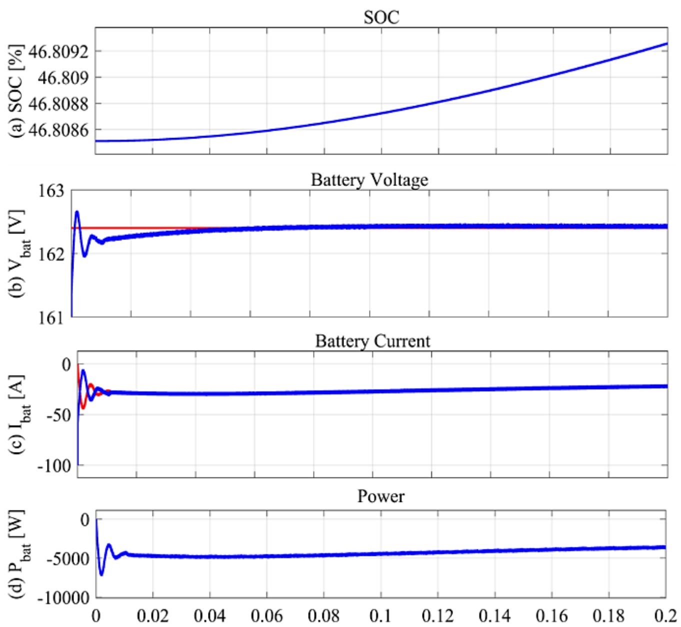

Figure 12. EV charging value V2G mode

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Figure 13 shows the discharge or energy conversion to EV value of the DC link. *Figure 13* shows the current, voltage, and power graphs at 5kW as shown in *figure 13(d)*. *Figure 13(a)* shows the SoC process when discharging energy from the storage in the DC link. The voltage selection for the switch for IGBT2 and IGBT4 is the same as IGBT3 and IGBT5 in the converter. The switch IGBT2 is the same as the selection of IGBT3 in mode 2 of the converter. In this mode, the converter performs bidirectional conversion in two forms: voltage boosting in the DC-link to EV direction and voltage reduction in the EV to DC-link direction. One difference from mode 2 is that the voltage at the DC-link is 400VDC, resulting in a smaller voltage boost factor and a shorter duty cycle for IGBT4 compared to IGBT5, thus improving efficiency compared to mode 2.

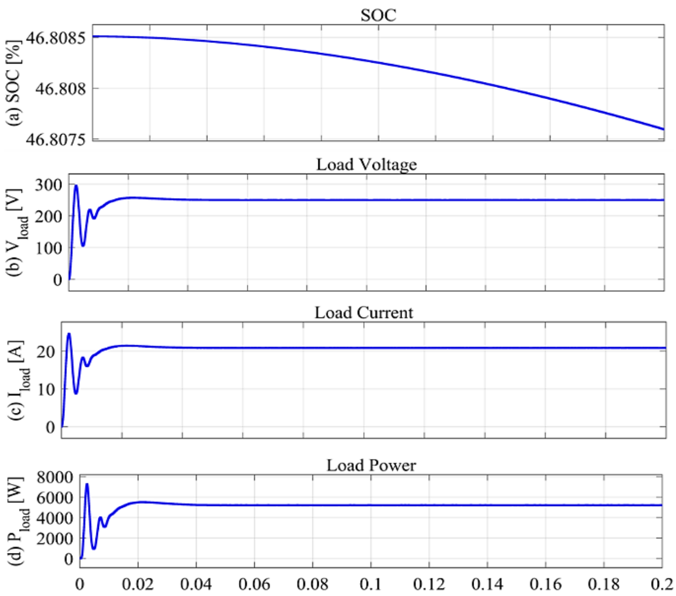

Figure 13. EV discharge value for DC link V2G mode

In mode 4 energy exchange mode, it is simulated as *figure 14* and *figure 15*. The power transmitted from the AC grid to the DC link is 4.5kW (step-up switching mode), and 4.7kW (step-down switching mode) in the direction from the DC link to the AC grid. The voltages across IGBTs 2 and 4, and IGBTs 3 and 5 are in a lower range compared to modes 2 and 3 due to the smaller voltage transfer coefficient, resulting in shorter duty cycles for IGBTs 4 and 5 compared to modes 2 and 3. The total losses at the circuit components in this mode equal the total losses of the switches minus IGBT1, thus reducing efficiency. The power quality is shown in *figure 15* when the harmonics of the converter are about 0.2%. The current and voltage harmonics exchange at both ends 1.02%. This mode is similar to; the electrical quality is guaranteed to meet the EN 50160 standard with a voltage of <5%.

