

THREE-PHASE OF BI-DIRECTIONAL Z-SOURCE CONVERTERS FOR VEHICLE-TO-GRID APPLICATIONS A LOW-HARMONIC AND FUZZY LOGIC CONTROL METHOD

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Abstract - This paper presents the plan of shut circle regulators working a solitary stage AC-DC three-level converter for further developing power quality at AC mains. Shut circle restrains external voltage regulator and inward current regulator. Reproductions of three level converter with three unique voltage and current regulator mixes, for example, PI-fluffy Rationale control are completed in MATLAB/Simulink. Execution boundaries, for example, input power variable and source current Total Harmonic Distortion (THD) are considered for examination of the three regulator mixes. The fluffy tuned PI voltage regulator with hysteresis current regulator blend gives an improved outcome, with a source-current THD of 0.93% and solidarity power factor with no source side channel for the three level converter. For load varieties of 25% to 100 percent, a THD of under 5% is gotten with a most extreme worth of just 1.67%. At last, the fluffy tuned PI voltage. A source-current THD of 1.351% is gotten in the exploratory review with a power factor close to solidarity. In this paper, three new balance plans for three-stage Z-source converters are proposed and explored. The best performed one is additionally evolved to a shut circle fluffy control strategy. While the voltage change proportion is adaptable, the result voltage Absolute Sounds Bending (THD) is beneath 3% inside the voltage proportion scope of 0.5 to 2.5. The adequacy of the proposed strategy has been completely approved in MATLAB/Simulink reproductions Contrasted with existing control techniques, the proposed one performs better with diminished music, adaptable voltage gain, and more straightforward control algorithm.

Key Words: Z-source converter, Bi-directional converter, shoot-through states, voltage harmonics, closed-loop closed-loop, fuzzy control method

1. INTRODUCTION

Shape impedance network composed of two inductors LZ1, LZ2 and two capacitors CZ1, CZ2 is combined in a traditional three phase full-bridge inverter [6]. Because of the existence of the X-shape impedance network, it is possible to turn on the two none bridge simultaneously without short-circuited the input voltage source [4]. Moreover, the Z-source

inverters take advantage of the shoot-through states ingeniously to achieve voltage boosting without any additional switches or control circuitry [7]. Therefore, the Z-source inverters could achieve voltage buck and boosting by a single-stage topology with high robust. The voltage level of different microgrids could vary considerably, which makes the Z-source converters more advantageous in the process of EV batteries' feeding to

The grids. The Z-source inverter could also operate bidirectional, which is essential in V2G applications. The input diode D_r is connected in parallel with a switch S1. When switch S1 is turned on, the Z-source inverter could operate as a conventional three-phase PWM rectifier. Because of the above-mentioned features, Z-source converters have been widely investigated in areas of not only EV charging [8] [9], but also EV motor drive [10] [11], PV solar energy system [12] [13], wireless energy transfer [14] [15] and integration of microgrid [16] [17]. The increasing voltage gain capability and modulation indexes of both rectifier and inverter stages are advantages of three-phase Z-source converters [18]. Different approaches of applying bi-directional Z-source inverters in V2G applications have been investigated [19] [20]. Paper [21] provided an overall introduction and comparison of space vector modulation schemes for three-phase Z-source inverters. Besides the basic Z-source impedance topology, many modified Z-source topologies have been developed [22]- [24] to reduce switching loss and improve power density. Though these proposed converters based on Z-source topology could generally achieve smaller size and wider voltage conversion ratio, they have issues in complicated structure, instability, voltage stress of switches, power level limitation [24] and output harmonics [7] [25]. Therefore,

This paper aims to improve the performance of converter by designing and optimizing the control method of a basic three-phase Z-source converter, rather than adding more devices or complicated circuits. India has relatively long sunny days for more than ten months and partly cloudy sky for most of the days i.e. almost two months. This makes India very rich in solar energy especially desert sides in west

