IJAREEIE

e-ISSN: 2278-8875
p-ISSN: 2320-3765

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

Volume 10, Issue 12, December 2021

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

Impact Factor: 7.282

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 7.282|

|| Volume 10, Issue 12, December 2021 ||

DOI:10.15662/IJAREEIE.2021.1012037

Electric Vehicle Battery Charging with Novel DC-DC Converter with Charging Current Limiter Controller

Anuradha H. Budhewar

Department of Electrical Engineering, Government College of Engineering, Aurangabad, India

ABSTRACT: The DC/DC converters are the heart of the two-stage onboard charger for the electric vehicles. The phase-shifted full-bridge soft-switching DC/DC converters currently have issues with lagging leg commutation, voltage fluctuations for the transformer's secondary side, and less efficiency. This study proposes the full-bridge DC/DC converters and two clamp diodes with synchronous rectification. Clamping diodes are used to control voltage oscillations on the transformer's secondary side and give commutating energy for lagging leg. Synchronous rectifications lowerswitching device's loss. DC/DC converter's operating principle and control mechanism are investigated, also switching device loss are estimated, and simulation result shows, when comparison to the DC/DC converters, the voltage impulses at secondary side on transformer are small and efficiency is high, so that soft switch has implemented over the large load range, meeting for requirement of fast charging of vehicles-mounted batteries.

KEYWORDS: Automotive Power Electronics, Dc-Dc Converters, Electric Vehicle, Battery.

I.INTRODUCTION

Vehicles that run on electricity (EVs) are grown in popularity due to their high efficiency with pollution-free benefits. As the number of electric vehicles grows, so that technological demand for onboard charger [1]. The onboard chargers (OBC) must get to know the requirement of high-power density and high charging efficiency with strong Effect of heat dissipation due to the limited internal space [2]. PFC converter and isolated DC-DC converter are included in the two-stage OBC. The converter AC - DC with the latter providing thelarge range of DC for charging electric vehicle batteries. The primary goal for electric vehicle onboard converter is to improve operational efficiency and reduce volume [3]. PFC research is relatively established, with prior research achieving an efficiency of over 98 percent [4]. As a result, the total efficiency, power density is highly dependent on the DC-DC converter's design and operation. The high-frequency switching converters are currently frequently utilise in DC-to-DC converters. Generally, the switching frequency that is in tens of kHz range [5]. The raising switching frequency reduce equipment volume, that causes issues like increased switching losses, decreased efficiency and increased electromagnetic interferences. Soft switching solutions like ZVS, ZCS, and LLC have been developed to address these issues [6]. This method in the high-frequency condition of the converter, it minimise switching loss with noise interferences for power switching devices, enhancing efficiency and power density while also lowering the converter's volume and weight [7].

Full bridge PWM circuit, full-bridge resonant circuit are two traditional DC-DC converter topologies used in OBC [8]. Switchless off voltage spike and low circulating current power are two advantages of the LLC converter. When A DC-DC converter's output voltage range is combined with charging curve of vehicle batteries, The converter's switching frequency deviates significantly from the resonant frequency, and the output voltage range is expanded the system loss increases [9]. A typical full-bridge PWM converter with significant reactive power circulation is unable to execute gentle switching under a light load, but it can adjust to a wide output voltage range and fixed switching frequency. [10]. As results full-bridge phase-shifted converters in conjunction with controlled supplementary current has propose, that achieve soft full-load switching transistor at a high cost with difficult in control [11]. The reverse recovery loss of the rectifier diode has been reduced by controlling the secondary side of the transformer with phase-shifting control, although the efficiency is less at full load [12]. This paper proposes the improved ZVS phase-shifted full-bridge DC/DC converter. The secondary rectifier's voltage oscillation is eliminated using two clamping diodes. To reduce system losses, a synchronous rectifier (SR) is used.

