A Power Factor Correction Technique Using Boost Converter

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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 Boost Converter, which is connected in shunt with the series diode rectifier to eliminate 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. In absence of diode rectifier (Non-linear Load), the boost converter draws purely sinusoidal current from source. In presence of diode rectifier the boost converter takes current in such a way that the total current drawn by the diode rectifier load from source becomes purely sinusoidal. Advantages of these boost converters include higher power ratings, simple control techniques, less harmonic control contents, nearly unity power factor. Optional principle, design analysis and conditions achieving for the proposed converters are described.*

Keywords*: Power Factor Correction, Boost Converter, And Active Filter.*

1. INTRODUCTION

Due to the large growth of nonlinear loads, such as power electronics converters, SMPS (Switching Mode Power Supplies), computer, serious power problem is produced and reflected in to the distribution and transmission network. The poor power factor and non-sinusoidal current from the AC source are the main drawbacks of the power electronic devices. This circuit generates serious power pollution in the transmission or distribution system. The power effects 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. Several topologies and control strategies of power factor correctors .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 [5-6] 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 standard 519 on the quality of input current that can be drawn by low power equipment, a PFC circuit is typically added as a front-end stage. The boost converter circuit is popularly used in most of the application because it is operating in continuous conduction mode. This is because the continuous nature of the boost converter's input current result in low conducted electromagnetic interference compared to other active PFC technique such as buck-boost converters.

The conventional power quality compensation approach is given in fig.1(c). The active rectifier of AC/DC /AC converter is used to regulate the DC bus voltage for motor drive. The nonlinear load produces a non-sinusoidal current with large current harmonics. An active power filter is used to compensate the reactive power needs of nonlinear load and additional inverters. The cost of implementation of this strategy is very high [4].

To combine the capabilities of power factor correction, active power filter and AC/DC converter, a new power factor correction technique using boost converter is proposed to work simultaneously as an active power filter to supply compensated currents that are equal to harmonic currents produced from the nonlinear loads, and AC/Dc converter supplies the DC power to its load ad takes a nearly sinusoidal current from supply and hence dedicated power devices are needed for the harmonic reduction.

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

2. CONVENSIONAL POWER FACTOR CORRECTION TECHNIQUE

The single phase diode rectifier associated with boost converter as shown in fig.1 (d), is widely employed in active PFC. In principle the combination of the diode bridge rectifier and DC to DC converter with filtering and energy storage elements can be extended to another technique such as buck, buck-boost converter. The boost technology is very simple and allows low distorted dedicated control techniques.

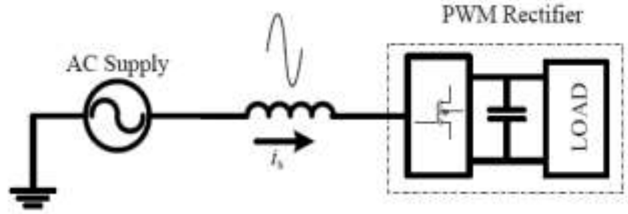

Fig.1 (a)

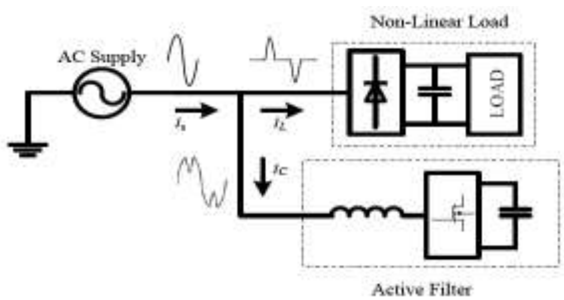

Fig.1 (b)

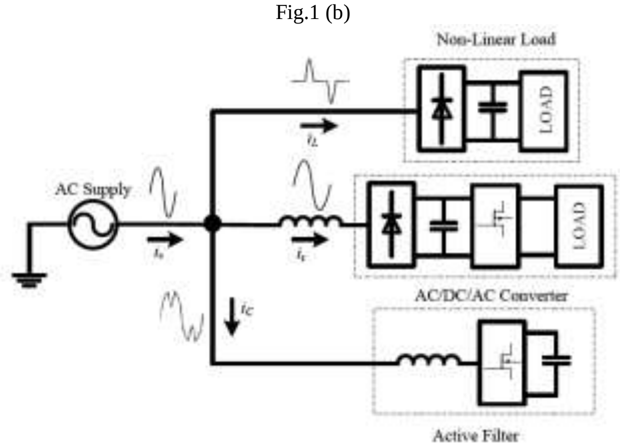

Fig.1 (c)

