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POWER FACTOR CORRECTED ISOLATED ZETA FED FORWARD CONVERTER FOR EV CHARGING

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Abstract – *In this paper a battery electric vehicle charger (BEV) with improved Zeta Power Factor Correction converter with reduced switch voltage stress on PFC devices for enhanced power quality is designed. This Zeta PFC converter is the modified version conventional Zeta converter with two switch and clamping diodes at the input. The main advantage is that efficiency of the charger is improved over chargers based on other Zeta PFC converters with switch voltage stress is reduced in supply voltage, which results into lower losses in PFC stage. The improved zeta converter as well as a fly back converter are designed to work in discontinuous conduction mode (DCM) and has greater advantage of reduced cost and size. The proposed model will be developed using MATLAB/Simulink.*

Key Words: Power Factor Correction, BEV Charger, Zeta Converter, Discontinuous Conduction Mode, Power Quality

1.INTRODUCTION

The major concerns with the conventional vehicles are hike in fuel prices and environmental issues. Thus in order to serve environment-friendly and energy saving mechanism, Electric vehicles (EVs) are designed. The lead–acid battery is considered as prominent power source in these vehicles, which needs to be charged continuously or intermittently to power the vehicle and other auxiliaries. The required AC–DC conversion by conventional EV battery chargers associate the power electronic circuits i.e. the diode bridge rectifier (DBR). Severe power quality (PQ) issues due to the presence of non-linear input DBR occurs in conventional chargers, which draws a peaky non-sinusoidal current from mains.

Unity power factor (UPF)-based converter is used between a DBR and DC link of the conventional battery charger in a single-stage or two-stage converter. Conventionally, a two-stage AC–DC converter is extensively preferred for improved PQ-based EV chargers. However, two stage topology has certain limitations such as additional semiconductor switches and control circuitry, in spite of offering the advantage of low DC-link capacitor value. Therefore, many improved PQ-based single-stage converters are identified with the advantage of compactness and high efficiency. Unidirectional or bidirectional charger with level 1, level 2, or level 3 chargers with EV battery charger may be built in several topologies known as off board charger or on-board charger. An off board charger must have a small form factor and high power density in order to maximize the energy utilization along with good packaging.

2. CONFIGURATION OF BEV CHARGER

Figure 2. Shows the configurations for BEV charger with improved isolated Zeta PFC converter.

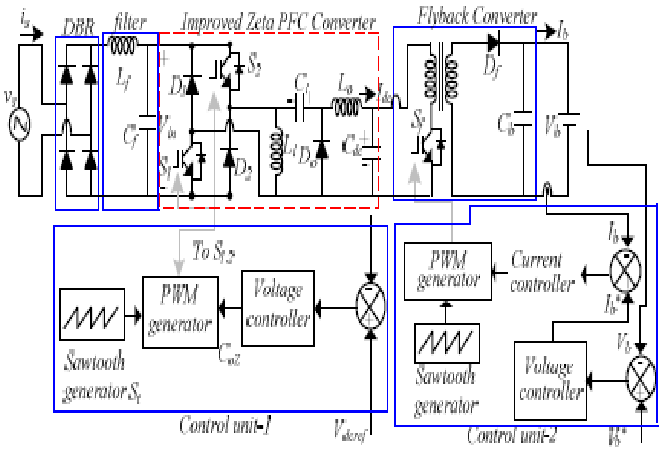


Figure 1 UPF zeta converters for electric vehicle battery charger

This improved front-end PFC converter has addition of one more switch S_2 and two clamping diodes D_1 and D_2 at the input is similar to traditional Zeta converter. In this way, traditional Zeta PFC converter i.e. (V_{in}+V_{dc}) which is half in comparison to the voltage stress across the two switches is clamped at input voltage V_{in},. Higher efficiency results in reduces losses in the charger. The DC-link voltage of PFC converter is maintained at constant voltage using other components input inductor L_i, output inductor L_o and the series capacitor C_i., The current through vehicle battery during CC-CV charging can be done by flyback converter is cascaded to this PFC converter.

