A COMPERATIVE PERFORMANCE ANALYSIS OF BRIDGELESS PFC BOOST CONVERTER WITH THE CONVENTIONAL CONVERTER

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ABSTRACT

Dc power supplies are extensively used inside most of electrical and electronic appliances such as in computers, televisions, audio sets and others. Power supplies make the load compatible with its power source. The presence of non linear loads results into low power factor operation of the power system. Several techniques for power factor correction and harmonic reduction have been reported and a few of them have gained greater acceptance over the others. In this paper a bridgeless power factor correction boost converter is proposed which results in improved power factor and reduced harmonics content in input line currents as compared to conventional single phase diode rectifier circuit with parallel input resonant filter. Bridgeless power factor correction boost converter eliminates the line-voltage bridge rectifier in conventional single phase diode rectifier circuit, so that the conduction loss is reduced.

Keywords-Power Factor Correction (PFC), Conventional Single Phase Diode Rectifier Circuit, Bridgeless PFC Boost Converter, Total Harmonic Distortion (THD), Power factor

I. INTRODUCTION

The extensive use of dc power supplies inside most of electrical and electronic appliances lead to an increasing demand for power supplies that draw current with low harmonic content & also have power factor close to unity.

Dc power supplies are extensively used inside most of electrical and electronic appliances such as in computers audio sets, televisions, and others. The presence of non linear loads results in low power factor operation of the power system. The basic block in many power electronic converters are uncontrolled diode bridge rectifiers with capacitive filter. Due to the non-linear nature of bridge rectifiers, non-sinusoidal current is drawn from the utility and harmonics are injected into the utility lines. The bridge rectifiers contribute to high THD, low PF, and low efficiency to the power system. These harmonic currents cause several problems such as voltage distortion, heating, noises etc. which results in reduced efficiency of the power system. Due to this fact, there is a need for power supplies that draw current with low harmonic content & also have power factor close to unity. [1] & [2]

The AC mains utility supply ideally is supposed to be free from high voltage spikes and current harmonics. Discontinuous input current that exists on the AC mains due to the non-linearity of the rectification process should be shaped to follow the sinusoidal form of the input voltage. Power factor correction techniques are of two types – passive and active. While, passive power factor correction techniques are the best choice for low power, cost sensitive applications, the active power factor correction techniques are used in majority of the applications due to their superior performance. [3] [4] [5] & [6]

Conventional single phase diode rectifier circuit with parallel input resonant filter has been widely used as a PFC converter because of its simplicity and high power capability. Recently, in order to improve the efficiency of the front-end PFC rectifiers, many power supply manufacturers have started considering bridgeless power factor correction circuit topologies. Usually, the bridgeless PFC topologies, also known as dual boost PFC rectifiers, reduce the conduction loss by reducing the number of semiconductor components in the line current path.

II. CONVENTIONAL SINGLE PHASE DIODE RECTIFIER CIRCUIT WITH PARALLEL INPUT FILTER

Fig. 1 shows the simulated prototype of single phase diode rectifier using parallel resonant circuit as a passive wave shaping method.

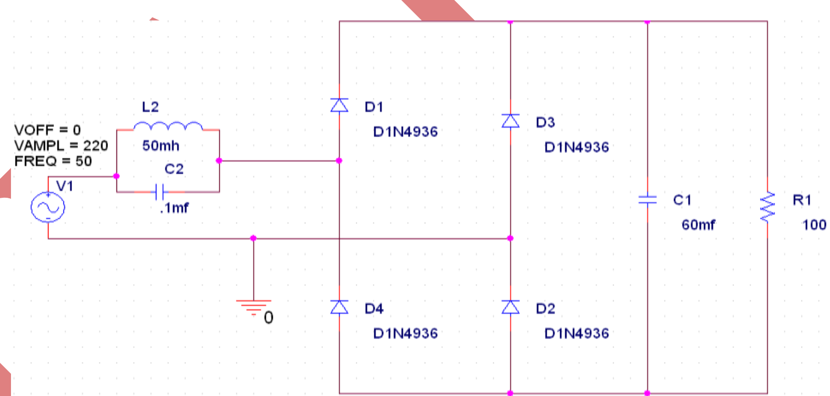

Fig. 1. Single Phase Diode Rectifier Circuit with Parallel Input Resonant Filter

Table 1 shows the values of all the calculated parameters for single phase diode rectifier with parallel input resonant filter in a tabulated form.

