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# Power Factor Correction Using Bridgeless Boost Topology

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***Abstract*— *Power quality is becoming a major concern for many electrical users. The high power non linear loads (such as adjustable speed drives, arc furnace, static power converter etc) and low power loads (such as computer, fax machine etc) produce voltage fluctuations, harmonic currents and an inequality in network system which results into low power factor operation of the power system. The devices commonly used in industrial, commercial and residential applications need to go through rectification for their proper functioning and operation. Due to the increasing demand of these devices, the line current harmonics create a major problem by degrading the power factor of the system thus affecting the performance of the devices. Hence there is a need to reduce the input line current harmonics so as to improve the power factor of the system. This has led to designing of Power Factor Correction circuits. Power Factor Correction (PFC) involves two techniques, Active PFC and Passive PFC. An active power factor circuit using Boost Converter is used for improving the power factor. This thesis work analyzes the procedural approach and benefits of applying Bridgeless Boost Topology for improving the power factor over Boost Converter Topology. A traditional design methodology Boost Converter Topology is initially analyzed and compared with the Bridgeless Boost topology and the overall Power Factor (PF) can be improved to the expectation. Method of re-shaping the input current waveform to be similar pattern as the sinusoidal input voltage is done by the Boost converter and the related controls that act as a Power Factor Correction (PFC) circuit. Higher efficiency can be achieved by using the Bridgeless Boost Topology. In this paper simulation of Boost Converter topology and Bridgeless PFC boost Converter is presented. Performance comparisons between the conventional PFC boost Converter and the Bridgeless PFC Boost Converter is done.*

***Keywords*— *THD, Power Factor Correction (PFC), PFC Boost Converter, Bridgeless PFC Boost Converter.***

## I. INTRODUCTION

In this paper the power factor correction of a system using Bridgeless Boost Topology. Power Factor is an important performance parameter of a system and improving power factor is very much essential for the better and economical performance of the system. If the power factor of a system at a given power requirement is poor, then large value of Volt-Amperes or large amount of current is required by the system which is drawn from the supply. Hence it is seen that various measures are taken to improve the power factor of a system. The use and study of a Boost Converter Topology for the Power Factor Correction is described. It also describes the use and study of Bridgeless Boost Topology for power Factor Correction. The basic purpose of a Power Factor Correction circuit is to make the line current follow the waveform of the line voltage so that the input to the power supply becomes purely resistive and hence to improve the power factor. Bridgeless Boost Topology is used in the Power Factor Correction circuit to improve the power factor. The paper shows the study and analysis of power factor of a system by doing simulations on MATLAB (R2009a) Software using full wave rectifier in the beginning. After studying and analyzing the input current and voltage waveforms and the power factor of the system using Rectifier circuit, the Boost Converter is introduced in the circuit and then analyzed its effect in improving the power factor of the system. Then Bridgeless Boost Topology is implemented which gives better results and improved power factor.

## II. POWER FACTOR

Power factor can be defined as the ratio of active or real power to the apparent power.

$$\text{Power Factor} = \text{Real Power} / \text{Apparent Power} \tag{1}$$

$$power\ factor = P \div (V_{rms} \times I_{rms}) \tag{2}$$

Where $V_{rms}$ Root Mean Square Voltage of Load $I_{rms}$ Root Mean Square Current of Load If the load is purely resistive, then the real power will be same as Vrms*Irms. Hence, the power factor will be unity. And if the load is not purely resistive, the power factor will be below unity. Assuming an ideal sinusoidal input voltage source, the power factor can be expressed as the product of two factors, the distortion factor and the displacement factor, as given

$$\mathrm{PF} = \mathrm{K_d K_\theta} \tag{3}$$

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The distortion factor $K_d$ is the ratio of the fundamental RMS current to the total RMS current. The displacement factor, Kθ, is the cosine of the displacement angle between the fundamental input current and the input voltage fundamental RMS current.

