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# Average Current Control Mode Boost Converter for the Tuning of Total Harmonic Distortion & Power Factor Correction using PSIM

By Kashif Habib, Aftab Alam & Shahbaz Khan
*Northwestern Polytechnical University, China*

*Abstract-* The aim of this paper is to investigate the power factor correction (PFC) of Boost Converter under an average current-mode control. Boost converter topology is used to accomplish this active power-factor correction in many discontinues/ continuous modes. The boost converter is used usually it is easy to implement and works well. In this paper comparative evaluation of different techniques for harmonic reduction in input current of ac-dc converter is presented. Converters employing as side switching and boost converter is simulated in PSIM Software. Average current tracks the current program with a high degree of accuracy. This is especially important in high power factor pre-regulators, enabling less than 5% harmonic distortion to be achieved with a relatively small inductor. In fact, average current mode control function works well even when the mode boundary is crossed into the discontinuous mode at low current levels. The outer voltage control loop is oblivious to this mode change. Firstly I have simulated only single bridge rectifier without any use of converter to find the THD (Total Harmonic Distortion) at input and then applied open loop converter with single bridge rectifier to see how it affects the input THD and at last applied a converter with current control and voltage control loops so that to improve the input THD. A step change at Load end is applied and the result is displayed so that to show the response of the system to be stable. All the results are shown below in the paper.

*Keywords: PSIM; average current control; power factor correction; total harmonic distortion (THD).*

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*Abstract-* The aim of this paper is to investigate the power factor correction (PFC) of Boost Converter under an average current-mode control. Boost converter topology is used to accomplish this active power-factor correction in many discontinues/ continuous modes. The boost converter is used usualy it is easy to implement and works well. In this paper comparative evaluation of different techniques for harmonic reduction in input current of ac-dc converter is presented. Converters employing as side switching and boost converter is simulated in PSIM Software. Average current tracks the current program with a high degree of accuracy. This is especially important in high power factor pre-regulators, enabling less than 5% harmonic distortion to be achieved with a relatively small inductor. In fact, average current mode control function works well even when the mode boundary is crossed into the discontinuous mode at low current levels. The outer voltage control loop is oblivious to this mode change. Firstly I have simulated only single bridge rectifier without any use of converter to find the THD (Total Harmonic Distortion) at input and then applied open loop converter with single bridge rectifier to see how it affects the input THD and at last applied a converter with current control and voltage control loops so that to improve the input THD. A step change at Load end is applied and the result is displayed so that to show the response of the system to be stable. All the results are shown below in the paper.

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## I. Introduction

AC-DC converters are used in adjustable speed drives, SMPS, UPS etc. Most of power Electronics (PE) system which get connected to AC utility mains use diode rectifier at the input. 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 and so on. Therefore, stringent international standard are imposed. Hence, harmonic reduction circuits are incorporated in PE system [1].

Earlier expensive bulky inductor and capacitor were installed [2] but they effectively eliminated certain harmonic. Active power line conditioners (APLC) used for harmonic reduction are generally hard switched, which result in low efficiency, low EMI, high component stress etc. Soft switched resonant converter are also used and are usually operated in variable frequency mode and thus component are required to be designed at lowest operating frequency. Active clamped technique is well known for zero voltage switching (ZVS) operation in various converters. Boost converter topology in continues conduction mode (CCM) is used in medium power AC/DC converter, as it gives near unity power factor at ac input [3, 4].

Power-factor-correction (PFC) converters are widely used in power supplies for pre -regulating of power factor. Generally speaking, any type of switching converters can be the candidate for PFC purpose [5-8]. But in practical the Boost converter has been the favorable and popular choice when taking into account the factor of current stress and efficiency. As a typical nonlinear circuit system, PFC Boost converters are recently revealed to exhibit fast-scale instability, such as bifurcation and chaos operation, over the time of line cycle. These complex behaviors implying instability should be avoided from the viewpoint of traditional design principles, which can be realized by the changing of circuit parameters, or enclosing the accessional control method when the circuit parameters are fixed. The basic practical requirement for power supplies is to regulate output voltage. Moreover, this requirement has to be combined with that of power-factor-correction (PFC) in the design of most practical power supplies. Defined as the ratio of the active power to the apparent power, the power factor represents a useful measure of the overall quality level of satisfaction of power supplies and systems in such areas of performance as harmonic distortion and electromagnetic interference. Generally speaking, any type of switching converters can be chosen as a PFC stage. In practice, taking into account the current stress and efficiency, the boost converter has been a favorable and popular choice. The discontinuous conduction mode of operation has the obvious advantage of simplicity since no additional control is required [9].