One of the major concerns is the presence of low AC ripple content in charging current of an EV battery charger. Due to huge capacitance in the battery circuit, the ripple current flows through the battery during charging. To ensure the reliable battery operation care should be taken for above concert. Large amount of heat (I^2R losses) are generated due to battery internal resistance and ripple in battery charging current. Due to excess heat, initial temperature of the battery will increase. Therefore, large amount of ripple current results into reduced lifecycle of the battery. In designing the AC–DC converter for EV charger care must be taken to meet the permissible ripple current requirements for the battery. Second harmonic component is avoided in the battery with the use of an isolated topology. To enhancing battery life a smooth charging current is available at the battery terminals. At the input of the isolated PFC converter a well-tuned EMI filter is used in order to minimize switching ripple. Using the dual loop PI control in CC-CV mode, the battery charging current is regulated. At the beginning, the battery is charged by a CC and its state of charge (SOC) increases.

The main contributions of proposed work are as follows.

• Proposed PFC-based EV charger is having the advantages of significant low ripple in output voltage and current of same number of conducting components over one switching cycle as conventional DBR fed and slightly more than buck–boost converter fed charger.

• In conventional DBR-fed battery charger life of the battery is low and the second harmonic component in the battery is quite high whereas the proposed EV charger with high-frequency isolation offers more advantage in terms of battery life and harmonic component.

•Without any additional component, DCM operation of magnetizing inductance and reduced diode reverse recovery time are achieved in the zero current switching operation.

3. OPERATION OF PROPOSED UPF ZETA CONVERTER

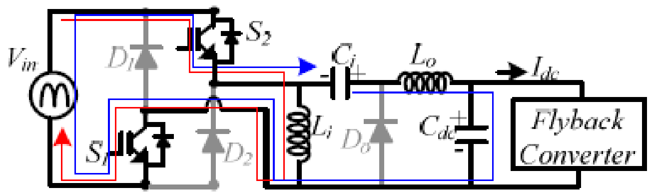
DCM based voltage feedback control is selected to operate in DCM to achieve cost-effective solution for charging in the two converters with number of voltage sensors used in this circuit are less. The operation is quite popular for fly back converter and operating modes which are given as follows of Zeta PFC converter for switch ON (S_1 and S_2) switch OFF and DCM operation as shows in Figure 2 (a)-(c).

***Mode-1 operation**: In* this mode two switches S_1, S_2 are triggered simultaneously. As shown in Figure. 3(a) inductance L_i, starts charging from the supply. At this instant, the diode *Do* remains in non-conducting state. inductance *Lo*, starts storing the energy when the voltage across the transfer capacitor C_i starts reducing.

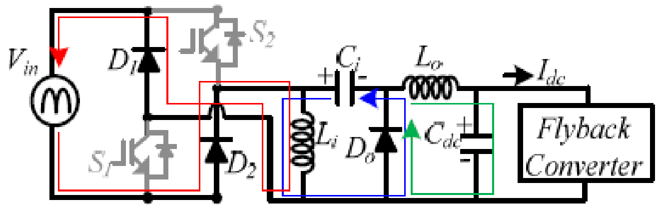
Mode-2 operation*:* In this mode switches S_1, S_2 are in OFF state. As shown in Figure. 2 (b), the clamping diodes, D_1 and D_2 *and* output diode D_o become forward biased. Through the diodes, D_1 and D_2 inductance L_i starts discharging. The Through the diode, *Do* transfer capacitor C_i starts charging. Through the diode *Do* and DC-link capacitor, C_{dc} inductance *Lo* supplies the next stage.

Mode-III*:* In this mode, clamping diodes and all switches remain in OFF state. As shown in Figure 2 (c), the converter enters freewheeling period which is known as DCM. The diode current is ceased to zero in such that current in the inductances L_i and L_o are flowing. Through the inductance, *Lo* and DC-link Capacitor C_{dc} transfer capacitor C_i provides required energy to the load.