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 7.282|

|| Volume 10, Issue 12, December 2021 ||

DOI:10.15662/IJAREEIE.2021.1012037

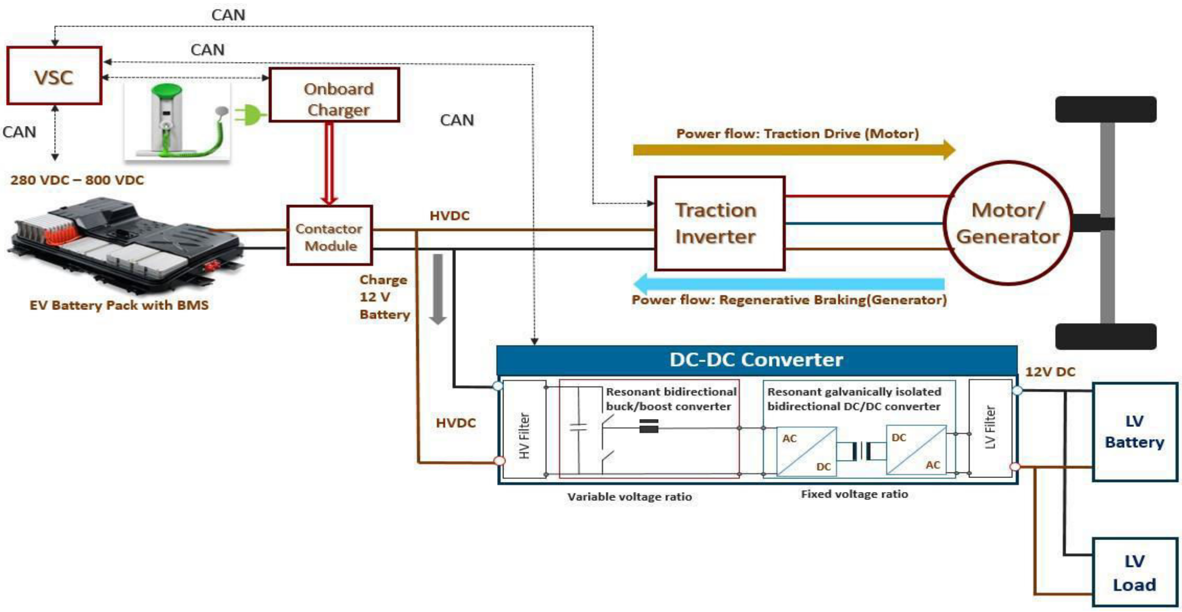


Fig. 1: General topology of electric vehicle

Battery Electric Vehicle's (BEV) batteries typically produce several hundred volts of Direct Current (DC). However, the voltage needs of the electric components inside the car vary, with the majority of them operating at a significantly lower level. The radio, dashboard readout, air conditioning, and built-in computer and display is the all example of this. A DC-to-DC converter is a category of power converters, which converts a DC source from one voltage level to another. It can be unidirectional, which transfers power only in one direction, or bidirectional, which can transfer power in either direction. Moreover, a DC-DC converter is a critical component in the architecture of a BEV, where It is employed in the conversion process of power from high voltage (HV) bus to that 12V Low Voltage (LV) bus to charge the LV battery and power the onboard electric devices. The architectural variations of battery electric vehicles are numerous, and figure 1 depicts a simplified block diagram of one of these architectures. The electric powertrain is driven by an HV bus, which is powered by the huge battery. The majority of the components are bidirectional, meaning that power can flow from the battery to the inverter, which rotates the motor and moves it (traction drive).

II.PROPOSED CONVERTER

Figure 2 depicts the traditional ZVS full bridge main circuit topology.

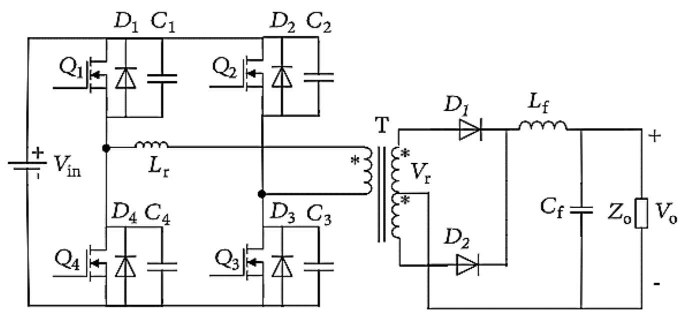


Fig. 2: Traditional converter

The input DC power supply is designated by the letter Vin. The inverter bridge is formed by switching devices including, the resonant inductor is formed by T, the high frequency transformer is formed by D1 and D2, and the high frequency filter is formed by L_f and C_f. The converter has issues with the stumbling block commutation and voltage fluctuation in the secondary side of transformer with less efficiency.

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 7.282|

|| Volume 10, Issue 12, December 2021 ||

DOI:10.15662/IJAREEIE.2021.1012037

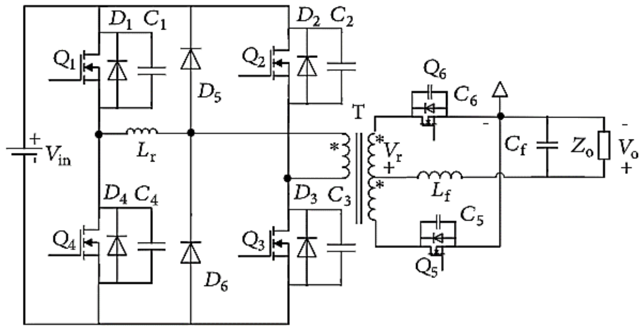


Fig. 3: Proposed converter

Figure 3 illustrates the enhanced ZVS phase-shift full-bridge circuit layout and clamping diodes with operational waveforms. Clamping diode D5 and D6 is used to suppress rectifier voltage oscillations and expand the soft-switch range; synchronous rectifications are used for secondary side on transformer and conduction of resistance for MOSFETs are lower compare to diodes, resulting in improved circuit efficiency. It describes the operation for phase-shifted full-bridge ZVS DC/DC converters, which is not described here.

Figure 4 explains the principle for controlling voltage oscillations on the second side of the transformer in detail.

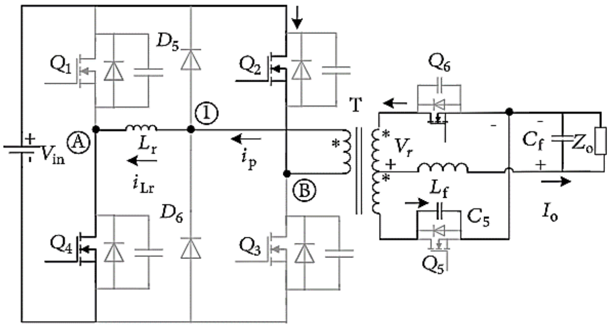


Fig. 4: Negative conduction mode

At, all of the load current travels from Q6, while the current flowing from Q5 goes to zero, simultaneously charging the junction capacitors C5 of Q5. Following that, the resonant inductance with the C5 resonance, as well as the voltage on the SR device Q5, the secondary side of transformer has followed. When no clamping diodes are used, the voltage on the output rectifier device oscillates at the same rate. It has a maximum value of 4/n. The voltage for output rectifier device has gradually decline to 2/n due to the damping effects for the resonance process, and the secondary voltage of the transformer have slowly reduced to 2/n.

