

A New Active Power Factor Correction Controller Using Boost Converter

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ABSTRACT: Today power system more and more complex with penetration of switching devices, DG sets, modified control technique, etc because of this, power system is having high amount of harmonics which effecting overall of power system. In electrical power system, a load with low power factor draws more current than load with high power factor for same amount of useful power transferred. Linear load with low power factor can be corrected with passive network of capacitors or inductors. Nonlinear loads (rectifier) distort the current drawn from system. In this paper, Boost Converter topology is used to accomplish this active power factor correction in many Continuous or Discontinuous modes. Boost converter is used as it is easy to implement and works well. Converter employing as a switch and simulated in MATLAB software. The major control techniques to absorbed sinusoidal input current in boost converter is reviewed and analysed. Furthermore, start up current has been reduced.

KEYWORDS: Average Current Control, Boost Converter, Control Techniques, Hysteresis Control, MATLAB(student version), Peak Current Control, PI Controller, PID Controller, Power Factor.

I. INTRODUCTION

Nowadays there are many appliances that require DC Power Supply. So to obtained DC power, interface must be provided between AC line and DC load. So this conversion is done by diode rectifiers. AC-DC converters are used in adjustable speed drives, SMPS, UPS etc. Most of power electronics system which is getting connected to AC utility uses diode rectifier at input.

So these converters rectify AC line voltage to obtain DC output voltage, but this DC voltage oscillates between zero and peak. The non-linear nature of diode rectifier causes significant line current harmonic generation, thus they degrade power quality, increases losses, failure of some crucial medical equipment etc. So to reduce this output ripple from DC voltage filter capacitor is used, and that is where problem of power factor arises. The capacitor maintains DC voltage at constant value but it draws non sinusoidal current from supply. The capacitor draws current from supply at line voltage peaks. So input current becomes pulsating which results in poor power factor and high THD. The input current can be controlled to follow sinusoidal reference using current control techniques. There are different current control mode techniques.

Power factor correction is used for improving power quality. Power factor correction can eliminate harmonics source of rectifier devices, through input current waveform automatically with input voltage waveform of grid and get former waveform as Sine waveform and have the same waveform with voltage waveform in phase.

II. BOOST CONVERTER

Boost converter is having tendency to resist change in current of inductor. In boost converter, output voltage is always higher than input voltage. When switch is on, current flows through inductor and energy is stored in it. When switch is off, stored energy in inductor tends to collapse and also it changes polarity such that it will add input voltage. Thus voltage across inductor and input voltage are in series and together charge output capacitor to voltage more than input voltage.

The basic principle of boost converter is shown in figure 2 consist of two distinct states:

1. In on state, switch S is closed, resulting in increase in inductor current.

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- In off state, switch is open and only path offered to inductor current is through diode D, capacitor C and load R, this result in transferring energy accumulated during on state into capacitor.

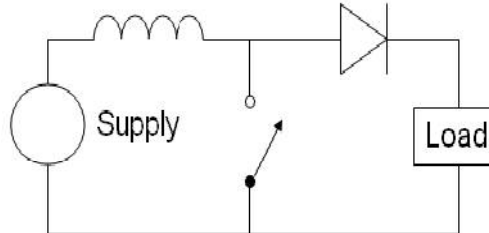


Figure 1 Boost Converter

Discontinuous Mode: If ripple amplitude of current is too high, inductor may be completely discharge before the end of whole commutation cycle. In this case, the current through inductor falls to zero during part of period as shown in figure (4). Although slight, difference has strong effect on output voltage equation. It can be calculated as follow:

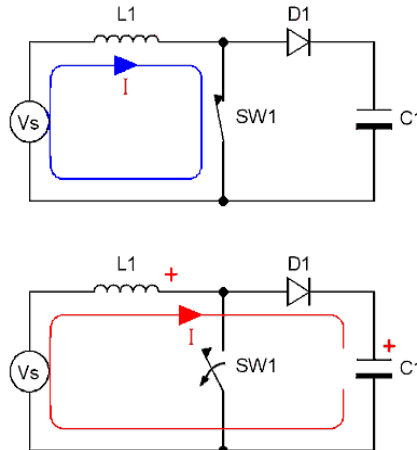


Figure 2 Boost Converter Operation Circuits

Continuous Mode: When a boost converter operates in continuous mode, the current through inductor never falls to zero. Figure 3 shows the typical waveform of current and voltages in converter operating in continuous mode. The output voltage can be calculated as follow, in case of ideal converter operating in steady conditions.

