Journal of Advanced Research in Power Electronics and Power Systems
Volume 7, Issue 3 - 2020, Pg. No. 6-10
Peer Reviewed Journal

Article

Study of Power Quality Phenomenon Based on Design and Simulation of Boost Type PFC Converters

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DOI: https://doi.org/10.24321/2456.1401.202005

I N F O

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How to cite this article:
Vijay S, Ali S. Study of Power Quality Phenomenon Based on Design and Simulation of Boost Type PFC Converters. *J Adv Res Power Electro Power Sys* 2020; 7(3): 6-10.

Date of Submission: 2020-09-05
Date of Acceptance: 2020-09-19

A B S T R A C T

This paper present design and simulation of boost type Power Factor Correction (PFC) converter which improved the power quality. With the enormous development in the usage of power converters circuits like rectifiers which is non linear loads, the current drawn by these non- linear loads will not follow the supply voltage (i.e. non simulation). This results in high Total Harmonic Distortion (THD) and poor Power Factor (PF). Hence there is a need of converter topology to improve the PF and reduce line current harmonic. Boost type PFC converters is most popular topology for improving the PF in supply AC side. Average Current Mode (ACM) control technique is employed to control the boost converter in Continuous Conduction Mode (CCM). Simulation of proposed system is carried out using MATLAB/ Simulink platform.

Keywords: Boost Converter, THD, ACM, Power Quality

Introduction

Now days there are numerous application areas such as Uninterrupted Power Supplies (UPS), Switch Mode Power Supplies (SMPS), Adjustable Speed Drives (ASD), Back-Up Energy Storage system, Hybrid Electric Vehicle Chargers which required solid state AC-DC power converters.[1-3]

The main drawback of power converters is, it drawn pulsating input current from AC supply which results in poor PF and create periodic non- sinusoidal or discontinuous current which involves fundamental and odd harmonic component cause additional losses. Hence supply-side power quality becomes poor and affects the other users fed from the same line.[4,5]

The low PF and high pulsating current at AC mains side are the main disadvantages of diode rectifier. To overcome these two types of power quality issue with diode bridge rectifiers, PFC techniques are used. There are two types of PFC techniques-

- Passive Power Factor correction
- Active Power Factor correction

In Passive PFC method, a passive LC filter is used to suppressed harmonic in current. An inductor of passive filter stores enough energy to preserve the rectifier in conduction mode for the whole of one-half cycle of input supply and decrease harmonic distortion in supply current which occurs by discontinuous conduction of rectifier.[6-8] PF also improved using inductors and capacitors substantially. As the rectifier circuit operates at AC mains frequency, inductor required in passive power factor correction circuit is very large which are expensive and bulky.[9,10]

An active PFC technique is most effective and commonly used to improved power quality for power electronic circuits (non- linear load). It senses the current and voltage of non linear load and adjusts the input supply current.[11,12]

An active PFC converter placed amid supply and load, gives constant DC voltage at the output and high-PF at input side. This ability makes PFC converters a vastly attractive choice for AC-DC power conversion application because of increasing concern about power quality. Number of topologies and control strategies has been proposed in literature to meet the specification of the target application.[13,14]

The boost type PFC converters are most popular configuration because it can provide smooth input current waveform and low Electromagnetic Interference (EMI) in CCM which results in reduce input filter requirements.[15,16] Due to the advantages mentioned above. The boost type PFC converter have been designed and simulate to improved the power quality at input AC side relating to high-PF and low THD with regulated output DC voltage.

Configuration of System

The boost type PFC converter shown in Figure 1. It consists two stage power converters. In the first stage, input AC supply is converted into DC with the help of Diode Bridge Rectifier. The second stage deal with DC-DC conversion as Boost converter is used. As Boost converter used only one power electronic switch, its control circuit is simple and easy to implement.

