A HIGHLY EFFICIENT INTEGRATED BUCK & BOOST PFC CONVERTER

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ABSTRACT

Now a day there has been a necessary need to keep the EMI emissions by different power circuits below the regulatory limit. Harmonic pollution created by these circuits have been of immediate concern. So in this paper a investigation has been done to find a new PFC converter which can provide us better results than the existing techniques. Bridgeless PFC technique is the most reliable technique for power factor correction in the circuits till now providing .90 PF but its efficiency is low. So here a new technique has been introduced to improve the efficiency of the circuit and to achieve the power factor almost unity. Simulation results are provided to verify the results of the new circuit.

Keywords*-Power Factor Correction (PFC), Conventional PFC converter, Bridgeless PFC Converter(BPFC) , Integrated PFC Converter, Total Harmonic Distortion (THD), Power Factor (PF)*

1. INTRODUCTION

Because of the regular use of the rectifiers in all electrical and electronic circuits unwanted harmonics get injected into the power supply causing undesired output and higher THD.[1] To solve this problem there are some regulatory limits imposed by International standards like IEC 31000 3-2 by Japan and IEC 61000 3-2 by America.[2] These systems are imposed to protect our grid systems from damages due to harmonic distortion.[1][2].

Initially the conventional method was used in the process of the development of the PFC circuits.[4] in all these circuits the rectifier was used for rectification causing higher switching and conduction losses at high power.[2][4].due to this PF was reduced to 0.4 to 0.6. Than conventional approach was used by using boost converter after the rectifier. This approach increased the power factor to 0.7-0.8 but at complex circuits in decreased the efficiency of the circuit because of the presence of the diode bridge rectifier to 70%.

Than bridgeless rectifier was used to improve the situation in which the rectifier was removed and conduction losses were controlled as the no of semiconductors was reduced in the current flow path of the circuit.[1]-[4]. But due to instability caused by output ground after eliminating the bridge rectifier the efficiency of the circuit was not improved remarkably.

So a new circuit is formed and introduces by combining the bridgeless PFC rectifier by the buck converter to get the desired results.[6]

2. REVIEW OF THE BRIDGELESS PFC CONVERTER

The basic bridgeless boost PFC converter is shown in fig 1. It is clear from the diagram that the bridgeless PFC circuit is exactly similar to the boost converter from the view of function. One more important thing to notice is the current flow path which shows that there are less no of semiconductor in the path i.e. one diode and one MOS.

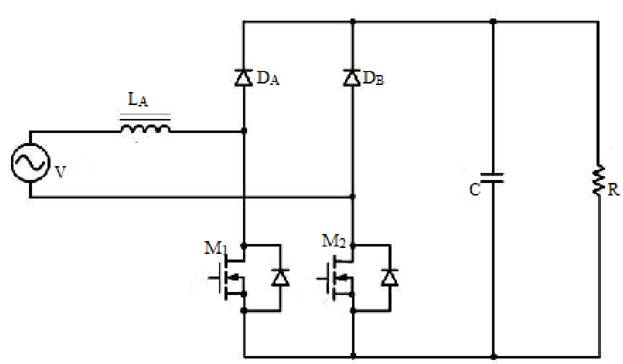

FIG.1: Basic Bridgeless PFC Boost Converter

Its operation can be analyzed in two ways:

1. Positive half cycle
2. Negative half cycle

(i) POSITIVE HALF CYCLE

When the applied AC input is positive than the gate of the power MOS M_1 is made high and thus the current start flowing through the inductor L_A storing energy into it fig 2(a).

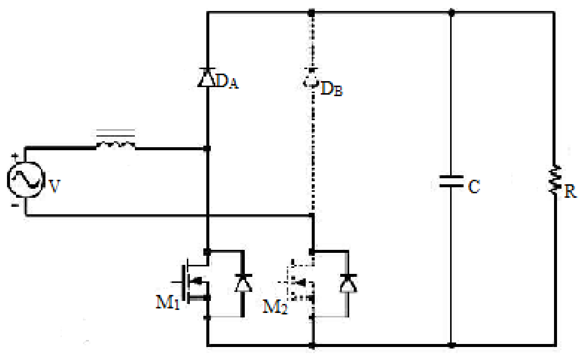

FIG.2 (a): Positive Half Cycle

When the MOS M_1 goes off than the stored energy into the inductor L_A is released and the current start flowing through diode D_A while the body diode of M_2 provides the return path to the current.