Figure 4 depicts that analogous circuit. Because the Q5 junction capacitor's reverse charging current vanishes, current is more that of current converted for primary, therefore it drops slowly until that two are equals. The current in inductance could not change. Two clamping diodes' neutral point voltages are zero when D6 is turned on then C5's voltage is clamp on 2/n. The voltage oscillations of Q5 have suppress as compared to expression.

When the current flow from clamping diode D6 reaches zero, D6 turns off spontaneously. Then continue to raise at the same rate. Power have transfer from primary to secondary side at this point.

Figure 5 depicts the current waveforms and driving waveforms of Q5Q6 based on the driving waveforms of Q1Q4. The following three methods can be used to obtain Q5 and Q6 driving signals.
(1) The equal reasoning for the lagging leg Q3 (Q2)
(2) And logic: Q1(Q4) and Q3(Q2) driving signal is carried out, as well as logics.
(3) Or logic: If Q1(Q4) and Q3(Q2) driving signals are carried out or logic.

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 7.282|

|| Volume 10, Issue 12, December 2021 ||

DOI:10.15662/IJAREEIE.2021.1012037

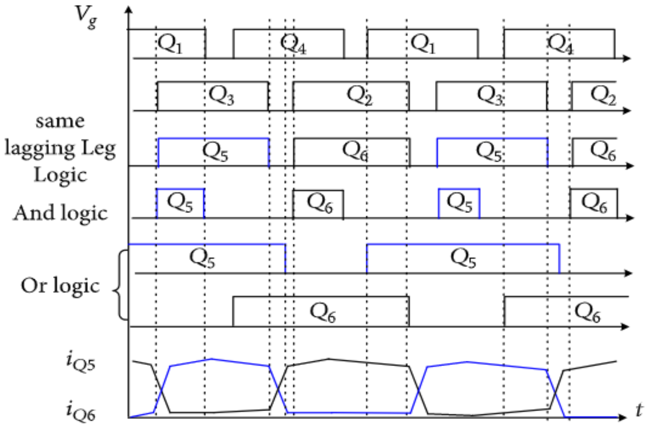


Fig. 5: Switching sequence

III.CONTROL SCHEME

Because electric vehicles rely on vehicle-mounted batteries for electricity, adopting charging systems that may achieve rapid charging while causing minimal damage to battery life is critical for their promotion [16]. At the moment, the most common charging of battery method are stable current charging, stable voltage charging, and stage charging [17]. Stable current charging is simple for use and control; however, the charging time will be excessive if the charging current is too low. If the charging current is set too high, it is easy to overcharge at a later stage of charging, causing significant damage to the battery plate and reducing battery life [18]. The stable voltage charging methods are very simple to use and avoids the problem of battery overcharging throughout the charging process. The shock of current will cause battery plate to bend and the temperature of the battery to rapidly rise, affecting the battery's life. Furthermore, if the charging voltages are set too less, it results that insufficient battery charging with short battery lifespan [19]. A two-step charged technique and three-stage charged technique are the most common charging of methods [20]. In that two-stage charged process, the stable current charging method has employed. when the battery has charged. Figure 6 depicts the charging curve. For two stage charging methods combine benefit for stable current with stable voltage charged method, Eliminate the issues of high charge of current and overcharging have a higher efficiency that could satisfy charging demand for lithium batteries.

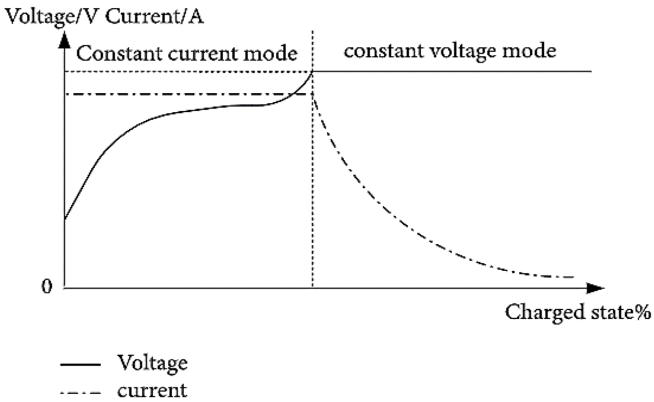


Fig. 6: Types of charging

The output voltage of the DC/DC converter of the vehicle charger changes greatly when charging in constant current mode. In constant voltage mode, the converter's output current drops from full load to zero. As a result, the onboard charging power source should be designed to meet the following specifications: The output voltage can be adjusted across a wide range; With a large load range, soft switching operation is possible; high power density, as well as voltage and current stress. Figure 7 shows a constant current and constant voltage switching charging controlmechanism. The PI controller obtains the error, as well as the modulation signal WCV. Similarly, the modulation signal WCV can be obtained.