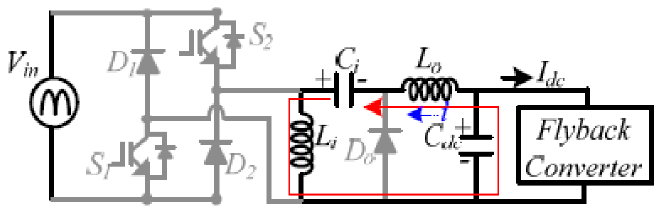
Due to the use of clamping diodes D_1, D_2, when compared with conventional Zeta converter, It is seen that numerical value ($VS_{1,2}=V_{in} + V_{dc}$) of maximum switch voltage stress of this converter, is quite lower.



(a)



(b)



(c)

Fig. 2 Operating Principle of improved Zeta PFC converter (a)-(c)

4. SIMULATIONS AND RESULTS

The software MATLAB was used in the simulations to obtain the results of a given circuit with improved Zeta Power factor correction converter devices for enhanced power quality battery electric vehicle charger as shown in figure 3.

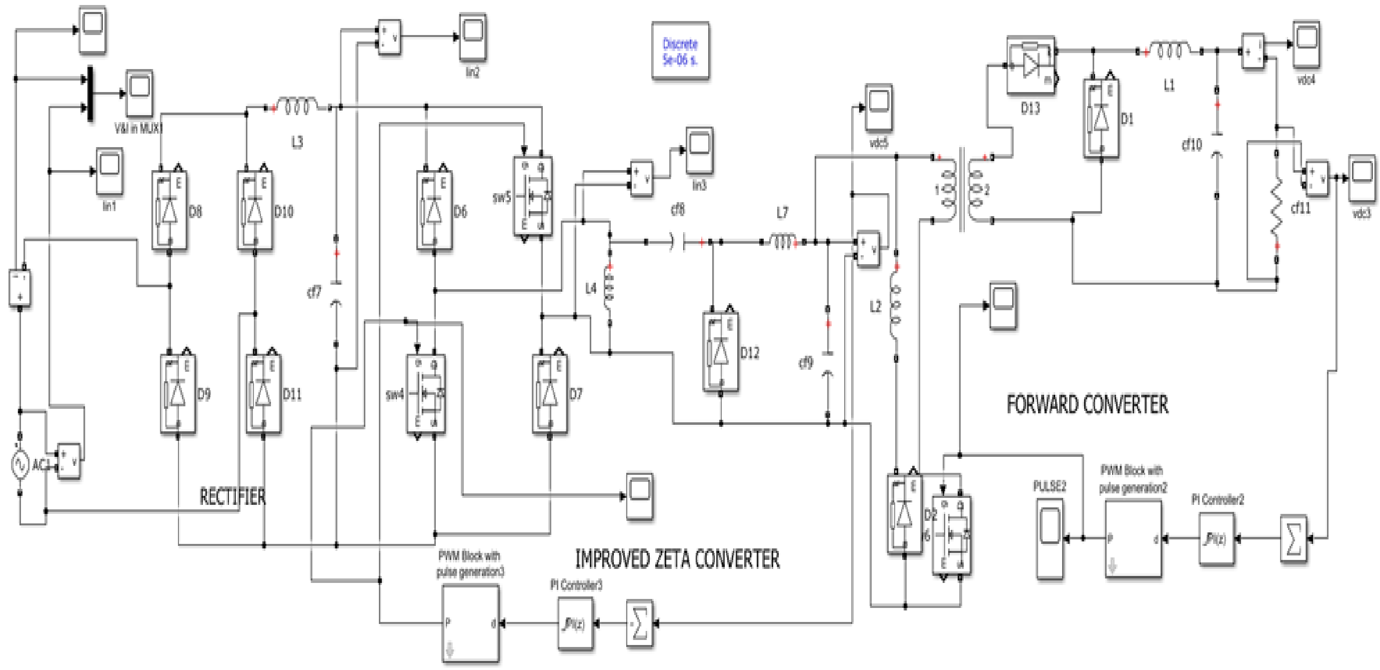


Figure 3 Simulation circuit with improved Zeta PFC converter

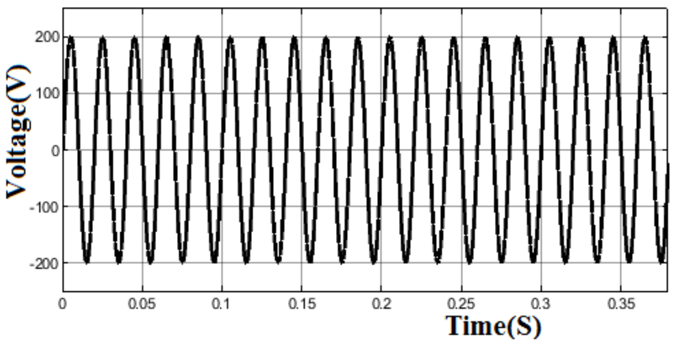


Figure 4 Input Voltage

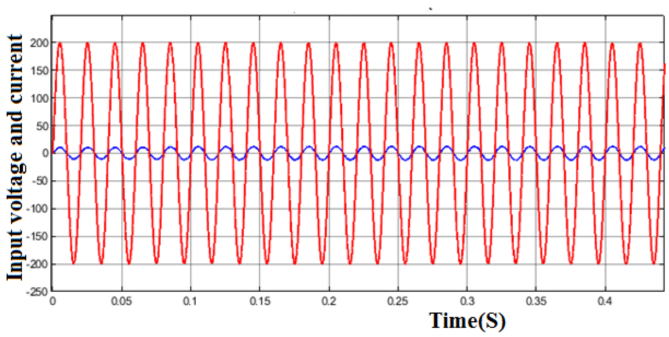


Figure 6 Input voltage and Current (unity Power factor)