Thus the current in this type of circuit flows through only one diode and one power MOS.

(ii)NEGATIVE HALF CYCLE

When the applied AC input is positive than the gate of the power MOS M_2 is made high and thus the current start flowing through the inductor L_A storing energy into it fig 2(b).

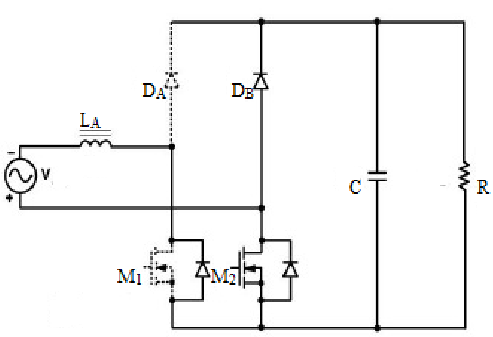

FIG.2 (b): Negative Half Cycle

When the MOS M_2 goes off than the stored energy into the inductor L_A is released and the current start flowing through diode D_B while the body diode of M_1 provides the return path to the current.[5]

Thus the whole operation in bridgeless technique takes place. Most important thing to notice is the numbers of only two semiconductors in the path of the flow of the current i.e. one diode and one MOS when compared to the conventional method.[4]

But in the conventional method the rectifier bridge provides the stability by providing output ground relative to the input voltage.

This thing is missing in bridgeless technique although it provides economical success by reducing the component count.

TYPES OF PFC CIRCUIT	SLOW DIODES	FAST DIODES	MOSFET	CONDUCTION PATH
CONVENTIONAL PFC	4	1	1	2 SLOW DIODES 1MOSFET
BRIDGELESS PFC	0	2	2	1 BODY DIODE 1MOSFET

To overcome this problem two additional inductors are inserted in the circuitry at the input side to reduce the overall conduction losses.

3. BRIDGELESS PFC CONVERTER WITH TWO INDUCTORS AND FOUR DIODES

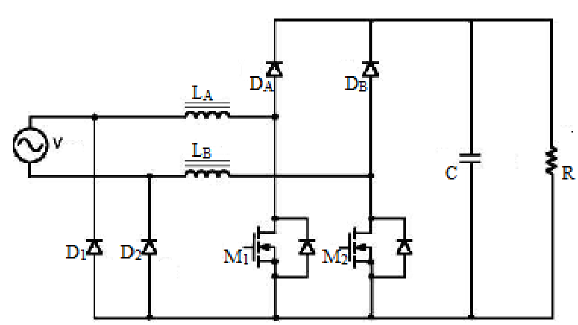

FIG.3: Bridgeless PFC Circuit with Two Inductors and 4 Diodes

In order to reduce the losses occurring due to waving output ground wrt input in the basic PFC circuit we add two extra diodes D_1 & D_2 at the input side. These diodes provide the low frequency path between the input and the positive and negative terminal of the output ground.[6][7] Diodes D_1 & D_2 are known as slow recovery diodes.

In this modified circuits there are two inductors used one for each cycle.

From the functional point of view now there are two boost converters mugged up in one circuit. When the input is positive than the one boost circuit with the components L_A-D_A-M_2 along with slow recovery diode D_1 is active. When the applied input is negative than second boost circuit is active i.e. L_B-D_B-M_1 comes into function while D_2 diode provides the low frequency path between the input source and output ground.

Thus this modified bridgeless circuit increases the PF to 0.90 which is far better than the conventional method.

The main problem of this circuit is the presence of two inductors which provides the thermal instability causing higher switching losses and lowering the efficiency of the circuit which is

better than the conventional yet but not up to the desired level.