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 7.282|

|| Volume 10, Issue 12, December 2021 ||

DOI:10.15662/IJAREEIE.2021.1012037

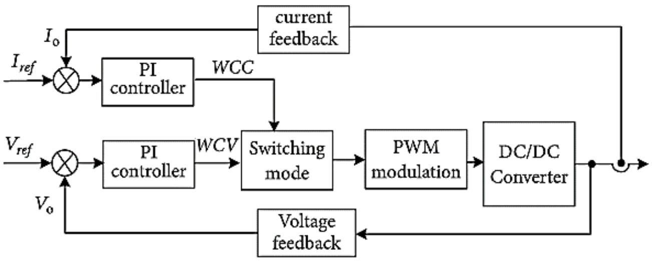


Fig. 7: CC and CV modes charging control scheme

The switching mode is “take a smaller value”. The battery's equivalent internal resistance is low and the charging current is high during the beginning stages of charge. The battery charge constant current mode at that point,WCV>WCC. The battery charge in constant voltage mode then the voltage increases so that electric reference value, WCV < WCC, and charging current drops continually until the charge is completed.

IV.SIMULATION RESULTS

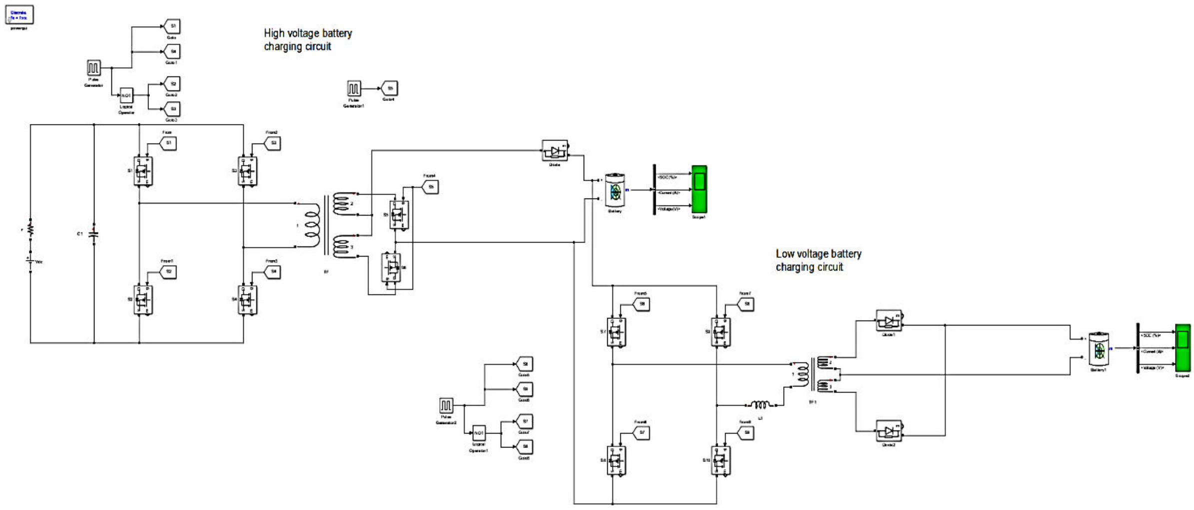


Fig. 8: Modeling of proposed test system with two batteries without LC filter

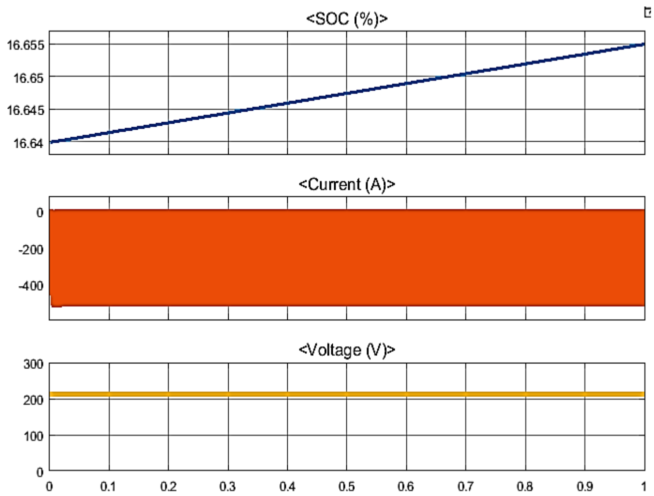


Fig. 9: High voltage battery characteristics without LCfilter

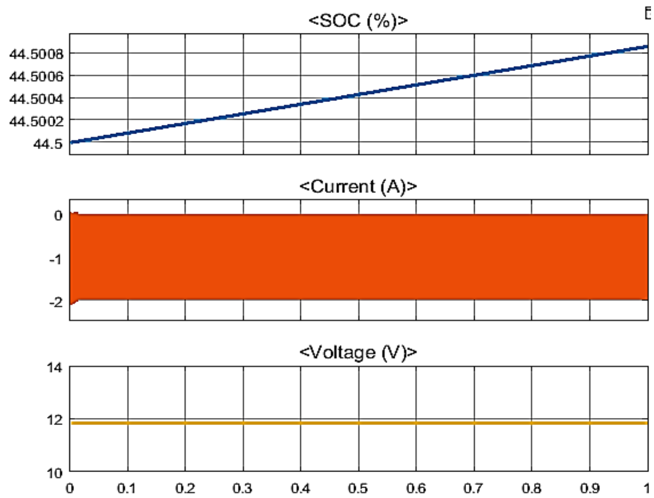


Fig. 10: Low voltage battery characteristics without LC filter