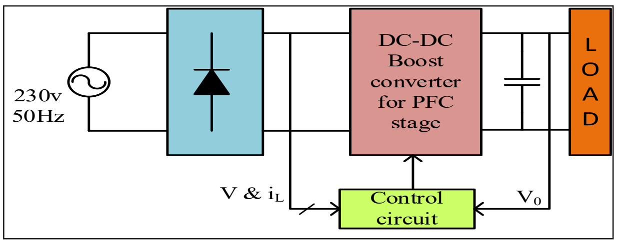


Figure 1.Boost type PFC Converter

Design of Boost Converter

Figure 2, shows the Boost converter circuit. It consists an inductor, switching device, diode and capacitor. It can increase the DC output voltage across the load to values greater than the source voltage; hence it is also known as step-up converter. The operation of Boost converter can be divided into two modes.

In the first mode of operation switch is ON. The supply current flow through the inductor and switch. Inductor stores energy during this period. Diode is in reverse biased and load is supplied by capacitor as it was discharging through load. The energy stored by inductor during this period is given as

$$E_s = V_s \times i_L \times t_{ON} \quad (1)$$

Where,

E_s is energy stored by inductor during mode 1,

V_s is the supply voltage (volt),

i_L is inductor current (A), and

t_{ON} is ON time of switch (sec).

In the second mode of operation switch is OFF. The inductor current cannot change immediately because of the tendency of it to resist change in current. Hence inductor current is forced to flow through diode and load. As current tends to decreasing, the polarity of inductor voltage is changed, as result voltage across load is the sum of supply voltage and inductor voltage and it is higher than the supply voltage. Inductor release their energy during this mode and it will be given as

$$E_r = (V_0 - V_L) \times i_L \times t_{OFF} \quad (2)$$

For lossless converter energy stored by inductor is equal to energy released by inductor i.e. $E_s = E_r$. From (1) and (2) we get the relation between output voltage and supply voltage which is given as

$$V_0 = \frac{V_s}{1-D} \quad (3)$$

Where D is the duty ratio.

As duty ratio varies between 0 and 1, the output voltage ideally rises from 0 to infinity. Hence it is called Boost converter.

The power flow is control by controlling the duty ratio of switch. Here MOSFET is used as a switching device. Inductor and capacitor are selected by using following equation.[13]

$$L = \frac{V_s \times D}{\Delta I_L \times f} \quad (4)$$

$$C = \frac{I_0 \times D}{\Delta V_r \times f} \quad (5)$$

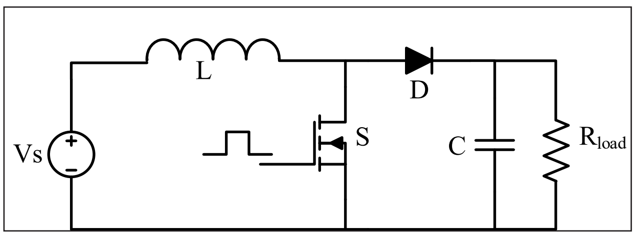


Figure 2.Boost converter

Control of Proposed System

Boost type PFC converter provides regulated DC output voltage under different load and input voltage condition. The values of converter component are also change with ambient temperature, pressure etc. Hence closed loop control technique is used to control the converter. Various control strategies can be performed to PFC circuit. The ACM control method is most popular among them because it provides regulated DC output voltage with a high input PF.

ISSN: 2456-1401
DOI: https://doi.org/10.24321/2456.1401.202005

Two control loops are used in this method namely voltage control loop and current control loop. The output voltage of Boost converter V_0 is sensed and compare with reference value V_{ref}, which generates an error signal V_e. The voltage error at n^{th} sampling instant is given as

$$V_e(n) = V_{ref} - V_0(n) \quad (6)$$

This error signal is amplified by PI voltage controller. PI controller is designed for zero steady-state error in DC voltage regulation. Its output at n^{th} sampling instant is given as

$$V_{pi}(n) = V_{pi}(n-1) + K_p\{V_e(n) - V_e(n-1)\} + K_i V_e(n) \quad (7)$$

Where K_p and K_I are the proportional and integral constant respectively.

This output is multiplied with input voltage to produce an input current reference i_{ref}. The magnitude of current is such that to keep the output DC voltage to near to its reference value and the shape and phase is identical to input voltage waveform. Input current i_L is sensed and compare with this current reference, which generate current error signal $i_e(n)$. This current error signal $i_e(n)$ passed through PI current controller. Its output is compared with sawtooth wave, which provides PWM (Pulse Width Modulation) signal to drive the switch. Figure 3 shows the schematic diagram of ACM control scheme.