4. PROPOSED CIRCUIT

We have seen that there have been lots of improvements in the power factor correction circuits. Now to achieve better results as we know that the bridgeless circuit is the most efficient circuit for power factor correction we integrate this circuit with buck converter. This integration is done by using single stage approach so that the component count of the circuit can be reduced and the circuit can be made economically fit.

Its circuit diagram is as follows in fig 4.

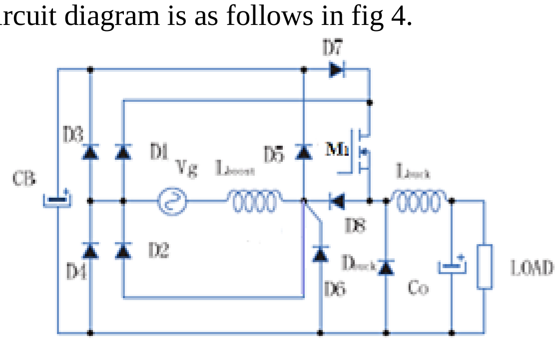

FIG.4: Proposed Circuit

Its operation is described in following way:

(A) MODE 1: In this mode let us consider that switch S_1 is ON during positive half cycle and due to this current start flowing and energy is stored into the inductor from the path M_1-L_{BOOST}-D_1. At the same time the capacitor C_B discharges the energy and provides the current in post regulator buck converter.

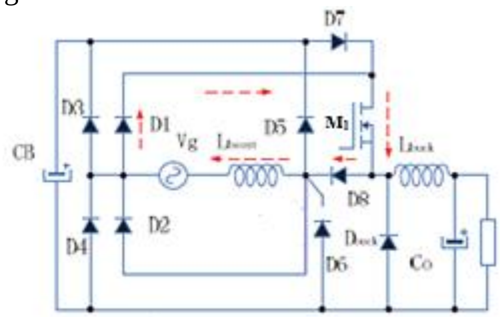

FIG.5(a): Mode 1

(B) MODE 2: In this mode now switch M_1 is turned OFF and the inductor gets discharged through D_3 and D_6. At the same time the capacitor C_B gets charged through the same current.

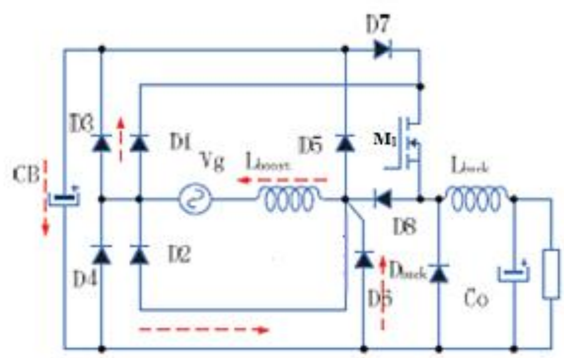

FIG.5 (b): Mode 2

(C) MODE 3: In this the operation takes place in the similar way to mode 1 and 2 in the positive half cycle. Because of the negative half cycle the inductor gets charged in reverse direction and at the same time the capacitor provides current to buck converter.

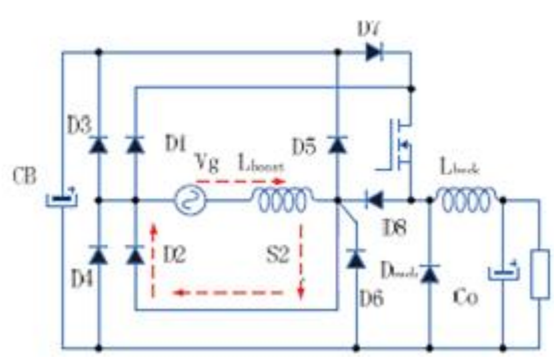

FIG.5(c): Mode 3

(D) MODE 4: in this mode now the current flows through D_6 and thus inductor is discharged and at the same time capacitor is charged.
Thus this system overcomes the drawbacks of the existing circuit and this provides better results than the existing ones.
Simulation results are described in next section.