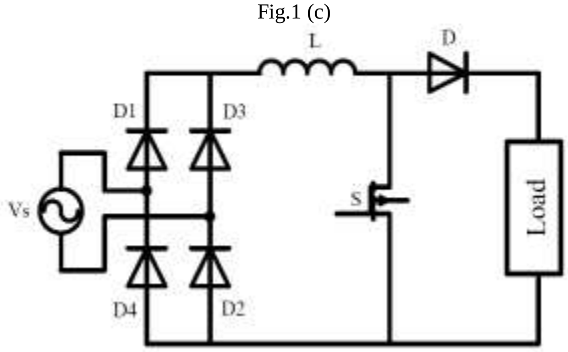

Fig.1 (d)

Fig.1.(a) power factor corrector (b) shunt active power filter(c) conventional power quality compensator (d) active power factor correction technique using (b),

Typical strategies are hysteresis control, average current mode control and peak current control. More recently on cycle control and self control have also employed. active power filter is used to eliminate the harmonic current generated by the power electronic 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 depends upon the number of switching devices,(c)some strategies use very complex control algorithm. To overcome all these type of problem, 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 number of switching devices, simple control strategy and uses one convertor to compensate harmonic current generated by 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 single-phase diode rectifier.

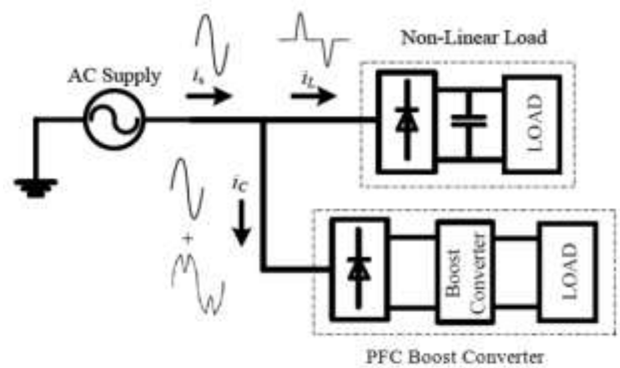

Fig.2: Proposed Configuration

The proposed arrangement acts as a current source connected in parallel with the non-linear load and control to produce the harmonic currents required for load. In this way, the AC source needs only to supply the fundamental currents. This method consists of one boost converter, which is connected, in parallel with the non-linear load to compensate the harmonic current drawn by non-linear load. This configuration uses hysteresis current control technique to track the line current command. Hence total arrangement draws nearly sinusoidal current from the 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 of supply current waveform and also regulate DC bus voltage.Fig.3 shows the proposed configuration. In this configuration the inductor current 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 load 1 operates in nominal DC voltage whereas the load to operating high voltage (i.e. more than nominal DC voltage).

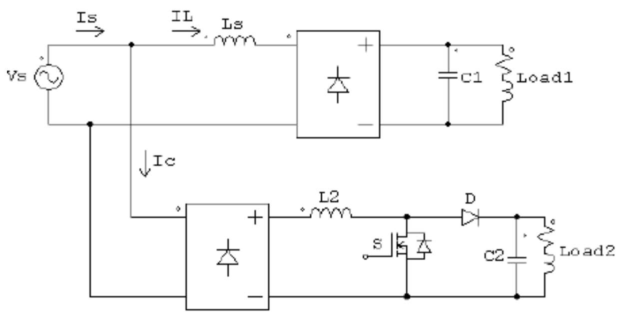

Fig.3: Proposed Power factor correction technique

4. ADOPTED CONTROL SCHEME

The control scheme adopted in this proposed technique is very simple and can be practically implemented easily.Fig.5 shows the block diagram representation of adopted control scheme v_0^* is the reference voltage that is expected at the output of boost converter and v0 is the actual output of boost converter. The error in the output voltage is given to voltage controller.

