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ANALYSIS, DESIGN AND IMPLEMENTATION OF AN APWM ZVZCS FULL BRIDGE DC TO DC CONVERTER FOR BATTERY CHARGING IN ELECTRIC VEHICLE

B MAHENDER [1], **D SAI SRILEKHA**[2], **G MAANASA**[3], **MAGANTI GOPICHAND**[4], **Dr J KARTIGEYAN**[5]

B. Tech student, Dept of EEE, JB INSTITUTE OF ENGINEERING AND TECHNOLOGY, Hyderabad, TS, India[1]
B. Tech student, Dept of EEE, JB INSTITUTE OF ENGINEERING AND TECHNOLOGY, Hyderabad, TS, India[2]
B. Tech student, Dept of EEE, JB INSTITUTE OF ENGINEERING AND TECHNOLOGY, Hyderabad, TS, India[3]
B. Tech student, Dept of EEE, JB INSTITUTE OF ENGINEERING AND TECHNOLOGY, Hyderabad, TS, India[4]
Associate Professor, Dept of EEE, JB INSTITUTE OF ENGINEERING AND TECHNOLOGY, Hyderabad, TS, India[5]

ABSTRACT:

An efficient power converter system plays a significant role in the design of battery charging systems for electric vehicles (EVs). In this paper, a new zero-voltage and zero-current switching (ZVZCS) full-bridge dc-dc converter is proposed to reduce the power conversion losses. The proposed converter incorporates a new asymmetrical pulse width modulation (APWM) gating technique for the dc-dc conversion stage in the battery charging system. The proposed dc-dc converter topology achieves zero-voltage switching (ZVS) for all the active switches and near zero-current switching (ZCS) for low-side active switches throughout the charging range of the battery. The proposed APWM technique can reduce the switching and conduction losses compared to the conventional phase-shift modulation (PSM) gating technique. The auxiliary inductance required to ensure ZVS with APWM can also be reduced compared to PSM. Analysis, design, and implementation of the proposed APWM ZVZCS full-bridge dc-dc converter are discussed in this paper. The results validate the analysis and performance of the proposed converter.

Keywords: ZVZCS, Full bridge converter, Controller block, BESS, High efficiency.

1. INTRODUCTION

The electric vehicles or plug-in electric vehicles (PEVs) are now a promising solution to curb the air pollution that uses pollution-free battery power to produce clean energy for the vehicle. The PEVs are combination of on-board charger, battery, and the inverter-drive system. In majority of PEVs, a bidirectional dc/dc converter is interfaced between the battery and dc-link of machine inverter for power flow during propulsion and regenerative braking operation. Therefore, an individual ac/dc converter is used to charge the battery from the grid side. In this conventional structure, two separate power electronic converters are needed for two independent operations (charging and discharging of the battery). The bidirectional dc/dc converter in conventional structure can be integrated with the on-board charger, to have one power electronics interface for complete operation of PEVs. The overall block diagram of an integrated charger with single power electronic is shown in Fig. 1a. This integration reduces the number of components because some of the switches and inductors are utilised both in ac/dc and dc/dc stages. Therefore, reduced number of switches and inductors lead to higher power density, compact size and lower cost. In this regard, this paper proposes, a new ZETA-SEPIC-based integrated converter for PEVs, as shown in Fig. 1b which has buck/boost capability in each mode of operation. In addition, buck/boost operation in each mode allows selection of wide range of the battery voltage, efficient control of dc-link voltage and capturing the regenerative braking with a wide variation of the motor speed. A comparison of existing integrated converters and other competitive converters with respect to the proposed converter is described in the following paragraph.