$$K_d = \frac{I_{1rms}}{I_{rms}} \quad (4)$$

$$K_\theta = \cos\theta_1 \quad (5)$$

Where the fundamental component of the line is current, is the total line current and is the phase shift of the current fundamental relative to the sinusoidal line voltage. The distortion factor is close to unity, even for waveforms with noticeable distortion; therefore, it is not a very convenient measure of distortion for practical use. The distortion factor is uniquely related to another figure of merit; the total harmonic distortion (THD).

$$THD = \sqrt[2]{\frac{I_{rms}^2 - I_{1rms}^2}{I_{1rms}^2}} \quad (6)$$

$$K_d = \sqrt[2]{\frac{1}{1+THD^2}} \quad (7)$$

Power factor correction circuits are developed so that the power factor is improved which means it tries to make the input to a power supply behave like purely resistive. This is done by trying to make the input current in response to the input voltage, so that a constant ratio is maintained between the voltage and current. This would ensure the input to be resistive in nature and thus, the power factor to be 1.0 or unity. When the ratio between voltage and current is not constant i.e. the load is not purely resistive, or the input to the power supply is not resistive, then the input will contain phase displacement and harmonic distortion, both of which will severely affect and degrade the power factor [1,2].

$$Kp = \frac{1}{\sqrt{1+(THDi)^2}} \quad (8)$$

$$THDi = \frac{\sqrt{\sum_{n=1}^{\infty} In\, rms^2}}{I1rms} \quad (9)$$

## III. EFFECTS OF HARMONICS

The non-linear loads result in production of harmonic currents in the power system. These harmonics in turn result in various undesirable effects on both the distribution network and consumers.

In transformers, shunt capacitors, power cables, AC machines and switchgear, they cause extra losses and overheating leading to their premature aging and failure.

In a three-phase four-wire system, excessive current flows in the neutral conductor. This is due to odd triple-n current harmonics (triple-n: 3rd, 9th, 15th, etc.) and eventually they cause tripping of the protective relay due to overheating of the neutral conductor. By interaction with the system components resonances take place in the power system. This causes huge increase in amplitude of peak voltages and RMS currents [3]. The line voltage that gets distorted due to the harmonics may affect other consumers connected to the electricity distribution network. The power factor gets reduced. Due to this the active power that is available is less than the apparent power supplied. Other effects include - telephone interference, extra audio noise, cogging and crawling of induction motors, errors observed in metering equipments.

## IV. STANDARS FOR LINE CURRENT HARMONICS

For limiting the line current harmonics in the current waveform standards are set for regulating them. One such standard was IEC 555-2, which was published by the International Electro-technical Committee in 1982. In 1987, European Committee for Electro-Technical Standardization – CENELEC, adopted this as an European Standard EN 60555-2. Then standard IEC 555-2 has been replaced by standard IEC 1000-3-2 in 1995. The same has been adopted as an European standard EN 61000-3-2 by CENELEC. Hence, these limitations are kept in mind while designing any instrument. So that there is no violation and the negative effects of harmonics are not highly magnified [4].

## V. CONVERTER TOPOLOGY

**Boost Converter**

It is a type of power converter in which the DC voltage obtained at the output stage is greater than that given at the input. It can be considered as a kind of switching-mode power supply (SMPS). The inductor has this peculiar property to resist any change of current in them and that serves as the main principle which drives a boost converter. The inductor acts like a load (like resistor) when it is being charged and acts as a source of energy (like battery) when it is discharged

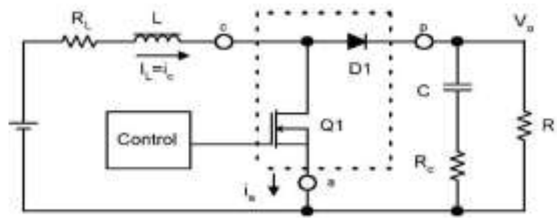


*Fig.1: Boost converter*

The input current and the inductor current are the same. Hence as one can see clearly that current in a boost converter is continuous type and hence the design of input filter is somewhat relaxed or it is of lower value.