The above converter with 4 basic operating modes performs conversion processes with three basic conversion forms in power electronics, which are DC-DC, DC-AC and AC-DC, corresponding to the power value of 1-5kW for each specific mode. With the simulation results, we see that the G2G mode conversion has the disadvantage of many switches working at the same time, leading to the largest loss on the switches in the modes and the total harmonics also have a larger value for mode2. Furthermore, the G2G mode in the proposed converter presents a problem with energy conversion through two stages. When converting energy from AC to DC-link microgrid, there are two stages: a voltage increases *via* IGBT5 and a diode in parallel with IGBT3, followed by a voltage decrease via IGBT2 and a diode in parallel with IGBT4. This leads to significantly increased losses due to the number of electronic switches involved in energy conversion. In which, it is assessed that the harmonics depend on the control frequency (switching frequency 10-40kHz for simulation) for the main switches in the proposed converter, which is IGBT2-IGBT5. When the frequency increases from 10-40kHz, the total harmonics decrease.

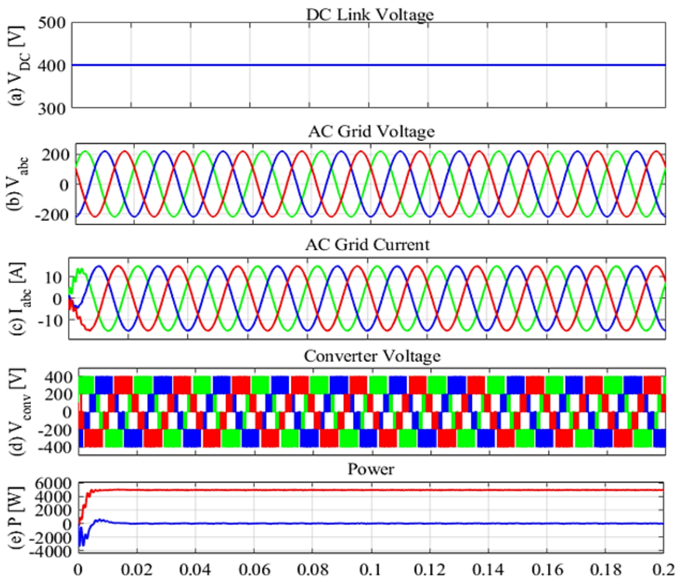

Figure 14. Current, voltage and power loss graphs of DC link and AC microgrid G2G mode

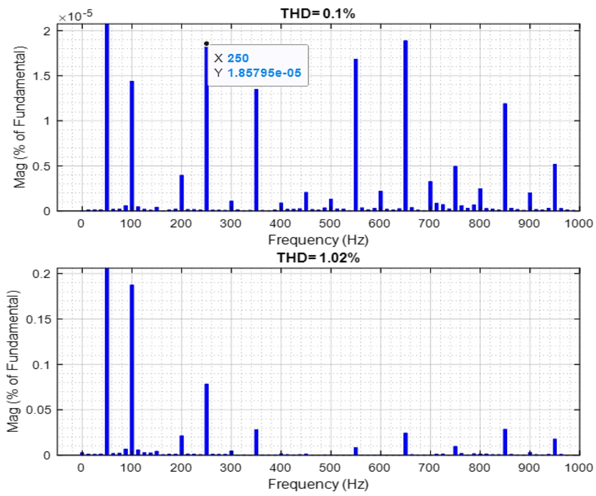

Figure 15. THD% value of energy conversion in converter G2G mode

The simulation results show the performance values for each operating mode of the proposed converter's energy conversion, as shown in *figure 16*. The highest efficiency value is shown in mode 1 when the V2V conversion energy between electric vehicles is 99.2% corresponding to 1kW capacity. The lowest efficiency for the charger is the energy conversion process of mode 4 energy from DC link to AC microgrid 95.4% at 5kW capacity. V2H and V2G modes have the highest efficiency of 98.1% at 1kW capacity. In addition, this converter also has V2G mode for DC microgrid with the highest efficiency of 97.8% at 3kW.