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 7.282|

|| Volume 10, Issue 12, December 2021 ||

DOI:10.15662/IJAREEIE.2021.1012037

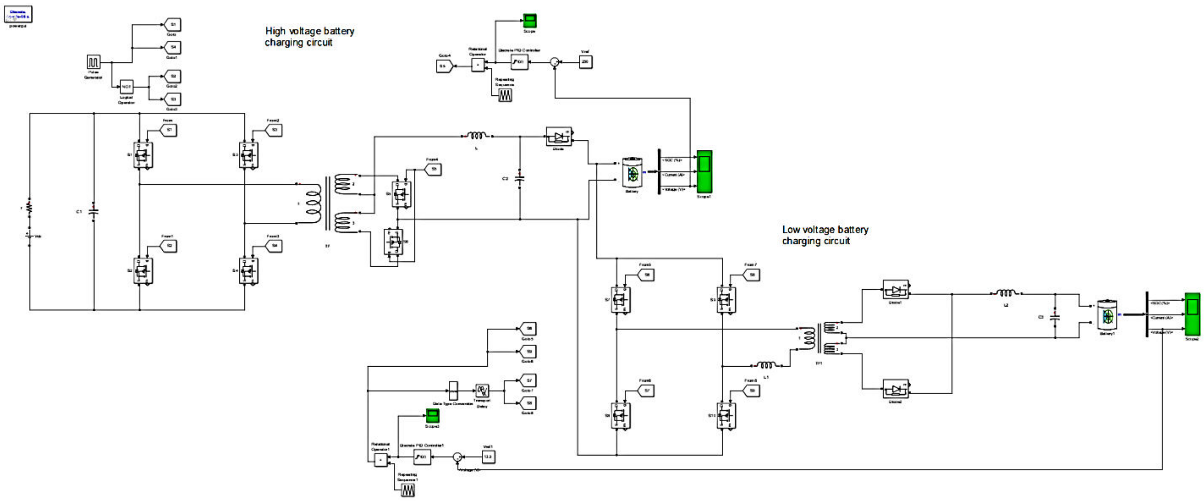


Fig. 11: Modeling of proposed test system with two batteries with LC filter

The above is the MATLAB Simulink modeling of the proposed converter with two circuits. The upper is high voltage circuit with controllable switches on the secondary side of HFTF. The below circuit is low voltage circuit with controllable switches on the primary side of HFTF. The controller adopted are PI controller with specific Kp and Ki gain for the generation of duty ratio for the controllable switches. The below are the signals generated for the switches to control the current input to the battery.

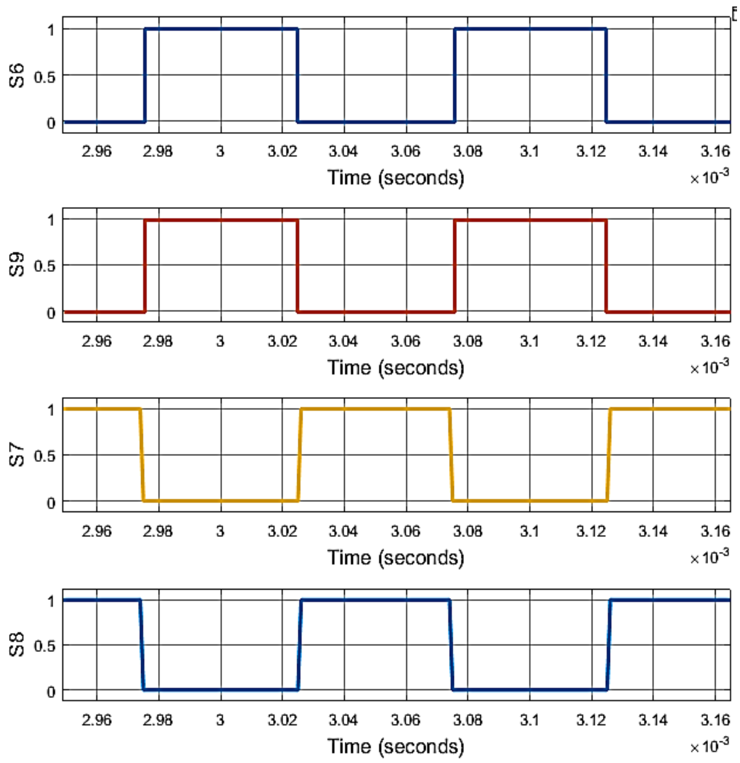


Fig. 12: Pulses for the full bridge switches

The characteristics of the high voltage battery and low voltage battery for the given reference value of voltage can be seen in Fig. 13.