OVER VIEW:

Full-bridge topology is the most popular topology used in the power range of a few kilowatts (1–5 KW) for DC/DC converters. Since the switch ratings are optimized for the full-bridge topology, this topology is extensively used in industrial applications. High efficiency, high power density, and high reliability are the prominent features of this topology. For applications in the range of a few kilowatts, MOSFETs are mostly used to implement the full-bridge converters. In order to have robust and reliable operation, MOSFETs should be switched under zero voltage. Operation with zero voltage switching (ZVS) has numerous advantages including, for example, reduction of the converter switching losses and a noise-free environment for the control circuit. Zero voltage switching is usually achieved by providing an inductive current flowing out of the full-bridge legs during the switch turn-ON and by placing a snubber capacitor across each switch during the switch turn-OFF. The inductive current can be produced by inserting an inductor in series with the power transformer or by inserting an inductor in parallel with the power transformer [4]–[11]. In a practical full-bridge configuration, the internal drain-to source capacitor of the MOSFET is usually utilized as the snubber capacitor, the series inductor is usually the leakage inductance of the power transformer, and the parallel inductor is implemented by using the magnetizing inductance of the power transformer.

2. RELATED STUDY

, external passive components are not required, which makes the power circuit very simple and efficient. However, the full-bridge converter with the series inductor loses its ZVS capability at light loads, and the converter with the parallel inductor loses its ZVS under heavy loads. Loss of ZVS implies extremely high switching losses at high switching frequencies and very high EMI due to the high di/dt of the snubber discharge current. Loss of ZVS can also cause a very noisy control circuit, which leads to shoot-through and loss of the semiconductor switches. The ZVS range can be extended by increasing the series inductance. However, having a large series inductance limits the power transfer capability of the converter and reduces the effective duty ratio of the converter. In battery charger applications, ZVS is vitally important since the converter might be operating at absolutely no-load for a long period of time. In this application, when the battery is charged, the load is absolutely zero and the converter should be able to safely operate under the zero load condition. Since ZVS in conventional full-bridge PWM converters is achieved by utilizing the energy stored in the leakage inductance to discharge the output capacitance of the MOSFETs, the range of the ZVS operation is highly dependent on the load and the transformer leakage inductance. Thus, this converter is not able to ensure ZVS operation for a wide range of load variations. In, a novel approach has been adopted to extend the ZVS range in the full-bridge converter. In this approach, an auxiliary inductor is put at the leading leg by deriving an auxiliary winding on the main transformer and confirms ZVS for the leading leg. Although the proposed scheme can effectively extend ZVS of the leading leg MOSFETs, it is not able to guarantee ZVS for the lagging leg of the converter. Thus, when the battery is fully charged, the lagging leg switches may not be switched under ZVS. Moreover, the voltage at the secondary side still suffers from the spikes due to the leakage inductance and voltage-fed rectifier, commonly seen in full-bridge converters. A fundamental problem related to the conventional full bridge phase-shift DC/DC converter is the voltage spikes across the output diodes.

3. PROPOSED SYSTEM

The proposed schematic of the conventional full-bridge converter. Basically, the leakage inductance of the transformer causes the voltage spikes across the output diodes. Theses spikes are intensified by increasing the switching frequency of the converter. Thus, the diodes should be designed overrated to be able to withstand the voltage spikes, which leads to higher losses due to the higher forward voltage drop of the diodes and poorer reverse recovery characteristics. In addition, the spikes significantly increase the EMI noise of the converter. This fact makes the topology not very practical for high frequency, high voltage applications. There are quite a few references that proposed solutions for the voltage spikes across the output diodes. Some references tried to decrease the leakage inductance as much as possible though the transformer winding structures, which effectively decreases the peak of the voltage spikes across the output diodes. However, reducing the leakage inductance decreases the ZVS operating range of the full-bridge converter, which results in a very narrow range of ZVS operation. In, an R-C-D snubber circuit is used to mitigate the voltage spikes across the diodes. The main problem with the snubber circuit is the amount of losses in the snubber resistor, which considerably degrades the efficiency of the converter especially at higher power and it can only reduce the peak value of the voltage spikes. An active clamp circuit has been added to the converter to clamp the voltage across the output diodes. This method can effectively clamp the voltage spikes of the output diodes. However, the active clamp circuit increases the complexity of the converter and causes small losses in the clamp circuit.

