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DESIGN, SIMULATION AND COMPARISON OF PFC BOOST CONVERTER TOPOLOGIES

Mirza Faizan Baig[1], Hitesh Lade[2]

[1]*M.Tech Scholar, Surabhi group of Institutions, Bhopal*
[2]*Asso. Professor, Surabhi group of Institutions, Bhopal*

Abstract: It is a big challenge to maintain a good power factor while working in industrial and domestic applications as well, since most of the loads are inductive which tend to make power factor more lagging. To remedy this situation many solutions are available, out of which boost converters are studied and analyzed in the upcoming work. There are various topologies of the boost converters which improve the power factor. This paper covers phase shifted bridgeless boost converter and interleaved boost converter topologies for the analysis of input power factor and THD.

I. INTRODUCTION

The power factor correction can be carried out by various methods. Thesel methods are mainly classified in two types as:

i. Passive power factor correction
ii. Active power factor correction.

Passive power factor correction involves the use of passive elements such as inductors and capacitors as filters for reactive power compensation. This technique suffers from the following drawbacks:

i. Bulky size of the passive components
ii. Fixed compensation characteristics
iii. Series and parallel resonance.

There are many solutions proposed by different scholars such as use of multi-pulse converters, PFC boost converters, Buck converters, Buck-Boost converters etc. The main objective of using these converters is to improve the system power factor as well as to reduce the input current harmonics, as they create distortions in the output voltage waveforms. The power factor correction devices are extensively in use in various power applications as well as in electric drives.

Phase Shifted Bridgeless Boost Converter: The phase shifted semi bridgeless topology shown in fig.1 is proposed as a solution to address the problems associated with the conventional boost and bridgeless boost topologies. This topology features high efficiency at light loads and low line, which is critical to minimize the charger size, charging time and the amount and cost of electricity drawn from the utility; the component count, which reduces the charger cost; and reduces EMI.

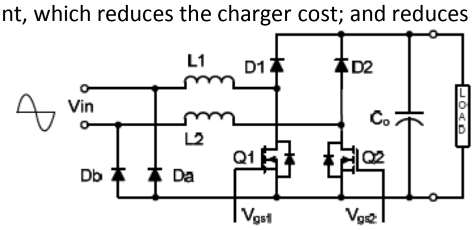

Fig.1 Phase shifted bridgeless boost converter

Interleaved Boost Converter: The interleaved boost converter is shown in fig.2. It is simply combination of two boost converters operating in parallel 180^{o} out of phase. The input current is the sum of the two inductor currents. Because the inductors ripple currents are out of phase they tend to cancel each other and reduce the input ripple current caused by the boost switching action.

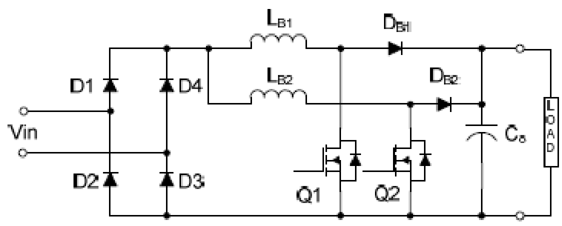

Fig.2. Rectifier + Interleaved boost converter topology

Furthermore, by switching 180^{o} out of phase, it doubles the effective switching frequency and introduces smaller input current ripple.

Performance Parameters: The performance of the boost converter topologies are analyzed on the basis of the following performance parameters:

i. Total Harmonic Distortions: The THD is a measurement of harmonic distortions present

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in the current or voltage waveforms. The THD can be easily found out by using the FFT analysis tool of the MATLAB

ii. Distortion factor or purity factor K_p: Mathematically distortion factor is represented as:

$$K_p = \frac{1}{\sqrt{1+THD^2}}$$

iii. Displacement factor K_d: It is defined as the cosine of the angle between the voltage and current.

iv. Power Factor: power factor can be found out using active and reactive power by the following relation:

$$P.F. = \frac{Active\_Power}{Apparent\_Power}$$

But this relation does not apply to all the circuits. When there is some THD present, power factor cannot be found out using this relation. Hence another relation which takes into consideration the THD as well should be used. This relation is as follows:

$$P.F. = K_p \times K_d$$

II. DESIGN CONSIDERATIONS

The first circuit which has to be designed is the bridge rectifier circuit. The rectifier circuit under consideration has the following parameters:

Input AC Voltage = 230V
Rectifier Type: Bridge rectifier
Internal resistance of diodes = 0.001Ω
Diode snubber resistance = 500Ω
Diode snubber capacitance = 250×10^{-9} F
Filter capacitance C_{in} = 2000µF
Load resistance R_L = 100 Ω

Next we have to design a boost converter. The taken parameters are as follows:

Input dc voltage from rectifier	=	317V
Boost Inductance	=	87.12mH
Boost Capacitance	=	12mF
Chopper Frequency	=	500Hz
Duty Cycle	=	30%
Load Resistance	=	100Ω
MOSFET Snubber Resistance	=	10^5 Ω
MOSFET Snubber Capacitance	=	Infinite
MOSFET Internal Resistance	=	0.1 Ω

III. SIMULATION AND RESULTS

To analyze the said topologies on the basis of performance parameters it has to be firstly simulated using MATLAB and then its performance parameters (such as THD and PF) are analyzed with the help of MATLAB itself.

Phase Shifted Bridgeless Boost Converter

Keeping the design parameters as described in the previous section the phase shifted bridgeless boost converter has been modeled and simulated. The simulation results are analyzed to reach to a conclusion. The figure below shows the schematic of a phase shifted bridgeless boost converter circuit.

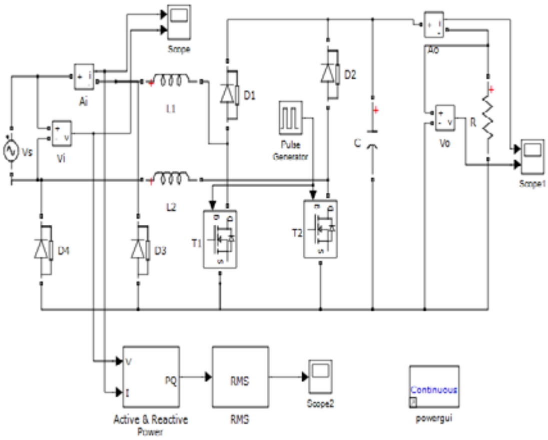

Fig.3. Schematic of phase shifted bridgeless boost converter

As analyzed with the help of the scope applied in the schematic the simulated model gives the following waveforms of voltages and currents on scope (for source) and scope1 (for load).

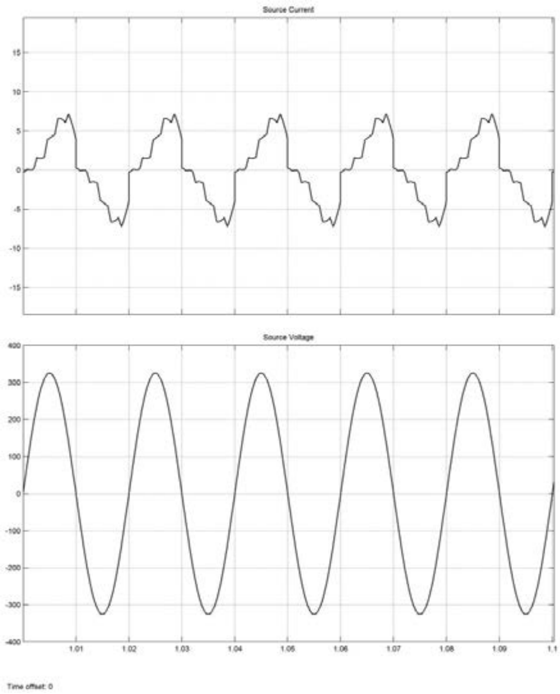

Fig.4. Source current and voltage waveforms for phase hifted bridgeless boost converter

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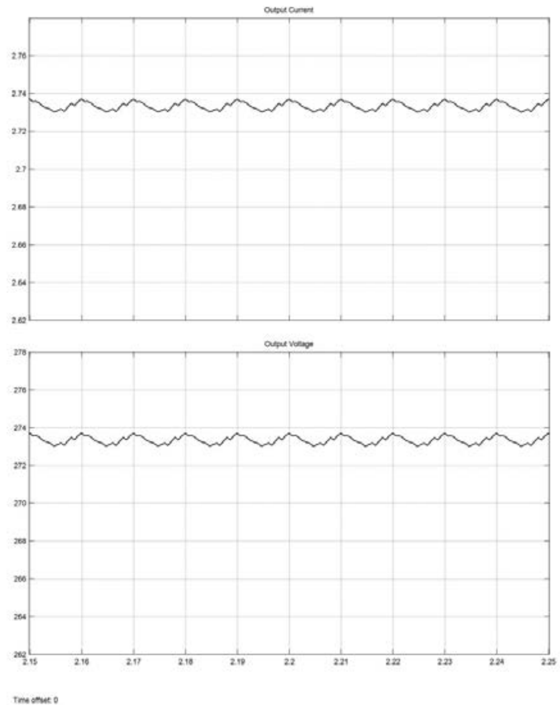

