

Enhancement of Power Factor by Using Boost Converter in Non Linear Loads

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Abstract: *Mostly, the loads used in the industrial and domestic purpose are inductive loads are non-linear in nature, which causes harmonics. In order to compensate these harmonics, a new power factor correction technique is proposed in this paper, to achieve power factor nearer to unity and to regulate the DC bus voltages. The proposed PFC technique consists of one full-bridge diode rectifier and one Boost PFC Converter, the full bridge diode rectifier is considered as the non-linear load which is the source of harmonics. Here the PFC boost converter is connected in shunt with the diode rectifier to compensate the harmonic current drawn by diode rectifier. This configuration uses hysteresis current control technique to track the line current command. The PFC boost converter supplies the required harmonic current produced by the non-linear load. Hence the total arrangement draws a nearly sinusoidal current with improved power factor.*

Advantages of the proposed converter is less harmonic control contents, simpler control strategy, higher power density, unidirectional power flow and can get nearer to power factor. Optional principle, design analysis and conditions achieving for the proposed converters are described.

1. INTRODUCTION

Due to the growth of nonlinear loads, such as Power Electronics converters, SMPS (Switching Mode Power Supplies), Computer, serious power pollution is produced & reflected in to the distribution & Transmission networks. The low power factor and high pulsating current from the AC mains are the main disadvantages of the diode rectifier and phase controlled rectifier. These circuits generate serious power pollution in the transmission or distribution system. The power pollutants such as reactive power and current harmonics results in line voltage distortion, heating of core of transformer and electrical machines, and increasing losses in the transmission

and distribution line. A passive filter is often used to improve the power quality because of its simple circuit configuration. Bulk passive elements, fixed compensation characteristics, and series and parallel resonances are the main drawbacks of this scheme. Two approaches for current harmonics elimination and power factor improvement are power factor correctors, as shown in Fig. 1(a), and active power filters, as shown in Fig. 1(b). The former is used to produce a sinusoidal current on their AC side. The latter can compensate current harmonics generated by nonlinear loads in the power system. Several circuit topologies and control strategies of power factor correctors [1-4] and active power filters [5-8] have been proposed to perform current or voltage harmonics reduction and increase the power factor. In order to meet the requirements in the proposed standards such as IEC 61000-3-2 and IEEE Std 519 on the quality of the input current that can be drawn by low-power equipment, a PFC circuit is typically added as a front end stage. The boost PFC circuit operating in continuous conduction mode (CCM) is the popular choice for medium and high power (400 W to a few kilowatts) application. This is because the continuous nature of the boost converter's input current results in low conducted electromagnetic interference (EMI) compared to other active PFC topologies such as buck-boost and buck converters.

The conventional power quality compensation approach is given in Fig. 1(c). The active rectifier of the AC/DC/AC converter is used to regulate the DC bus voltage for motor drive. The nonlinear load produces a pulsating current with large current harmonics. An active power filter is employed to compensate the reactive power and current harmonics drawn from the nonlinear load and the AC/DC/AC converter. This strategy needs an additional inverter and measurement of both the nonlinear load currents and the compensated currents. The cost of implementation of this strategy is very high [11-13].

To combine the capabilities of power factor correction, active power filter and AC/DC converter, a new power factor correction technique using PFC Boost converter is proposed to work simultaneously as an active power filter to supply compensated currents that are equal to the harmonic currents produced from the nonlinear loads, and a AC/DC converter supplies the DC power to its load and takes a nearly sinusoidal current from the supply. This approach reduces the cost of the filter, since no especially dedicated power devices are needed for the harmonics elimination.

The proposed PFC technique consists of one full-bridge diode rectifier and one Boost PFC Converter. Here the full bridge diode rectifier is considered as the non-linear load which is the source of harmonics. A hysteresis current control is adopted to track the required line current command. In this arrangement PFC boost converter can be used to eliminate the harmonic current generated by the diode rectifier. The PFC boost converter supplies the required harmonic current produced by the non-linear load, hence the total arrangement draws a nearly sinusoidal current with improved power factor.

2. CONVENTIONAL POWER FACTOR CORRECTION TECHNIQUE

The single-phase diode rectifier associated with the boost converter, as shown in Fig. 1(d), is widely employed in active PFC. In principle, the combination of the diode bridge rectifier and a dc-dc converter with filtering and energy storage elements can be extended to other topologies, such as buck, buck-boost, and Cuk converter [9]. The boost topology is very simple and allows low-distorted input currents, with almost unity power factor using different dedicated control techniques.