which include Gujarat, Rajasthan, Madhya Pradesh etc. Photovoltaic Panel or modules are used directly to create electricity. Besides this solar panels however, it also needs “Balance of System” components including inverters, wiring, breakers and switches, which can account for up to half of the system cost. Inverters like string inverters, micro-inverters are used with PV panels. In string inverters the several numbers of panels are connected in series with one centralized inverter, while micro-inverter invert the electricity from single PV panel, as each panel has a single inverter attached beyond it. Micro-inverter is an upcoming field of research in PV technology as it has more advantage over other PV systems. It is used as plug and play devices. Typically, the microinverter are design for lower ranges; as the capacity of solar panel increases, the size of micro-inverter should increases as well[1,2]. In this paper the simulation of micro-inverter is discussed with analysis of control techniques of it Global temperature changes have become a major problem in global warming in recent years. In addition to energy demand, there is also an environmental threats. Many countries are concerned to reduce their ozone-damaging emissions and to continue their efforts to improve the energy system. Renewable energy sources see how these problems are solved. In 2017, an estimated 17 countries generated more than 90% of their electricity from renewable sources [1]. Solar energy is considered to be one of the most important renewable sources available in abundance, free of pollution and free of charge in remote areas where there is still no electricity. [2]-[3].

Solar power extracted from solar photovoltaic (PV) cells delivers low efficiency [4]. Because of these problems, it is important to extract maximum power from solar photovoltaic cells and improve efficiency in different weather and temperature conditions. An MPPT or Maximum Power Point Tracking is an electronic tracking device usually digital DC to DC converter which is connected between solar panels and battery or the utility grid that optimizes the match between the solar array (PV panels), and the battery bank or utility grid. It monitors the PV array for the maximum power point and tries to use this information not only to control the output Typically, this means that the voltage is reduced while the current is increased and most of the overall

2. CLOSED-LOOP CONTROL METHOD

Open-loop simulations are presented above where M and B are constant. To achieve closed-loop control, M and B shall be calculated according to the measured output voltage via PI control in real-time to ensure that the output voltage magnitude would follow the reference. The dynamic response design process is the same as the one of conventional PI control. The closed-loop control diagram of switching signals generation is presented as shown in Fig. 1.

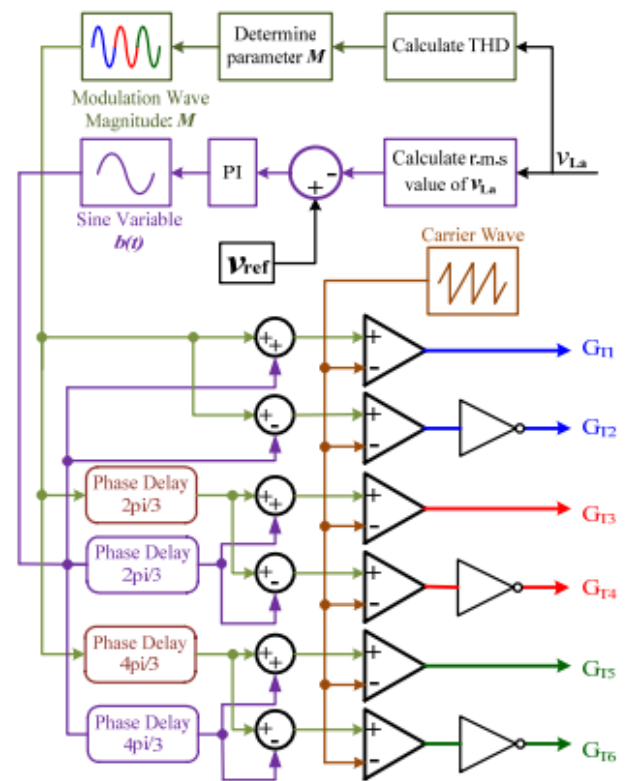


Fig. 1 Generation of switching signals in closed-loop control at balanced load case

Two closed-loop simulations are conducted. First, the reference voltage has a step change from 750V to 900V (r.m.s.), i.e. the peak voltage changes from 1060V to 1273V. Fig. 1 shows that the balanced three phase voltages increased to the new reference smoothly within eight cycles, which takes 0.16s. Secondly, the resistance R_{load} of each resistive load in star connection switches from 112.5Ω to 200Ω. As shown in Fig. 2, at the moment of load change when $t=0.5s$, the output voltage increases for a short time because of the disturbance in load resistance. Then the output voltage is soon regulated and reduced to the rated value 1060V. The output voltage and current become stable within two cycles. The design of this closed-loop control is based on applying the new sine variable modulation scheme to the traditional closed-loop SPWM PI control methods. There is no modification in the topology of the three-phase Z-source inverter. The common control variable of Z-source inverters is the shoot-through duty ratio D , which is equal to $6B/\pi$ in the proposed modulation schemes. The common output variable of the closed-loop control design is the capacitor voltage $VCZ1$ Fig.13 Simulation waveforms when reference voltage changes Fig.14 Simulation waveforms of output phase voltages and currents when Rload changes (equal to $VCZ2$), which directly determines VZ and output voltage magnitude. Therefore, the methodology of small signal analysis, transfer function and dynamic response design by bode plot of typical three-phase Z-source inverters could be directly adopted in the proposed modulation scheme. The