A current-fed zero-voltage zero-current switching (ZVZCS) full-bridge DC-DC converter and a new asymmetrical pulse width modulation (APWM) gating technique are proposed. A passive auxiliary circuit is used in the converter to extend the soft-switching range of active switches. The proposed topology ensures ZVS turn-on for all active switches, near ZCS turn-off for low-side active switches, and ZCS turn-off for output rectifier diodes over the entire battery charging range. The proposed APWM controls the auxiliary inductor current to minimize the auxiliary circuit losses and conduction losses on the primary side. This feature improves the overall efficiency of the proposed converter over the battery charging range compared to the conventional phase-shift modulation (PSM) gating method. The proposed APWM gating scheme also reduces the auxiliary inductance required to achieve ZVS turn-on of all active switches compared to the PSM. The proposed converter is designed to charge the battery using CC-CV method.

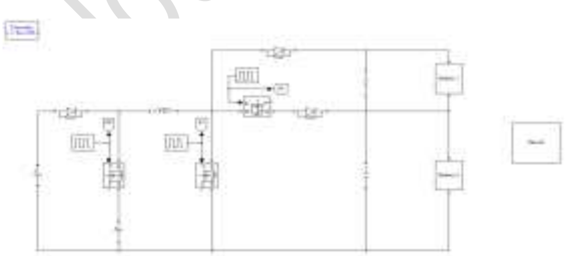

Fig.3.1. Proposed model.

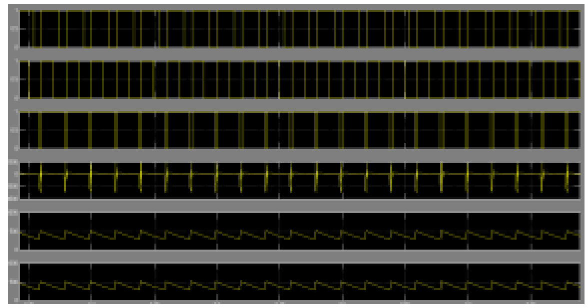

Fig.3.2. Applied triggering pulses.

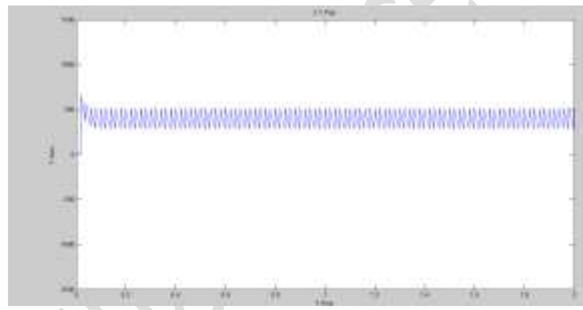

Fig.3.3. Voltage across the Output1.

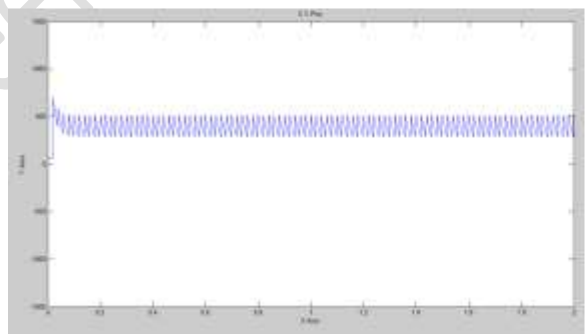

Fig.3.4. Voltage across the Output2.

4. CONCLUSION

In this paper, a ZVZCS full-bridge DC-DC converter and a new APWM gating technique have been proposed for battery charging applications in electric vehicles. Theoretical operation of the converter for achieving the ZVS turn-on of the main switches has been discussed. The circuit parameters design and magnetics design have been presented. The results have verified the capability of the proposed converter to achieve ZVS condition over the entire battery charging range. The proposed converter showed significant reductions in switching losses, auxiliary circuit losses and required auxiliary inductance. The high voltage spikes on output rectifier diodes have been mitigated. The features have been validated by the experimental results from the laboratory-scale 1.2kW converter prototype. The efficiency results have proved the improved performance of the proposed APWM converter over the proposed PSM converter and the conventional ZVZCS converter.

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