Among different PFC topologies, the single switch conventional PFC is the most widely used topology because of its simplicity. The circuit topology is shown in Figure 2. A Conventional Boost PFC is considered to be the best choice for designing the power stage of the active power factor corrector. The boost converter can operate in two

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modes, continuous and discontinuous. The conventional input stage for single phase power supplies operates by rectifying the ac line voltage and filtering with large electrolytic capacitors. This process generates a distorted input current waveform with large harmonic content. Thus, the resulting power factor is very poor. The reduction of input current harmonics and high power factor operation are important requirements for power supplies. In these applications, ac-dc converters featuring almost unity power factor are required.[5]

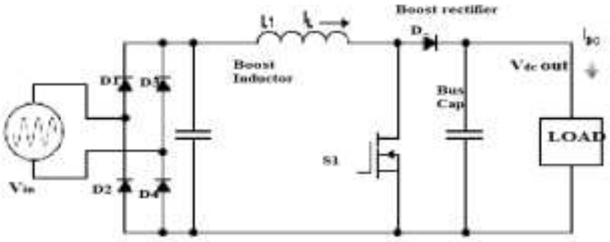



*Fig.2: Conventional PFC boost converter*

The technique usually employed to correct power factor of single-phase power supplies consists of a front-end full-bridge diode rectifier followed by a boost converter. The circuit is constructed by an uncontrolled diode-bridge rectifier and a Boost DC/DC stage. By adjusting Boost converter duty cycle, input current shape can be controlled and meets the current harmonic standard requirement.

**Bridgeless Boost Topology**

The basic Bridgeless PFC converter is shown in figure 3. Comparing to the traditional most popular Boost type PFC this smart concept improves PFC's efficiency by removing the bridge rectification system in front of it. Compare to the conventional Boost PFC the most important advantage of it is that it doesn't need four line frequency diodes operating as voltage rectifier.

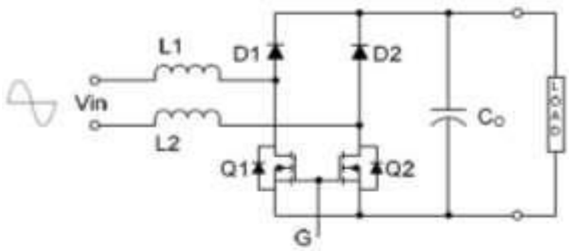



*Fig.3: Bridgeless Boost Topology*

## VI. CONTROL TECHNIQUE OF CONVERTER

Converter provides a regulated dc output voltage under varying load and input voltage conditions. The converter component values are also changing with time, temperature and pressure. Hence, the control of the output voltage should be performed in a closed-loop manner using principles of negative feedback. There are many control techniques discussed below [6-8].

**Peak current control**

In the basic scheme of the peak current controller the switch is turned on at constant frequency by a clock signal, and is turned off when the sum of the positive ramp of the inductor current (i.e. the switch current) and an external ramp (compensating ramp) reaches the sinusoidal current reference. This reference is usually obtained by multiplying a scaled replica of the rectified line voltage vg times the output of the voltage error amplifier, which sets the current reference amplitude. In this way, the reference signal is naturally synchronized and always proportional to the line voltage, which is the condition to obtain unity power factor.

**Advantages**

- Constant switching frequency.
- Only the switch current must be sensed and this can be accomplished by a current transformer, thus avoiding the losses due to the sensing resistor.
- No need of current error amplifier and its compensation network.
- Possibility of a true switch current limiting.

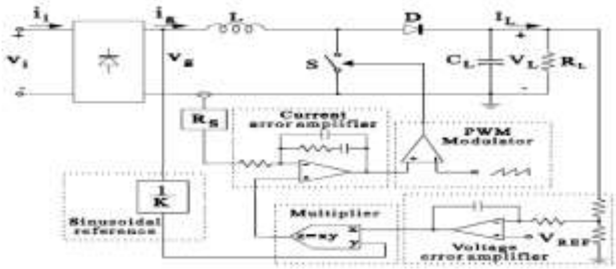
**Disadvantages**

- Presence of sub harmonic oscillations at duty cycles greater than 50%, so a compensation ramp is needed.
- Input current distortion which increases at high line voltages and light load and is worsened by the presence of the compensation ramp.
- Control more sensitive to commutation noises.