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 7.282|

|| Volume 10, Issue 12, December 2021 ||

DOI:10.15662/IJAREEIE.2021.1012037

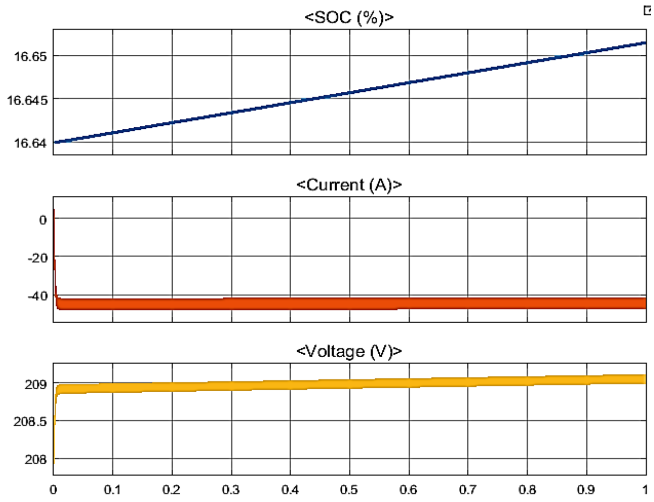


Fig. 13: High voltage battery characteristics

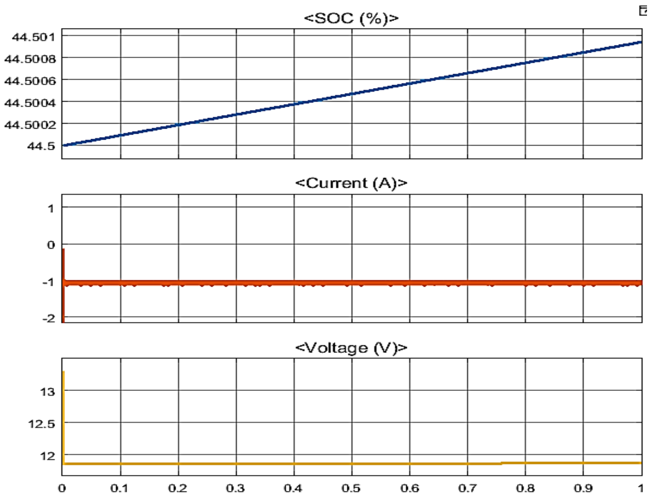


Fig. 14: Low voltage battery characteristics

For the given reference value of the controller the generated duty ratio of the high voltage circuit and low voltage circuit are shown below.

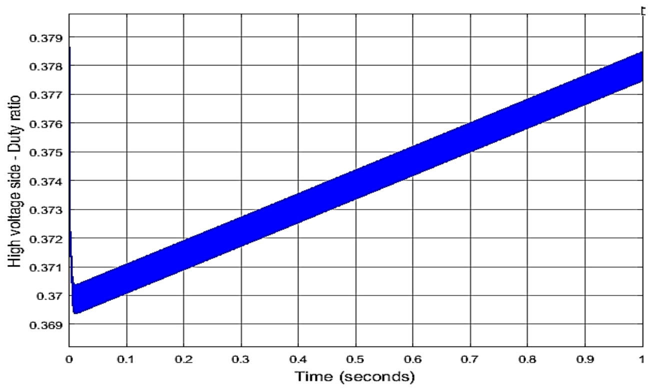


Fig. 15: High voltage circuit duty ratio

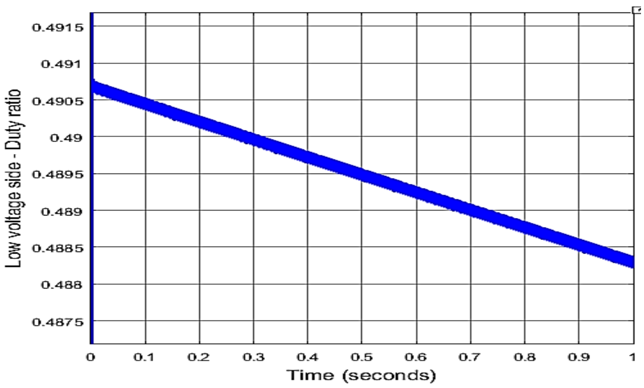
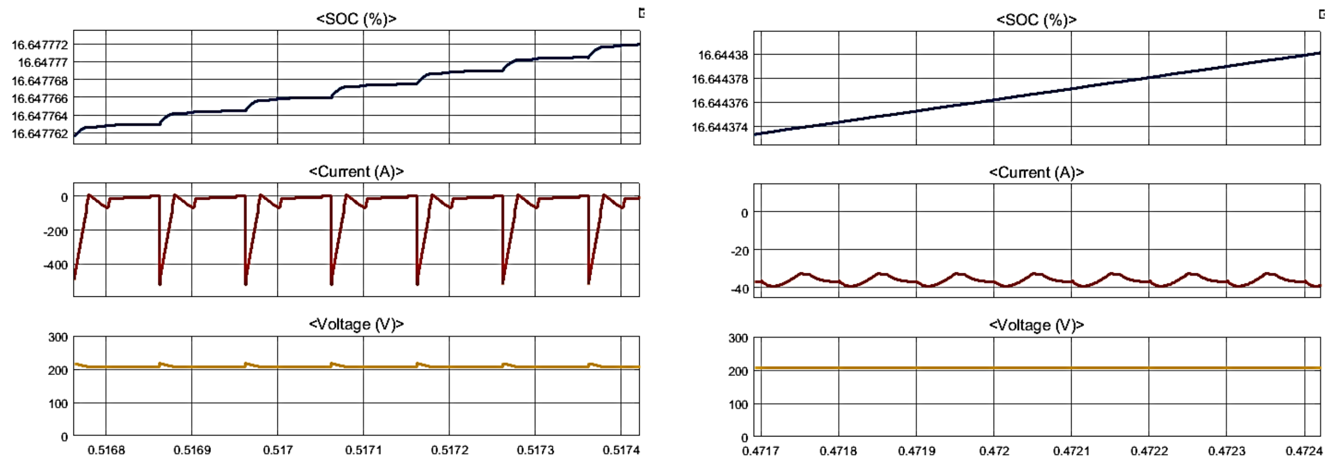


Fig. 16: Low voltage circuit duty ratio



Without LC filter **With LC filter**

Fig.17: Battery characteristics comparison with and without LC filter

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 7.282|

|| Volume 10, Issue 12, December 2021 ||

DOI:10.15662/IJAREEIE.2021.1012037

As seen in the Figure 17, battery current has very high ripple when charged by the circuit and the ripple of the battery current isvery less with operated with LC filter.