In a conventional switching power supply employing a buck derived topology, the inductor is in the output. Current mode control then is actually output current control, resulting in many performance advantages [10-12]. On the other hand, in a high power factor pre-regulator using the boost topology, the

*Author α σ ρ: Master Students in the School of Automation, Northwestern Polytechnical University, Xi'an, Shaanxi, China.
e-mail: kashi62@gmail.com*

inductor is in the input. Current mode control then controls input current, allowing it to be easily conformed to the desired sinusoidal wave shape. In high power factor boost pre-regulators the peak/average error is very serious because it causes distortion of the input current waveform. While the peak current follows the desired sine wave current program, the average current does not. The peak/average error becomes much worse at lower current levels, especially when the inductor current becomes discontinuous as the sine wave approaches zero every half cycle. To achieve low distortion, the peak/average error must be small. This requires a large inductor to make the ripple current small. The resulting shallow inductor current ramp makes the already poor noise immunity much worse. The average current mode method can be used to sense and control the current in any circuit branch. Thus it can control input current accurately with buck and fly back topologies, and can control output current with boost and fly back topologies.

## II. Design of System

I have used average current control Boost Converter for the improvement of power factor and total harmonic distortion. The boost converter is a high efficiency step-up DC/DC switching converter. The converter uses a transistor switch, typically a MOSFET, to pulse width modulate the voltage into an inductor. Rectangular pulses of voltage into an inductor result in a triangular current waveform. For this discussion we assume that the converter is in the continuous mode, meaning that the inductor's current never goes to zero.

Some formulas and mathematical notations of Boost Converter are shown below in table 1.

*Table 1 :* Basic Formulas of Boost Converter

| Components/ Parameters | Formulas |
|---|---|
| Peak inductor current | $i_{pk}$ |
| Min inductor current | $i_o$ |
| Ripple Current | $\Delta i = \left(i_{pk} - i_o\right)$ |
| Ripple Current Ratio to Average Current | $r = \Delta i / i_{ave}$ |
| Off Duty Cycle | $1 - D = T_{off} / T$ |
| Switch Off Time | $T_{off} = \left(1 - D\right) / f$ |
| Average and Load Current | $i\_ave = \Delta i / 2 = i\_load$ |
| RMS Current for a Triangular Wave | $i_{rms} = \sqrt{i_o^2 + \left(\Delta i^2\right) / I^2}$ |

The boost converter has two conduction states, continuous conduction mode and discontinuous conduction mode. The block diagram of boost converter is shown in figure (1).

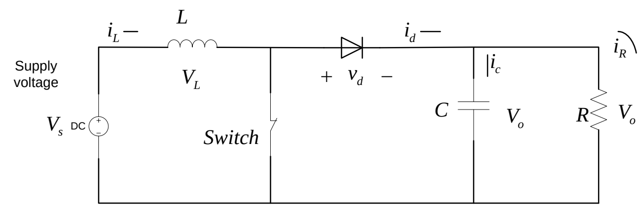


*Figure 1 :* Basic Diagram of Boost Converter

The average current mode control method is feedback control for current. I have used two PI controllers to stabilize the system. After using this average current control method, I have taken good results.

## III. Simulation & Results using PSIM Software

I have selected the PSIM software for simulation. Firstly I have explained only the bridge rectifier. Then calculate its THD, which is good because no energy using equipments in the circuit so it's THD is very good. Then I have shown the bridge rectifier using boost converter. The results show that its THD is very high so I have to improve this THD. For this purpose I have selected the average current controlled method.

The circuit diagram of PSIM software are shown below.

*a) Simple Bridge Rectifier*

The circuit diagram of simple bridge rectifier is shown in figure (2).