proposed control could also be easily modified for the operation in grid-connected mode. In conventional SPWM control methods of grid-connected three-phase full-bridge inverters, the magnitude of modulation waves is derived for generating switching signals [38]. The values of parameter M and B could be obtained based on the value of $Sabc$. Parameters mAu , mAl , mBu , mBl , mCu , mCl are thus obtained which represent the magnitudes of modified corresponding modulation waves to insert shoot-through states. The main characteristics of conventional control methods are maintained. It is assumed that the three output phase voltages or three-phase loads are balanced in this paper, thus only phase voltage vLa is being measured and calculated for the closed-loop control as shown in Fig. 12. If there is a voltage or load unbalance, only phase voltage vLa could catch the reference while the other two phase voltages would vary. Therefore, the proposed closed-loop control method works the best when there is no voltage unbalance present in the connection point to the grid. Input voltage so that the output (load) is higher than the input [6]

Implementation of Boost Converter Fig.9. Boost converter circuit containing an inductor, a transistor, a diode, and a capacitor. The connection of the transistor behaves similarly to a switch which can turn on or off by controlling transistor gate voltage. If we close the switch DC voltage appears across the inductor and continue increasing so long as the switch is closed. The current through an inductor cannot change instantaneously [7] therefore the moment we open the switch the inductor will create a force causing the current to continue flowing towards output circuit

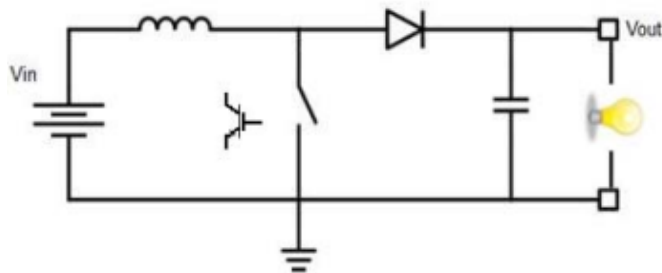


Fig.2 Basic schematic of step-up/Boost converter with load.

Continuous switch on and off We can control DC output voltage by controlling the percentage of time that turning the switch on and off.

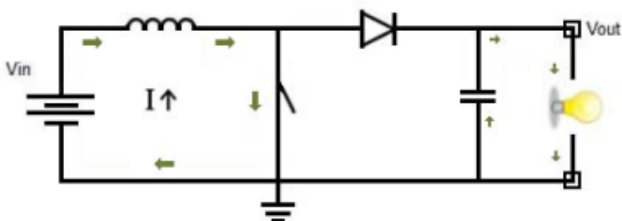


Fig. 3: Step-up/Boost converter (switch on for D% duty cycle)

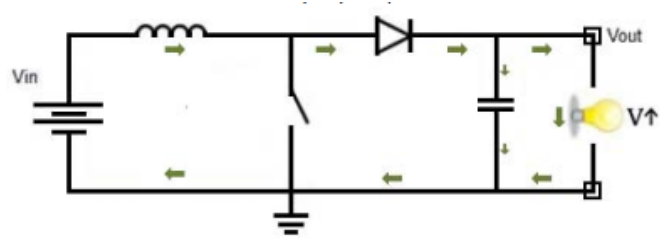


Fig.4: Step-up/Boost converter (switch off for D% duty cycle)

ii. Switch off (0% duty cycle) If we leave the switch turn off 100% of the time, the output voltage will equal to the battery voltage.

