A New Converter for Dc Motor Applications with Power Factor Correction

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Abstract — **Generally non-linear loads are the main source of harmonics. This paper presents one new control scheme to compensate the harmonic current generated by the diode rectifier so as to achieve a power factor nearer to unity and regulate the DC-bus voltage. This scheme uses one PFC Boost Converter which is connected in shunt with the diode rectifier to compensate the harmonic current drawn by the single phase diode rectifier. The line current command is derived from a dc link voltage regulator and an output power estimator. The hysteresis current controller is used to track the line current command. In absence of diode rectifier (Non-linear Load), the PFC boost converter draws purely sinusoidal current from source. In presence of diode rectifier the PFC boost converter draws current in such a way that the total current drawn from source becomes purely sinusoidal. Merits of the proposed converters include higher power density, simpler control strategy, less harmonic control contents, nearly unity power factor and unidirectional power flow. Optional principle, design analysis and conditions achieving for the proposed converters are described.**

Keywords:— ***Power factor Correction, PFC Boost Converter, Active Filter.***

I. 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.

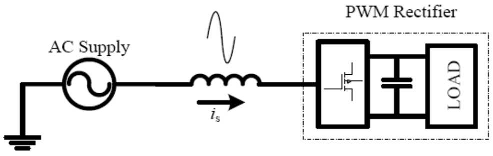
The conventional power quality compensation approach is given in Fig. 1(c). The active rectifier of the AC/DC/AC converter is used to regulate the DC bus voltage for motor drive. The nonlinear load produces a pulsating current with large current harmonics. An active power filter is employed to compensate 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.

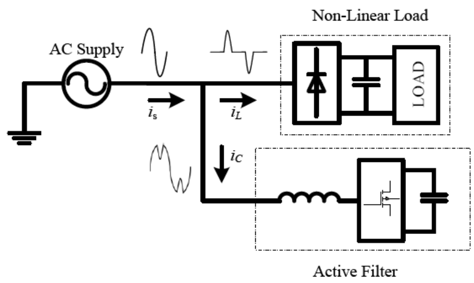
The proposed PFC technique consists of one full-bridge diode rectifier and one Boost PFC Converter. Here the full bridge diode rectifier is considered as the non-linear load which is the source of harmonics. A hysteresis current control is adopted to track the required line current command. In this arrangement 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.

II. CONVENSIONAL 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.



(a)



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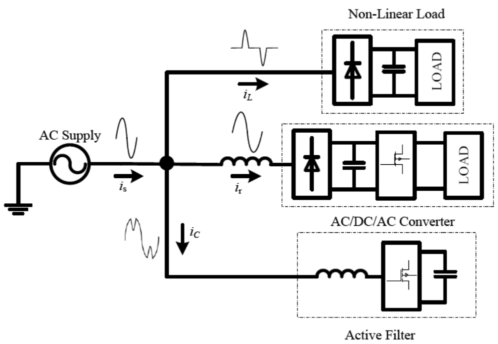
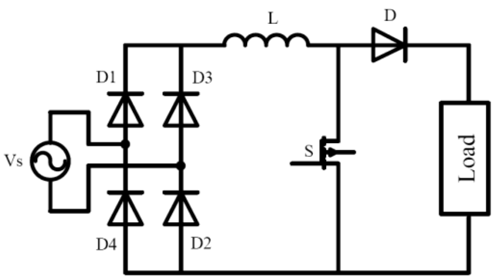


(c)



(d)

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.

III. 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.

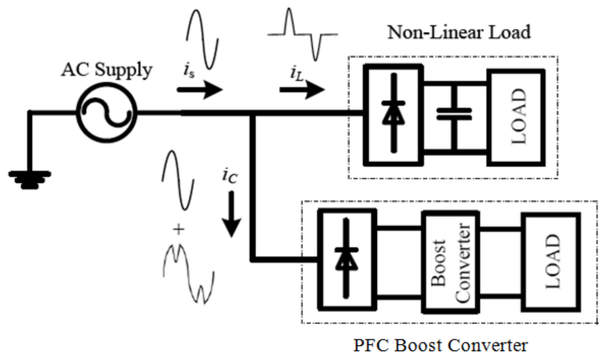


Fig.2. Proposed Configuration

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', shown in Fig. 3 (a) & (b). In this configuration the load1 operates in nominal DC voltage where as the load 2 operate in high voltage (i.e. more than nominal DC voltage).

