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Improved Power Quality of Active Power Filter using pi Controller

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ABSTRACT
Conventionally, the major part of electrical power was consumed by linear loads, which carry the sinusoidal current in proportion to supply voltage. However majority of these linear loads is phase displaced with respect to the supply voltage resulting in low power factor. In recent years, the application of power electronics has grown tremendously. These power electronics systems offer highly non-linear characteristics and draw non sinusoidal current from utility, causing harmonic pollution into supply system. Increase in such non-linearity results in undesirable features such as distortion of supply voltage, low system efficiency and a poor power factor. They also cause disturbance to other consumers and interference in nearby communication networks. To overcome these problems, active power filters have been developed. In this work both PI controllers based , three-phase shunt active power filter to compensate harmonics and reactive power by nonlinear load to improve power quality is implemented for three-phase three wire systems. MATLAB simulation model has been developed to simulate the system operation. Various simulation results are presented under steady state conditions and performance.

Key words: Harmonic reduction, Active filter, PI controller, THD.

Introduction
In recent years, the increasing use of power electronics in the commercial and industry processes results in harmonics injection and lower power factor to the electric power system [16]. Conventionally, in order to overcome these problems, passive R-L-C filters have been used. The use of this kind of filters has several disadvantages. Recently, due to the evolution in modern power electronics, new device called “shunt active power filter (SAPF)” was investigated and recognized as a viable alternative to the passive filters. The principle operation of the SAPF is the generation of the appropriate current harmonics required by the non-linear load.In fact active filters do not present all the typical drawbacks of passive systems such as the detuning of single tuned filters due to changes of system operative conditions and surrounding environment or the generation of resonance at particular frequencies, between the network and filter reactance, that amplifies unwanted harmonics.

Active power filters are more and more capturing the interest of researchers and industries owing to the decreasing quality of power supplied by the electrical distribution companies and the difficulties in fulfilling the constraints imposed by national and international standards only by using traditional compensating strategies. The use of active systems for compensating harmonic distortion and reactive power in the supply electrical networks, both at user level or at a higher voltage level, is now more often preferred to the classical passive compensating methods.

In a modern electrical distribution system, there has been a sudden increase of nonlinear loads, such as power supplies, rectifier equipment, domestic appliances, adjustable speed drives (ASD), etc. As the number of these loads increased, harmonics currents generated by these loads may become very significant. These harmonics can lead to a variety of different power system problems including the distorted voltage waveforms, equipment overheating, malfunction in system protection, excessive neutral currents, light flicker, inaccurate power flow metering, etc.

To reduce harmonic distortion and power factor improvement, capacitors are employed as passive filters. But they have the drawback of bulky size, component aging, resonance and fixed compensation performance. These provide either over- or under-compensation of harmonics, whenever a load change occurs [4]. In order to overcome these problems, active power filters (APFs) have been developed. The voltage-source-inverter (VSI)-based shunt active power filter has been used in recent years and recognized as a viable solution [5].

Active filters, besides, permit the control and the compensation of distorted line currents adapting themselves to the load changes and to changing in working frequency. The most effective and the most diffuse structure in active filtering systems is certainly the shunt one composed by an inverter fed by a capacitor and a passive filter used to inject the compensating currents in the grid (Fig. 1).In order to overcome these problems, active power filters (APFs) have been developed. The voltage-source-inverter(VSI)-based shunt active power filter has been used in recent years and recognized as a viable solution [5]. The control scheme, in which the required compensating currents are determined by sensing line currents only, is givenin [6]-[7], which is simple and easy to implement. The scheme uses a conventional proportional plus integral (PI) controller for the generation of a reference current template.

2. The Active Power Filter

When linear loads are connected to the supply the waveforms are linear. Whereas non linear loads are connected harmonic appears on electric voltage or current. The harmonics are integer multiples of system frequency. This leads to various power quality problems like heating of the devices, mis–triggering of the drives, pulsating output in the motors, etc., a harmonic filter are used to eliminate the harmonics. There are three basic types of harmonics filters given below.

2.1 Passive power filters (PPF)

It is a type of filter, which consists of only passive components. It consists of linear elements like resistors, capacitors and inductors. They are also called as LC filters, which produce series resonance or parallel resonance that forms a major drawback of this type of filter. Another drawback of PPF is the cost which increases as the voltage rating of the inductor and capacitor increases.

