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Harmonics Reduction Using Shunt Active Filter in Balanced Sinusoidal Source Voltage

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Abstract

Voltage, current and frequency are physical characteristic that define the power quality of the system. If any disturbance in physical characteristics of that results in damage, upset or failures of end use equipment. These are higher switching frequency and the non linearity in the properties of the power electronics being mostly responsible for the power quality problem. So the development of active filter to solve this problem to improve power quality among this which shunt active power filter used to compensate the harmonics and reactive power. A shunt active power filter with instantaneous active and reactive power theory (P-Q theory) has been proposed for its performance and ability to compensate the harmonics and reactive power. It has been investigated through simulation that under three phase, three wire system with balanced sinusoidal source voltage. Shunt active filter is able to mitigate the total THD specified by power quality standard. Matlab/simulink is used as a simulation tool for analyzing.

Keywords: Shunt active filter,pq theory,THD

Nomenclature

THDv total harmonics distortion in voltage

THDi total harmonics distortion in current

IGBT insulated gate bipolar transistor

1. Introduction

Harmonics current produced by non linear loads like use of power electronics in system can interact adversely with a wide range of power system equipment, mainly transformer, capacitors and motors, causing additional losses, overheating and overloading[2]. These harmonics current is also cause interference with telecommunication lines and errors in protective relays and power metering. In the past tuned passive filter are used to solve the problem of harmonic distortion but this filter offered some disadvantage like: They filter the frequency only tuned for it, their operation cannot be limited to a certain load, resonance can occur because of the interaction between the passive filter and load with severe effects[2].To compensate this drawback use of active power filter line conditioners or simply active power filter. The performance of active power filter mainly depends on the reference current generation strategy, control technique and topology of filter inverter. There are basically two types of Active filters one is shunt active filter and other is series active filter[1].They reduce harmonics specified by power quality standard[3].

1.2 Shunt Active Filters

Shunt active filter mostly have two mains blocks:
1. The PWM converter (power processing)
2. The active filter controller (signal processing)

The PWM converter is responsible for power processing in synthesizing the compensating current that could be drawn from the power system. The active controller is responsible for signal processing in determine in real time the instantaneous compensating current reference, which is continuously passed to the PWM converter[1].

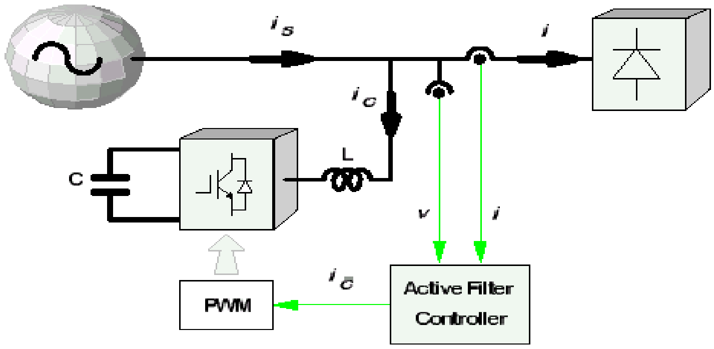

Fig: 1 Block Diagram of Shunt Active Filter

Fig.1 shows the basic block diagram of a shunt active filter[1] for harmonic current compensation of a specific load. It consists of a voltage source converter with a PWM current controller and an active filter controller that realizes and instantaneous control algorithm[4]. The shunt active filter controller works in a closed loop system. The controller sensing continuous the load current ic and calculating current reference ic* for the PWM converter[5]. When compensating current ic is equal to ic* reference current, the PWM converter may works as a linear power amplifier.The dc capacitor and the IGBT (insulated gate bipolar transistor) with antiparallel diode are used to indicate a shunt active filter that is built up from a voltage source converter. Both voltage source converter and current source converter can be used in shunt active filter[6].