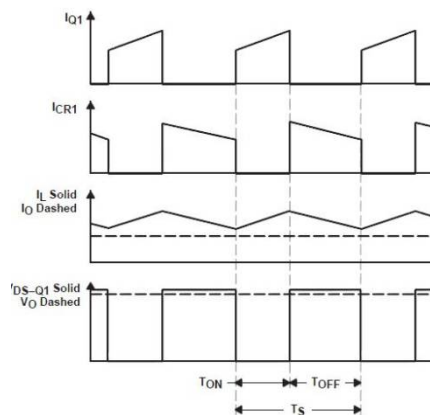


Figure 3 Continuous Mode

Discontinuous Mode: If ripple amplitude of current is too high, inductor may be completely discharge before the end of whole commutation cycle. In this case, the current through inductor falls to zero during part of period as shown in figure (4). Although slight, difference has strong effect on output voltage equation. It can be calculated as follow:

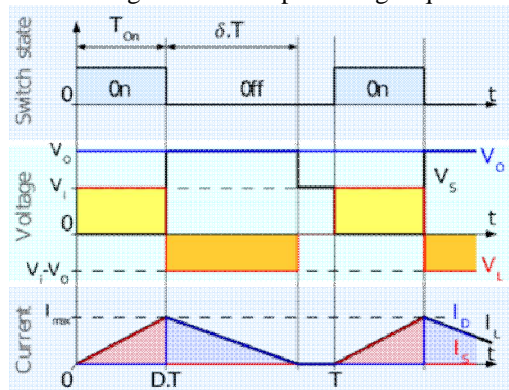


Figure 4 Discontinuous Mode

III. POWER FACTOR CORRECTION

The quality of absorbed from utility line by electronic equipment is increasing due to several reasons. In fact, low power factor reduces the power available from utility grid, while high harmonic distortion of line current which causes EMI problems and cross-interferences, through line current impedance, between different systems connected to same grid.

An ideal power factor should emulate resistor on supply side while maintaining regulated output voltage. In case of sinusoidal line voltage, means that converter must draw sinusoidal current from utility; in order to do that, suitable sinusoidal reference is generally needed and control objective is to force input current to follow as possible to reference current.

IV. RESULTS AND DISCUSSION

This paper involves simulation of simple circuits with gradual increase in complexity by inclusion of new components. All simulation work is done in MATLAB Simulink. First I have explained only boost converter without any technique. Then its THD calculation and ripple factor. Then I have shown different control techniques using boost converter. So, results shows that without control technique power factor is not improved and also THD is very high and ripple factor is high. So to improve power factor, THD and ripple factor, I have selected few control techniques. The simulations of simple boost converter using control techniques are shown as below.

a. Simple Boost Converter

The simulation of simple boost converter is shown in figure (4).

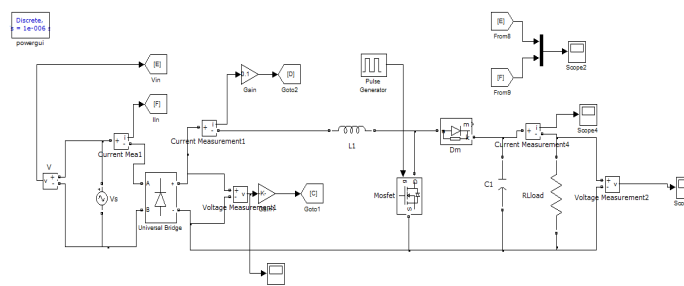


Figure 5 Boost Converter

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Figures show the simulation and results of boost converter. Below results are of input current and voltage. The results are given as below.

