

# A New Active Power Factor Correction Controller using Boost Converter

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## Abstract

In an electrical Power systems, a load with a low power factor draws more current than a load with a high power factor for the same amount of useful power transferred. Linear loads with low power factor (induction motor) can be corrected with a passive network of capacitors or inductors. The hysteresis current controller is used to track the line current command. Non-linear loads (rectifier) distort the current drawn from the system. In this paper, Boost converter topology is used to accomplish this active power factor correction in many discontinuous or continuous modes. Furthermore the start up current has been reduced.

**Keywords:** Power factor, boost converter, linear loads, power factor correction, border line control.

## Introduction

An ac to dc converter consists of a line frequency diode bridge rectifier with a large output filter capacitor which is cheap and robust and it demands a harmonic rich ac line current. So the input power factor is poor<sup>1</sup>. The most common power quality disturbance is instantaneous power interruption. Various power factor correction (PFC) techniques are employed to overcome these power quality problems out of which the boost converter topology has been extensively used in various ac/dc and dc/dc applications<sup>2</sup>. In fact, the front end of today's ac/dc power supplies with power-factor correction (PFC) is almost exclusively implemented with boost topology<sup>3</sup>. The use of Power Factor Correction (PFC) is necessary in order to comply the recent international standards, such as IEC- 1000-3-2 and IEEE-519. The basic boost topology does not provide a high boost factor<sup>4</sup>. This has led to many proposed topologies such as the tapped inductor boost, cascaded boost and interleaved boost converters. This paper introduces another variation, Boost PFC Converter which provides a higher boost factor and also provides proper controlling both with hardware and software design. Here Hysteresis Current Control method is used for better control<sup>5</sup>.

This paper initially involves simulation of basic conventional rectifier circuits and the analysis of the current and voltage waveforms. It starts with simple circuits and switches to advanced circuits by implementing advanced techniques such as active PFC IC L6561 both with hardware and software and their subsequent effect on the current and voltage waveforms expecting better results. All the simulation work is carried out in MATLAB – Simulink.

## Mathematical Formulation

**Boost Converter:** The key principle that drives the boost converter is the tendency of an inductor to resist changes in current. In a boost converter, the output voltage is always higher

than the input voltage<sup>6</sup>. When the switch is turned-ON, the current flows through the inductor and energy is stored in it. When the switch is turned-OFF, the stored energy in the inductor tends to collapse and its polarity changes such that it adds to the input voltage as shown in Figure-1. Thus, the voltage across the inductor and the input voltage are in series and together charge the output capacitor to a voltage higher than the input voltage<sup>7</sup>.

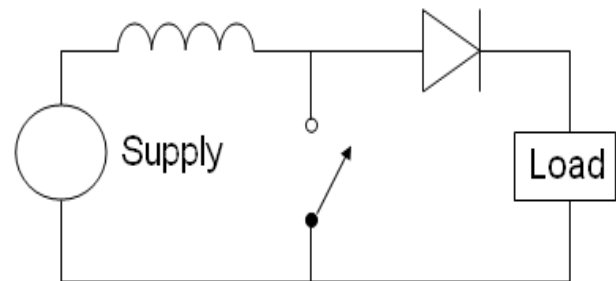


Figure-1  
Boost Converter

The basic principle of a Boost converter as shown in Figure-2 consists of 2 distinct states: i. In the On-state, the switch S is closed, resulting in an increase in the inductor current, ii. In the Off-state, the switch is open and the only path offered to inductor current is through the fly back diode D, the capacitor C and the load R. This result in transferring the energy accumulated during the On-state into the capacitor.

**Continuous Mode:** When a boost converter operates in continuous mode, the current through the inductor ( $I_L$ ) never falls to zero. Figure-3 shows the typical waveforms of currents and voltages in a converter operating in continuous mode<sup>8</sup>. The output voltage can be calculated as follows, in the case of an ideal converter operating in steady conditions.