2.2 Active Power Filter (APF)

APF is a type of filter that uses either current or voltage source as its major component. They compensate voltage or current harmonics by injecting the negative of the harmonic signal measured injected signals fed are of same magnitude but in phase opposition with the measured harmonic signals. It is controlled to draw/supply a compensated current from/to the utility, such that it eliminates reactive and harmonic currents of the non-linear load. Thus, the resulting total current drawn from the ac mains is sinusoidal. Ideally, the APF needs to generate just enough reactive and harmonic current to compensate the non-linear loads in the line [12].

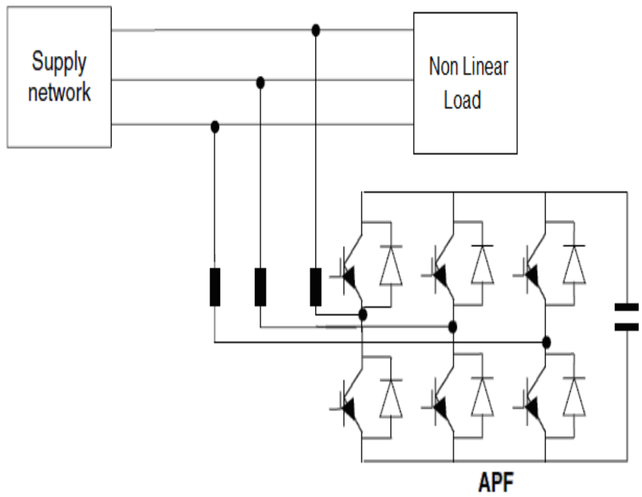
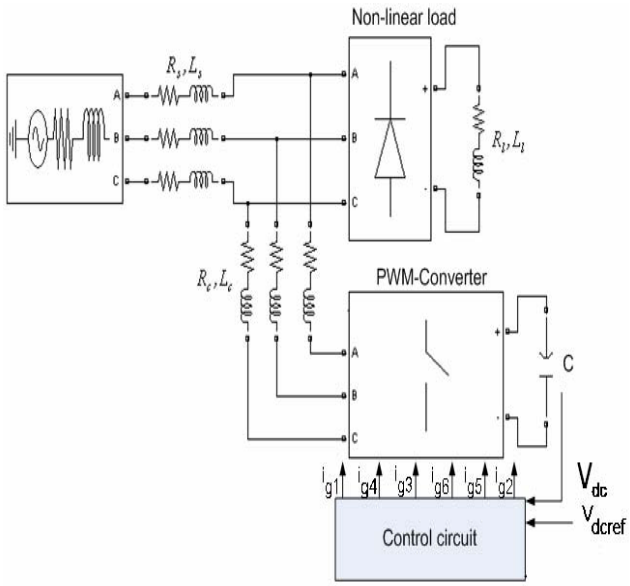


Fig. 1 Active power filter connected with transmission line

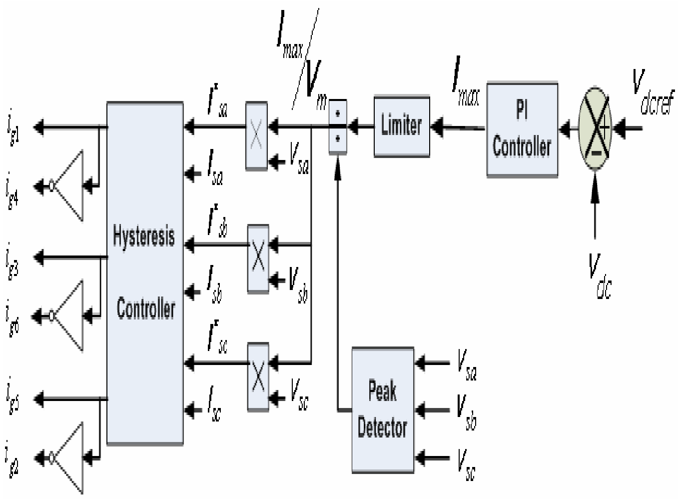
3. Active Filter Control Scheme

3. 1 PI Control Scheme

Fig.2shows the active power filter compensation systemwith PI control scheme. In order to implement the control algorithm of ashunt active power filter, the DC capacitor voltage (V_{dc}) issensed and compared with the reference value (V_{dcref}). The Input of PI controller is the value of Error, e = V_{dcref}− V_{dc},and its output, after a limit, is considered as the magnitude ofpeak reference current max I . The switching signal for thePWM converter are obtained from comparing the actualsource currents (isa , isb ,isc) with the reference currenttemplates (Isa IsbIsc) in a hysteresis current controller. Theoutput pulses are applied to the switching devices of the PWMconverter [14]. Since coefficients of PI controller, Kpand Ki , are fixed in this model, the performance of active power filter under random load variation conditions is not as well as 'fixed load' condition.