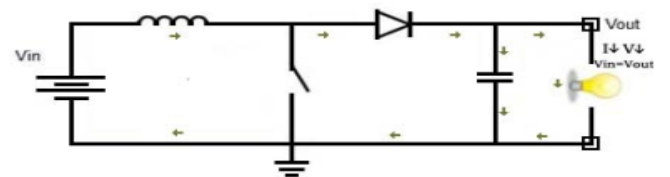


Fig. 5: Step-up/Boost converter (switch off for 100% duty cycle)

Switch on (100% duty cycle) If we leave the switch always on 100% of the time, the current will theoretically keep increasing to infinity and overcurrent flow can generate an excess amount of heat which can cause damage the entire circuit

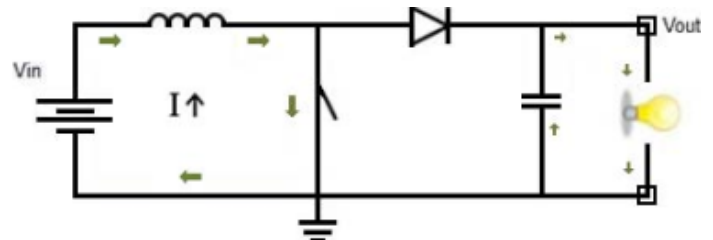


Fig. 6: Step-up/Boost converter (switch on for 100% duty cycle)

SIMULATION RESULTS

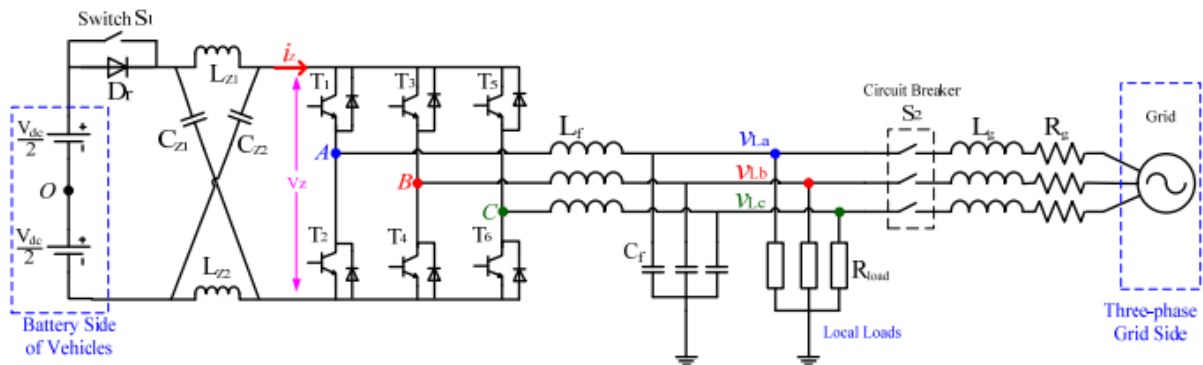


Fig7. Open-loop simulations have been conducted in Matlab Simulink.

The DC side voltage V_{dc} is set as 500V to represent a typical EV battery voltage. The balanced three-phase loads are composed of three resistors whose resistance R_{load} is 112.5Ω in star connection, $LZ1=LZ2=280\mu H$, $CZ1=CZ2=141\mu F$, $L_f=8.95mH$, $C_f=7\mu F$, AC output frequency $f=50Hz$. The calculation of these parameters is presented in the Appendix.

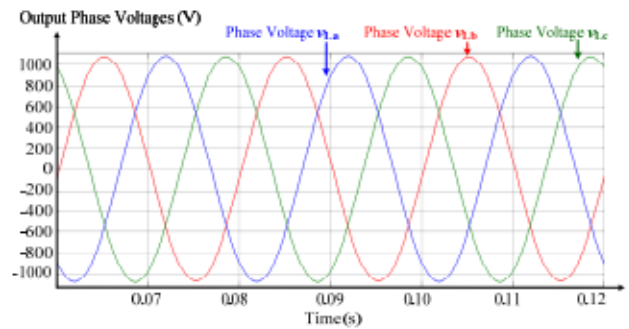


Fig. 8 Output phase voltages of sine variable method at rated output voltage.

