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A Bridgeless PFC Converter for Plug-In Hybrid Electric Vehicle

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ABSTRACT

This paper proposes the bridgeless bi-directional PFC Converter on the front-end stage of the on-board electric vehicle. The proposed converter uses the IGBT to reduce the losses that occurs due to the MOSFET body. The PFC converter PFC Converter using SiC MOSFET is used widely. The MOSFET body in the converter usually suffers from the reverse recovery issue and this limits the topology in CCM mode. The ultra-fast IGBT has the high switching frequency and the low losses. It also offers the high efficiency even in the hard switching and also the low conduction losses. The PFC converter using IGBT also enables the use of PFC under CCM mode in the high power applications. The availability of the Ultra-Fast IGBT of high switching frequency makes it possible to use it in the PFC converter.

Keywords: Bridgeless, Power factor, Electric vehicle and Onboard charger.

1. Introduction

In the conventional plug-in electric vehicles, in the earlier days, the input current harmonics is reduced using the LC filter. Then it became impossible to meet the requirement of the high power applications. Then the active power factor correction using the buck, buck-boost, sepic and cuk converter are used. The methods were also suffered from huge losses in the high power application mode.

Then, the onboard charger used comprised the rectifier followed by a DC-DC converter. The rectifier usually suffers from the conduction losses and hence the efficiency gets affected. In addition to that, usage of rectifier is not bi-directional. Hence, in order to reduce the losses and also to improve the efficiency, the bridgeless topology is investigated. The dual – boost bridgeless topology is proposed initially to improve the efficiency.

Although, the dual boost bridgeless topology is considered it suffers from the serious common mode noise. The Electromagnetic Filter is required in order to reduce the common mode noise. The topology with the bi-directional switches has the drawbacks such as gate drive design to be difficult and also the diode rectifier used is also inefficient.

Then, the semi-bridgeless boost converter topology is introduced in order to reduce the noise. But the converter has to handle the peak current so more number of the components was used to handle the current. The more number of the components results in the increase in the size and the cost. These factors makes the topology impractical to apply as the power factor correction converter.

Then, the bridgeless PFC converter using silicon MOSFET is introduced. However, the silicon body of the MOSFET suffers from the reverse recovery issue. The intrinsic body of the MOSFET diode suffers from the large reverse recovery current in the current conduction mode (CCM). This makes the topology to be impractical to use it in the high power applications. To eliminate this, the fast recovery diodes can be used in anti-parallel, but it has a main drawback it increases the cost and size of the topology.

The current control method such as hysteresis current control method, Peak control method, average control method are also used to improve accurate current tracking and reduction in harmonic currents and the losses due to the electromagnetic effect can be reduced by using average current method.

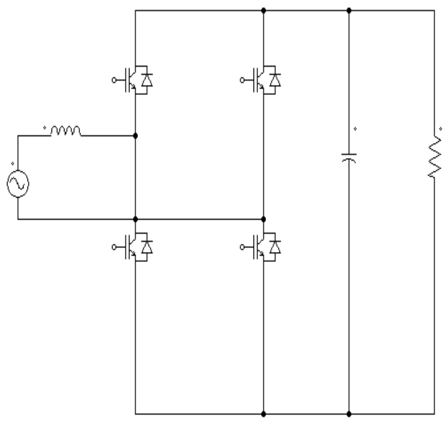

Fig.1.1.Interleaved PFC converter

This paper introduces an IGBT based bridgeless interleaved PFC converter on the on-board charger of the electric vehicles. When compared with that of the other PFC converters the proposed topology has much superiority in terms of the low conduction losses, high efficiency, small reverse recovery current. The numbers of the components used are also reduced. The simple control and the simple gate –drive design makes the topology a cost effective solution. The ultra-fast IGBT in the PFC converter makes it possible to apply it in the current conduction mode operation in the high power applications. The IGBT enables the bidirectional operation and also it acts a new alteration for the bridgeless PFC topology. The results are implemented and also verified

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using the simulation and hardware. The MATLAB simulation is used to verify the results.

2. BRIDGELESS INTERLEAVED PFC CONVERTER

The proposed bridgeless interleaved converter consists of the four IGBTs that are connected in two legs. The boost converters are interleaves and are separated with 180 degree phases.

The IGBT works in two modes.