(a) Active filter system



b) Active filter system using PI controller

Fig. 2 a) Active filter system b) Active filter system using PI controller

4. Simulink model of Active power filter

Fig. 3 shows the block diagram of PI controller used for the controlling of active power filter.

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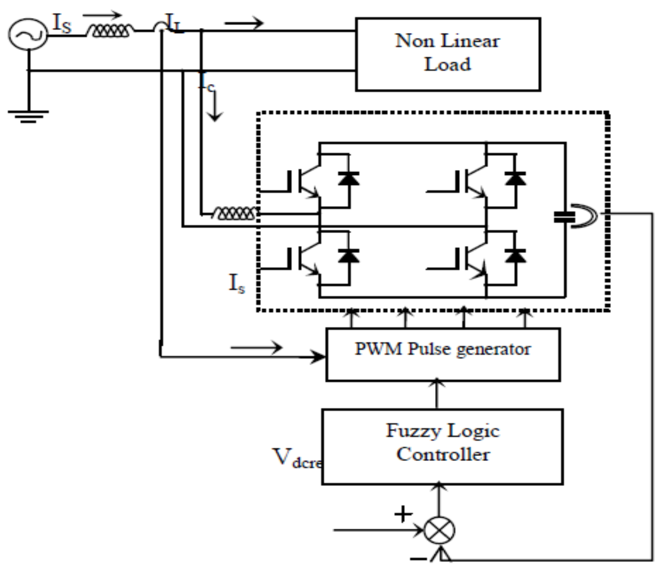

Fig. 3 Block Diagram of PI controlled improved power quality converter

The simulation is done using MATLAB for the PI controlled voltage source PWM rectifier. The complete rectifier system is composed of mainly (1) three phase source, (2) voltage source PWM rectifier, (3) PI controller, and (4) hysteresis controller.

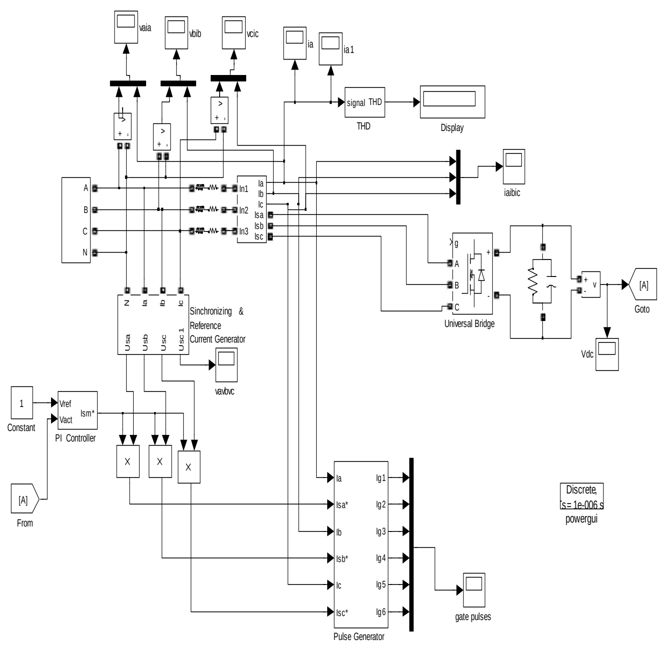

Fig. 4 Simulated power circuit without controlled improved power quality converter

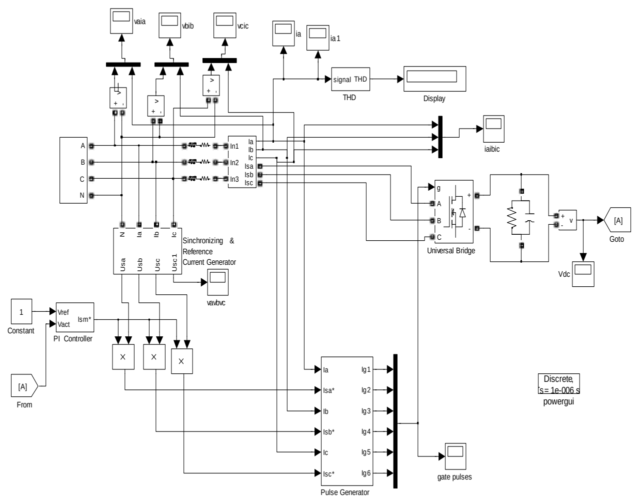

Fig. 5 Simulated power circuit for PI controlled improved power quality converter

5. Simulation Results

The current and voltage waveform of the conventional three phase rectifier without controller is shown in fig 6. The current waveform for one cycle and its harmonica spectrum is shown in fig 7 (a) & (b). The current is non sinusoidal and total harmonica distortion (THD) is very high (88.84%). To make the current sinusoidal and THD within permissible limit current controller is used.

