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Comparative Study of Active Power Factor Correction between Conventional and Interleaved Boost Converters

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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 conventional boost and interleaved boost topologies for the analysis of input power factor and THD.

I. INTRODUCTION

The power factor correction can be carried out by various methods. These 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.

Conventional Boost Converter: A boost converter is a DC to DC converter which is used to step up the dc voltage, depending on the duty cycle of the converter. The boost converter contains a switching device, which can be a MOSFET, IGBT, GTO or thyristor etc, a capacitor in parallel to the load and an inductor in series with the load. When the switch is closed, the DC source energizes the inductor. Meanwhile, the capacitor maintains the output voltage using previously stored energy. When the switch is opened, both the DC source and the energy stored in the inductor will supply power to the load, thus boosting the output voltage. By controlling the duty ratio appropriately, a desired value of output voltage, higher than the input voltage can be obtained.

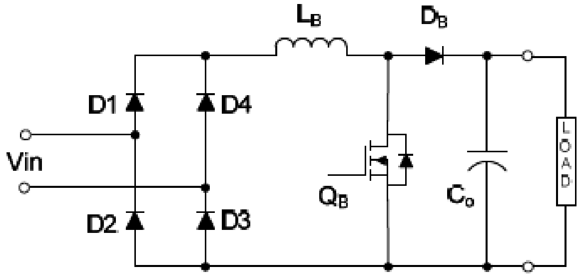


Fig. 1. Rectifier + Conventional boost converter.

Interleaved Boost Converter: The interleaved boost converter is shown in Fig. 2. It is simply combination of two boost converters operating in parallel 180° 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.

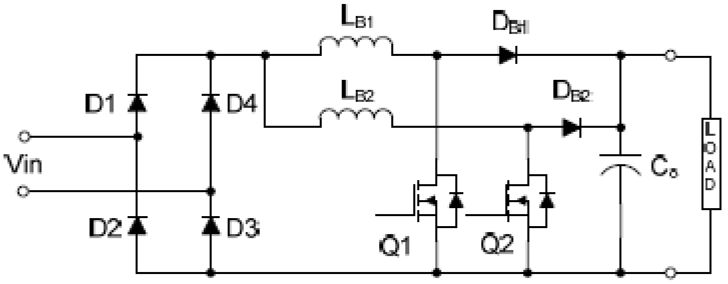


Fig. 2. Rectifier + Interleaved boost converter topology.

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

II. 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 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:

$P.F. = K_p \times K_d$

III. 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 = $250\text{x}10^{-9}$ 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

IV. 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.

Rectifier + Conventional boost converter:

Keeping the design parameters as described in the previous section the conventional 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 rectifier + conventional boost converter circuit.

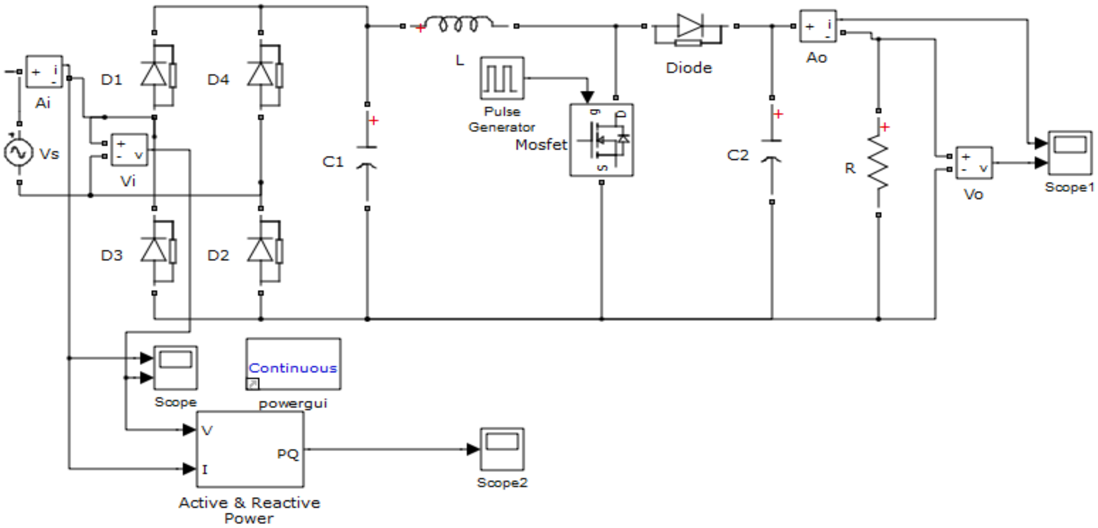


Fig. 3. Schematic of rectifier + conventional boost converter.