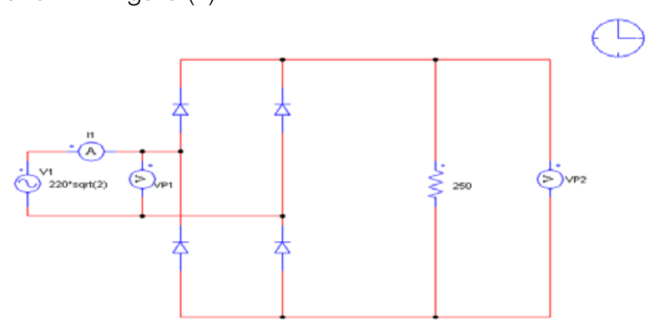


*Figure 2 :* Bridge Rectifier

The results are as given below

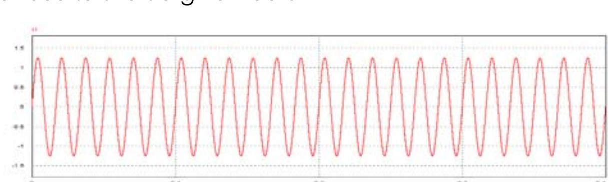

*Figure 2 :* Input Current

The THD of bridge rectifier is shown below in figure (3). It shows that if the circuit is simple BRIDGE

RECTIFIER then its THD will be very low, because no any complex circuit is attached in the diagram.

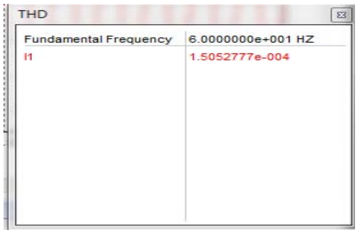


*Figure 3 :* Total Harmonic Distortion of Simple Brigde

*b) Bridge RectifierUsing Boost Converter*

The circuit diagram of Boost Converter is shown in figure (4).

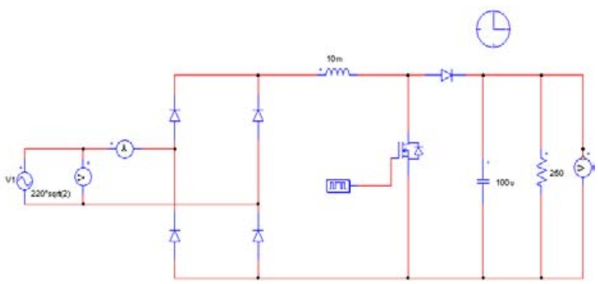


*Figure 4 :* Boost Converter

The results of input current are shown in figure (5).

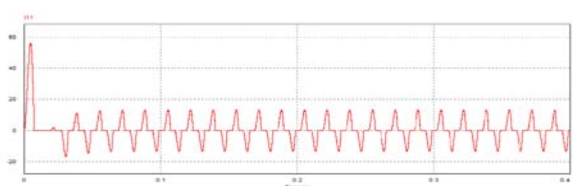

*Figure 5 :* Input Current of Boost Converter

The result shows clearly that a lot of ripples in the waveform. So it must be sure that its THD must be very high. The THD data is shown below in figure (6).

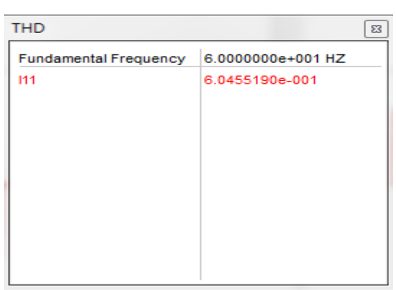


*Figure 6 :* Total Harmonic Distortion of Boost Converter

We can see clearly that its THD is more than 60% and we see a lot of ripples in the input current so our task is to reduce the ripples and make the THD around 5%. So for this we have to design a controller that gives us good results and improved power factor.

*c) Average Current Control Method using Boost Converter*

The circuit diagram of Average Current Control method using Boost Converter is shown below in figure (7). I have worked on PSIM Software. The value of each component is shown in the circuit. I am using 220 RMS in the input and getting 400V in the output. I have arranged the values according to the circuit like duty cycle of 0.4 and the values of PI controller are set according to the circuit requirement.