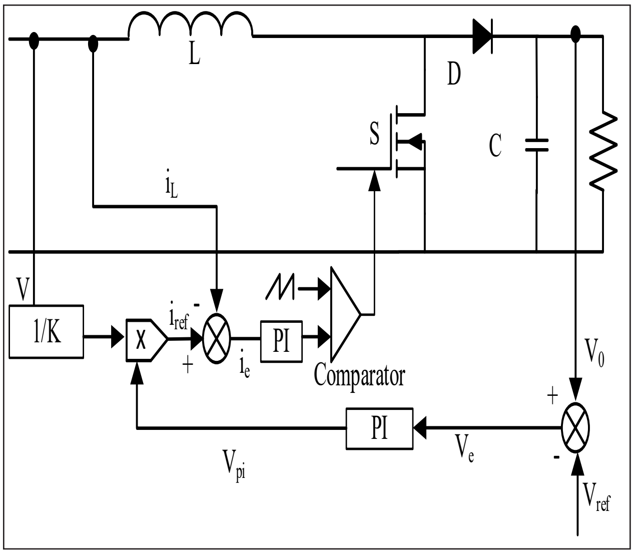
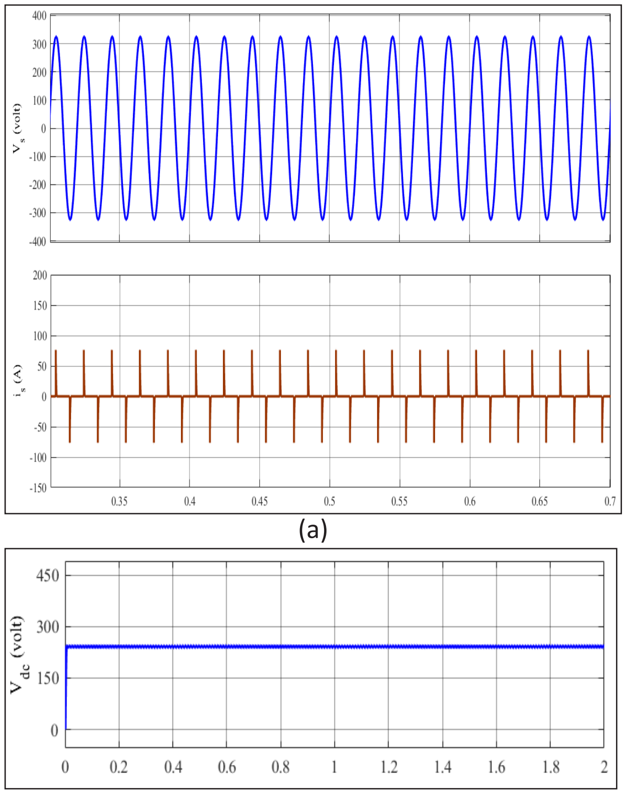


Figure 3.Average Current Mode Control scheme

Simulation Result

The simulation of proposed system is done with the help of MATLAB/ Simulink software. Simulation involves the analysis of current and voltage waveform.

The simulation of conventional diode bridge rectifier is study. This system consist four diode that form a bridge network. The waveform related to this system is shown in Figure 4.



(a)

(b)

Figure 4.Simulation Result, (a) Input voltage and current waveform, (b) output voltage

It supplies a power to non-linear load. It can see from Figure 4(a) that input current consists of THD 338% which is more than as per IEEE standard (IEEE 519-1992). The output voltage is 230 volts. Figure 5 shows the THD of the system.