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).

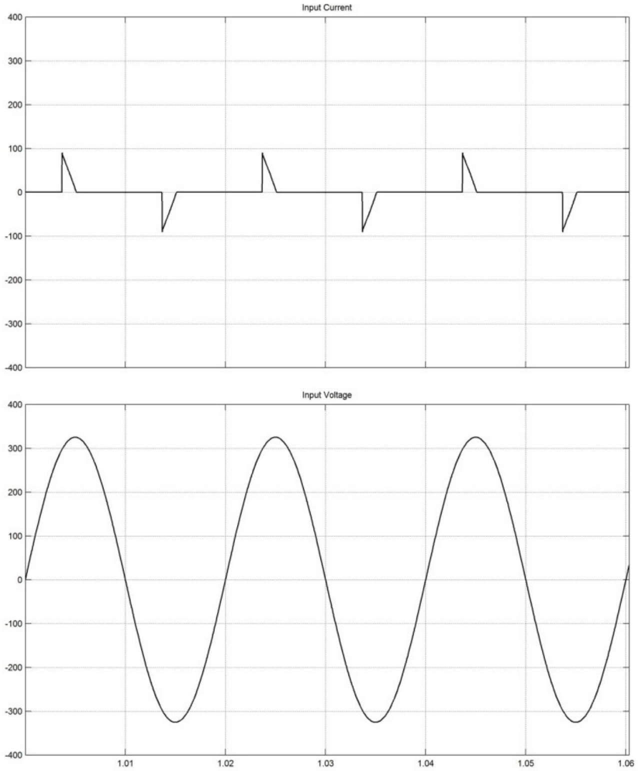


Fig. 4. Source current and voltage waveforms for conventional boost converter.

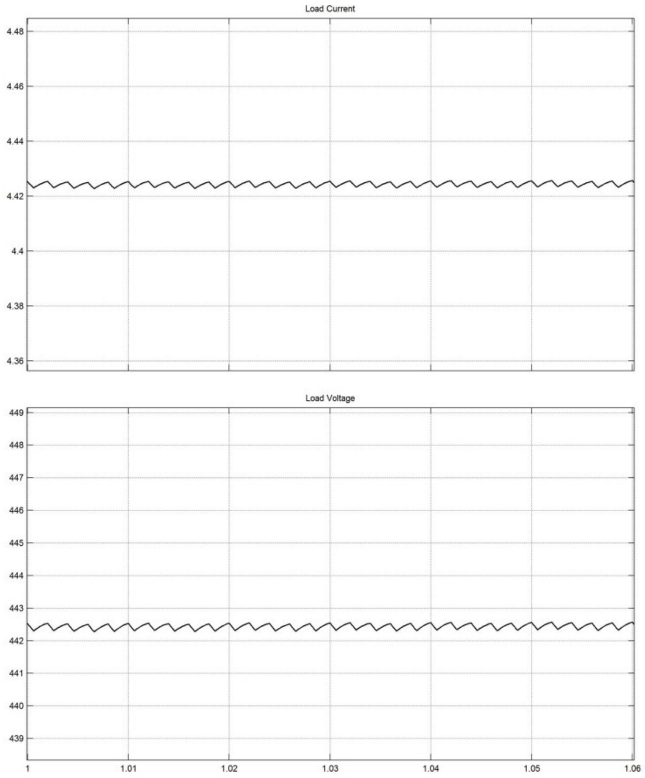
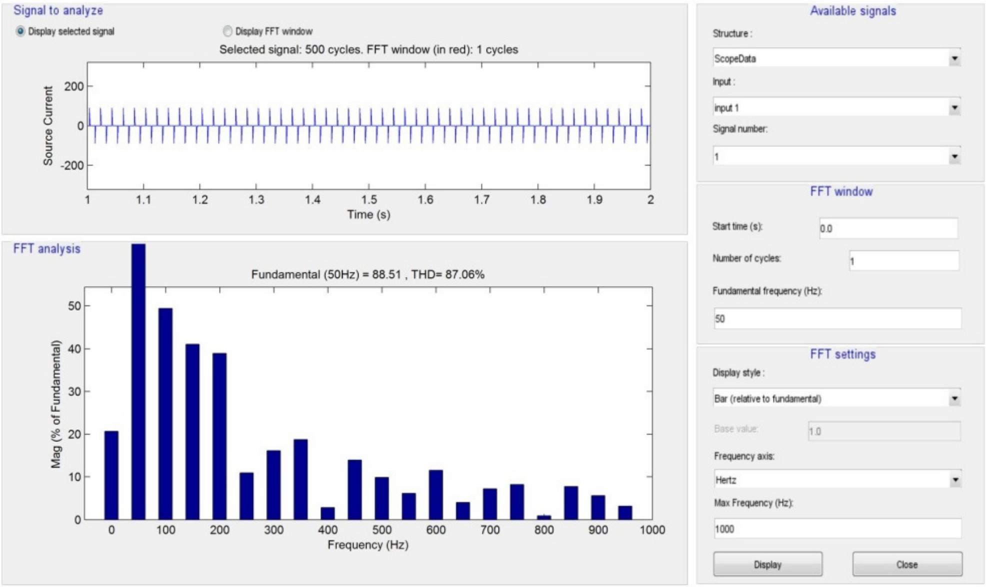