- Positive half line cycle operation
- Negative half line cycle operation

2.1 Positive Half Line Operation

The positive cycle operation has two semiconductors in the path of current. When the switch is on, the inductor gets charged due to the input source and the capacitor is used to deliver the load. The IGBT S4 is conducting current and connects the AC source to the ground.

When the switch 2 is in off condition the charge from the inductor gets discharged and the power from the inductor is used to supply the load.

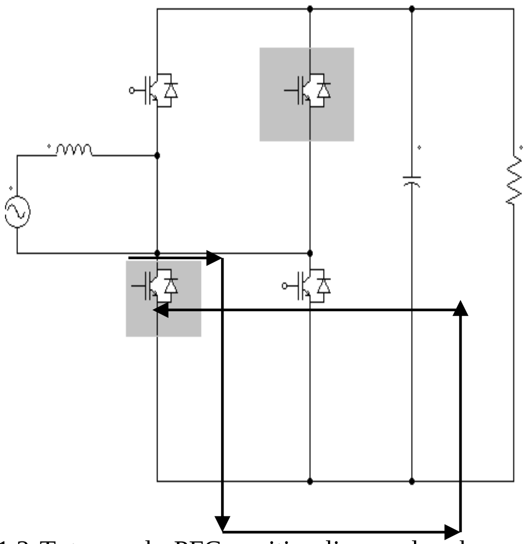

Fig.1.2 Totem-pole PFC positive line cycle when switch is ON

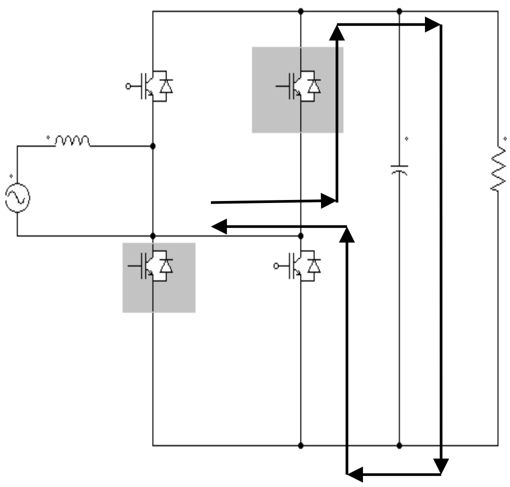

Fig.1.3 Totem-pole PFC positive line when switch is OFF

2.2 Negative Half Line Cycle Operation

The operation of the negative half line cycle is similar to that of the positive half cycle. When the switch1 is on the inductor gets charges and the capacitor supplies the power to the load. The S3 becomes conducting and closes the circuit by connecting it to the ground.

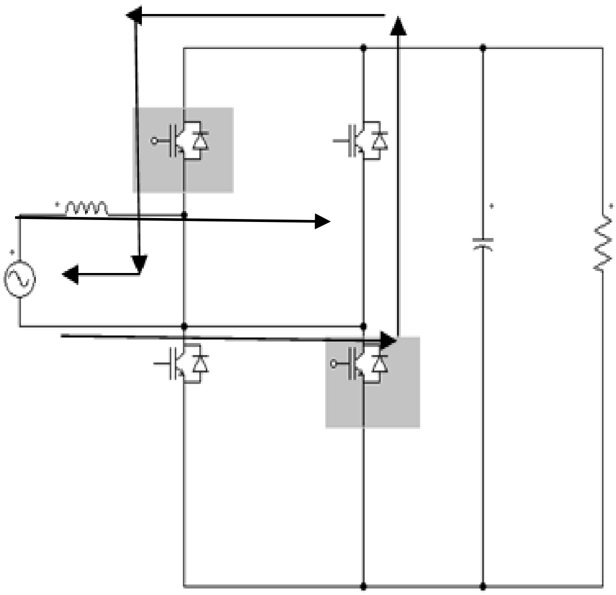

Fig.1.4 Totem-pole PFC negative cycle when switch is ON

When the switch is in OFF condition, the charge in the inductor gets discharged and supply the power to the load. Two IGBTs conducts during the negative half cycle.

