DESIGN & SIMULATION OF ACTIVE POWER FACTOR CONTROLLER USING BOOST CONVERTER

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ABSTRACT

Currently extensive use of power electronic devices has made power management smart, flexible and efficient. But the increase in number of power electronic devices has also led to increase in distortion and power pollution in the distribution networks. This is due to injection of current and voltage harmonics into the networks which leads to reduction of power factor and negative impact on electrical equipment. So the need of power factor improvement along with the reduction in Total Harmonic Distortion (THD) has now gained prime importance.

This paper discusses an approach for the power factor improvement using an Active Power Factor Correction (APFC) technique. It uses multiplier logic to obtain current wave shaping which allows source current to follow sinusoidal voltage. It improves power factor (PF), reduces harmonics distortion noticeably and automatically corrects the distorted line current in the presence of nonlinear load. The work includes THD reduction and improvement of power factor at input side in the presence of nonlinearities produced by rectifier, UPS, telecom supplies, electronic ballast etc. It is an effort to explain design and simulation of boost converter operating in continuous conduction mode (CCM) as a power factor correction controller. Comprehensive study of boost power factor controller is carried out. Simulation model of the system is developed in MATLAB to analyze variations in THD and power factor.

KEYWORDS: nonlinear, power factor,continuous conduction mode,harmonic distortion

INTRODUCTION

Current waveform is distorted at the source side in the presence of nonlinear devices such as diode rectifier as shown in the Figure 1.This can be alleviated by using power factor correction techniques, either by using controlled power electronics in single-phase or multi-phase (e.g three-phase) topologies or passive solutions. The aim of performing power factor correction is to align input current and voltage waveforms in an AC-system and also reduce the amount of harmonics in the system. Distortion in the current waveform occurs due to the capacitor across the rectifier or if the load is continuously switching or if any transients are generated. Thus, the need of power factor improvement within the system has now gained prime importance.Electronic devices primarily require D.C power supply and normally switching devices such as diodes, thyristors, power MOSFET's, etc. are used to convert A.C to D.C. Due to the nonlinear behavior of these switching devices they tend to draw highly distorted input current in short bursts or spikes relative to the line voltage. This results into high Total Harmonic Distortion (THD), low Power Factor (PF) and increased interference with other electrical equipment. Low power factor also results in poor output voltage regulation.

To mitigate the problems associated with poor power factor, power factor correction (PFC) circuits are being increasingly used. These PFC circuits are categorized into two, namely active and passive PFC. Passive PFC circuits provides reactive power compensation but lack in dynamic response for continuously variable nonlinear load conditions whereas Active PFC circuits can dynamically respond to nonlinear load in dc circuit and provide improved power factor at the input side .It improves power factor using waveshaping of current waveform by making the source current waveform in the phase with voltage waveform using voltage feedback,feed forward,inductor current and rectified voltage.[1,3]

OBJECTIVES OF PROPOSED SYSTEM

The proposed system aims to implement improvement in Power Factor (PF) on input (A.C) side and reduction in THD for single-phase rectifiers for 80W load using boost converter. Converter operates at an input voltage of 80V~230V AC and output is 375V DC. Aim of the proposed active power factor correction system is

- To simulate and analyse the methodology chosen for Power Factor Correction (PFC).
- To observe and analyse Total Harmonic Distortion (THD) and source voltage and current waveforms with and without Power factor Correction Circuit (PFC).

NEED OF PFC IN DC POWER SUPPLIES

Highly distorted input ac current is drawn by the rectifier unit as shown in the Figure 1 below , which will result in high THD and reduced power factor.

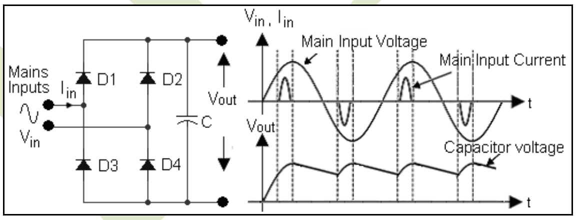

Fig.1 Power supply unit using rectifier and capacitor.

Power factor correction method shapes the distorted input current waveform to approximate a sinusoidal current that is in phase with the input voltage

Different types of power factor correction topologies are:

1. Active power factor control topology.
2. Passive power factor control topology.

Passive power factor correctors have certain advantages, such as simplicity, reliability, ruggedness, insensitive to noises and surges, no generation of high-frequency EMI, no high-frequency switching losses etc.