Fig. 5. Load current and voltage waveforms for conventional boost converter.

As can be seen in fig. 4 that the pulsating current is drawn from the supply in case of conventional boost converter which obviously will increase the THD of the input current waveform further degrading the performance of the circuit. The THD can be found out with the help of FFT analysis tool.



● Display selected signal ○ Display FFT window

Selected signal: 500 cycles. FFT window (in red): 1 cycles

Fundamental (50Hz) = 88.51 , THD= 87.06%

Structure : ScopeData

Input : input 1

Signal number: 1

Start time (s): 0.0

Number of cycles: 1

Fundamental frequency (Hz): 50

Display style : Bar (relative to fundamental)

Base value: 1.0

Frequency axis: Hertz

Max Frequency (Hz): 1000

Fig. 6. FFT analysis of conventional boost converter.

It can be seen in the above figure that the THD of the rectifier + conventional boost converter is 87% and power factor of the circuit has been calculated as below:

K_d = 0.91

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

$$K_p = \frac{1}{\sqrt{1+0.87^2}}$$

$$K_p = \frac{1}{1.325}$$

***K_p* = 0.755**

Since,

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

Therefore,

$$PF = 0.755 \times 0.91$$

PF = 0.6868

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.

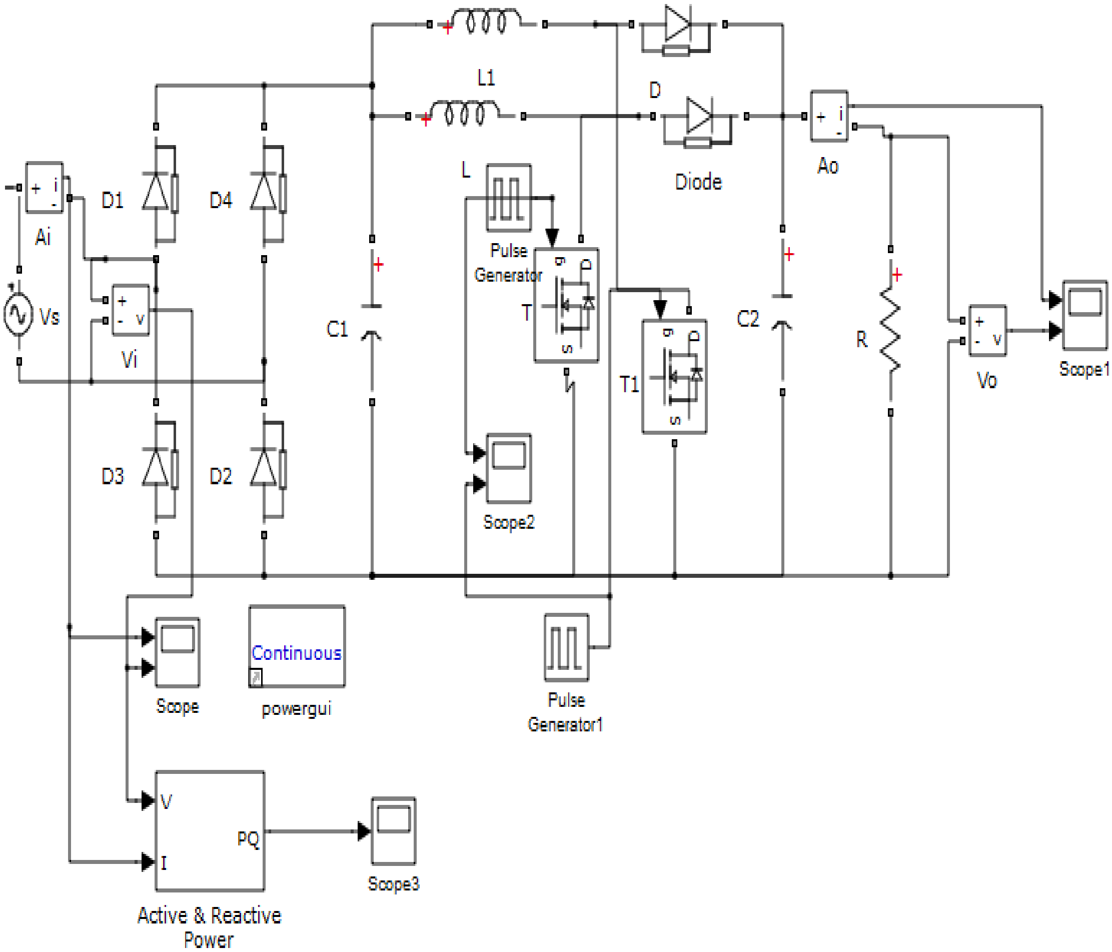


Fig. 7. Schematic of rectifier + interleaved boost converter.

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

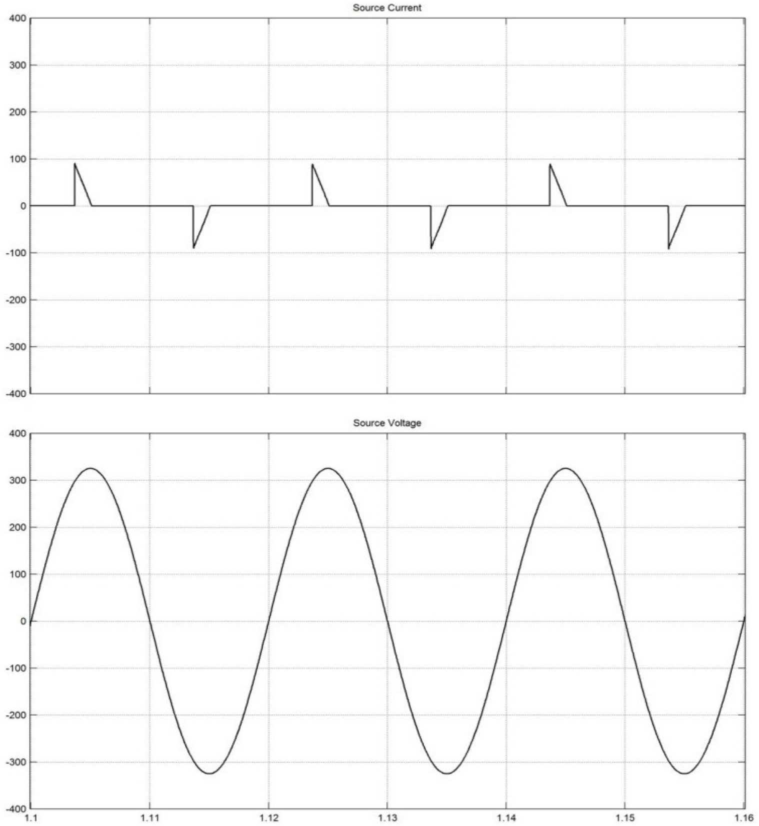


Fig. 8. Source current and voltage waveforms for conventional boost converter.