Fig.5. Load current and voltage waveforms for phase shifted bridgeless boost converter

As can be seen in fig.4 that a distorted current is drawn from the supply in case of phase shifted bridgeless boost converter which will produce less THD as compared to pulsating current and hence will improve the THD of the input current waveform further upgrading the performance of the circuit. The THD can be found out with the help of FFT analysis tool.

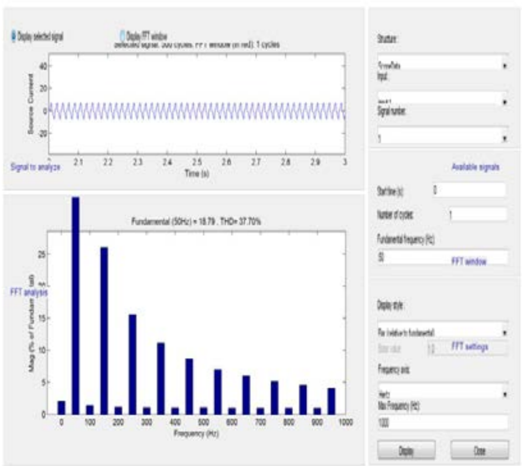

Fig.6. FFT analysis of phase shifted bridgeless boost converter

It can be seen in the above figure that the THD of the phase shifted bridgeless boost converter is 37% and power factor of the circuit has been calculated as below:

K_d = 0.81

The THD is found out to be 37.7%

$$K_p = \frac{1}{\sqrt{1+THD^2}}$$

$$K_p = \frac{1}{\sqrt{1+0.377^2}}$$

$$K_p = \frac{1}{1.069}$$

***K_p* = 0.935**

Since,

$$P.F. = K_p \times K_d$$

Therefore,

$$PF = 0.935 \times 0.81$$

PF = 0.757 (lagging)

Rectifier + Interleaved boost converter:

The interleaved boost converter is a combination of two boost converters operating in parallel to each other and the load resistance. The simulation results are analyzed to reach to a conclusion. The figure below shows the schematic of a rectifier + interleaved boost converter circuit.

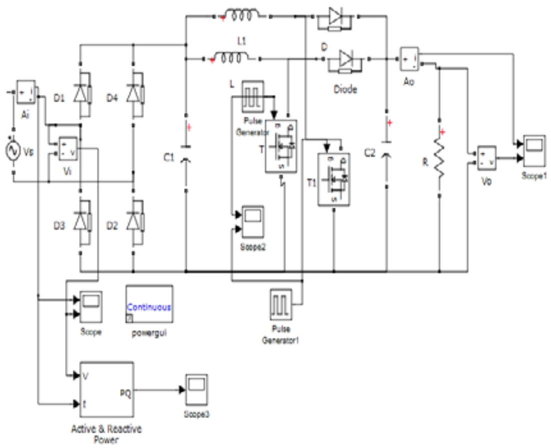

Fig.3. Schematic of rectifier + interleaved boost converter

The simulated model of interleaved boost converter gives the following waveforms of voltages and currents on scope (for source) and scope1 (for load).

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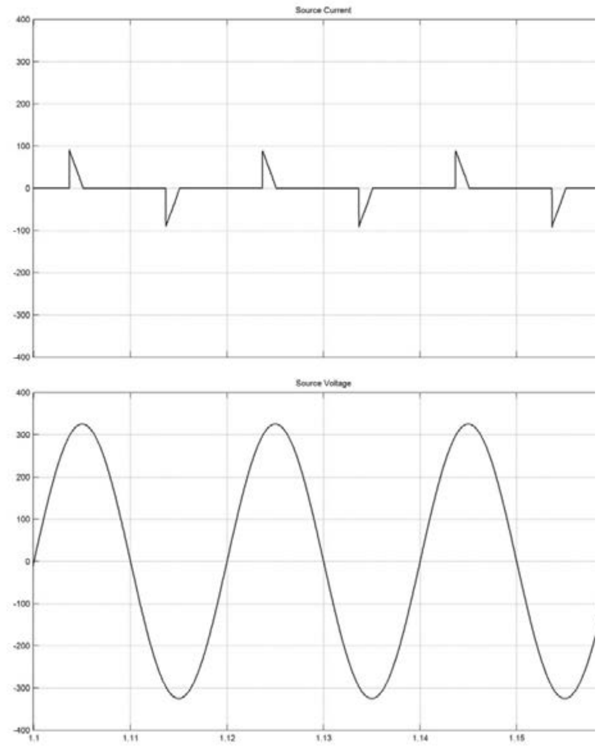