*Table 2 :* Circuit Parameters Used In Simulation

| Components/ Parameters | Values |
|---|---|
| Input Voltage | 220V RMS |
| Duty cycle | 0.4 |
| Inductor | 10 mH |
| Capacitor | 100 uF |
| Resistor | 250 Ω |
| Switching Frequency | 100 KHz |
| Reference Voltage | 400 V |

The table shows the basic components of the circuit Diagram.

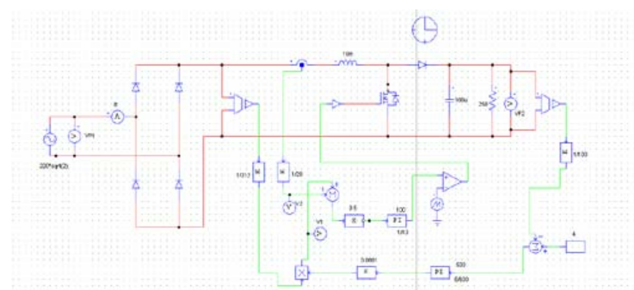

*Figure 7 :* Average Current Control Method

The results of the simulation are shown below. Here the input voltage is shown in figure (8), which I set 220V RMS.

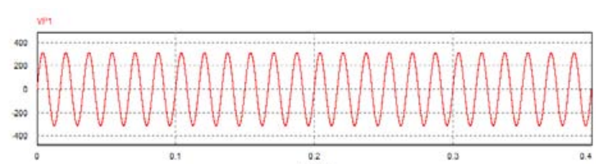


*Figure 8 :* Input Voltage

Because it is Boost Converter, its output must b higher than the original one. So we can see that its output is 400V DC. Because it is Boost Converter, the output waveform is shown in figure (9).

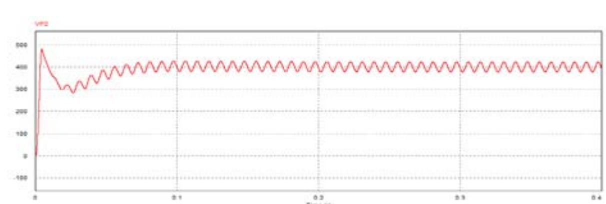

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*Figure 9 :* Output Voltage

The Input Current is shown below in figure (10)

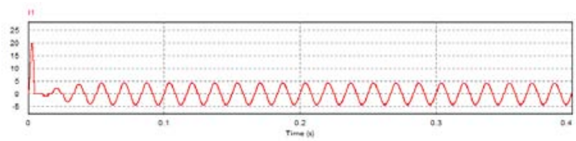
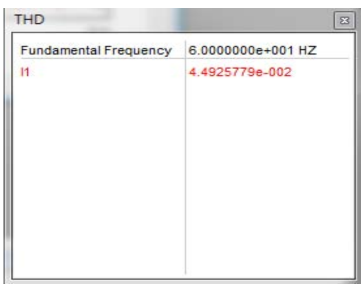


*Figure 10 :* Input Current

It can be seen that there is no ripple in the input current, so its THD must be very good. The THD of input current is shown below in figure (11).



| THD | |
|---|---|
| Fundamental Frequency | 6.0000000e+001 HZ |
| I1 | 4.4925779e-002 |

*Figure 11 :* Total Harmonic Distortion

So now THD is around 4.5%. It means that its THD is very good. So our results are improved by applying the average current control method to the Boost Converter.

In the average current control method, we use a feedback circuit diagram as we can see in figure (7). In the feedback circuit diagram, we have the comparison analysis of Inductor Current and Reference Current as shown in figure (12).

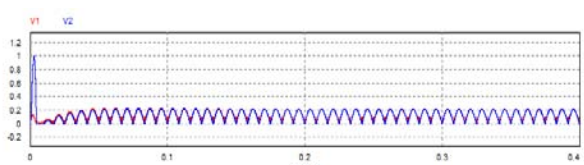


*Figure 12 :* Comparison of Inductor Current and Reference Current

So it is clear from the diagram that both have same waveform and same periodic cycle.

