Analysis of Bridgeless PFC Boost Converter

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Abstract

Conventional boost PFC converter has disadvantage having high conduction loss in the rectifier-bridge. Bridgeless PFC boost converter reduces conduction loss and improves efficiency by omitting rectifier-bridge. This converter has advantages like reduced conduction loss, reduced hardware and high performance. This paper presents simulation of bridgeless PFC boost converter, also called dual boost PFC rectifier. This bridgeless PFC circuit has much higher common mode EMI than conventional PFC circuit. Common mode EMI is reduced by adding slow recovery diodes in bridgeless PFC circuit. Power factor is more improved by adding capacitor in parallel with AC source.

Keywords - Power factor correction (PFC), bridgeless, conventional, boost converter, conduction loss, common mode electromagnetic interference (EMI).

I. Introduction

Presently, there is increasing demands of high power factor and low total harmonic distortion in the current drawn from the utility. There is a requirement of good power quality; significant efforts have been made for the developments of the PFC converters. The boost topology is widely used as PFC converter.

Conventional boost PFC converters are composed of a full bridge AC to DC diode rectifier followed by a boost converter. The bridge-rectifier offers high conduction losses which lowers the system efficiency. Bridgeless boost PFC is a high efficiency topology which omits rectifier-bridge, there are only two semiconductors in any given conduction path. In each circuit, the boost converter is implemented by replacing a pair of bridge rectifier with switches and employing an ac side boost inductor. Having high efficiency, the bridgeless PFC boost implementations have received more attention. The bridgeless PFC boost topologies are most suitable for medium -to-high power applications [2]. The block diagram of a bridgeless PFC boost converter is shown in fig. 1. Power factor is more improved by adding capacitor in parallel with ac source in bridgeless PFC boost converter.

II. Bridgeless PFC circuit

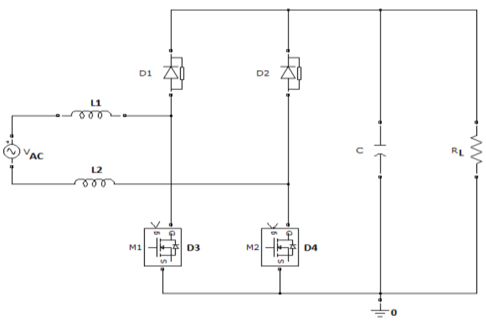

Fig. 1. Bridgeless PFC converter

Unlike the conventional PFC circuit, the inductor is split and placed at the AC side to perform the boost structure. The bridgeless topology presented in this paper omits the bridge-rectifier and also maintains the classic boost topology. This is easily done by connecting intrinsic body diode between drain and source of Power MOS switches.

Table-1 Differences between conventional topology and bridgeless topology

	Slow diode	Fast diode	MOSFET	Conduction path On/(Off)
Conventional PFC	4	1	1	2slowdiode, 1mosfet/(2 slowdiode,1fast diode)
Bridgeless PFC	0	2	2	1body diode,1mosfet/(1mosfet body diode,1 diode)

The difference between the bridgeless and conventional topology is inductor current of bridgeless flowing through two semiconductor devices, but in case of conventional converter, it flows through three semiconductor devices [1],[6]. Thus, bridgeless topology reduces conduction losses. This topology also replaces the two slow diodes of the conventional topology by using one MOSFET body diode. Since, both of them are working as a boost DC/DC converter; the switching loss should be same. The efficiency of bridgeless PFC circuit is improved due to more conduction losses in the two slow diodes with respect to body diode of MOSFET. Besides, comparing with the conventional topology, the bridgeless topology not only reduces conduction loss, but also reduces total components. The working of bridgeless PFC boost converter is explained below [7].

1. Positive half cycle:

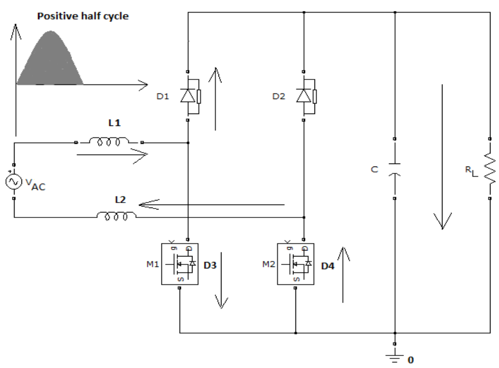

Fig. 2. Positive half cycle of the converter

The equivalent circuit of bridgeless PFC boost converter for the positive half cycle is shown in fig. 2. When MOSFET M1 turns on, the inductor L_1 stores energy and current flows through the path- inductor L_1, MOSFET M1, internal diode D4 of MOSFET M2, inductor L_2.As M1 turns off, L_1 discharges stored energy by D1 to load and current flows through the path- diode D1, load R_L, internal diode D4 of MOSFET M2, inductor L_2, input line.