The input current distortion can be reduced by changing the current reference wave shape, for example introducing a dc offset or by introducing a soft clamp. Moreover, if the PFC is not intended for universal input operation, the duty-cycle can be kept below 50% so avoiding also the compensation ramp.

**Average Current Mode Control**

Another control method, which allows a better input current waveform, is the average current control represented in Figure 4.



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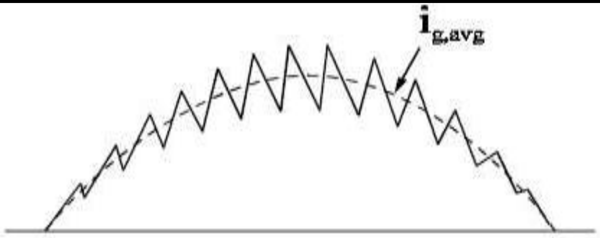


*Fig.4: Average current control scheme*

Here the inductor current is sensed and filtered by a current error amplifier whose output drives a PWM modulator. In this way the inner current loop tends to minimize the error between the average input current ig and its reference. This latter is obtained in the same way as in the peak current control. The converter works in CICM, so the same considerations done with regard to the peak current control can be applied [9-12].

**Advantages**

- Constant switching frequency.
- No need of compensation ramp.
- Control is less sensitive to commutation noises, due to current filtering.
- Better input current waveforms than for the peak current control since, near the zero crossing of the line voltage, the duty cycle is close to one, so reducing the dead angle in the input current.

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**Disadvantages**

- Inductor current must be sensed.
- A current error amplifier is needed and its compensation network design must take into account the different converter operating points during the line cycle.

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**Hysteresis Control**

In this type of control two sinusoidal current references are generated, one for the peak and the other for the valley of the inductor current. According to this control technique, the switch is turned on when the inductor current goes below the lower reference and is turned off when the inductor current goes above the upper reference, giving rise to a variable frequency control. Also with this control technique the converter works in CICM.

**Advantages**

- No need of compensation ramp.
- Low distorted input current waveforms.

**Disadvantages**

- Variable switching frequency.
- Inductor current must be sensed.

In order to avoid too high switching frequency, the switch can be kept open near the zero crossing of the line voltage so introducing dead times in the line current .

The boost converter input current is forced to be proportional to the input voltage waveform for power factor correction. Feedback is necessary to control the input current. The average current mode control (ACMC) technique is applied.

## VII. SIMULATION AND RESULTS

Firstly, simulation of Full bridge rectifier is done. For Full Bridge rectifier circuit, RLC load has been used and the variations in the input and output voltages and currents and the amount of distortions present in them. Further, improvement of power factor is taken care of in the successive circuits. First Conventional Boost Topology is simulated and power factor is improved up to an extent then the Bridgeless Boost Topology is simulated for getting better and improved power factor.

**Full Bridge Rectifier**

The Full Bridge Rectifier is shown in figure 5. The corresponding AC input voltage and output voltage waveforms are shown in figure 6. DC input current is shown in figure 7. DC output current is shown in figure 8. FFT Analysis of Full Bridge Rectifier is shown in figure 9 having a THD of 28.32 %.