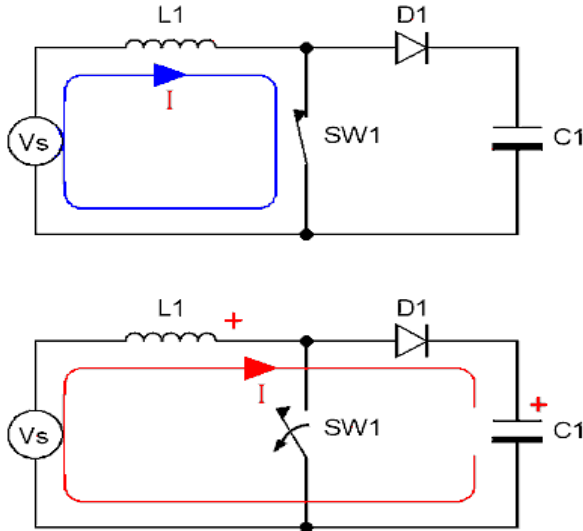


Figure-2  
 Boost converter operation circuit

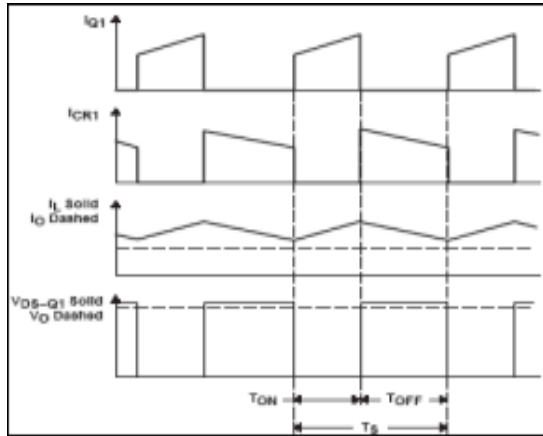


Figure-3  
 Continuous mode

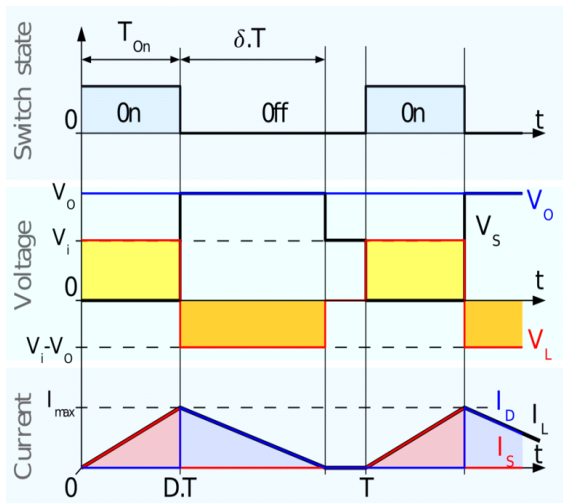


Figure-4  
 Discontinuous mode

**Dis Continuous Mode:** If the ripple amplitude of the current is too high, the inductor may be completely discharged before the end of a whole commutation cycle<sup>9</sup>. In this case, the current through the inductor falls to zero during part of the period as shown in Figure-4. Although slight, the difference has a strong effect on the output voltage equation. It can be calculated as follows:

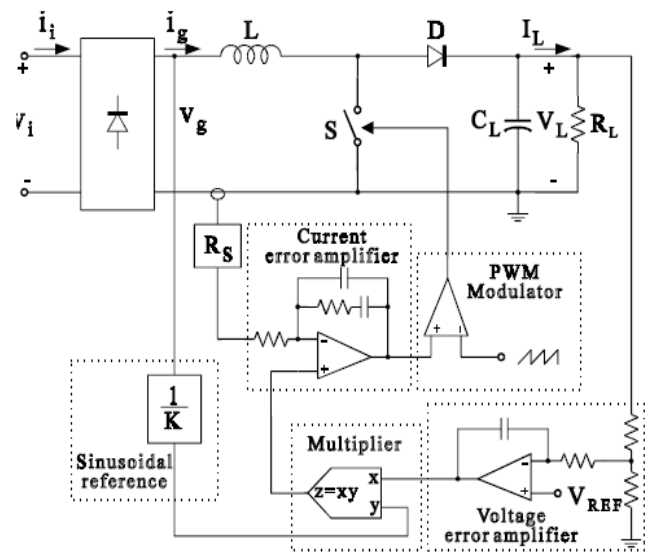
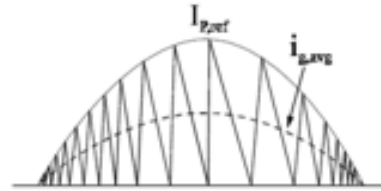