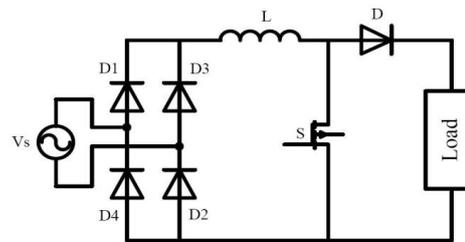
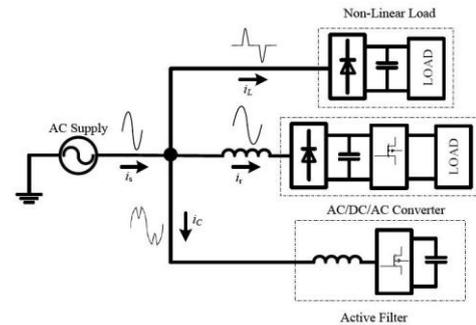
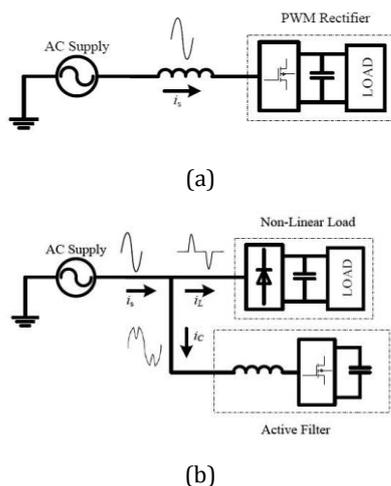


Fig 1: (a) Power factor corrector; (b) shunt active power filter; (c) conventional power quality compensator; (d) Active power factor correction technique using boost converter (Boost PFC).

Typical strategies are hysteresis control, average current mode control and peak current control [10]. More recently, on-cycle control and self control have also been employed. Some strategies employed three level PWM AC/DC converter to compensate the current harmonics generated by the diode rectifier. Some strategies employed active power filter to compensate the harmonic current generated by the non-linear load. Disadvantages of these strategies are; (a) for each non-linear load, one separate converter should be employed, (b) due to presence of more switching devices used in some strategies, switching losses occurs is more, as the switching losses depend upon the no of switching devices (c) some strategies use very complex control algorithm. To overcome all these type of problems, a new power factor correction technique using PFC boost converter is proposed.

3. PROPOSED POWER FACTOR CORRECTION TECHNIQUE

The block diagram of proposed configuration is shown in Fig. 2. This uses less no of switching devices, simple control strategy and uses one converter to compensate the harmonic current generated by the non-linear load. The Power factor correction technique is proposed in this paper in order to avoid harmonic pollution along the power line caused by a single phase diode rectifier.

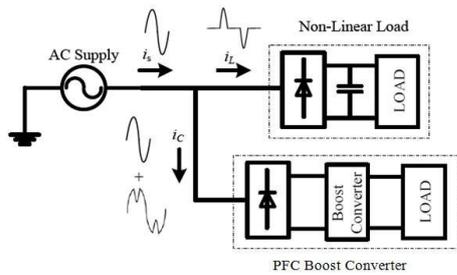


Fig 2: Proposed Configuration

The proposed arrangement acts as a current source connected in parallel with the nonlinear load and controlled to produce the harmonic currents required for the load. In this way, the ac source needs only to supply the fundamental currents. This configuration consists of one PFC boost converter which is connected in shunt with the non-linear load (diode rectifier) to compensate the harmonic current drawn by the non-linear load. This configuration uses hysteresis current control technique to track the line current command. Hence the total arrangement draws nearly sinusoidal current from source. Power switch in the proposed converter are controlled to draw a nearly sinusoidal line current with low current distortion and low total harmonic distortion (THD) of supply current waveform and also regulate the DC bus voltage. Fig. 3 shows the proposed configuration. In this configuration the inductor current i_c is forced to fall within the hysteresis band by proper switching the power switch 'S'. In this configuration the load1 operates in nominal DC voltage where as the load2 operates in high voltage (i.e. more than nominal DC voltage).