2. Controller Design in Shunt Active Filter.

2.1Mathematical Modelling of Instantaneous P-Q Theory

The Instantaneous active and reactive power theory or simply the *p-q* theory is based on a set of instantaneous values of active and reactive powers defined in the time domain[7]. There are no restrictions on the voltage or current waveforms, and it can be applied to three-phase systems with or without a neutral wire for three-phase generic voltage and current waveforms.
Thus, it is valid not only in the steady state, but also in the transient state[13]. This theory is very efficient and flexible in designing controllers for power conditioners based on power electronics devices. Other traditional concepts of power are characterized by treating a three-phase system as three single-phase circuits[8]. The *p-q* Theory first uses Clarke transformation to transforms voltages and currents from the *abc to αβ0* coordinates, and then defines instantaneous power on these coordinates. Hence, this theory always considers the three-phase system as a unit, not a superposition or sum of three single-phase circuits[15].

2.1.1The Instantaneous Powers of the P-Q Theory

The *p-q* Theory can be defined in three-phase systems with or without a neutral conductor. Three instantaneous powers: the instantaneous zero-sequence power *p*0, the instantaneous real power *p*, and the instantaneous imaginary power *q* are defined from the instantaneous phase voltages and line currents on the αβ0 axes are given in equation (2.1)[10].

$$\begin{bmatrix} p0 \\ p \\ q \end{bmatrix} = \begin{bmatrix} Vo & 0 & 0 \\ 0 & V\alpha & -V\beta \\ 0 & V\beta & V\alpha \end{bmatrix} \begin{bmatrix} i0 \\ i\alpha \\ i\beta \end{bmatrix} \quad (2.1)$$

Since there are no zero-sequence current components in three-phase, three-wire systems, that is, $i0 = 0$. In this case, only the instantaneous powers defined on the αβ axes exist, because the product $v0i0$ in (2.1) is always zero. Hence, in three-phase, three-wire systems, the instantaneous real power *p* represents the total energy flow per time unity in terms of αβ components. In this case, $p3\phi = p$[9].

2.1.2The Instantaneous P-Q Theory in Three-Phase Three Wire Systems

Let us consider a three phase system with voltages *va*, *vb*, and *vc* are the instantaneous phase voltages and *ia*, *ib*, and *ic* the instantaneous line currents. Since zero sequence power in threephase three wire system is always zero, the equation (2.1) becomes:

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} V\alpha & V\beta \\ -V\beta & V\alpha \end{bmatrix} \begin{bmatrix} i\alpha \\ i\beta \end{bmatrix} \quad (2.2)$$

In the proceeding discussion, the $\alpha\beta$ currents will be set as functions of voltages and the real and imaginary powers p *and* q to explain the physical meaning of the powers defined in the *p-q* Theory[11]. From (2.2), it is possible to write

$$\begin{bmatrix} i\alpha \\ i\beta \end{bmatrix} = \frac{1}{V\alpha^2 + V\beta^2} \begin{bmatrix} V\alpha & -V\beta \\ V\beta & V\alpha \end{bmatrix} \begin{bmatrix} p \\ q \end{bmatrix} \quad (2.3)$$

If current and voltages from αβ variables are replaced to their equivalent abc variables in equation (2.2), the instantaneous imaginary power will be:

$$q = V_\alpha i_\beta - i_\alpha V_\beta = \frac{1}{\sqrt{3}}[(Va - Vb)i_c + (Vb - Vc)i_a + (Vc - Va)i_b]$$

$$= \frac{1}{\sqrt{3}}[(Vab)i_c + (Vbc)i_a + (Vca)i_b] \quad (2.4)$$

This expression is similar to that implemented in some instruments for measuring the three-phase reactive power. The difference is that voltage and current phasors are used in those instruments. Here, instantaneous values of voltage and current are used instead. According to p-q theory real and reactive powers can be written as:

$$p = \check{p} + \overline{p}, \; q = \check{q} + \overline{q}, \quad p0 = V0i0 \quad (2.5)$$

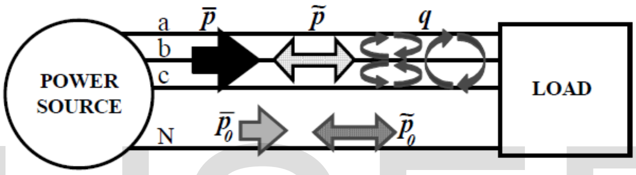

Fig.2. Power components of the p-q theory in *a-b-c* coordinate.