However, due to following drawbacks new technique such as active power factor correction is considered in this paper. [2-4]

DRAWBACKS OF PASSIVE PFC

1. As line-frequency reactive components are used, solutions based on filters are heavy and bulky.
2. Poor dynamic response.
3. Lack in voltage regulation and the shape of their input current depend on the load.
4. Even though line current harmonics are reduced, the fundamental component may show an excessive phase shift that reduces the power factor.

IMPLEMENTATION OF BOOST ACTIVE POWER FACTOR CORRECTION CONVERTER OPERATING IN A CCM MODE FOR 80 W, 400VDC LOAD.

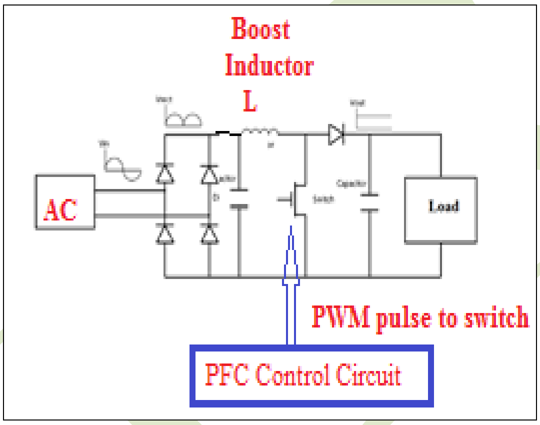

Fig. 2 (A): Block Diagram boost PFC topology

The converter will operate throughout the entire line cycle, so the input current does not have distortions and will be continuous as shown in Figure 2(B). It has a smooth input current because an inductor is connected in series with the power source. In addition, the switch is source-grounded; therefore it is easy to drive. This topology is a universal solution for power supplies.

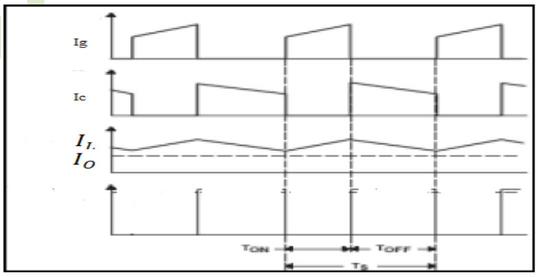

Fig 2(B): Waveforms of Gate current, capacitor charging current, output current

Boost converter controls two functions viz: shape of the input current and magnitude of the output voltage. To accomplish this, there are two necessary conditions- first - the output voltage should be higher than the peak of the rectified input voltage, and second – the power flow should be unidirectional. Current path for different time instants can be considered as shown in the Figure 3 and Figure 4. While the switch is conducting, the current will flow through the inductor and through the switch and back to the mains shown in the Figure 3. This is because the diode is in the blocking state. The load current will be supplied from the capacitor, depleting it and decreasing the voltage. However, when the switch is blocking as shown in Figure 4, the inductor will force the current to flow through the diode into the capacitor and load, which will recharge the capacitor bank and thereby increasing the voltage.[6].

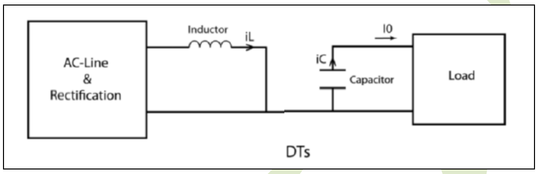

Fig 3: Current path when switch is turned on

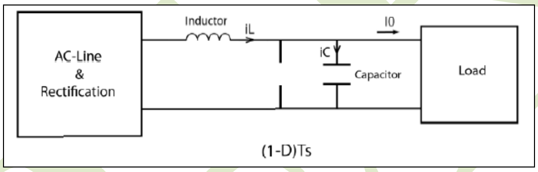

Fig 4: Current path when switch is turned off

In this project power factor correction (PFC) circuit is developed using boost converter in continuous conduction mode (CCM) which will continuously improve power factor in the presence of nonlinear load or in transient load condition. Due to PFC circuit, current drawn by the mains will be minimum for the real power required to perform needful work which in long run will minimize the cost of the distribution of power and cost of generation, as well as capital cost.[8] It will also comply regulatory requirements guided by IEC61000-3-2 for the permissible harmonic level and PFC requirement such as Energy Star 5.0 for computers and Energy Star 2.0 for external power supplies and computers. [1,8]