V. CONCLUSION

The full bridge DC to DC converters along with clamp diodes with synchronous rectifications are presents to address the challenges that arise with electric vehicles converters. Clamping diode are used for achieve a wide range of soft switches to avoid secondary rectifier voltage oscillation. To reduce high frequency rectification losses, synchronous rectification technology on the secondary side of the transformer is applicable. The DC/DC converter's operating principle and control mechanism are investigated, and the switching device losses are estimated. The simulation of this result shows that the transformer' secondary side of voltage oscillation is doubled, and the OBC's efficiency reaches 95% with a load of 20% -100% rated load, which matches the onboard charger's application criteria.

REFERENCES

[1] B. Li, Q. Li, F. C. Lee, Z. Liu, and Y. Yang, "A high-efficiency high-density wide-bandgap device-based bidirectional on-board charger," *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 6, no. 3, pp. 1627–1636, 2018.

[2] T. R. Granados-Luna, I. Araujo-Vargas, and F. J. Perez-Pinal, "Sample-data modeling of a zero voltage transition DC-DC converter for on-board battery charger in EV," *Mathematical Problems in Engineering*, vol. 2014, Article ID 712360, 15 pages, 2014.

[3] J. Liang, L. Jian, G. Xu, and Z. Shao, "Analysis of electromagnetic behavior in switched reluctance motor for the application of integrated air conditioner on-board charger system," *Progress in Electromagnetics Research*, vol. 124, pp. 347–364, 2012.

[4] A. Cavallo, B. Guida, and L. Rubino, "Boost full bridge bidirectional DC/DC converter for supervised aeronautical applications," *International Journal of Aerospace Engineering*, vol. 2014, Article ID 808374, 2014.

[5] C.-J. Shin and J.-Y. Lee, "An electrolytic capacitor-less bi-directional EV on-board charger using harmonic modulation technique," *IEEE Transactions on Power Electronics*, vol. 29, no. 10, pp. 5195–5203, 2014.

[6] K.-K. Chen, "A novel application of zero-current-switching quasiresonant buck converter for battery chargers," *Mathematical Problems in Engineering*, vol. 2011, Article ID 481208, 16 pages, 2011.

[7] A. Hariya, K. Matsuura, H. Yanagi, S. Tomioka, Y. Ishizuka, and T. Ninomiya, "Considerations of physical design and implementation for 5 MHz-100 W LLC resonant DC-DC converters," *Active and Passive Electronic Components*, vol. 2016, Article ID 4027406, 11 pages, 2016.

[8] J.-Y. Lee, "An EL capacitorless EV on-board charger using harmonic modulation technique," *IEEE Transactions on Industrial Electronics*, vol. 61, no. 4, pp. 1784–1787, 2014.

[9] F. Xie, X. Liu, S. Cui, and K. Li, "Design of power factor correction system for on-board charger," *Communications in Computer and Information Science*, vol. 463, pp. 529–538, 2014.

[10] G. Liu, Y. Jang, M. M. Jovanović, and J. Q. Zhang, "Implementation of a 3.3-kW DC-DC converter for EV on-board charger employing the series-resonant converter with reduced-frequency-range control," *IEEE Transactions on Power Electronics*, vol. 32, no. 6, pp. 4168–4184, 2017.

[11] Y. Zhou, C. Huang, J. Chen, G. Shi, and M. Zhou, "A novel research of ZVZCS synchronous rectification converter based on phase-shifted full-bridge control," *International Journal of Signal Processing, Image Processing and Pattern Recognition*, vol. 8, no. 6, pp. 117–124, 2015.

[12] B.-K. Lee, J.-P. Kim, S.-G. Kim, and J.-Y. Lee, "An isolated/bidirectional pwm resonant converter for V2G(H) EV on-board charger," *IEEE Transactions on Vehicular Technology*, vol. 66, no. 9, pp. 7741–7750, 2017.

[13] S. Zou, J. Lu, A. Mallik, and A. Khaligh, "Modeling and optimization of an integrated transformer for electric vehicle on-board charger applications," *IEEE Transactions on Transportation Electrification*, vol. 4, no. 2, pp. 355–363, 2018.

[14] T. Kaneyama, K. Awane, M. Takikita, N. Uehara, R. Kondo, and M. Yamada, "High efficiency isolated AC-DC converter with gradationally controlled voltage inverter for on-board charger," *SAE International Journal of Alternative Powertrains*, vol. 2, no. 2, pp. 389–393, 2013.

[15] X. Yun, H. Yu, Z. Zaimin, and Z. Tong, "Research and design on digital PFC of 2kW On-board charger," *World Electric Vehicle Journal*, vol. 4, no. 1, pp. 202–207, 2011.

[16] D. Cesiel and C. Zhu, "A closer look at the on-board charger: the development of the second-generation module for the chevrolet volt," *IEEE Electrification Magazine*, vol. 5, no. 1, pp. 36–42, 2017.