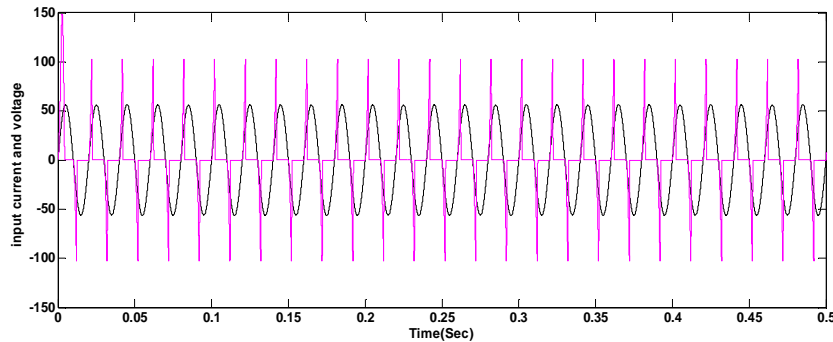


Figure 6 Input Current And Voltage

The THD of simple boost converter is shown in figure (6). It shows that if circuit is simple boost converter then THD is very high.

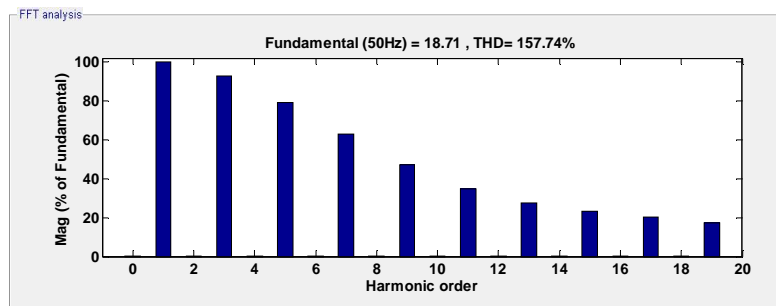


Figure 7 Total Harmonic Distortion Of Boost Converter

Result shows lots of ripple in the waveform, so it shows THD must be very high as THD data given above. We can see clearly that THD is more than 60% and we see lot of ripple in input current so our task is to reduce and make THD around 5%. So for this we have to design controller that gives us good results and improved power factor.

b. Peak Current Control Method Using Boost Converter

The circuit diagram of peak current control method using boost converter is shown in figure (8). It is in MATLAB software. The value of each component is shown in table. I am using 56.4 RMS in input and it gets boost up in output. Values of PI controller are set according to circuit.

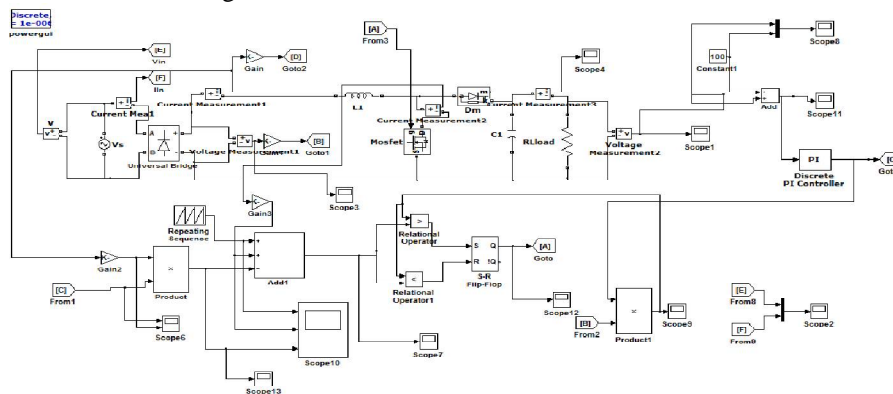


Figure 8 Peak Current Control Method

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The table shows basic component of circuit diagram.