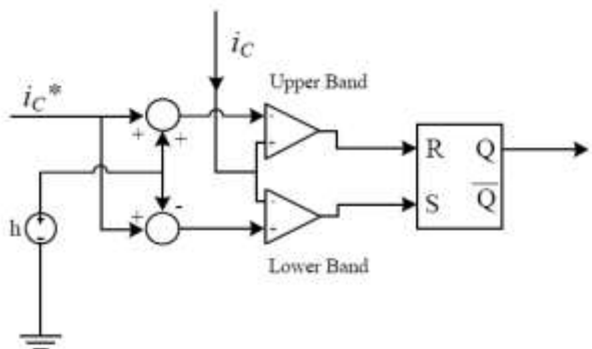

Fig.5 (a)

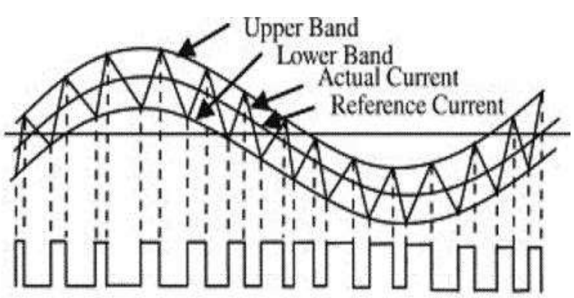

Fig. 5(b)

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

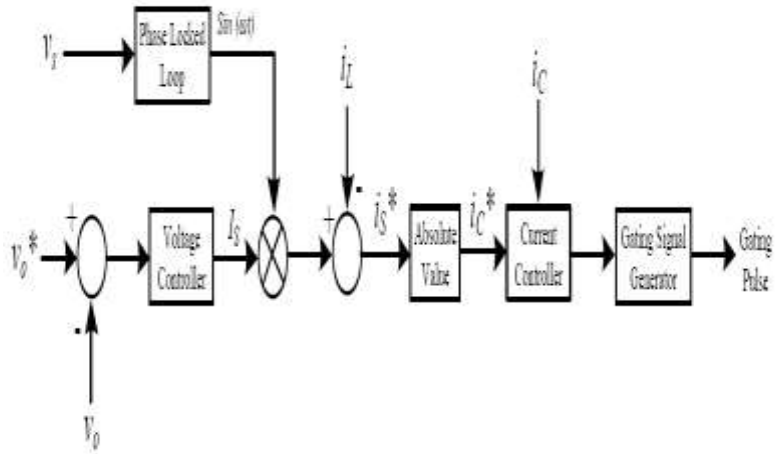

Fig.5 (b). Adopted control scheme for the proposed power factor correction technique

The voltage controller (PI controller) processes the error signal and produces appropriate current signal (Is). 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_L is subtracted from Is sinωt 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.

The actual signal and the required reference signal are given to 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 band h with the reference signal i_c* shown fig.4 (a) & (b). The inductor current is forced to fall within the hysteresis band. When the current goes below the lower hysteresis band the pulse is given to the switch, so the current is increases linearly. In this way the switching of the power switch can be done to track the reference current command and the resultant current drawn by both the loads will be linearly sinusoidal with low harmonic contain and low total harmonic distortion, hence the power factor of supply is improved

5. 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 1. Parameter Taken For Simulation

Sr. No.	Name	Value

1	Supply Voltage	230v,50Hz
2	Source Impedance	0.12mH
3	Boost Inductor	2.2mH
4	Output Of Boost Converter	300v
5	Non-linear Load	20mH,550Ω,1000μF
6	Boost Converter	480μF, 105Ω, 10mH
7	Hysteresis Band	0.05

Fig. 6 shows different waveforms 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 the supply voltage is more than the 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). Fast Fourier transform (FFT) analysis of the supply current is given in the Fig. 6 (b). As the harmonic content is very high in the supply current, the total harmonic distortion of the supply current is 242% & the power factor of the system is very poor & of the order of 0.38 lagging.

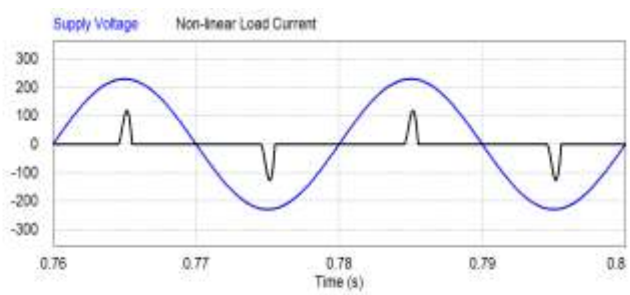

Fig.6. (a)