3. Pulse Width Modulation Controller

PWM controller is used to produce switching signals for the voltage source inverter of shunt active filter. In VSI IGBT is used for the switch of the shunt active filter[12].

4. Simulation Model

Simulation is very important and powerful tool to reduce development time and study the dynamic of the systems. In this work matlab/simulink is used as a simulation tool to implement the proposed active filter and study the operation of the active power filter under different operating conditions. In this model close loop control is used[14].The model so in fig:3.

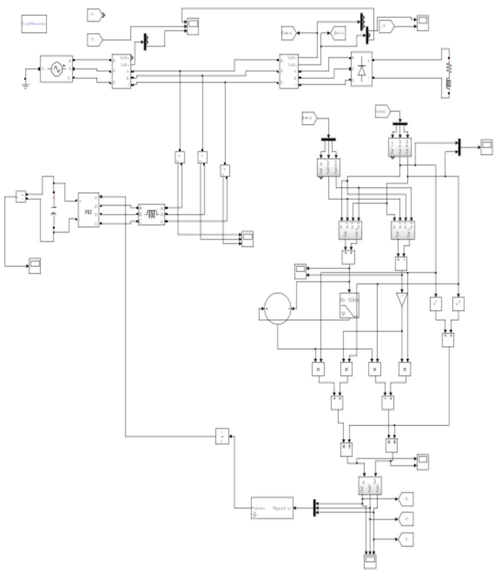

Fig:3 Simulation model of shunt active filter

5.Simulation Results and Discussions

The analysis of the three-phase system has been done in simulink/matlab environment. The system parameters values are shown in table 1.

Table.1 System Parameters

name	symbols	value
AC Voltage Source	Vs	400v
Fundamental frequency	F	50Hz
Load	RL	50ohms/100mH
DC bus capacitor	Cdc	440F
Filter inductor	Lf	0.7H