The results of simulation are shown in below. Here input voltage is 56.4 RMS and it boost up to 100 V DC, as it is Boost Converter it will boost up its output voltage. The output waveform is shown in figure (9) as below.

Table 1 Table Shows Simulation Parameters

Components / Parameters	Values
Input Voltage	56.4 RMS
Inductor	0.26e-3 H
Capacitor	3000e-6 F
Resistor	50 Ohm
Switching frequency	20 kHz
Reference Voltage	100 V

Above table shows components parameters and values as per component. Below table shows power factor, ripple factor and its THD analysis.

Table 2

Topology	THD (%)	Power Factor	Ripple Factor	
			Voltage	Current
Boost Converter	157.74%	0.7788	7.5%	7.25%

The results of simulation of peak current control technique are as below.

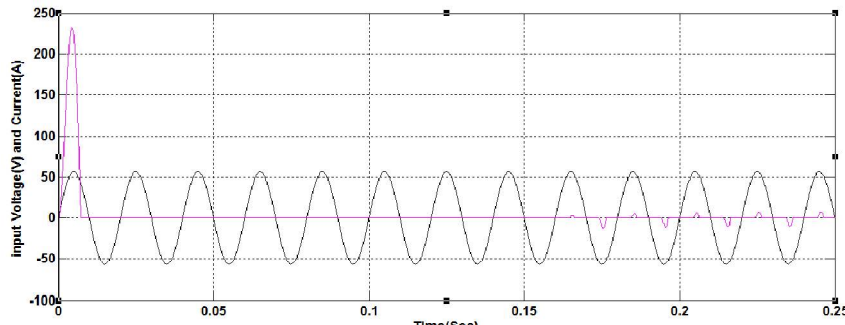


Figure 9 Input Voltage And Current

According to simulation of peak current control using boost converter is as below. The below waveforms give dc voltage nearer to 100 volt.

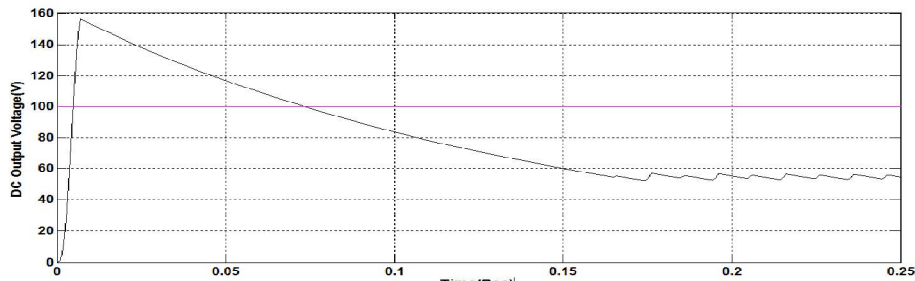


Figure 10 DC Voltage

Here is THD, Power factor and ripple factor analysis of peak current control technique using boost converter.

Table 3 Parameters Of Peak Current Control

Topology	THD (%)	Power Factor	Ripple Factor	
Peak Current control	145.85%	0.991	Voltage	Current
			5.35%	5.75%

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c. Average Current Control Method Using Boost Converter

The circuit diagram of average current control method using boost converter is shown in figure (11). It is also in MATLAB software. The value of each component is shown in table 1. The results of simulation are shown as below.

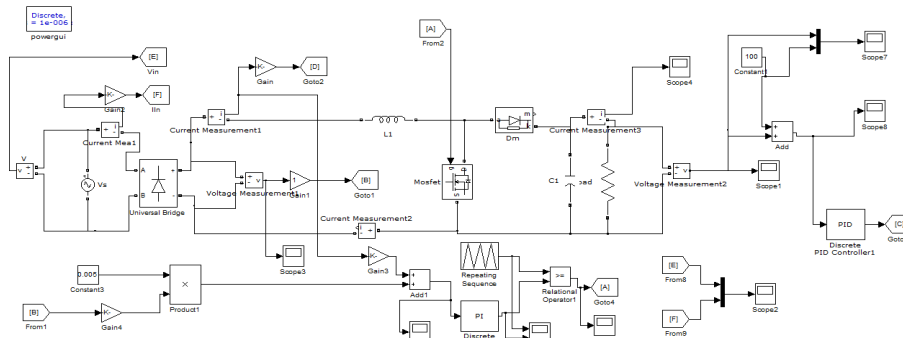


Figure 11 Average Current Control

The results of simulation of average current control technique as below.