Table1 Values of Parameters for Single Phase Diode Rectifier with Parallel Input Resonant Filter

Parameters	Values
PF	0.592
DF	0.919
CDF	0.644
HF	1.186
THD	23.39%

Where PF- POWER FACTOR
CDF- CURRENT DISTORTION FACTOR
HF- HARMONIC FACTOR
THD- TOTAL HARMONIC DISTORTION
DF - DISPLACEMENT FACTOR

The input Total Harmonic Distortion is 23.39% which is too high and power factor is still non-unity. Therefore, some more efficient topologies are required.

The Fourier components of transient response of I are tabulated in table 2

DC COMPONENT = 2.068956E-01

Table 2 Fourier Components of Transient Response of Input Current of Fig 1

Harmonic Number	Frequency (Hz)	Fourier component	Normalized component	Phase (deg)	Normalized phase (deg)
1	6.000E+01	3.020E+00	1.000E+00	4.668E+01	0.000E+00
2	1.200E+02	2.264E-01	7.497E-02	-2.401E+01	-1.174E+02
3	1.800E+02	2.798E-01	9.265E-02	-3.394E+00	-1.434E+02
4	2.400E+02	6.070E-02	2.010E-02	3.620E+01	-1.505E+02
5	3.000E+02	1.063E+00	3.521E-01	5.087E+01	-1.825E+02
6	3.600E+02	6.216E-02	2.059E-02	-5.691E+01	-3.370E+02
7	4.200E+02	4.385E-01	1.452E-01	4.164E+01	-2.851E+02
8	4.800E+02	6.601E-02	2.186E-02	-3.784E+00	-3.772E+02
9	5.400E+02	5.237E-01	1.734E-01	4.035E+01	-3.797E+02
10	6.000E+02	2.281E-02	7.553E-03	-3.759E+01	-5.044E+02

The input total harmonic distortion is 43.6% which is better but still the efficiency is poor. The novel method uses a parallel resonant circuit at the input side in order to remove third harmonic component from the input current. The power factor is improved because the third harmonic component is the main reason for the low power factor. The calculated values shows that the efficiency is improved .The advantages of the novel method are the improved power factor and the improved efficiency. The disadvantages of the novel method include non unity power factor and still there should be significant improvement in efficiency.

III. BRIDGELESS PFC BOOST CONVERTER

The bridgeless PFC Boost Converter is shown in Figure 2. From a functional point of view, the circuit is similar to the common boost converter. In the conventional boost topology, current flows through two of the bridge diodes in series, whereas, in the bridgeless power factor correction configuration, current flows through only one diode and the return path is provided by Power MOSFET.

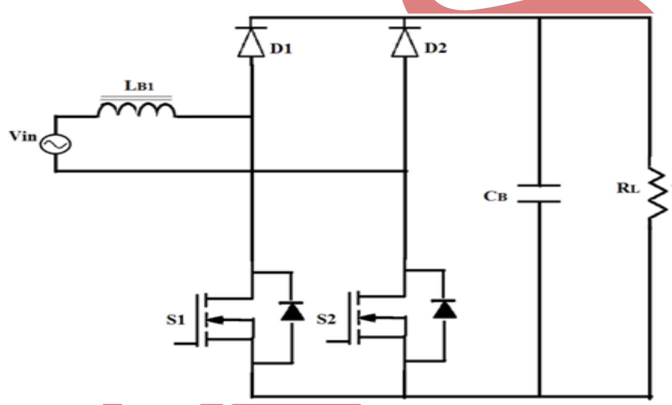

Fig. 2 Bridgeless PFC Boost Converter

When the AC input voltage goes positive, the gate of S1 is driven high and current flows from the input through the inductor LB, storing energy. When S1 turns off, energy stored in the inductor gets discharged and the current flows through diode D1, through the load and returns through the body diode of switch S2. During the negative half cycle, switch S2 is operated. When switch S2 turns on, current flows through the inductor, storing energy.