Unlike [24] in *table 2*, the V2V of the converter has 4 balanced switches and two capacitor-balanced switches, the switching frequency is high at 200kHz, such a structure has a relatively high efficiency of up to 98.9% in V2V mode. In [23], there are also eight switches that can reasonably balance the capacitor voltage. However, although in this converter, the four A–D switches can withstand the entire DC bus voltage switched at low frequency, such a structure has a lower efficiency due to the higher stress on the remaining switches, *i.e.* GH in V2G mode and EF in V2G mode. According to *table 2*, its efficiency in V2G and G2V modes is 96.5%, respectively.

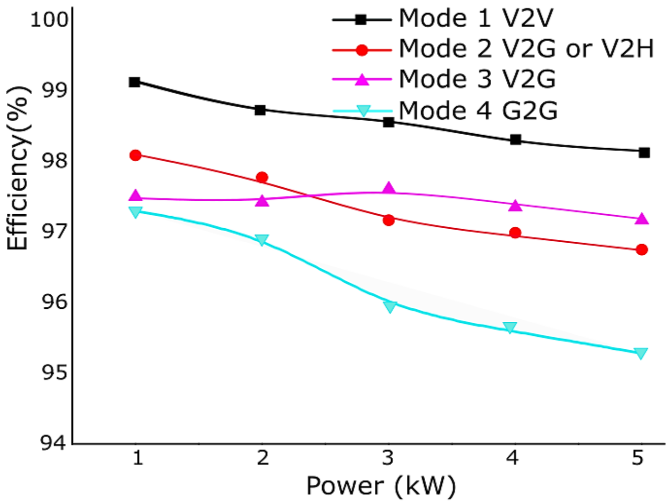

Figure 16. Efficiency of 4-mode conversion circuit

Table 2. Performance comparison with different converters

Converter	V2V	V2G (V2H)	G2G
[24]	98.9%		
[23]		96.4%	
[21]			95.5%
[22]			97.4%
Proposed	99.2%	98.1%	97.2%

Compared to [21] in *table 2*, the proposed microgrid interconnected converter has more than five switches and in which two switches are used. However, unlike [21], it is capable of increasing and decreasing the voltage by single-side switching with no performance degradation despite the same number of switches, while in contrast to [22] which has three switches, it not only achieves higher performance but also reduces the stress on the switches and distributes the power loss more evenly. The efficiency of the proposed structure is 97.4% in G2G mode. Within the scope of this paper, the research focuses on theoretical analysis and performance evaluation of the system through simulation. Hardware experimental implementation has not been carried out due to time and resource limitations and the need to refine the design to ensure safety and reliability. Further studies will focus on building an experimental model to verify and extend the results obtained.

5. CONCLUSIONS

The EV portable charger features four basic ports and achieves a high conversion efficiency of up to 98.6% at the average charging power level of Level-1 electric vehicles. In addition, the charger can supply electric vehicles with a high DC voltage of up to 860 V through direct energy conversion between the ports. The total harmonic value is less than 3.8% for the conversion modes. The research proposal proposes a universal charger for a common electric vehicle that can implement flexible modes, convenient for vehicle users, with the following advantages:

- Reduce the number of charging stations in the EV charging station network, reduce investment costs, reduce travel time of electric vehicle owners.
- Coordinate multiple energy sources simultaneously to enhance system stability and reduce stress on power supply from the grid.
- Increase the awareness of energy saving for vehicle users.
- Save money on vehicle operation by implementing flexible energy use from the proposed converter.
- Reduce greenhouse gas emissions in the living environment.
- Develop flexible microgrids that contribute to the integration and advancement of smart grids.
- Further research to evaluate the economics of a universal charger for electric vehicles will be presented in other future publications.

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