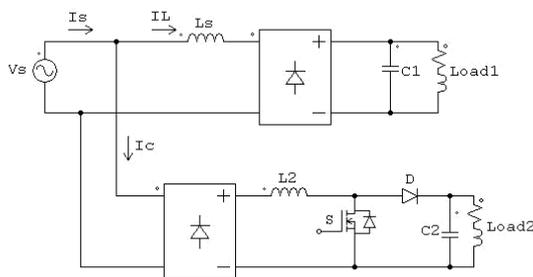


Fig 3: Proposed Power factor correction technique

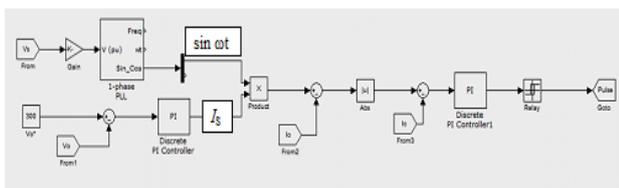


Fig 4: Adopted control scheme for the proposed power factor correction technique.

4. ADOPTED CONTROL SCHEME

The control scheme adopted in this proposed technique is very simple and can be practically implemented easily. Fig. 4 shows the block diagram representation of the adopted control scheme. v_0^* is the reference voltage that is expected at the output of the boost converter & v_0 is the actual output of the boost converter. The error in the output voltage is given to the voltage controller.

The voltage controller (PI controller) processes the error signal and produces appropriate current signal (I_s). The current signal (I_s) is multiplied with unit sinusoidal template which is produced by using phase locked loop (PLL), to produce $I_s \sin \omega t$. The load current i_o subtracted from the $I_s \sin \omega t$ to produce the reference current signal i_s^* . As the boost inductor current can't be alternating, the absolute circuit gives the absolute value of the reference current signal i_s^* that is i_o^* . The actual signal (i_o) and the required reference signal (i_o^*) are given to the current controller to produce the proper gating signal. The current controller adopted is a hysteresis current controller. Upper and lower hysteresis band is created by adding and subtracting a band 'h' with the reference signal i_c^* respectively shown in the Fig. 4. The inductor current is forced to fall within the hysteresis band. When the current goes above the upper hysteresis band, i.e. i_c^*+h , the pulse is removed resulting the current forced to fall as the current will flow through the load. When the current goes below the lower hysteresis band i.e. i_c^*-h , the pulse is given to the switch, so the current increases linearly. In this way the switching of the power switch can be done to track the reference current command & the resultant current drawn by both the loads will be nearly sinusoidal with low harmonic (THD); hence the power factor of the supply can be improved.

5. SIMULATION RESULT

By using the sample circuit, we designed the proposed circuit of improved PFC boost converter by using MATLAB software. Main aim of this project is to reduce the harmonics and to achieve the power factor nearer to unity.

In the proposed circuit we mainly convert into ac-dc converting is mainly done by using diode rectifier. Due to rectifier (non linear loads) converting the ac-dc in that period the harmonics are produced in the circulating current that will affect the both input side and as well as to load. In fig.7, boost converter circuit is isolated, which the breaker switch is in 0 states. The capacitor is connected at the load side to hold the DC output voltage, when the instantaneous value of the

supply voltage is more than DC output voltage current will be supplied by the source. So the current is pulsating type, this pulsating current produces large amount of harmonics which will enter to the system. As the harmonic content is very high in the supply current, the total harmonic distortion of the supply current is 240% & the power factor of the system is very poor & of the order of 0.38 lagging with non-linear load valued as 20mH, 500Ω, 1000μF.

This harmonic current should be removed at the point of generation. So to remove the harmonic current generated by the non-linear load, a PFC boost converter is connected in shunt with the diode rectifier by using a breaker switch with initial state as 1 as shown in Fig.8. The loads at the boost converter circuit are said to be sensitive loads and valued as 470μF, 100Ω, 10mH. As this sensitive load is affected by the non-linear load, the boost converter circuit produces compensating current to compensate the harmonics. The compensating current is shaped in such a way that the total current drawn by the total arrangement becomes sinusoidal. Then we can achieve the improved power factor and the harmonic contents will be decreased. Hence, we can obtain total harmonic distortion of the supply current is 13% and the power factor of the system is improved to 0.98. The boost converter circuit is controlled by using improved hysteresis current control scheme.

Mainly in improved hysteresis current control is a controlling circuit to the proposed PFC boost converter circuit, from which the gate pulses are given to the boost converter. Mainly the switch used in this project are MOSFET, because it is having higher switching frequency and less cost when compared to other switching devices.