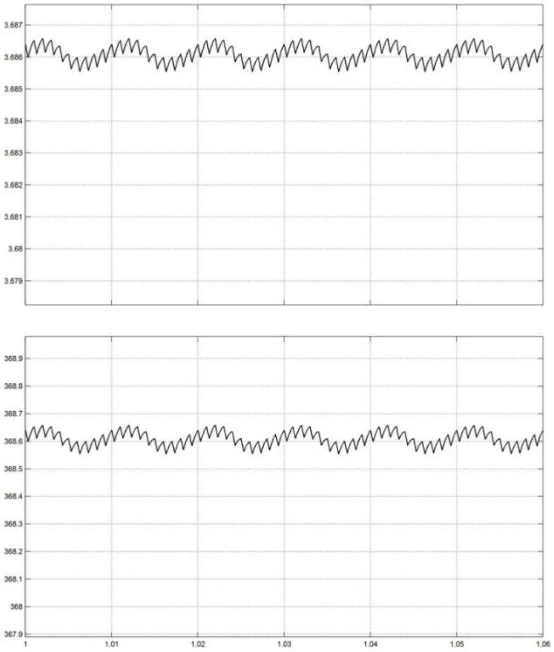
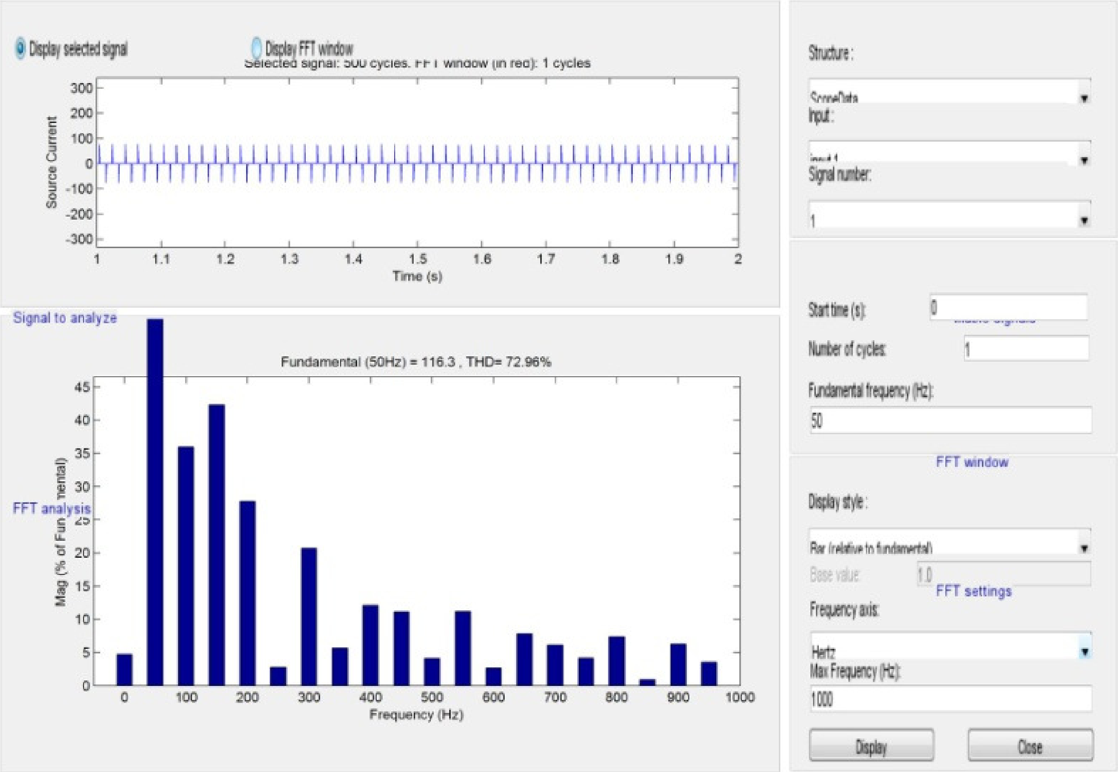


Fig. 9. Load current and voltage waveforms for conventional boost converter.

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



Structure: ScopeData

Input: input 1

Signal number: 1

Start time (s): 0

Number of cycles: 1

Fundamental frequency (Hz): 50

Display style: Bar (relative to fundamental)

Base value: 1.0

Frequency axis: Hertz

Max Frequency (Hz): 1000

Fig. 10. 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 = 0.808 × 0.94

***PF* = 0.7595**

The following table shows the comparison between the two topologies.

Table 1: Comparison of parameters.

Parameter	THD	K_d	K_p	PF
Topology				
Rectifier + Conventional Boost Converter	87%	0.91	0.755	0.6868
Rectifier + Interleaved Boost Converter	72.9%	0.94	0.808	0.7595

V. CONCLUSION

As can be seen in the above table that the performance parameters of the interleaved boost converter are better than that of a conventional boost converter. The interleaved boost converter topology however is more expensive as it has more component count as compared to other topologies. But it gives a good power factor as well as an improved THD.

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