Figure-5  
 Border line control

**Power Factor Correction:** The attention devoted to the quality of the currents absorbed from the utility line by electronic equipment is increasing due to several reasons. In fact, a low power factor reduces the power available from the utility grid, while a high harmonic distortion of the line current causes EMI problems and cross-interferences, through the line impedance, between different systems connected to the same grid<sup>10</sup>.

An ideal power factor corrector (PFC) should emulate a resistor on the supply side while maintaining a fairly regulated output voltage. In the case of sinusoidal line voltage, this means that the converter must draw a sinusoidal current from the utility; in order to do that, a suitable sinusoidal reference is generally needed and the control objective is to force the input current to follow, as close as possible, this current reference<sup>11</sup>. In this paper, a hardware design using IC having border line control is used. Figure-5 shows the circuit diagram for border line control.

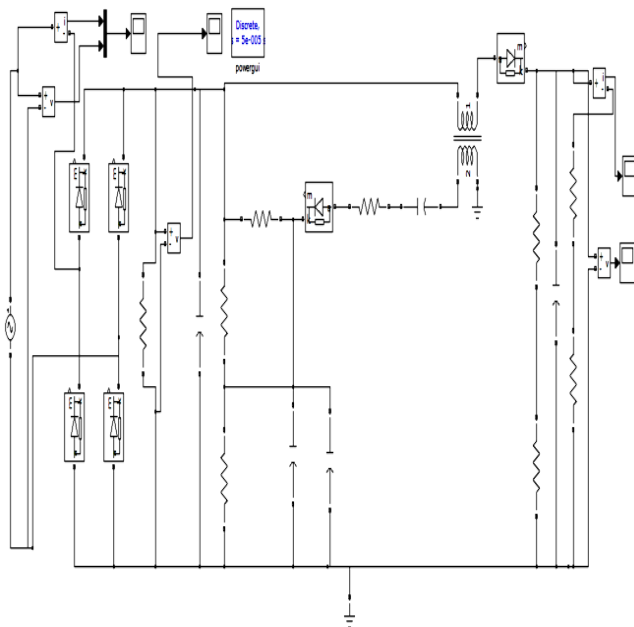
In this control approach the switch on-time is held constant during the line cycle and the switch is turned on when the

inductor current falls to zero, so that the converter operates at the boundary between Continuous and Discontinuous Inductor Current Mode (CICM-DICM)<sup>12</sup>. In this way, the freewheeling diode is turned off softly (no recovery losses) and the switch is turned on at zero current, so the commutation losses are reduced. On the other hand the higher current peaks increase device stresses and conduction losses and may call for heavier input filters (for some topologies).

This type of control is a particular case of hysteretic control in which the lower reference is zero anywhere.