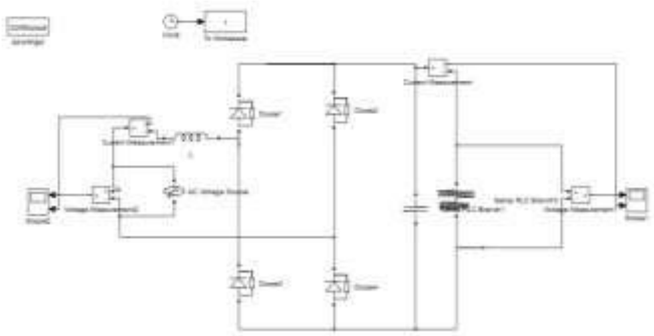

***Fig.5:*** *Circuit diagram of Full Bridge Rectifier*

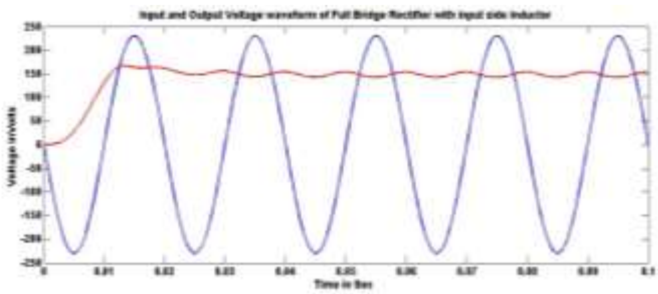

*Fig.6: Input Voltage and Output Voltage waveform of Full Bridge Rectifier*

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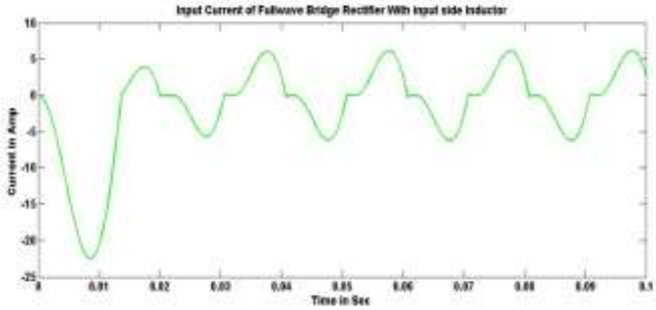


*Fig.7: Input Current waveform of Full Bridge Rectifier*

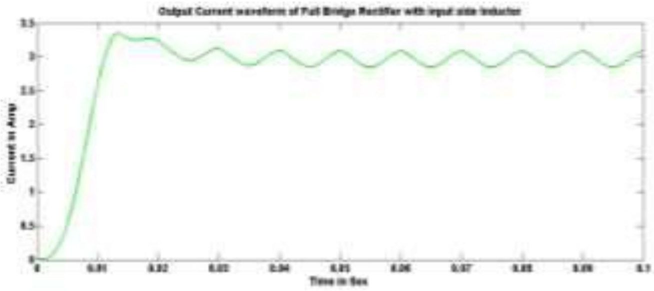


*Fig.8: Output Current waveform of Full Bridge Rectifier*

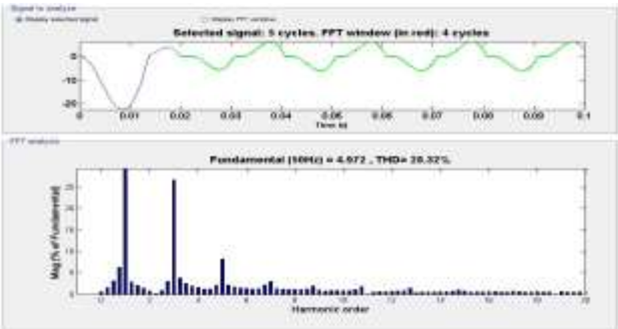


*Fig.9: THD of Full Bridge Rectifier*

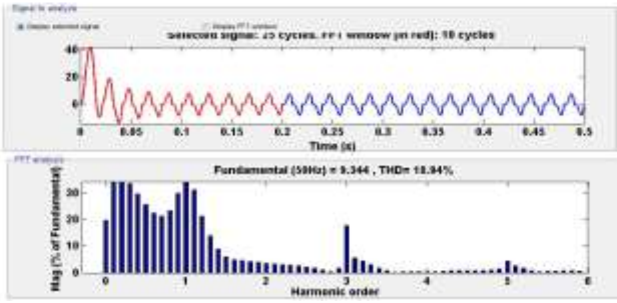


*Fig.10: Closed Loop Conventional Boost PFC*

The closed loop conventional boost converter is shown in figure 9. The corresponding AC input voltage and current waveforms are shown in figure 10. DC output voltage is shown in figure 11. DC output current is shown in figure 12. FFT Analysis of closed loop Conventional Boost Converter is shown in figure 13 having a THD of 18.84%.