When S2 turns off, energy stored in inductor is released and the current flows through D2, through the load and back to the mains through the body diode of switch S1.

Thus, in each half line cycle, one of the MOSFET operates as an active switch and the other one operates as a diode. The difference between the bridgeless PFC and conventional PFC is that in bridgeless PFC converter the inductor current flows through only two semiconductor devices, but in conventional PFC circuit the inductor current flows through three semiconductor devices. The two slow diodes of the conventional PFC converter are replaced by one MOSFET body diode in bridgeless PFC converter. Thus, the efficiency improvement in bridgeless PFC converter relies on the conduction loss difference between the two slow diodes and the body diode of the MOSFET. The bridgeless PFC converter also reduces the total components count as compared to a conventional PFC converter.

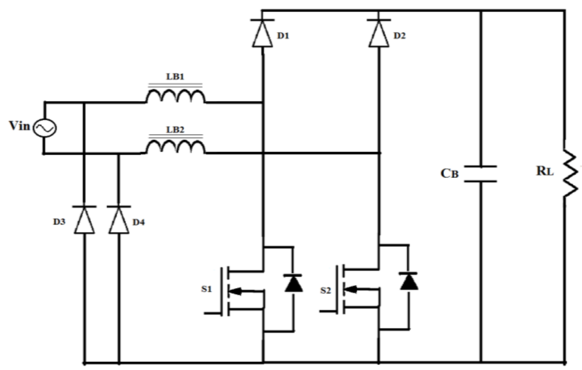

Fig.3 Proposed Bridgeless PFC Boost Converter

To reduce the common-mode noise, the bridgeless PFC boost rectifier is modified so that it always provides a low frequency (LF) path between the ac source and the positive or negative terminal of the output. In Fig.3, in addition to diodes D3 and D4, which are slow recovery diodes, a second inductor is also added. Inductor LB1 operates during positive half cycle and inductor LB2 operates during negative half cycle.

In bridgeless PFC boost rectifiers, the switches S1 and S2 can be driven with the same PWM signal. This simplifies the implementation of the control circuit.

The main drawback of the bridgeless PFC boost converter in Fig.3 is that it requires two inductors. However, two inductors compared to a single inductor provide better thermal performance.

IV OPERATION OF BRIDGELESS PFC BOOST CONVERTER

The operation of bridgeless power factor correction boost converter can be divided into four modes. Modes I and II comes under positive half cycle of input voltage and modes III and IV comes under the negative half cycle of input voltage.

1. Positive half cycle: During the positive half cycle of the input voltage, the first dc/dc boost circuit, LB1-D1–S1 is active through diode D4. Diode D4 connects the ac source to the output ground. The positive half cycle operation can be divided into two modes (Mode I Fig. 3a and Mode II fig.3b).

During mode I operation, the switch S1 is in on condition. When switch S1 turns on, inductor LB1 stores energy through the path Vin-LB1-S1-D4.

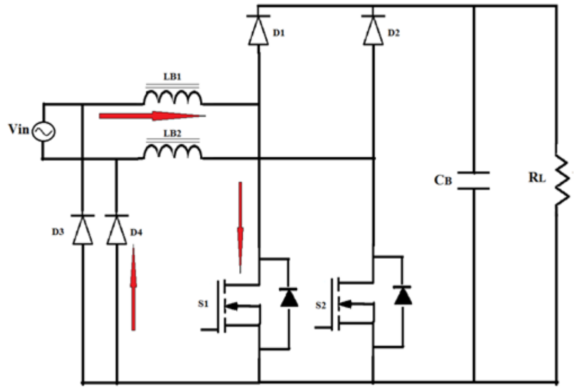

Fig. 3(a) Mode I operation

During mode II operation, the switch S1 is in off condition. When switch S1 turns off, the energy stored in the inductor LB1 gets discharged and the current flows through diode D1, load RL, and returns back to the mains through the diode D4.