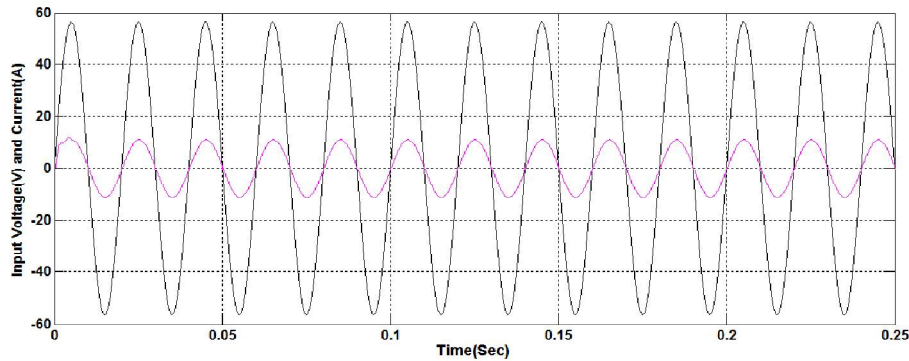


Figure 12 Input Voltage And Current

According to simulation of average current control using boost converter is as below. The below waveforms give dc voltage nearer to 100 volt.

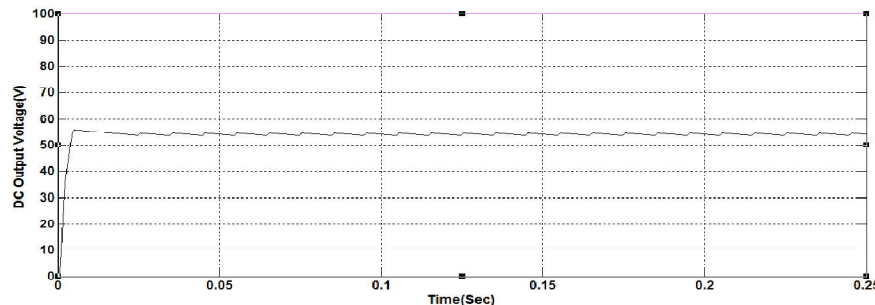


Figure 13 DC Voltage

Here is THD, Power factor and ripple factor analysis of peak current control technique using boost converter

Table 4 Parameters Of average Current Control

Topology	THD (%)	Power Factor	Ripple Factor	
Average Current Control	24.38%	0.9985	Voltage	Current
			3.25%	3.65%

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d. Hysteresis Control Method

The circuit diagram of hysteresis current control method using boost converter is shown in figure (14). It is also in MATLAB software. The value of each component is shown in table 1.

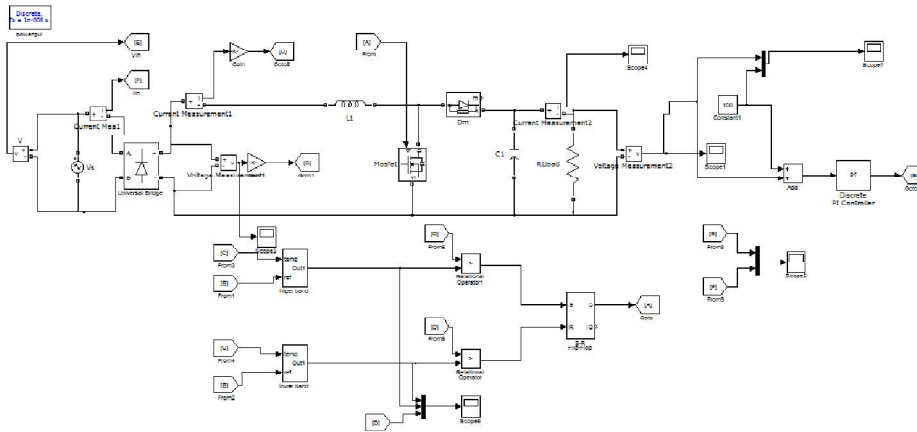


Figure 14 Hysteresis Control

The results of simulation of hysteresis control technique as below.