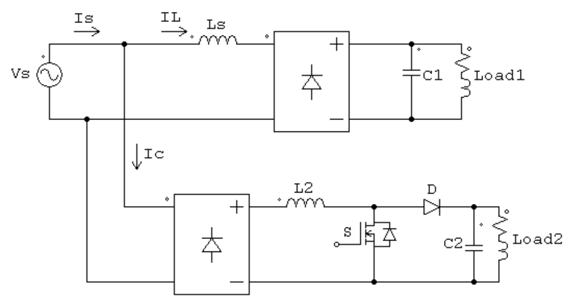
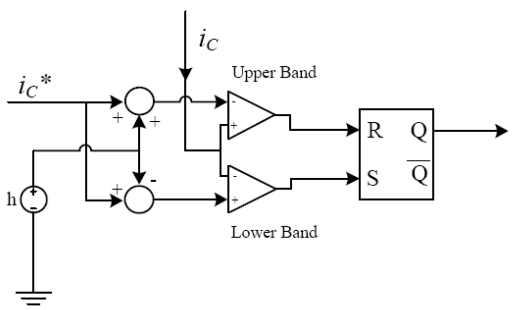


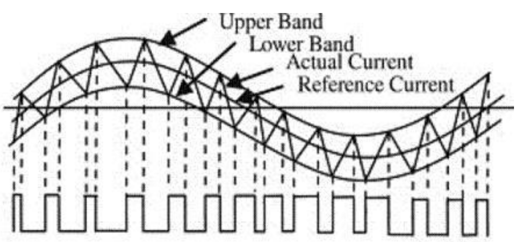
Fig.3. Proposed Power factor correction technique

IV. ADOPTED CONTROL SCHEME

The control scheme adopted in this proposed technique is very simple and can be practically implemented easily. Fig. 5 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.



(a)



(b)

Fig.4. (a) Hysteresis band, (b) pulses depending upon the actual current wave form [14]

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 ωt. The load current i_L subtracted from the I_S sin ωt 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_C^*. The actual signal (i_C) and the required reference signal (i_C^*) 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 (a) & (b). 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 content and low total harmonic distortion (THD); hence the power factor of the supply can be improved.

V. SIMULATION RESULT

The proposed power factor correction technique is simulated by using PSIM software and the results obtained are shown below. The values taken in the simulation circuit are given in the below table. The different results are shown & explained briefly.

TABLE I. PARAMETER TAKEN FOR SIMULATION

Sl. No.	Name	Value
1.	Supply voltage	100V (P-P), 50Hz
2.	Source impedance	0.1mH
3.	Boost Inductor	10mH
4.	Output of Boost Converter	495V
5.	Non-linear Load	20mH, 2000Ω, 100mF
6.	Boost Converter	1000μF, 2000Ω, 10mH
7.	Hysteresis Band (h)	0.05

Fig. 6 shows different wave forms of the system feeding to a non-linear load. As the capacitor is connected in the load side to hold the DC output voltage, when the instantaneous value of

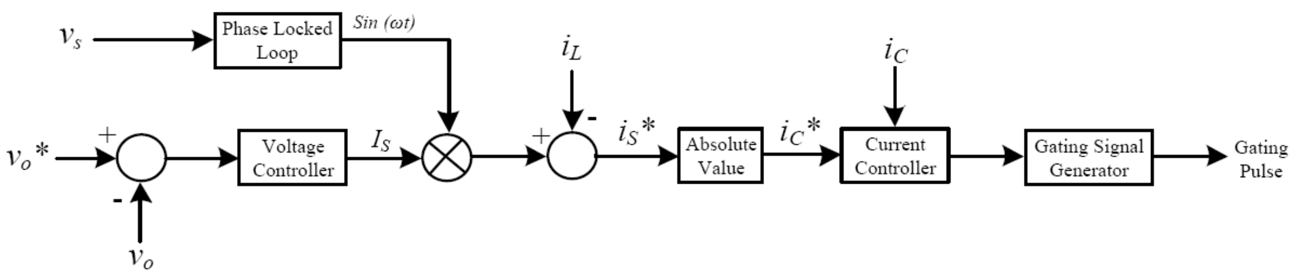


Fig.5. Adopted control scheme for the proposed power factor correction technique

the supply voltage is more the than DC output voltage current will supplied by the source. So the current is pulsating type which is shown in the Fig.6 (a). Generally this pulsating type current contains large amount of harmonics, mainly dominant lower order harmonics which when enters into the system results harms to the other loads connected at point of common coupling (PCC).

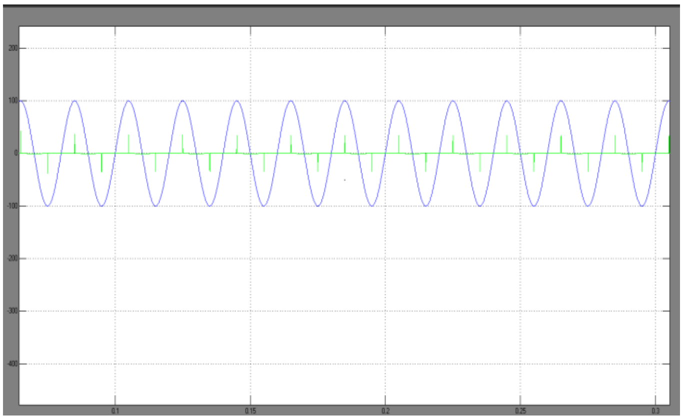


Fig.6. (a) Supply voltage & Non-linear load current without compensation

Fig. 7 shows different waveforms of the system after compensation using PFC boost converter. As we know, the more harmonics 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 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 without compensation is shown in Fig. 7 (a) and Supply voltage& Non-linear load current with compensation