2. Negative half cycle:

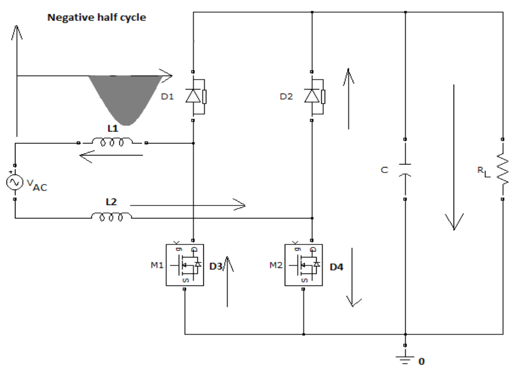

Fig. 3. Negative half cycle of the converter

The equivalent circuit of bridgeless PFC boost converter for the negative half cycle is shown in fig. 3. When MOSFET M2 turns on, the inductor L2 stores energy and current flows through the path- inductor L2, MOSFET M2, internal diode D3 of MOSFET M1, inductor L1. As M2 turns off, L2 discharges stored energy by D2 to load and current flows through the path- diode D2, load R_L, internal diode D3 of MOSFET M1, inductor L1, input line. The MOSFET M1 can be driven on/off only in positive half cycle and the MOSFET M2 only in the negative half cycle. Both MOSFETs can be driven on and off simultaneously because of the freewheeling diodes D3 and D4, providing the right flow of the current in each alteration of the input line.

III. Modified boost converter

The bridgeless PFC boost converter has disadvantage of having larger common mode noise than the conventional PFC boost converter. In case of conventional PFC boost converter, the output ground is always connected to ac source through the diode rectifier. But in case of bridgeless, the output ground is connected to ac source through the body diode of switch only during positive half cycle, while during negative half cycle the output

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ground is pulsating relative to ac source with high frequency (HF) and its amplitude is equal to the magnitude of output voltage [3]. This HF pulsating voltage source is charging and discharging the parasitic capacitance between the output ground and ac line ground, which results in a significantly increased common mode EMI.

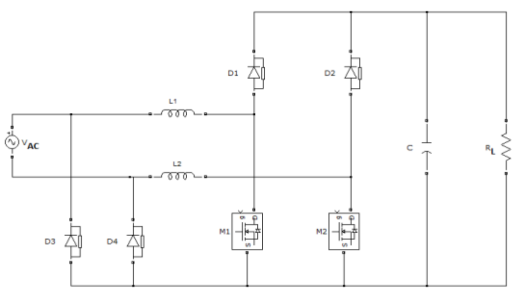

Fig. 4. Bridgeless PFC boost converter with reduced CM noise

The common mode (CM) EMI is reduced by providing a LF path between ac source and positive or negative terminal of output. This is achieved by making bridgeless PFC circuit is shown in fig. 1, similar to conventional PFC circuit [5][8]. Bridgeless PFC circuit is modified by adding two slow recovery diodes D3 and D4 is shown in fig. 4. There are two DC/DC boost circuits; one is for each half cycle. The drawback of bridgeless is that it requires an additional gate drive transformer. Second drawback is it requires two inductors. But, two inductors have better thermal performance in comparison to single inductor. The symmetric boost inductors operate as a common mode filter which can be expected to achieve higher common mode noise reduction [8]. The working of modified boost converter is discussed below:

1. Positive half cycle:

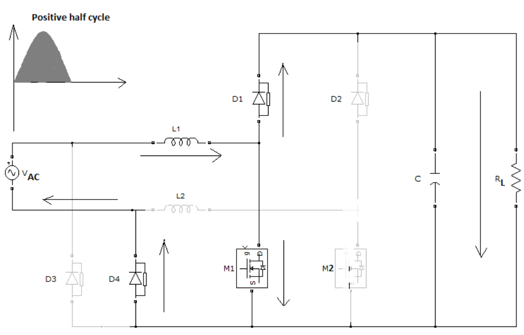

Fig. 5. Positive half cycle of modified boost converter

The equivalent circuit diagram of modified boost converter for positive half cycle is shown in fig. 5. During positive half cycle, first dc/dc boost circuit is active i.e. L1-D1-M1-D4 is shown in fig. 5 by bold lines [4]. Diode D4 connects the output ground to the ac source during positive half cycle. When M1 turns on, inductor L1 stores energy and current flows through the path- inductor L1, MOSFET M1and diode D4. As M1 gets off, the stored energy of the inductor L1 is released by D1 to load R_L and current flows through the path- diode D1, load R_L, return diode D4 and ac source.

2. Negative half cycle:

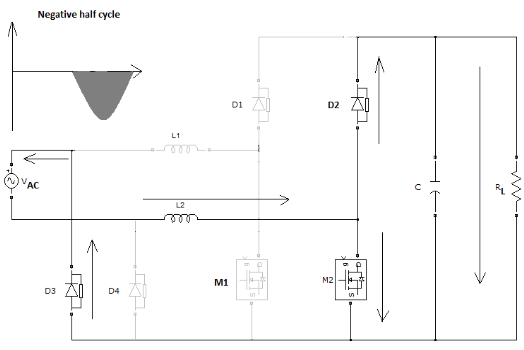

Fig. 6. Negative half cycle of modified boost converter

The equivalent circuit diagram of modified boost converter for negative half cycle is shown in fig. 6. During negative half cycle, second dc/dc boost circuit is active i.e. L2-D2-M2-D3 is shown in fig. 6 by bold lines [4]. Diode D3 connects the output ground to the ac source during negative half cycle. When M2 turns on, inductor L2 stores energy and current flows through the path- inductor L2, MOSFET M2 and diode D3. As M2 gets off, the stored energy of the inductor L2 is released by D2 to load R_L and current flows through the path- diode D2, load R_L, return diode D4 and ac source.

The power factor of the bridgeless PFC boost converter, also called as dual boost PFC rectifier shown in fig. 4. has also been calculated. As the result obtained in Matlab, the voltage and current are almost in the same phase. Therefore, power factor correction is done as the name used PFC boost converter. The calculated value is 0.8037. Power factor of this bridgeless PFC boost converter can be more improved by adding capacitor in parallel with ac source. Capacitor cannot connect direct with ac source in parallel, so small resistance is connected in series with ac source and capacitor is connected in parallel with ac source. The circuit diagram of the bridgeless PFC boost converter with capacitor in parallel with ac source is shown in fig. 07.

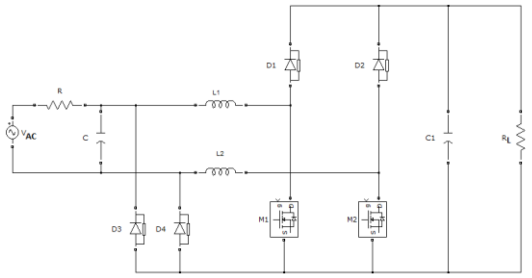

Fig. 7. Modified boost converter with capacitor in parallel with ac source

After adding capacitor, the shape of the input current improves and it follows sinusoidal input voltage. Therefore, power factor is improved and the calculated value is 0.9748.

IV. Simulation & Results

Simulation is done in MATLAB and the obtained results are presented. Simulation of modified boost converter is shown in fig. 8a. The input current and voltage is shown in fig. 8b & 8c respectively. Similarly, the Voltage across MOSFET 1 & 2 is shown in fig. 8d & 8e respectively. Further, the output dc voltage and current are shown in fig. 8f & 8g respectively. The active and reactive power is shown in fig. 8h, where the blue line indicates active power and green line reactive power. The output voltage is boosted to 199.7 V. The calculated value of pf is 0.8037. Thus, power factor correction is done.