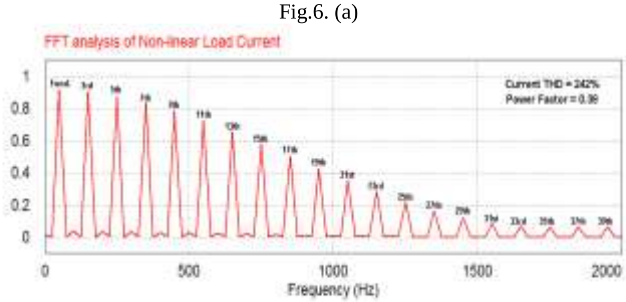

Fig.6. (b)

Fig.6. (a) Supply voltage & Non-linear load current (b) FFT analysis of supply current

Fig.7 shows different waveforms of the system after compensation using PFC boost converter. The more harmonics present in the supply current raise the total harmonic distortion of the system. This harmonic current should be removed at the point of generation. So to remove the harmonic current generated by the diode rectifier load, a proposed boost converter is connected across 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. supply nearly sinusoidal current with nearly unity power factor. The current drawn by the non-linear load is shown in Fig. 7 (a) and the compensating current waveform is-

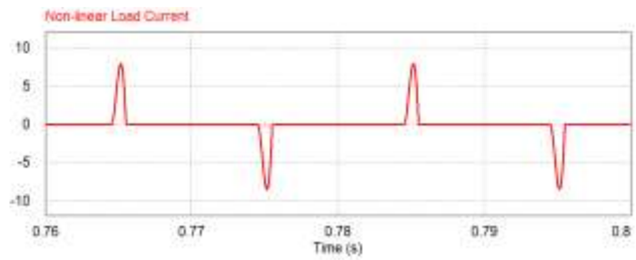

Fig. 7(a)

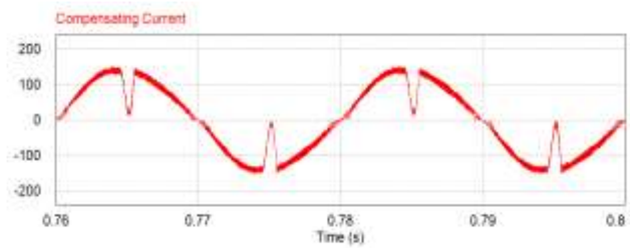

Fig. 7 (b)

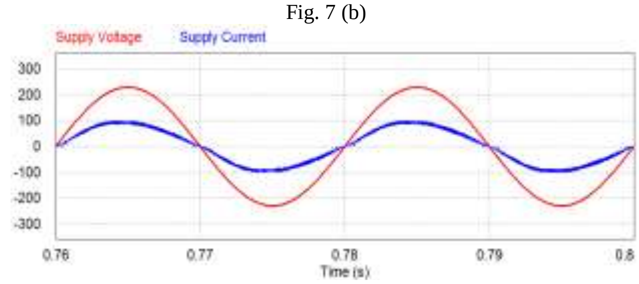

Fig. 7 (c)

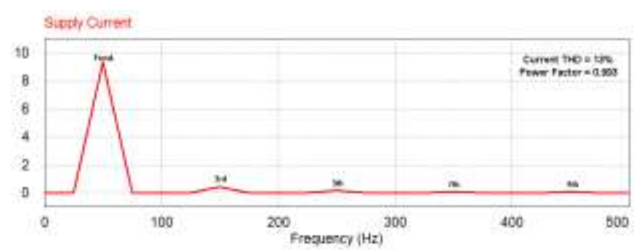

Fig. 7 (d)

Fig.7.(a) Non-linear load current, (b) Compensating current, (c) Supply voltage and supply current (d) FFT analysis of supply current. shown in the Fig. 7 (b) resulting supply current to be nearly sinusoidal shown in Fig. 7 (c). From Fig.7.(d), we observe the harmonics present in the supply current with proposed boost converter technique is almost neglected. The lower order harmonics content in the load current almost removed and only fundamental current drawn from the supply shown in Fig. 7 (d), resulting supply current to reduce to 15% and improve the supply power factor to 0.993.

Table 2. Comarision of diffierent parameters

Sr No.	Parameters	Before Compensation	After Compensation
1	THD	242%	15%
2	Power Factor	0.38	0.993
3	Current Shapes	Pulsating	Nearly Sinusoidal

6. CONCLUSION

This paper has presented one new and interesting AC/DC boost type converters for PF applications. Without using any dedicated converter, one converter can be used to eliminate the harmonic current generated by 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 16%. However, this technique can be limited to application where the non-linear load current is less and fixed.

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