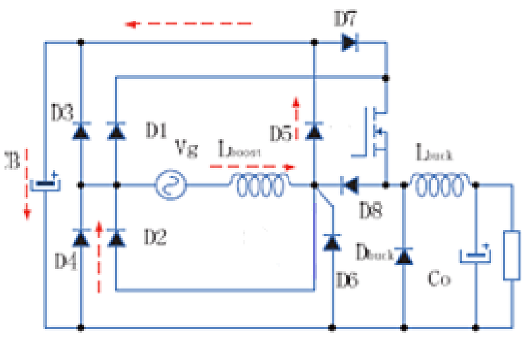

FIG.5(c): Mode 4

5. SIMULATION RESULTS

A prototype by integrating bridgeless with the buck converter is fully tested. Simulated waveforms of applied input are shown in fig 6(a). Simulated waveform of power factor for bridgeless model and proposed model is shown in fig 6(b) & 7(a) respectively. Efficiency comparison is done in fig 8.

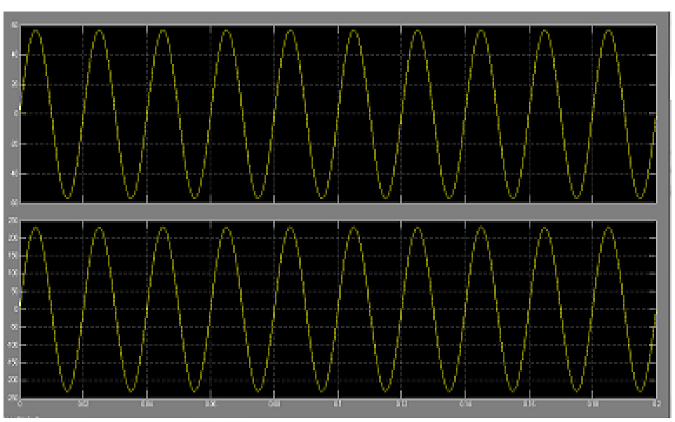

FIG 6(a): Input Voltage and Current Waveform

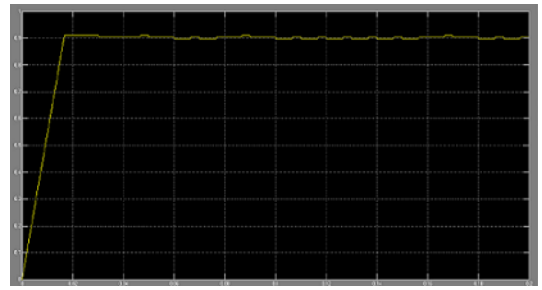

FIG. 6(b): Power Factor Waveform of Bridgeless PFC Circuit

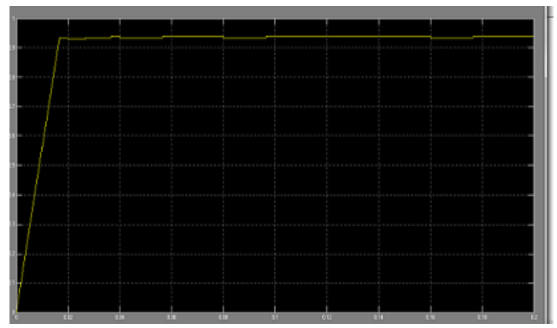

FIG.7 (a): Power Factor of Proposed Circuit

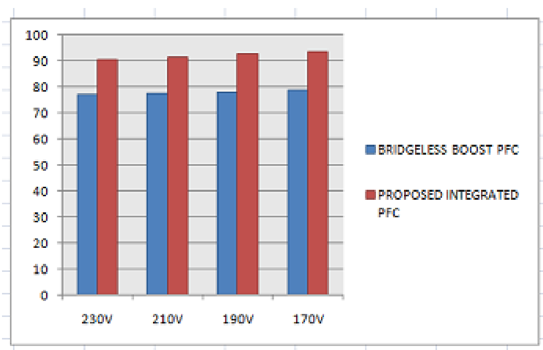

FIG.8: Efficiency Calculation

6. RESULTS

From the simulation results it is clear that the power factor of the proposed circuit is 0.94 which is highly reliable and closes to unity. All simulation is done at 230volts. While power factor of the bridgeless PFC circuit is 0.90 which is lower than requisite level. Efficiency of the circuit is increased to 90%.

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