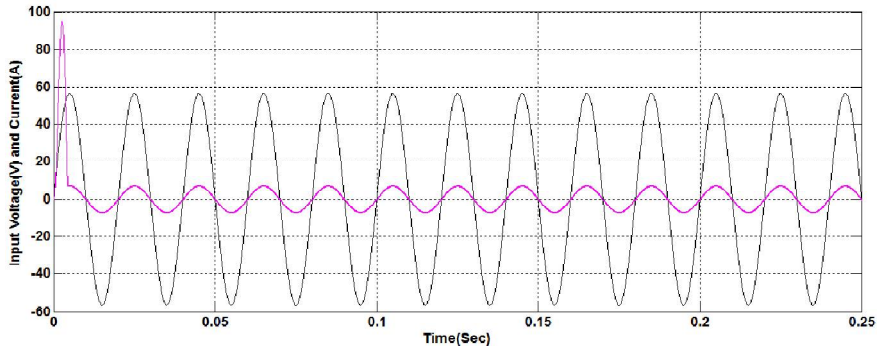


Figure 15 Input Voltage And Current

According to simulation of average current control using boost converter is as below. The below waveforms give dc voltage nearer to 100 volt.

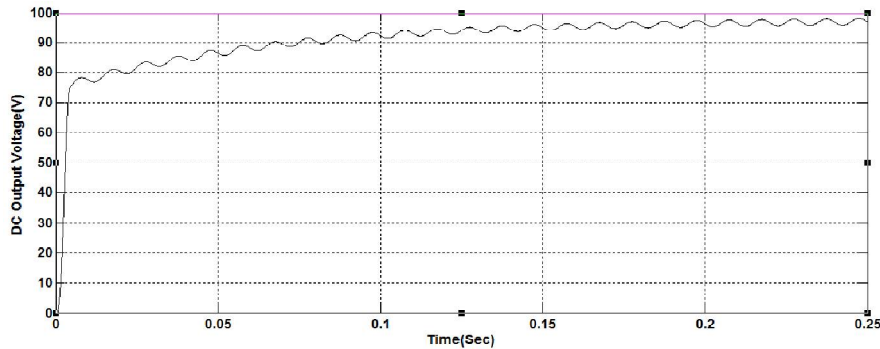


Figure 16 DC Voltage

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Table 5 Parameters Of Hysteresis Control

Topology	THD (%)	Power Factor	Ripple Factor	
			Voltage	Current
Hysteresis Control Method	3.12%	0.9999	2.00%	2.00%

Comparative results of performance parameters of boost converter topology with various current control strategies incorporated from below table, it can be preferable that hysteresis control technique is most preferable as it affords low THD for supply voltage and improved power factor.

Table 6 Comparison Of Various Voltage

Topology	THD(%)	Power Factor	Ripple Factor	
			Voltage	Current
Boost converter	157.74%	0.7788	7.5%	7.25%
Peak current control	145.85%	0.999	5.35%	5.75%
Average current control	24.38	0.9985	3.25%	3.65%
Hysteresis control	3.12	0.9999	2.00%	2.00%

V. CONCLUSION

A boost converter using various topologies has been studied and it is found that proposed topology has improved power factor and supply current, THD and ripple factor. The current control technique for improving power quality for boost converter has been analysed. Comparative analysis of peak current, average current and hysteresis has been also carried out in MATLAB Simulink. The simulation obtained show that hysteresis control offers power factor very close to unity and supply current THD is 2.00% compared to other techniques.

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