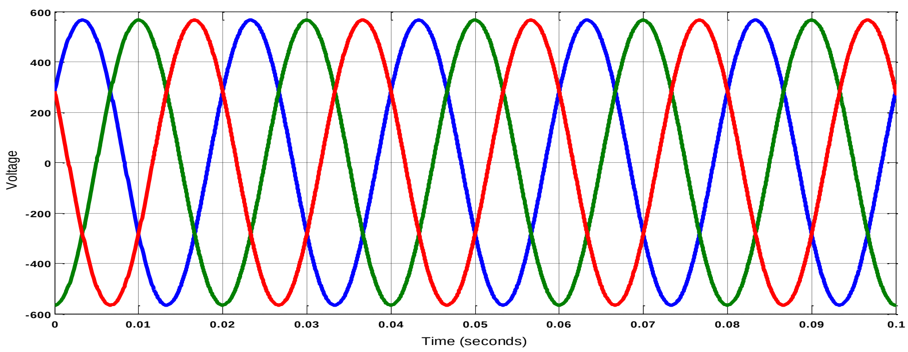

Fig:4 Three phase supply voltage at balance condition

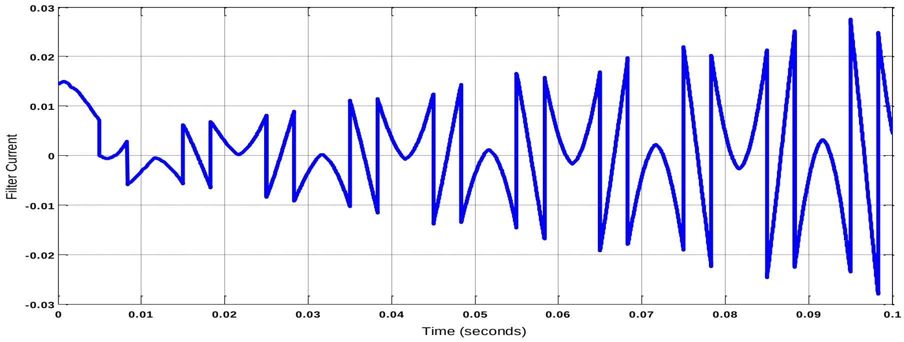

Fig:5 Filter current at balance supply voltage

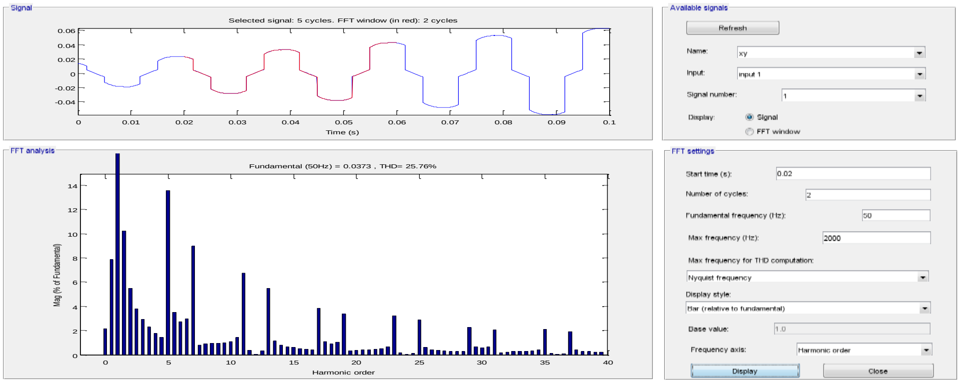

Fig:6 THDi at without filter in balance supply

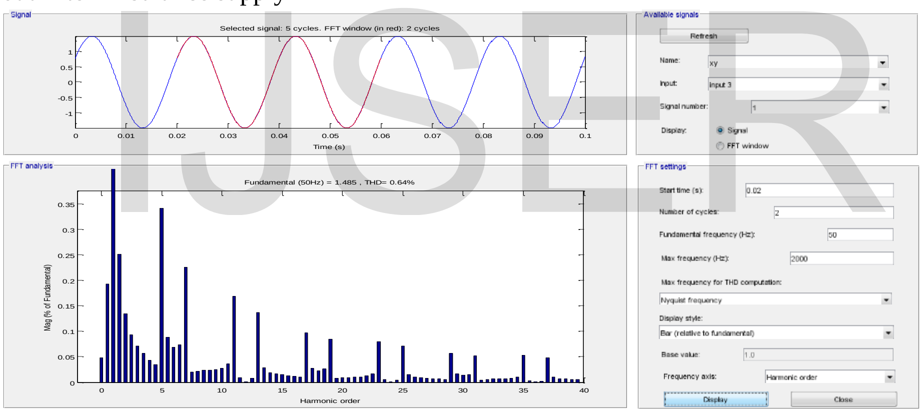

Fig:7 THDi at with filter in balance supply

The total harmonics current distortion in balance supply condition is 25.67% without filter then using shunt filter THDi reduced to 0.64%.They are so in above figure 6,7.In figure 5 so the filter wave form during balance.

5. Conclusion

The three phase three wire shunt active filter with controller based on instantaneous active and reactive power (p-q) theory is simulated in matlab/simulink to compensate the problems of the harmonics and reactive power which are encountered from power electronic non linear load. The performance of shunt active power filter is investigated under different scenarios. It is investigated that the p-q theory based active filter manages to compensate the harmonics and reactive power of the three phase three wire network even under balance and unbalance supply voltage. The shunt active filter is able to reduce the THD in source current at a 25.67% to 0.64% in balance condition that level well below the defined standards specified by power quality standards. so shunt active power filter is best topology for harmonics mitigation than passive filter.

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"Obstacles are what we see when we take out eyes off the goals"

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