*d) Average Current Control Method Boost Converter using Variable Load*

The circuit diagram shown in Figure (13), it shows the Average Current Control Method using variable load. I have selected a step of 0.2 sec and with parallel resistance of 500 OHM. You can see clearly that after 0.2 sec step output voltage, input current and input voltage goes down on 0.2 and then comes to the original position. The Block Diagram of the circuit is shown in figure (13).

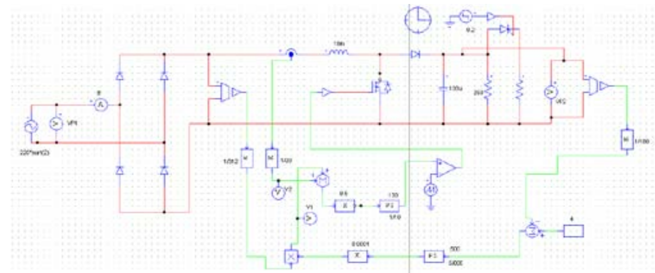


*Figure 13 :* Average Current Control Method with Variable Laod

It is the output voltage, which clearly shows that at 0.2 steps it goes down and then come to its original position. The diagram of the output Voltage is shown in Figure (14).

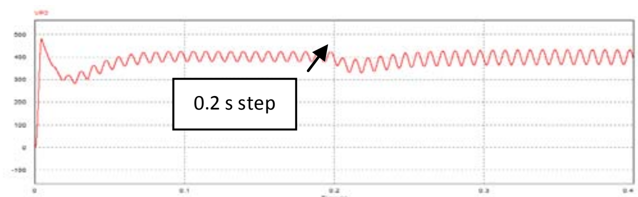



*Figure 14 :* Output Voltage with Variable Load

The input current shown below in figure (15) shows the change at 0.2 sec.

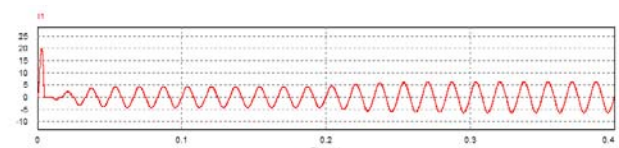
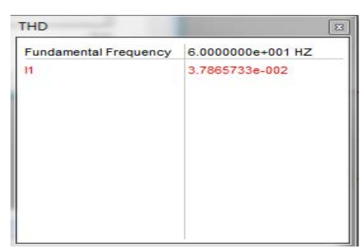


*Figure 15 :* Input Current with Variable Load

After applying the variable load, the THD is shown in figure (16) this is good around 4%.



| THD | |
|---|---|
| Fundamental Frequency | 6.0000000e+001 HZ |
| I1 | 3.7865733e-002 |

*Figure 16 :* Total Harmonics Distortion with Variable Load

It is the comparison of Inductor Current and Reference Current shown below in Figure (17).

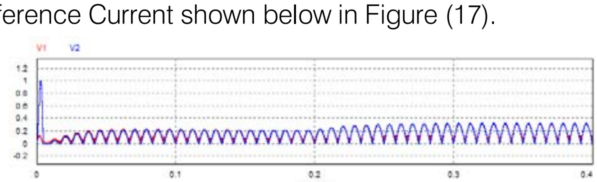


*Figure 17 :* Comparison of Inductor Current and Reference Current with Variable Load

It can be seen clearly that both have same waveforms.

## IV. Conclusion

I have used the Software PSIM, which helped me for the measurement of THD and Power Factor. Firstly I show the results of open loop uncontrolled rectifier and then shows the average current control method. The average current control method improves the results (THD and Power Factor). In the results of uncontrolled rectifier, we can see that harmonics are very high so our task is to reduce the harmonics. I used the close loop controlled rectification and arranging the PI controllers to get the good results. I have also shown the comparison of Inductor current and the reference current which is the comparison of rectified scaled voltage and the output DC voltage. I have also shown the transient analysis of average current control method, which also shows good results. So I got the good THD which is 4.45%.

## V. Acknowledgment

I will take this opportunity to express my deepest regards and thanks to my professor, without his guidance I would not be able to complete this paper. His attitude and guidelines during this paper is very valuable and helpful for me. During this paper I have explore new horizon of this field and I am confident that with the guidance of my professor I will excel in this field.

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