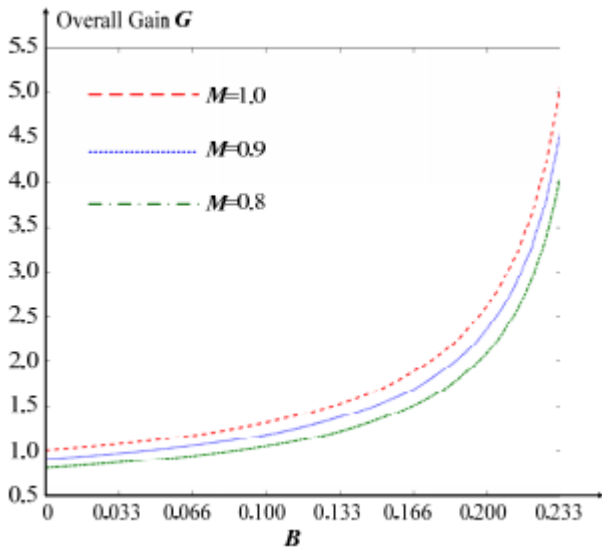


Fig.7 Relationship between the overall gain G and parameter B First, the simulation at rated output voltage of sine variable method is conducted.

The peak magnitude of rated output phase voltage is set as 1060V, whose r.m.s. value is 750V at the medium voltage level. Fig. 8 shows the waveforms of three output phase voltages v_{La} , v_{Lb} and v_{Lc} respectively. The THD of each phase voltage is only 2.66%.

To further investigate the difference among the three methods on output voltage harmonics, open-loop simulations have been conducted with $M=0.9$ and $B=0.25$ such that the magnitude of modified modulation waves would go beyond the magnitude of the carrier wave and the output harmonics would increase undoubtedly. In this way, the effect of the three control methods on output harmonics could be clearly illustrated. Waveforms of output phase voltages are presented in Fig. 9. It is clear that with such a large value of B , the output harmonic of sine variable method still maintains within a low level. In contrast, the harmonics of cosine variable method is much greater. The harmonics level of constant variable method is slightly lower than one of cosine variable method, but the voltage magnitude is lower than expected.

This is because the total duration of the shoot-through states in a three-phase topology has become too long, and the average magnitude of both the capacitor voltage $VCZ1$, $VCZ2$ and voltage VZ could not reach the ideal values in (3). The harmonic analysis plots of three methods are shown in Fig. 10. The cosine variable method produces the highest 5th order harmonics. The 5th, 7th and 11th order harmonics account for most of the total harmonics in the three methods, while there is little even order harmonics because of the

symmetricity of the control logic. Fig. 11(a) represents the relationship between the THD of phase voltage V_{La} and parameter B when $M=0.9$. As the magnitude and frequency of output phase voltage V_{La} are the same as V_{Lb} and V_{Lc} , only V_{La} is presented as a representative.

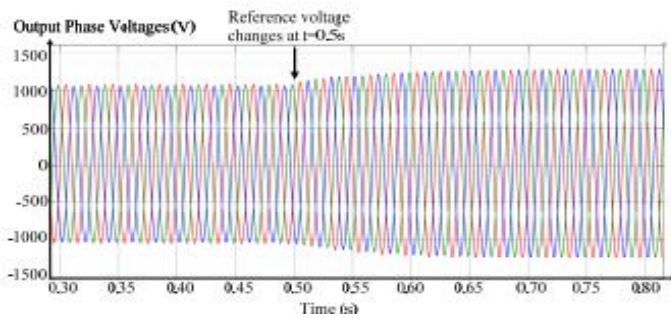


Fig9. The THD increases as B increases because of the shoot-through states insertion.

Cosine variable method has the greatest output harmonics, while sine variable method leads to lowest output harmonics. For sine variable method, the total THD of output phase voltage V_{La} is only 2.83% when $B=0.2$, which means the magnitude of the modified modulation wave already exceeds the magnitude of the carrier wave. Since the output load is resistive, the voltage distortion and current distortion are the same. For reference, the harmonics of 2nd - 19th orders are compared with the limits in the IEEE 1547 standard [37] as shown in red in Fig. 10(d). It is clear that the output harmonics are well below harmonic limits of the IEEE 1547 standard.