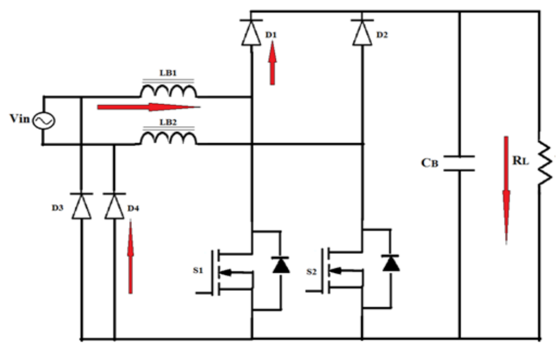

Fig. 3(b) Mode II operation

2. Negative half cycle: During the negative half cycle of the input voltage, the second dc/dc boost circuit, LB2-D2–S2 is active through diode D3. Diode D3 connects the ac source to the output ground. The negative half cycle operation can be divided into two modes (Mode III Fig.3c and Mode IV fig.3d).

During mode III operation, the switch S2 is in on condition. When switch S2 turns on, inductor LB2 stores energy through the path Vin-LB2-S2-D3.

During mode IV operation, the switch S2 is in off condition. When switch S2 turns off, the energy stored in the inductor LB2 gets discharged and the current flows through diode D2, load RL, and returns to the mains through the diode D3.

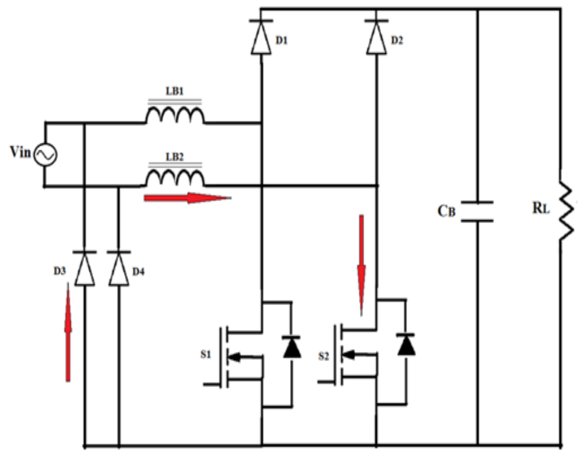

Fig. 3(c) Mode III operation

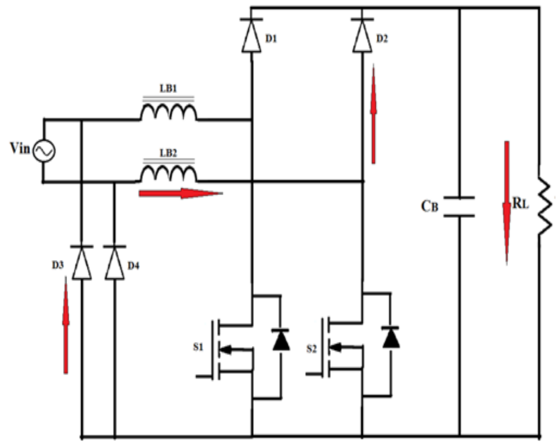

Fig. 3(d) Mode IV operation

Based on the Two PFC topologies, it is found that the best efficiency is obtained from the Bridgeless topology followed by the full-bridge with 1 DC/DC converter. It is found that by using less number of components, the efficiency can be improved up to 8% and in some cases up to 10% as explained previously. However, the Bridgeless converters discussed in this paper were unable to be used as SMPS due to its output voltage which is not regulated at 19V. Thus, some work should be done to show that the Bridgeless converter can give the same results on its efficiency if it is designed to suit the SMPS requirements. Although it shows very good efficiency when the output voltage regulated at voltage around 390V but it is still a doubt that this Bridgeless converter can still giving high efficiency in SMPS environment. On the other hand, the effect of switching frequency to the converter is not being discussed extensively in most work although it is a well known fact that by increasing the switching frequency, the switching losses will increase as well. On top of that, it can be observed that several works have been using variable switching frequency especially for fully DCM or CCM/DCM boundary operation.

V. CONCLUSIONS

A single-phase Bridgeless PFC Boost Converter is modeled and simulated using Matlab. Compared to the conventional PFC converter, the bridgeless PFC boost converter, also called the dual-boost PFC rectifiers, generally, improves the efficiency of the front end PFC stage by eliminating one diode forward-voltage drop in the line-current path. The Bridgeless PFC Boost Converter provides a good solution to implement low cost high power factor AC–DC converters with fast output regulation.

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