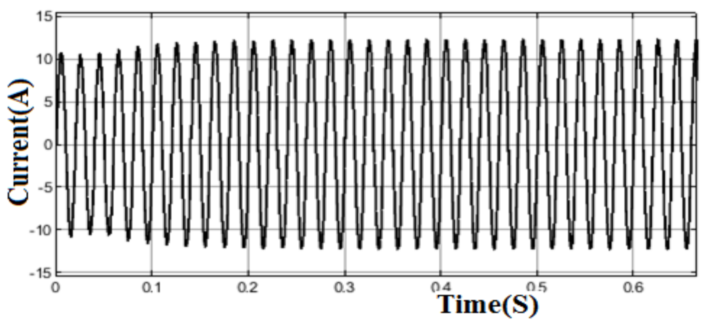


Figure 5 Input Current

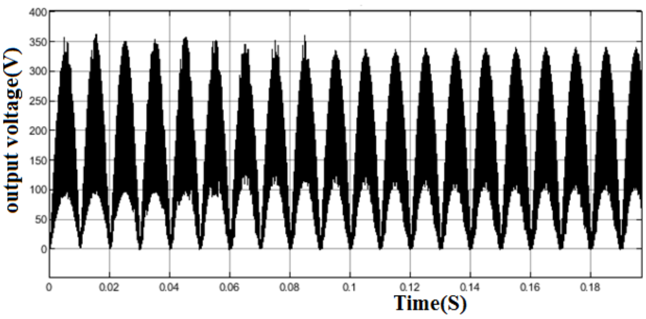


Figure 7 Rectified Output Voltage

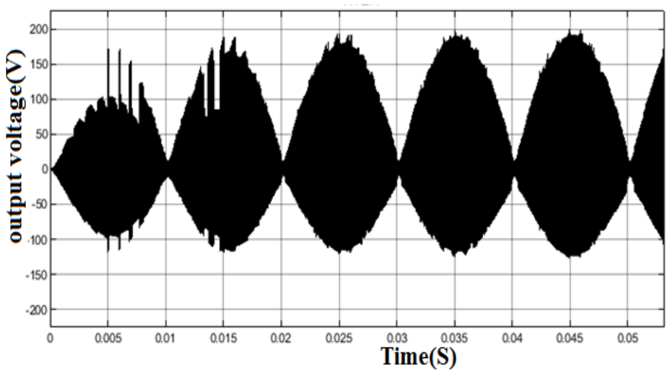


Figure 8 Inverter Output Voltage

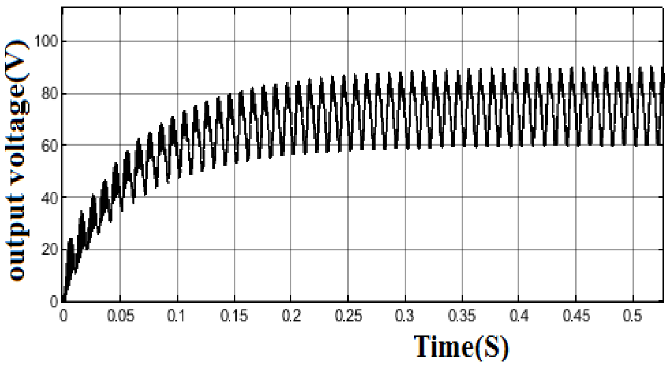


Figure 9 ZETA converter Output Voltage

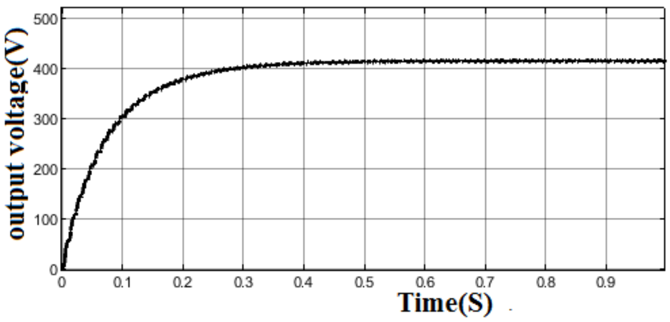


Figure 10 Forward converter Output Voltage

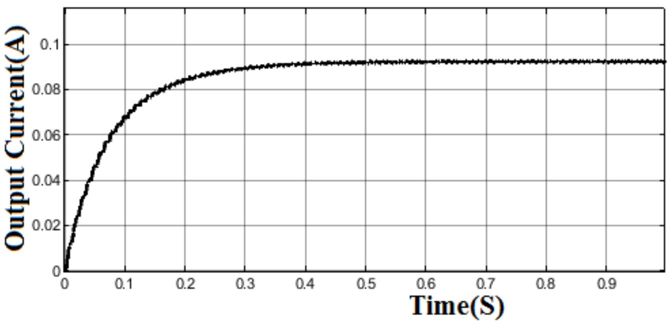


Figure 11 Forward converter Output Current

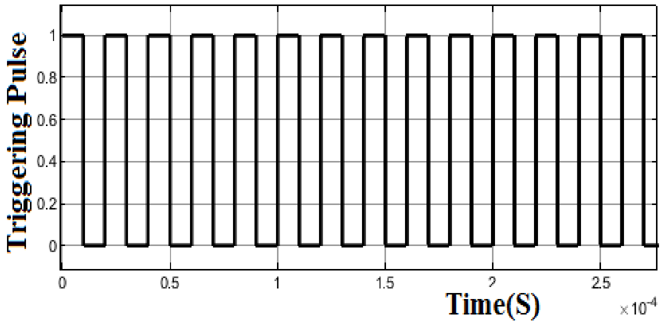


Figure 12 Forward converter Triggering pulse

5. CONCLUSION

In this paper, an improved Zeta converter with reduced device stresses based BEV charger is designed. Almost half the voltage stress on PFC devices is achieved by voltage stress reduction technique than in the conventional Zeta converter. It requires no additional inductors and capacitors to ensure low losses in the converter. The proposed charging system provides improved efficiency over the traditional Zeta PFC converter. Moreover, low switch voltage stress enables the use of lower rating devices, which is cost-effective.

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BIOGRAPHIES

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