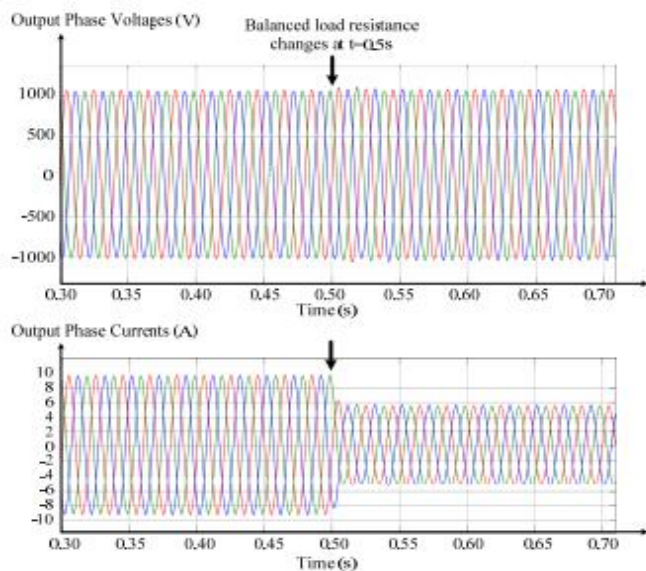


Fig.10 Simulation waveforms of output phase voltages and currents when Rload changes.

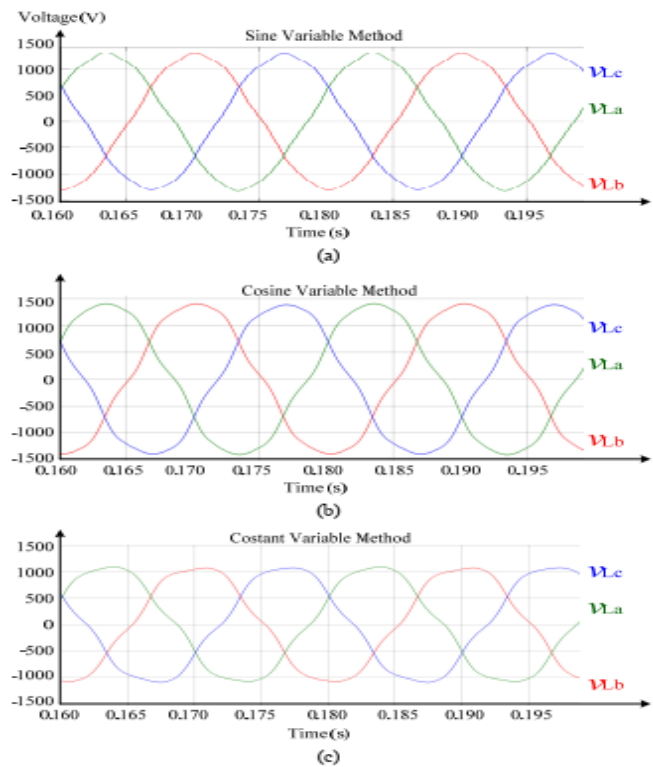


Fig. 11 Waveforms of output phase voltages with high shoot-through duty ratio D : (a) Sine variable method; (b) Cosine variable method; (c) Constant variable method

CONCLUSION

This paper presents the design of closed loop controllers operating a single-phase AC-DC three-level converter for improving power quality at AC mains. Closed loop inhibits outer voltage controller and inner current controller. Simulations of three level converter with three different voltage and current controller combinations such as PI-fuzzy Logic control are carried out in MATLAB/Simulink. Performance parameters such as input power factor and source current total harmonic distortion (THD) are considered for comparison of the three controller combinations. The fuzzy-tuned PI voltage controller with hysteresis current controller combination provides a better result, with a source-current THD of 0.93% and unity power factor without any source side filter for the three level converter. For load variations of 25% to 100%, a THD of less than 5% is obtained with a maximum value of only 1.67%. Finally, the fuzzy-tuned PI voltage. A source-current THD of 1.351% is obtained in the experimental study with a power factor near unity in this paper, three new modulation schemes for three-phase Z-source converters are proposed and investigated. The best performed one is further developed to a closed-loop fuzzy control method. While the voltage conversion ratio is flexible, the output voltage Total Harmonics Distortion (THD) is below 3% within the voltage ratio range of 0.5 to 2.5. The effectiveness of the proposed method has been fully validated in MATLAB/Simulink

simulations Transient waveforms showed the dynamic response with the disturbance of input voltage and load resistance. The output phase voltages could catch the reference quickly and smoothly. Compared to existing control methods, the proposed one has better performance on harmonics suppression with an uncomplicated control algorithm, thus would be suitable for its application in vehicle chargers with bi-directional power flow between the vehicle batteries and the three-phase AC bus of a microgrid. The future work mainly includes the implementation of an EV charger prototype to testify the charging performance and conversion efficiency in a Power Hardware-In-Loop (PHIL) testing platform, suppression of the input current spikes and the advanced control in unbalanced load cases.

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