## Results and Discussions

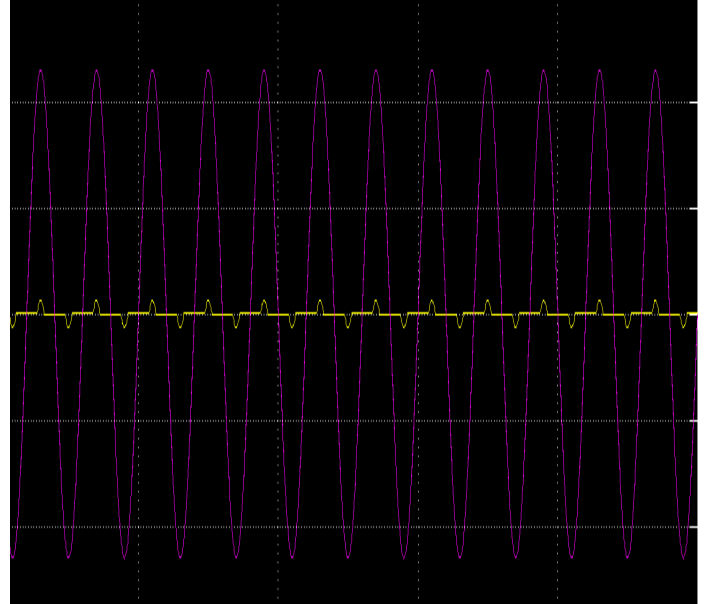
This paper involves simulation of simple circuits with a gradual increase in complexity by inclusion of new components<sup>13</sup> and also the hardware implementation and their subsequent effect on the current and voltage waveforms. The waveforms with software and hardware are compared. All the simulation work is done in MATLAB Simulink.



**Figure-6**  
**IC Implementation in MATLAB before PFC**

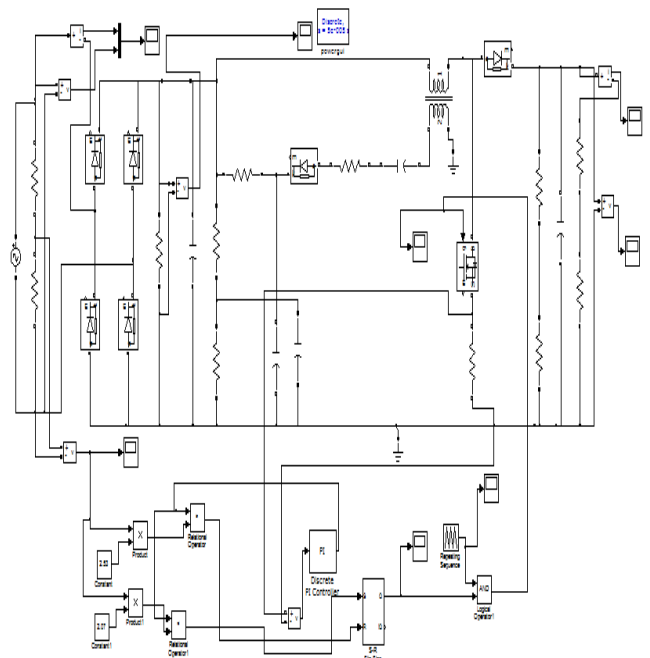
**Simulation and results for Conventional Converter:** Figure-6 shows that this circuit consists of two groups of diodes: top group with diodes 1 and 3 and bottom groups with diodes 2 and 4. It is easy to see the operation of each group of diodes with  $L_s = 0$ . The current  $i_d$  flows continuously through one diode of the top group and one diode in the bottom group.

The circuit is simulated using Simulink and output waveforms are plotted in graph as shown in the Figure-7 which represents poor power factor.



**Figure-7**  
**Simulation result representing poor power factor**

**Simulation and results for rectifier with Power Factor Correction IC L6561:** Figure-8 shows the circuit with implementation of Power factor correction using IC L6561 in MATLAB and the output waveforms are plotted in graph as shown in figure-9 in which there is an improvement in power factor.



**Figure-8**  
**Implementation of PFC using IC L6561 in MATLAB**

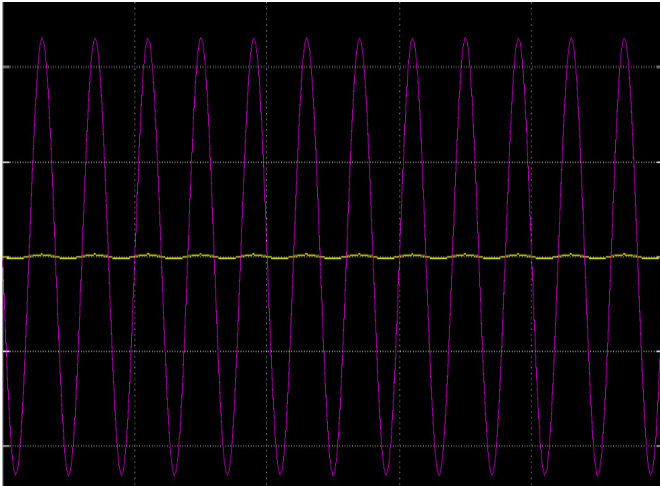


Figure-9

Simulation result representing improved power factor

**Hardware results:** Figure-10 shows the hardware circuit without IC which results in poor power factor when incandescent lamps are used as load observed in CRO.