Fig. 10 shows different waveforms of the system after compensation using PFC boost converter. As we know, the more harmonic content in the supply current increases the total harmonic distortion (THD) of the system hence the overall power factor of the system decreases. This harmonic current should be removed at the point of generation. So to remove the harmonic current generated by the non-linear load, a

Block Diagram of PFC Boost Converter

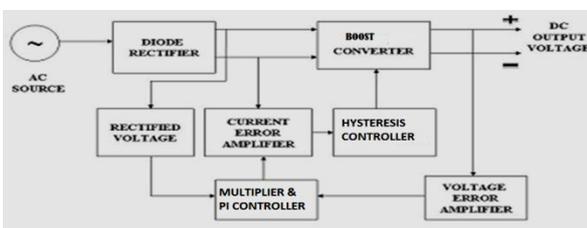


Fig 6: Block diagram representation

Simulated Circuits

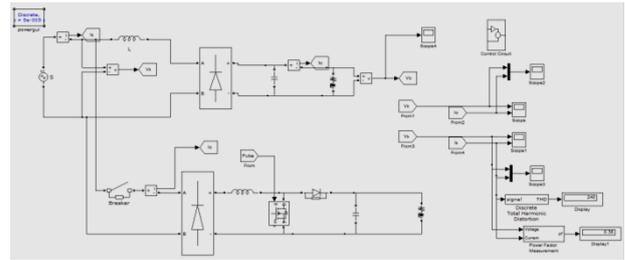


Fig 7: Simulated circuit when the boost converter circuit is isolated.

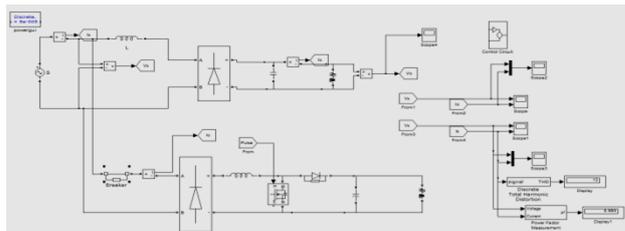


Fig 8: Simulated circuit for power factor enhancement when the boost converter circuit is connected

Simulated Waveforms



Fig 9(A): Supply voltage and non-linear load current

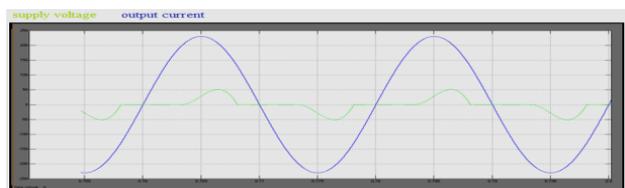


Fig 9(B): supply voltage and output current before compensation

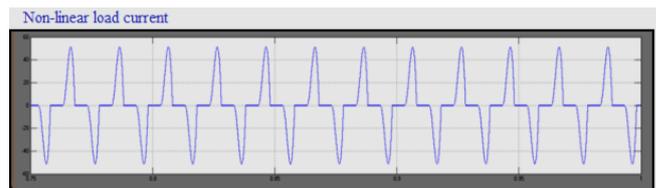


Fig 10(A): Non-linear load current

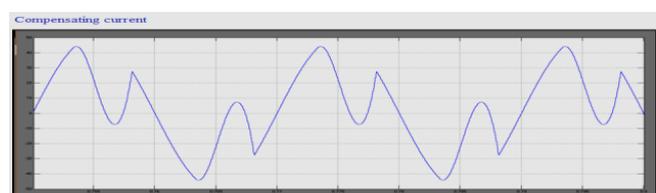


Fig 10(B): Compensating current



Fig 10(C): supply voltage and output current after compensation.

PFC boost converter is connected in shunt with the non-linear load & the compensating current is shaped in such a way that the total current drawn by the total arrangement becomes sinusoidal. The source feels the total arrangement to be resistive load and supply nearly sinusoidal current with nearly unity power factor. The current drawn by the non-linear load is shown in Fig. 10(a) and the compensating current wave form shown in the Fig. 10 (b) resulting supply current to be nearly sinusoidal shown in Fig. 10 (c). Resulting supply current to reduce to 13% and improve the supply power factor to 0.993.

6. COMPARISION RESULT

Table I: Comparison of Different Parameters

S.No	Parameter	Before Compensation	After Compensation
1	THD	240%	13%
2	Power factor	0.38	0.993
3	Current shape	Pulsating	Nearly Sinusoidal

7. CONCLUSION

This paper has presented one new and interesting AC/DC boost-type converters for PFC applications. Without using any dedicated converter, one converter can be used to eliminate the harmonic current generated by the other non-linear load. With the help of simulation study, it can be concluded that, this configuration removes almost all lower order harmonics, hence with this configuration we can achieve power factor nearer to unity, THD less than 15%. However, this technique can be limited to application where the non-linear load (pulsating) current is less and fixed. Besides, the literature review has been developed to explore a perspective of various configurations of for power factor correction techniques.

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