Fig.4. Source current and voltage waveforms for conventional boost converter

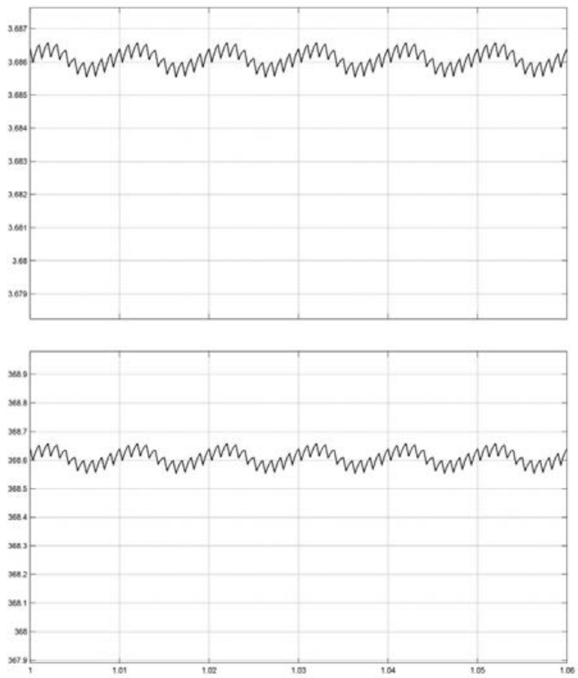

Fig.5. Load current and voltage waveforms for conventional boost converter

The THD can be found out with the help of FFT analysis tool.

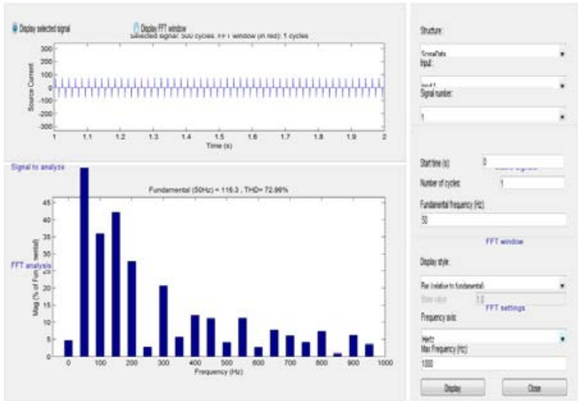

Fig.6. FFT analysis of conventional boost converter

It can be seen in the above figure that the THD of the rectifier + interleaved boost converter is 72.9% and power factor of the circuit has been calculated as below:

K_d = 0.94

The THD is found out to be 72.9%

THD = 72.9% = 0.73 pu

$$K_p = \frac{1}{\sqrt{1+THD^2}}$$

$$K_p = \frac{1}{\sqrt{1+0.73^2}}$$

$$K_p = \frac{1}{1.238}$$

K_p = 0.808

Since,

$$P.F. = K_p \times K_d$$

Therefore,

$$PF = 0.808 \times 0.94$$

PF = 0.7595

The following table shows the comparison between the two topologies.

Parameter	**THD**	**K_d**	**K_p**	**PF**
Topology				
Phase Shifted	37%	0.81	0.935	0.757 (lagging)

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Bridgeless Boost Converter				
Rectifier + Interleaved Boost Converter	72.9%	0.94	0.808	0.7595 (leading)

Table.1. Comparison of parameters

IV. CONCLUSION

A close examination of the above described performance characteristics and the table 1 reveals that the THD provided by the bridgeless boost converter topology (37%) is better than that of the interleaved boost converter (73%). Whereas the input power factor for interleaved boost converter is far better as compared to that of a bridgeless boost converter. Moreover the THD of an interleaved boost converter can be improved by increasing the no of parallel converters.

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