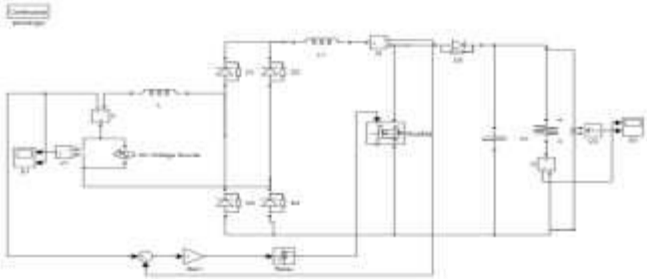

*Fig.11: Closed Loop Conventional Boost PFC*

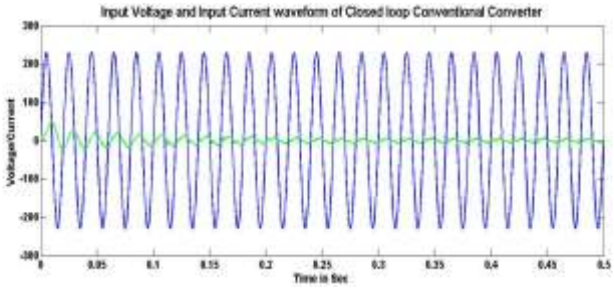


*Fig.12: Input Voltage and Current waveform of Closed loop Conventional Boost PFC*

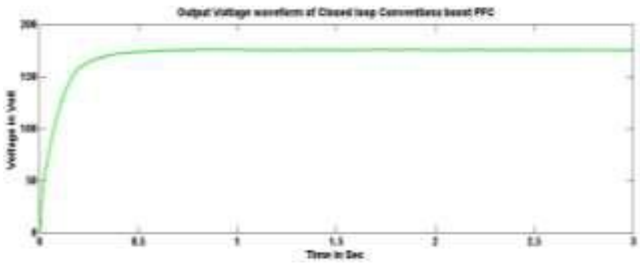


*Fig.13: Output Voltage waveform of Closed loop Conventional Boost PFC*

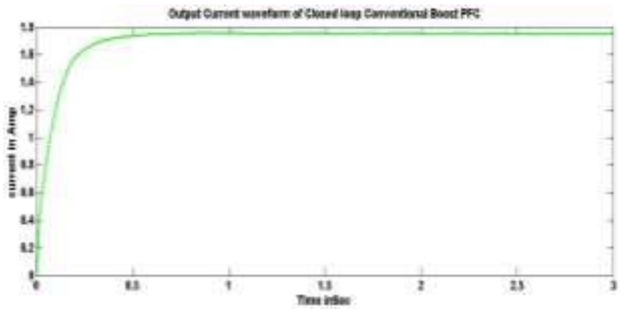


*Fig.14: Output Current waveform of Closed loop Conventional Boost PFC*

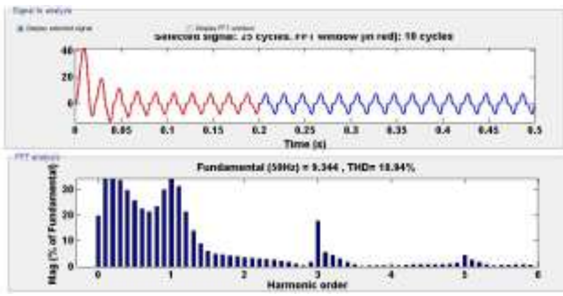


*Fig.15: FFT Analysis of Conventional Boost Converter*

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**Bridgeless Boost PFC**

The Bridgeless boost PFC converter is shown in figure 14. The corresponding AC input voltage and current waveforms are shown in figure 15. DC output voltage is shown in figure 16. DC output current is shown in figure 17. FFT Analysis of Bridgeless boost PFC Converter is shown in figure 18 having a THD of 5.44 %.