SIMULATION OF ACTIVE PFC USING MATLAB

Figure 5 shows simulation of implementation of power factor correction circuit. It includes AC source with Voltage PLL(phase lock Loop) and current PLL. Power factor is calculated from the angle obtained from PLL. Further it continues with diode bridge (D1-D4), input capacitor C1, boost inductor L, MOSFET S, diode D5, output capacitor C2 and load. Control circuit includes PID controller, current sensing resistors and S-R Flipflop. Inductor current signal and rectified voltage are given to the controller block. PWM signal will be generated by comparing square wave signal and carrier wave. When diode rectifier is supplying the nonlinear load, results are analyzed with and without PFC circuit

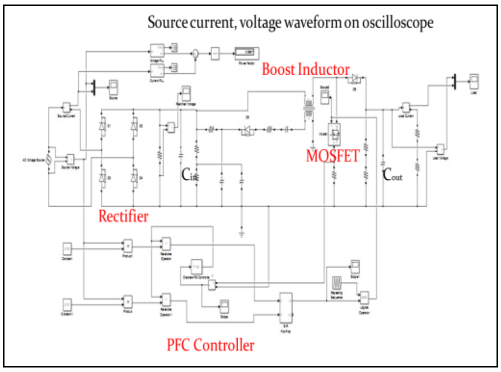

Fig.5 Simulation Of Active PFC using MATLAB/SIMULINK

SIMULATION RESULTS

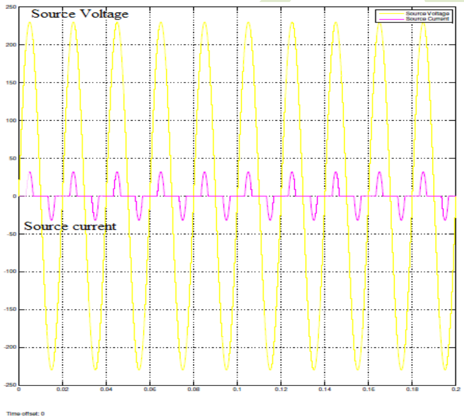

Fig.6 (A) Source voltage, distorted current waveforms obtained without PFC

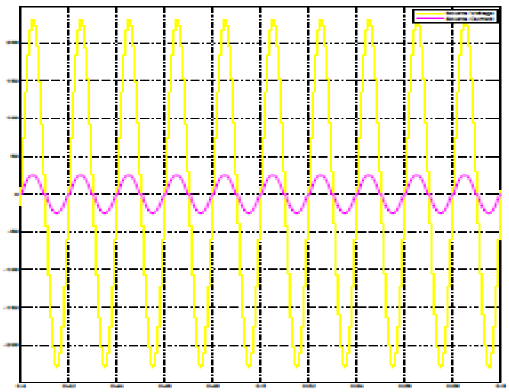

Fig 6(B) With Implementation PFC Controller –Sinusoidal Current, Voltage waveform (Current in phase with voltage waveform)

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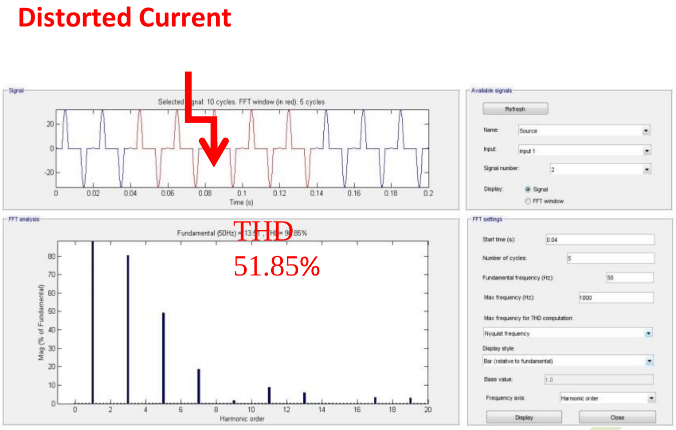


Fig 7(A): Total harmonic distortion (THD=51%) & Source voltage ,distorted current waveforms obtained without PFC.