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 7.282|

|| Volume 10, Issue 12, December 2021 ||

DOI:10.15662/IJAREEIE.2021.1012037

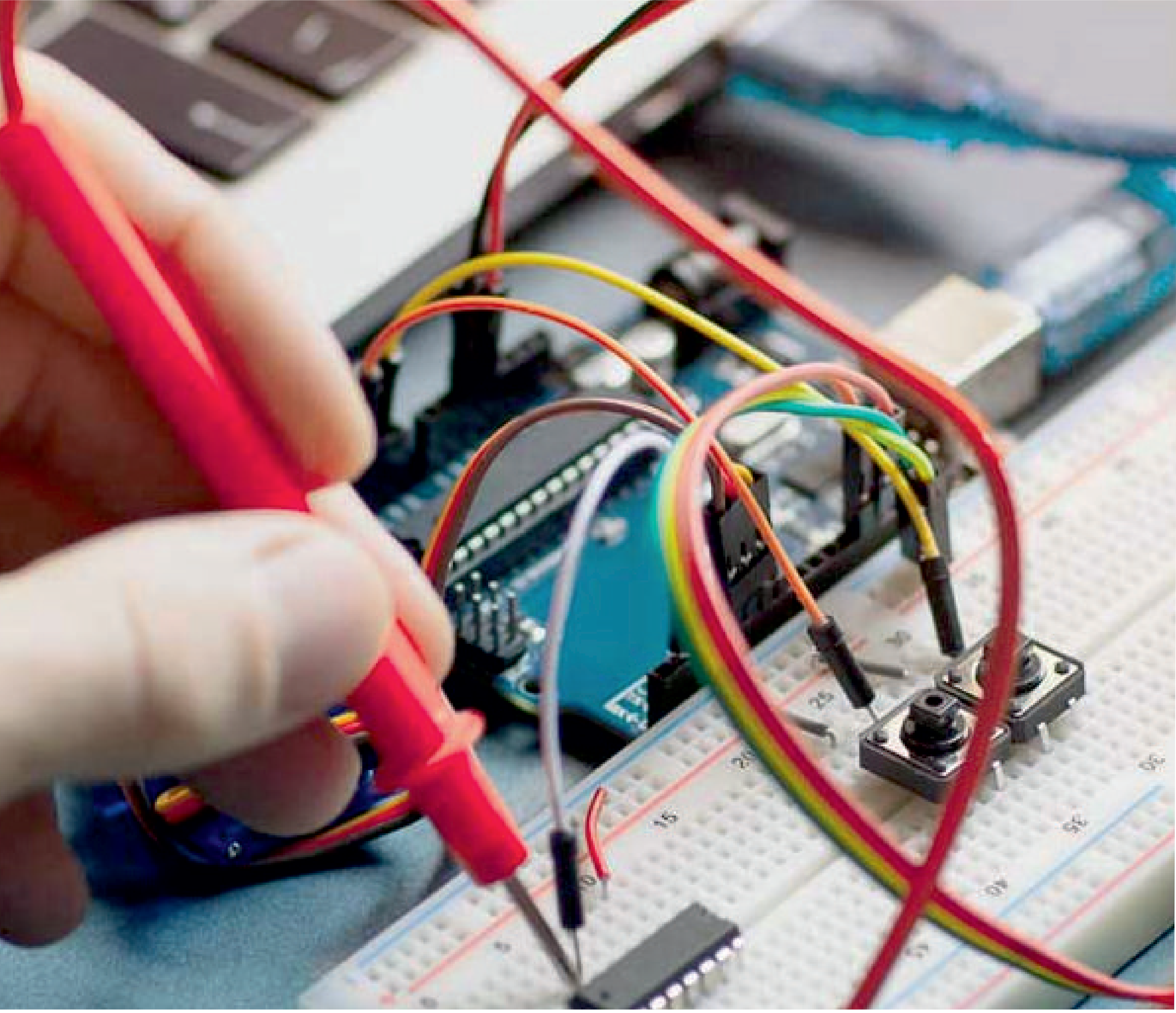
[17] S.-G. Jeong, W.-J. Cha, S.-H. Lee, J.-M. Kwon, and B.-H. Kwon, "Electrolytic capacitor-less single-power-conversion on-board charger with high efficiency," *IEEE Transactions on Industrial Electronics*, vol. 63, no. 12, pp. 7488–7497, 2016.

[18] Z. Liu, B. Li, F. C. Lee, and Q. Li, "High-efficiency high-density critical mode rectifier/inverter for WBG-device-based on-board charger," *IEEE Transactions on Industrial Electronics*, vol. 64, no. 11, pp. 9114–9123, 2017.

[19] B.-G. You, B.-K. Lee, and D.-H. Kim, "Inductor design method of DCM interleaved PFC circuit for 6.6-kW on-board charger," *Journal of Electrical Engineering & Technology*, vol. 12, no. 6, pp. 2247–2255, 2017.

[20] T. Tera, H. Taki, and T. Shimizu, "Loss reduction of laminated core inductor used in on-board charger for EVs," *IEEJ Journal of Industry Applications*, vol. 4, no. 5, pp. 626–633, 2015.

[21] L. Huang, X. Dong, C. Xie, S. Quan, and Y. Gao, "Research and modeling of the bidirectional half-bridge current-doubler DC/DC converter," *International Journal of Rotating Machinery*, vol. 2017, Article ID 4854169, 9 pages, 2017.



International Journal of Advanced Research

in Electrical, Electronics and Instrumentation Engineering