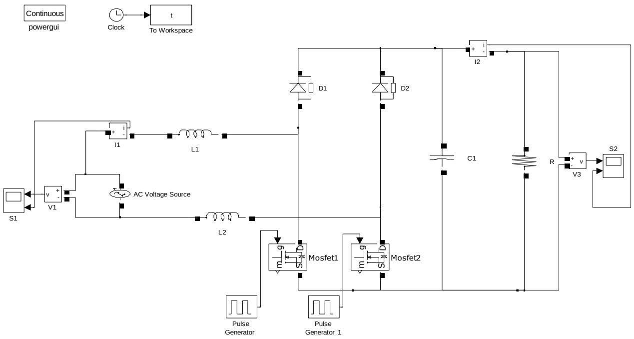


*Fig.16: Bridgeless Boost Topology*

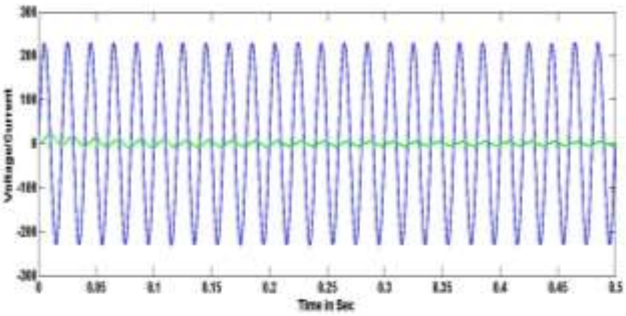


*Fig.17: Input Voltage and Output Voltage waveform of Bridgeless Boost Topology*

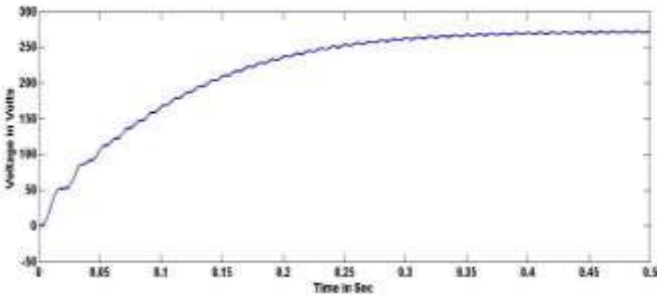


*Fig.16: Output voltage waveform of Bridgeless Boost Topology*

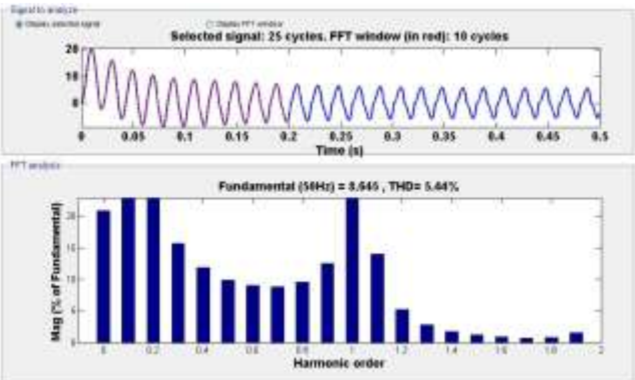


*Fig.18: Output Current waveform of Bridgeless And FFT Analysis of Bridgeless Boost Topology*

*TABLE I.*

| PFC Convertor | Conventional PFC | Bridgeless PFC |
|---|---|---|
| Slow Diode | 4 | 0 |
| Fast Diode | 1 | 2 |
| Switch (MOSFET) | 1 | 2 |
| Conduction Path On/Off | 2 slow diode and 1 MOSFET/ 2 slow diode and 1 fast diode | 1 diode and 1 MOSFET/ 1 MOSFET and 1 diode |

## VIII. CONCLUSION

The distortion produced in the line current in the electronic devices used for industrial and domestic applications due to harmonics and phase displacement caused by the non-linearity can be nullified by implementing bridgeless boost topology. A Conventional PFC Boost Converter is simulated. The Bridgeless PFC Boost Converter is simulated and compared to the Conventional PFC Boost Converter, generally, improves the power factor. The simulation studies indicate that the power factor is nearly unity by employing Bridgeless PFC Converter. Bridgeless PFC Converter has advantages like reduced hardware, high performance and better power factor.

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