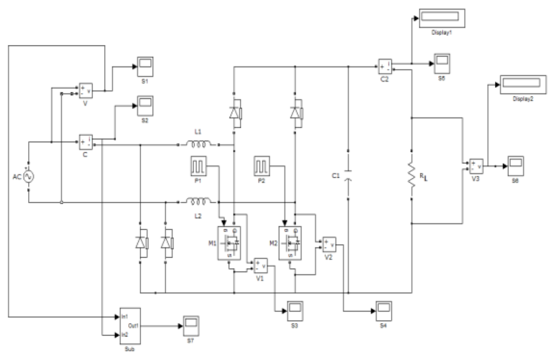

Fig. 8a. Modified boost converter

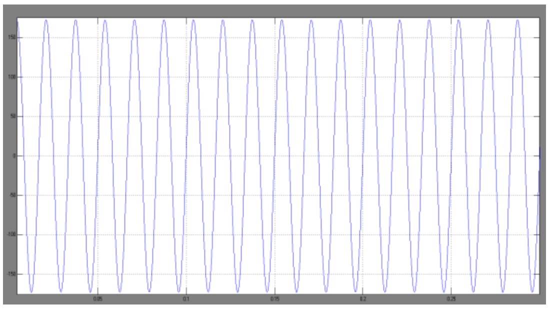

Fig. 8b. Input voltage of modified boost converter

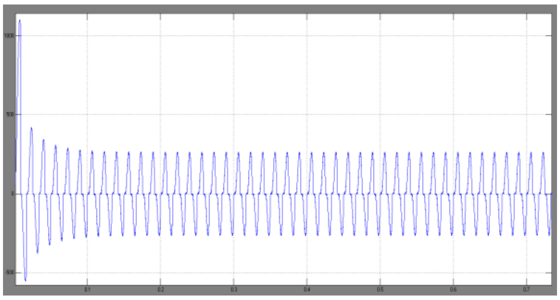

Fig. 8c. Input current of modified boost converter

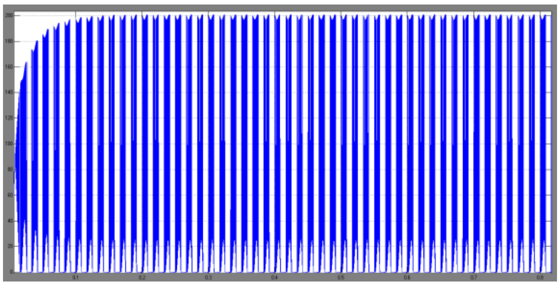

Fig. 8d. Voltage across MOSFET-1

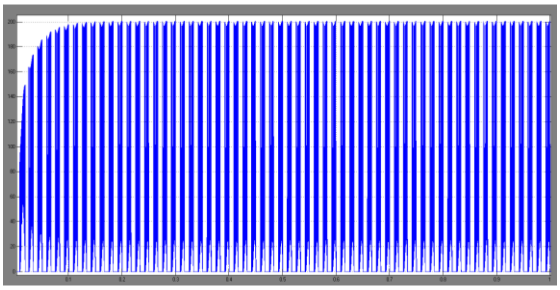

Fig. 8e. Voltage across MOSFET-2

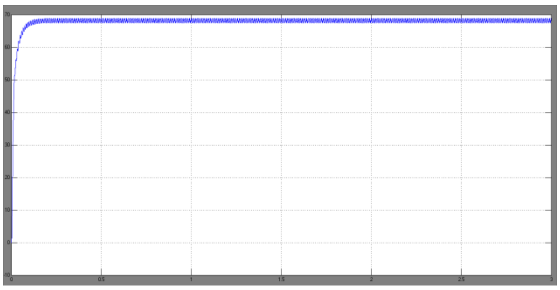

Fig. 8f. DC output current of modified boost converter

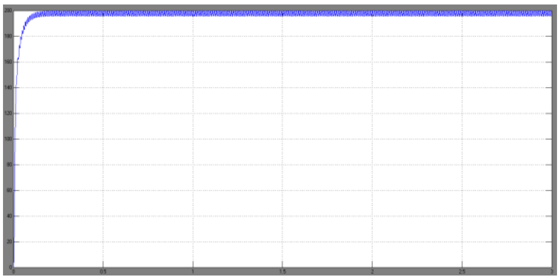

Fig. 8g. DC output voltage of modified boost converter

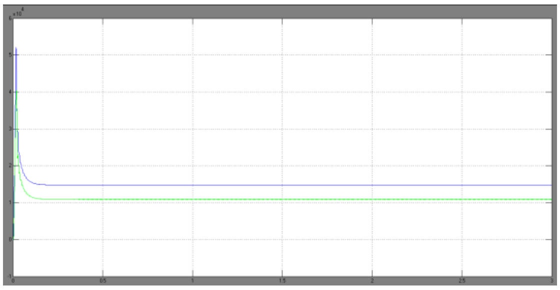

Fig. 8h. Active and reactive power of modified boost converter

Power factor is more improved by connecting capacitor in parallel with ac source in modified boost converter shown in fig.9a. Capacitor cannot be added in parallel with the ac source. Thus, resistor is connected in series with ac source which is very small of 0.1 Ω. The current and voltage are almost in same phase. The calculated value of pf is 0.9748. Thus, power factor is more improved. The output voltage is boosted to 182.5 V.