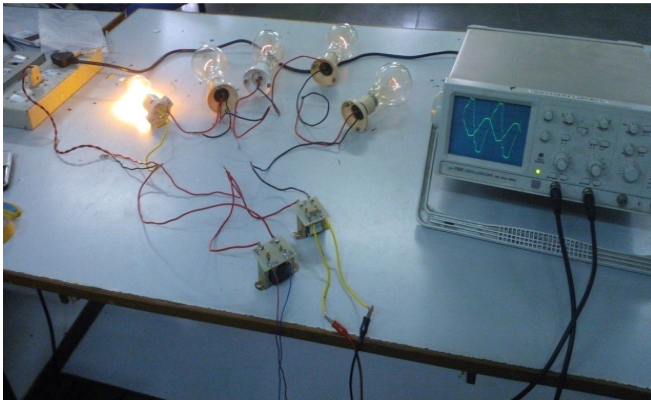


Figure-10

Poor Supply p.f waveform using incandescent lamps as load

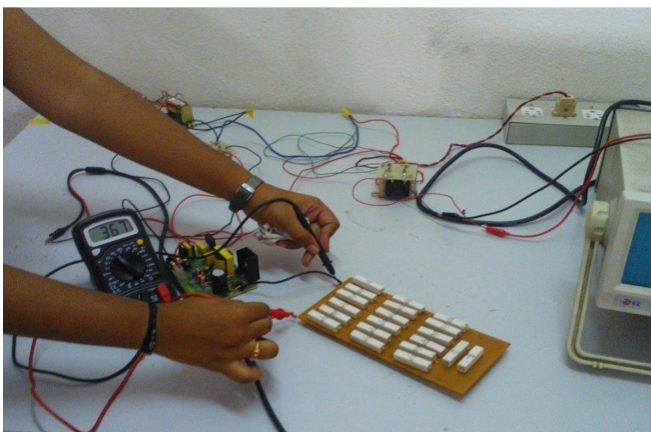


Figure-11

Voltage Boost across the load

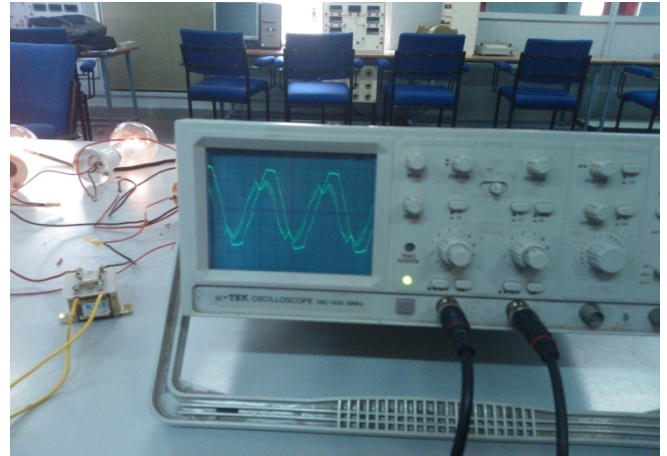


Figure-12

Improved power factor

Figure-11 shows the boost voltage at load when boost converter has used. Figure-12 shows the hardware circuit with IC which results in improved power factor observed in CRO.

### Conclusion

The Power Factor Correction with boost converter are simulated with MATLAB Simulink and also hardware design is implemented. In this paper conventional converter, Boost converter using border line Control is discussed. It is noticed that the power Factor is better for Boost Converter Circuit. It is observed that there is an improvement in power factor with boost converter both in simulation as well as in hardware implementation.

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