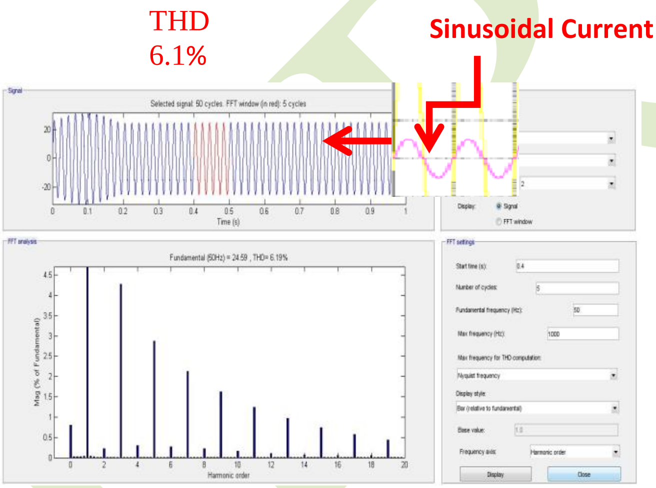
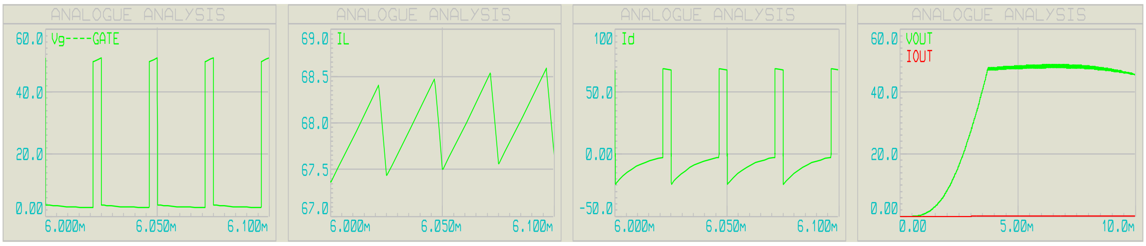


Fig 7(B): Total harmonic distortion (THD=6.1%) & Source voltage ,current waveforms in phase obtained with PFC.

It is observed from the simulation results as obtained in Figure 6(A) and Figure 7(A) distorted current with high THD is drawn by the single phase rectifier in absence of PFC with reduced power factor which may cause malfunctioning of the critical load connected to point of common coupling .Figure 6(B) and 7(B) shows current waveform follows voltage waveform with improved PF as well as reduction in THD from 51% to 6.1%.

After implementation of PFC circuit simulation result shows , current wave form is almost in phase with voltage waveform as shown in Figure 6(B) compared to Figure 6(A).



A)Gate voltage B) Inductor Current, C)Diode current, D)Vout- Output capacitor voltage

Fig. 8: Waveforms of voltage and Current

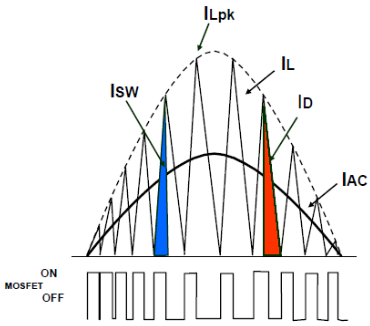


Fig.9 Waveform of inductor current and gate pulse

Figure 8 and 9 shows waveforms of inductor current and voltage across MOSFET switch along with output voltage across capacitor.
MOSFET gate is triggered when inductor current reaches zero. Inductor current is continuously compared with reference current and according to error signal generated by current comparator block, MOSFET is triggered with PWM pulse

RESULTS AND DISCUSSIONS

1. From the simulation results as shown in Figure 7 (A)and (B), it is observed that without PFC circuit power factor is reduced up to 0.6 with distorted current waveform at the input ac side and THD is very high ranging from 27-51 %
It is very necessary to improve PF and reduce THD within permissible limits which will help to maintain high power quality. PFC driven circuits results shows improved PF from 0.6 up to 0.99 by adjusting inductor current follow sinusoidal voltage at the source side.
2. As the value of the inductor increases ripple will be minimum, continuous current will be supplied to load but at the same time it will become bulky and increase in size. If the inductance value is reduced to very small value it will operate in discontinuous mode which is not suitable for high power applications.
3. As the value of the output capacitor changes output voltage increases. To keep the output voltage constant and reduce the ripple with the size considerations capacitor value will be selected. If the capacitor value is very high, current distortion can be observed. NTC resistor is required to reduce inrush current.

CONCLUSION

This paper presents application of boost converter power factor correction circuit to analyse power factor improvement in dc nonlinear load such as computers, IT load etc. It is verified by simulation results that, using multiplier logic for active PFC gives improved power factor upto 0.98~0.99 and with significant reduction in Total Harmonic Distortion (THD).

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