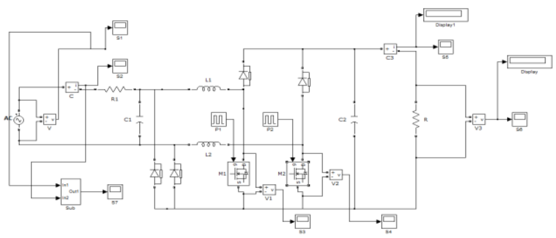

Fig. 9a. Capacitor in parallel with AC source in modified boost converter

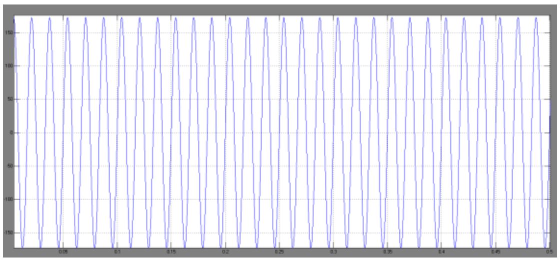

Fig. 9b. Input voltage

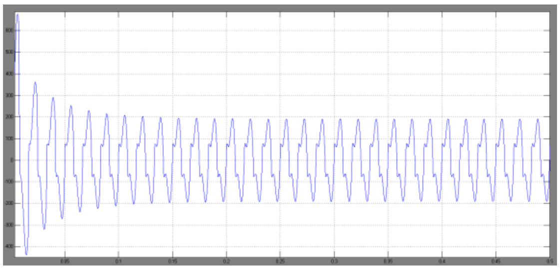

Fig. 9c. Input current

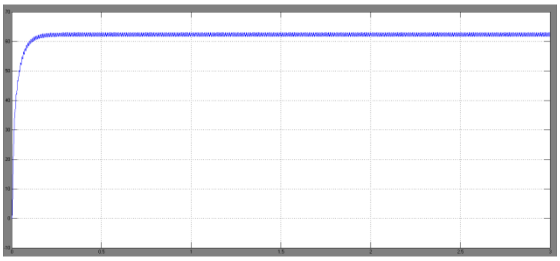

Fig. 9d. Output current

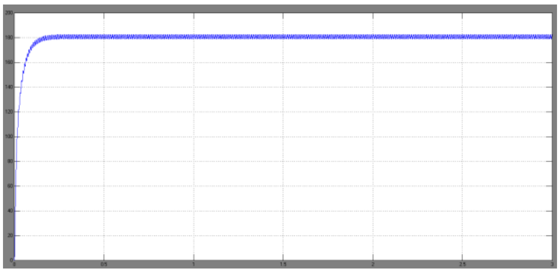

Fig. 9e. Output voltage

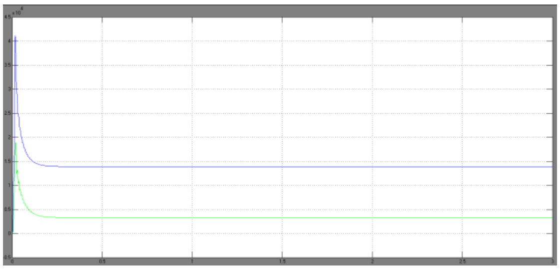

Fig. 9f. Active and reactive power

V. Conclusion

In this paper, the bridgeless PFC boost converter with two dc/dc boost circuits is selected as a representative member of bridgeless PFC boost rectifier family. The bridgeless PFC boost converter is analyzed, modeled and simulated using MATLAB. It has advantages like high efficiency, low conduction loss & less components. But, it has larger common mode EMI than conventional PFC converter. It is reduced by adding slow recovery diodes in bridgeless PFC circuit. Power factor correction is done by using bridgeless PFC boost converter. Power factor is more improved by adding capacitor in parallel with AC source.

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