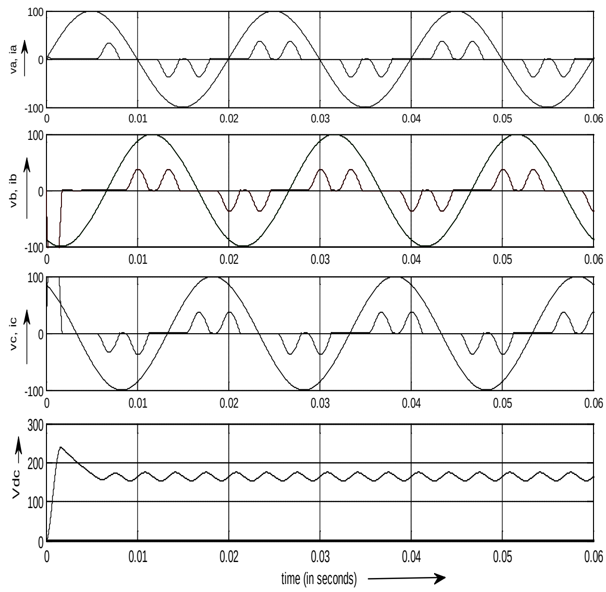

Fig. 6 Waveform without controller

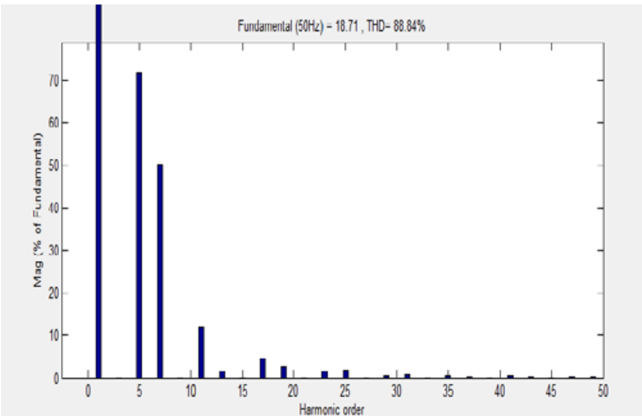

Fig. 7 Harmonics spectrum without controller

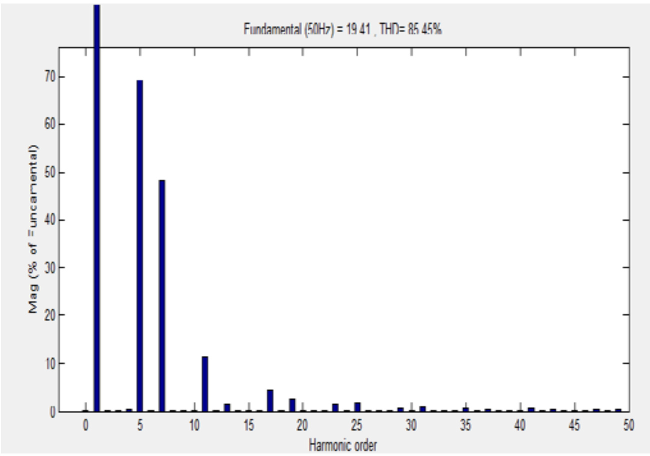

Fig. 8 Harmonics spectrum with PI controller

Table 1: Comparative Analysis of THD By Using Various Controllers

S.No.	Name of controller	THD(%)
1	Without controller	88.84
2	With PI controller	85.45

6. Conclusion

Based on the simulation results, it can be concluded that, PI controlled PWM rectifier perform satisfactory for the compensation of line current. After compensation, line current become sinusoidal, balanced and in phase with the respective source voltage and reduces the THD of the source current below 5% limit. It is clear from simulation result that the transient performance of the source current and DC side capacitor voltage is better for the PI controller in term of the setting time and % rise/fall in DC link voltage.

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