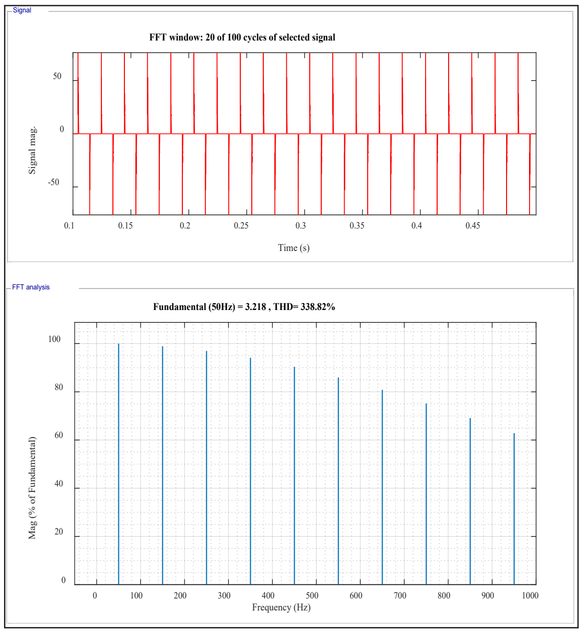
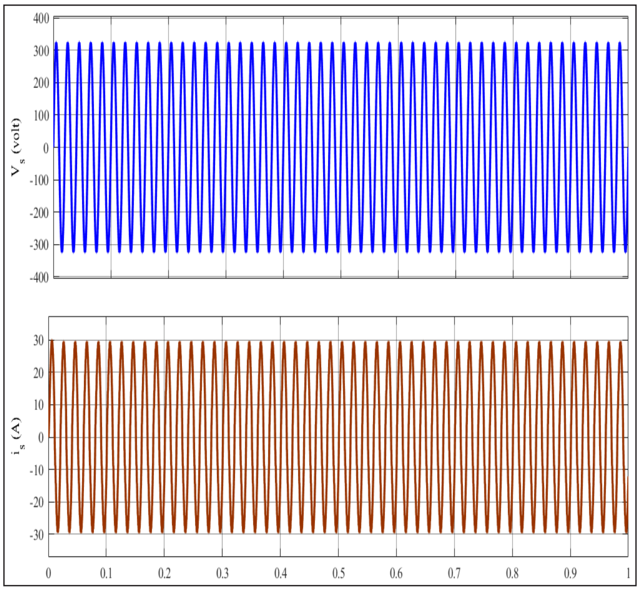


Figure 5.FFT window of system

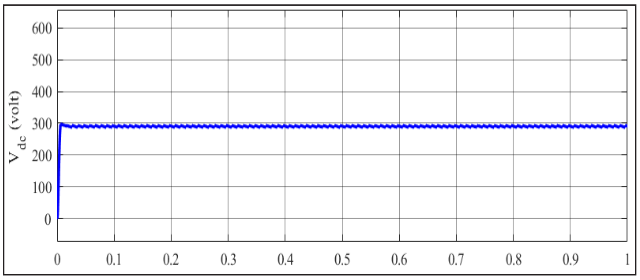
The simulation of diode bridge rectifier with PFC circuit is carried out. A plot between input voltage and current

ISSN: 2456-1401
DOI: https://doi.org/10.24321/2456.1401.202005

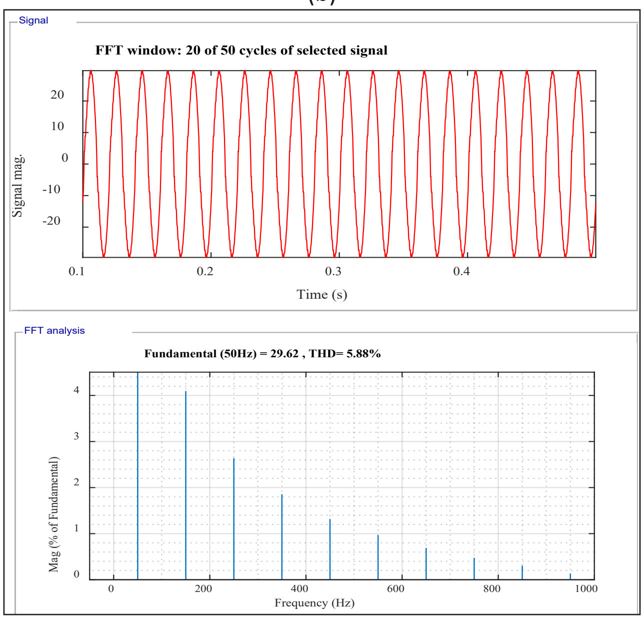
is shown in Figure 6(a). It can be notice from Figure 6(b) that input current wave form is almost sinusoidal and in phase with voltage waveform i.e. power factor is closed to unity. This system also improved the THD to 5.88% which is shown in Figure 6(c).