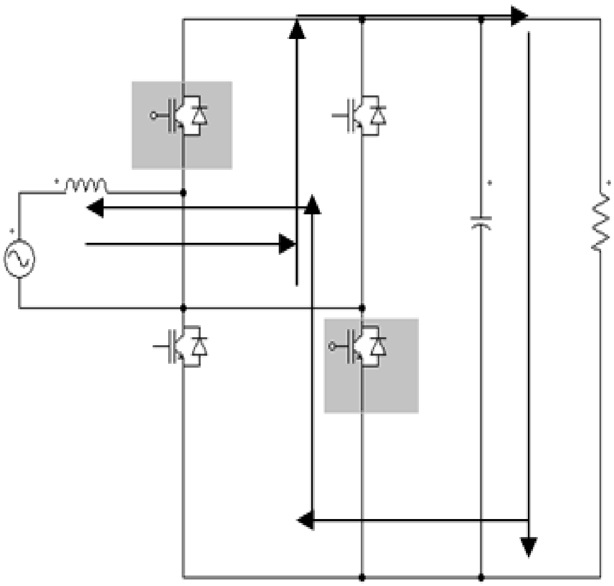

Fig.1.5 Totem-pole PFC negative cycle when switch is OFF

The zero-crossing detector is used to give the input pulse. The input is given with the PWM generator. The pulse is generated by using the Pulse Width Modulation Technique

3. SIMULATION CIRCUIT AND RESULTS

The simulation is done for the single phase input circuit with the 230 V as input to the PFC converter.

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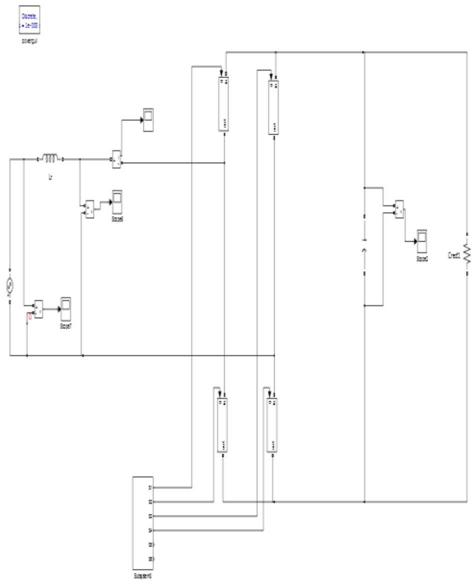


Fig.1.6. Simulation Circuit

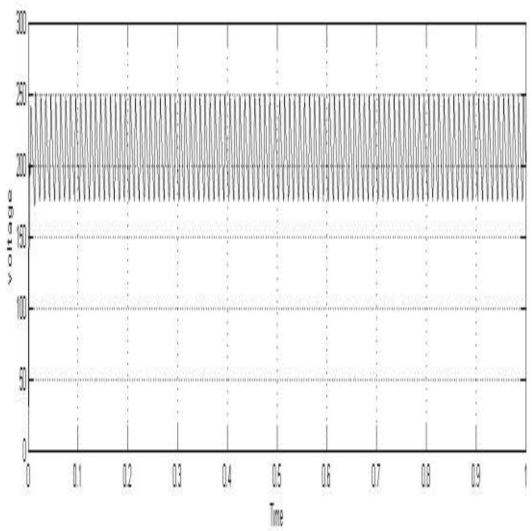
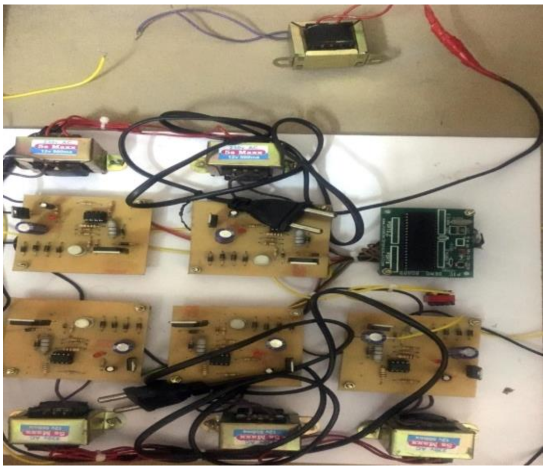


Fig.1.7 Simulation output

4. HARDWARE AND RESULT

The hardware setup for the bridgeless PFC converter is shown below.



The input given is 12 V and the output obtained is 23.4 V

5. CONCLUSION

Power factor is the important factor to be considered while using the loads that draws power from the grid. While using Bridgeless PFC converter on the electric vehicle charger, the losses that happens due to the diode rectifier such as reverse recovery losses, conduction losses can be eliminated. The harmonics can also be reduced and the power factor correction can be made by using this setup in a cost effective manner.

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