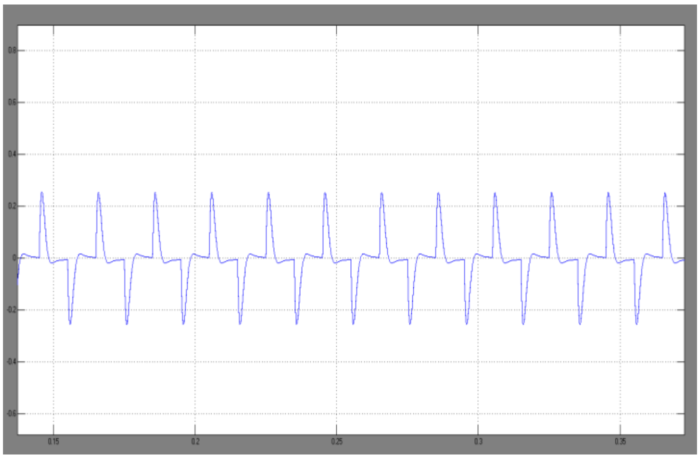


Fig.7. (a) Non-linear load current without compensation

shown in the Fig. 7 (b) Non-linear load current with compensation shown in Fig. 7 (c).

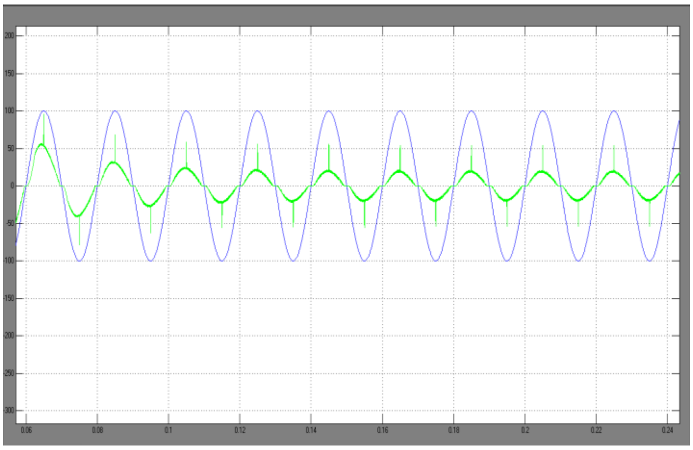


Fig.7(b) Supply voltage& Non-linear load current with compensation

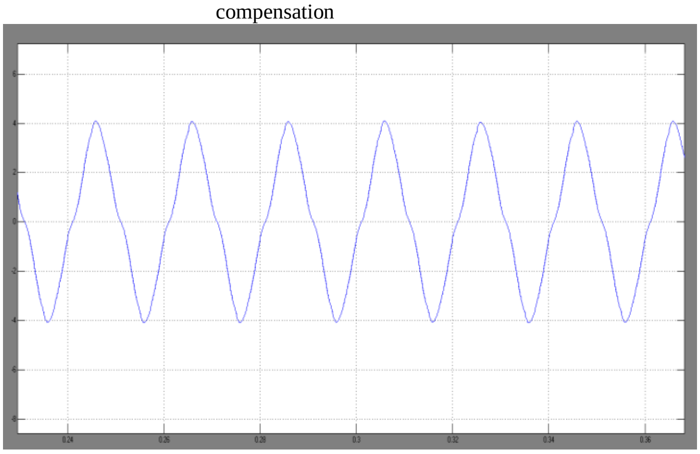
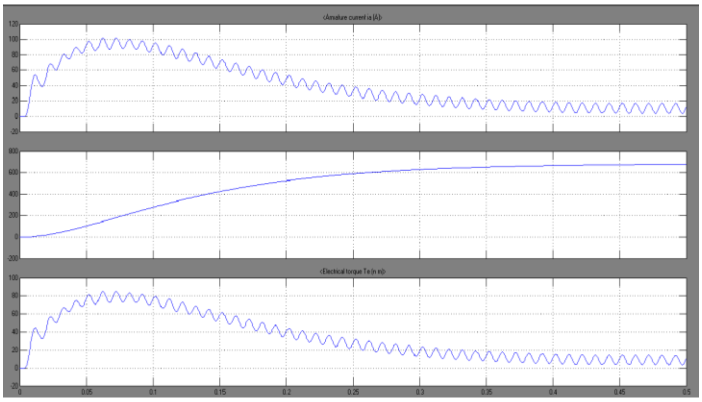


Fig.7(c) Non-linear load current with compensation

Following wave forms shows the output waves of DC motor load at PFC boost converter output terminal. First wave form represents the Armature current ,second wave form shows the speed variation of motor and third one is Electrical torque of motor.



VI. COMPARISION OF RESULTS

TABLE II. COMARISION OF DIFFIRENT PARAMETERS

Sl. No.	Parameter	Before Compensation	After Compensation
1	THD	109%	12%
2	Power Factor	0.133	0.989
3	Current Shape	Pulsating	Nearly Sinusoidal

VII.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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