(a)



(b)



(c)

Figure 6.Simulation result of proposed system

Conculsion

The Power Factor Correction with different converters are Simulated with MATLAB Simulink. In this paper conventional converter and Boost converter using Current Mode Control are discussed. It is noticed that the Power Factor is better for Boost converter Circuit. Also, THD is minimized to an extent. This can be improved further using Dual Boost Converter with PI as well as FUZZY controllers.

References

1. Zhe C. Boost APFC device design[J]. *Electrical technology* 2010; 1: 45-50.
2. Jovanovic MM, Jang Y. State-of-the-art, single phase, active power factor-correction techniques for high-power applications - an overview. Industrial Electronics, IEEE Transactions on 2005; 52: 701-708.
3. Zhang AW, Zhang MT, Lee FC et al. Conducted EMI analysis of a boost PFC Circuit. Proc. IEEE Applied Power Electronics coni. APEC-2009; 1.
4. Crebier J, Brunello M, Ferrieux JP. A new method for EMI study in PFC rectifiers. Proc. *IEEE Power Electronics Spc Coni* PESC-20J J. 855-860.
5. Brown R, Soldano M. One Cycle Control IC Simplifies PFC Designs. IEEE Applied Power Electronics Conference. 2005: 825-829, 6-202.
6. Maksimovic D, Jang Y, Erickson R. Nonlinearcarrier control for high power factor Boost rectifier. *IEEE Trans* 1996; 11(4): 578-584.
7. Sebastián J, Lamar DG, Arias M et al. The Voltage-Controlled Compensation Ramp: A New Waveshaping Technique for Power Factor Correctors. *IEEE Applied Power Electronics Conference*, 2008; 722-728.
8. Buso S, Spiazzi G, Tagliavia D. Simplified control technique for high-power-factor Flyback, Cuk and SEPIC rectifiers operating in CCM. *IEEE Trans. Industry Applications* 2000; 36(5): 1413-1418.
9. Lazar J, Cuk S. Open loop control of a unity power factor, discontinuous conduction mode rectifier. INTELEC 1995; 671-677.
10. Kumawat RK, Chourasiya S, Agrawal S et al. Self-excited induction generator: A review. IARJSET, NCREE-2015; 2: 37-42. ISSN (Online) 2393-8021, ISSN (Print) 2394-1588.
11. Peng FZ, Akagi H. A new approach to harmonic compensation in power systems- a combined system of shunt passive and series active filters. *IEEE Trans Ind Appl* 1990; 26: 983-990.
12. Bing Z, Chent M, Miller SKT et al. Recent Developments in Single-Phase Power Factor Correction. IEEE Power Conversion Conf., Nagoya. 2007.
13. Kumawat RK, Agrawal S, Chourasiya S et al. A Comparative Study of Power Inverter Topology and Control Structures for Renewable Energy Recourses. *IARJSET*, NCREE. 2015; 2(1): 350-354, ISSN (Online)

ISSN: 2456-1401
DOI: https://doi.org/10.24321/2456.1401.202005

2393-8021, ISSN (Print) 2394-1588.

14. Singh B, Singh BN, Chandra A. A review of single phase improved power quality AC_DC converters. *IEEE Trans Ind Electron* 2003; 50: 96-981.
15. Tomioka S, Terashi H, Sonoda T. Interleaved-boost fullbridge PFC converters, Proc. IEEE PESC 16. 2005; 2339-2344.
16. Kumawat RK, Palwalia DK. A comprehensive analysis of reduced switch count multilevel inverter. *Australian Journal of Electrical and Electronics Engineering, Taylor and Francis journals* 2019. DOI:10.1080/1448837X.2019.1693884.
17. Kumawat RK, Palwalia DK. Half bridge module asymmetric multilevel inverter based on novel PWM control strategy. IEEE *6th International Conference on Computer Applications in Electrical Engineering-Recent Advances (CERA)*, Roorkee 2017; 303-307.