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Simulation of Three-Phase Three-Wire Active Power Filter using *p-q* Theory

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Abstract: This paper presents a simulation of three-phase, three-wire shunt active filter whose control strategy based on p-q theory for compensation of harmonics, reactive power and imbalance in current under non-sinusoidal supply voltage conditions. The control algorithm has been validated under various supply and load conditions using MATLAB-SIMULINK based computer simulations. With the proposed technique, the THD is reduced and power factor is improved significantly. All the simulation results are presented. The results show that the proposed algorithm is capable of meeting the requirements of IEEE 519 standard.

Keywords: Shunt active filter, p-q theory, MATLAB-SIMULINK, THD.

I. INTRODUCTION

In recent years, the usage of modern electronic equipments has been increasing rapidly [1, 2]. These electronic equipments offer non-linearity, draw harmonic and reactive power components of current from ac mains in addition to active current. In 3 phase systems they also cause unbalance and draw excessive neutral currents. Moreover these power quality polluting equipments expect good quality power from the utilities as their performance is greatly affected by distorted supply. The injected harmonics, reactive power burden, unbalance and excessive neutral current, cause low system efficiency and poor power factor. They also cause disturbance to other consumer and interference in nearby communication networks. Conventionally passive L-C filters were used to reduce harmonics and power capacitors were employed to improve the power factor of the ac load [3]. However passive filters have the demerits of fixed compensation, large size and resonance.

To reduce severity of harmonic pollution in power networks new equipment called “ACTIVE FILTER (AF)” is used [4-6]. They are also called as “Active power line conditioner”. AF technology can now provide compensation for harmonics, reactive power and neutral currents. They are also used to regulate terminal voltage, to suppress voltage flicker and to improve voltage balance in three phase system.

This paper presents simulation of shunt active filter, including application of *p-q* Theory in three-phase, three-wire power system.

II. BASICS OF P-Q THEORY

The *p-q* theory is based on a set of instantaneous power defined in the time domain [7]. This theory is very efficient and flexible in designing controller for power conditioners based on power electronics devices. The *p-q* theory first transforms voltage and current from the *abc* to $\alpha\beta 0$ 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. Fig. 1 shows pictorial representation of p-q theory control technique.

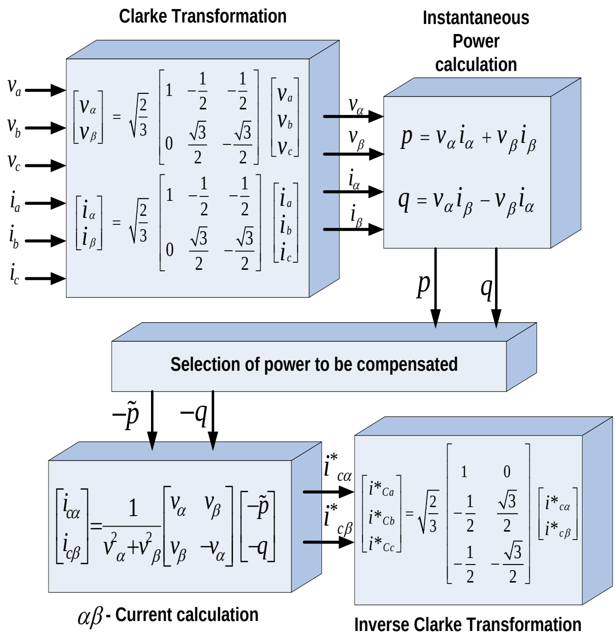

Fig. 1 Control method of *p-q* theory

III. SHUNT ACTIVE POWER FILTER

A shunt active filter can compensate reactive power and only for the harmonic current of a nonlinear load, and can continuously track changes in its harmonic content. This paper will present simulation of 3-pahse shunt active power filter with different types of load and its harmonic analysis. The shunt active power filter described and simulated in this paper have controller based on the instantaneous active and reactive power theory (the *p-q* Theory).

Shunt active filter generally consist of two main blocks:

(i) The PWM converter

(ii)The active filter controller

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The PWM converter is responsible for power processing in synthesizing the compensating current that should be drawn from the power system. The active filter controller is responsible for signal processing in determining in real time the instantaneous compensating current references, which are continuously passed to PWM converter. Fig. 2 shows the basic configuration of a shunt active filter for harmonic current compensation of a specific load. It consists of a voltage-fed converter with a PWM current controller and an active filter controller that realizes an almost instantaneous control algorithm. The shunt active filter controller works in a closed-loop manner, continuously sensing the load current i_L, and calculating the instantaneous values of the compensating current reference $i*_C$ for the PWM converter. In an ideal case, the PWM converter may be considered as a linear power amplifier, where the compensating current i_C tracks correctly its reference $i*_C$.

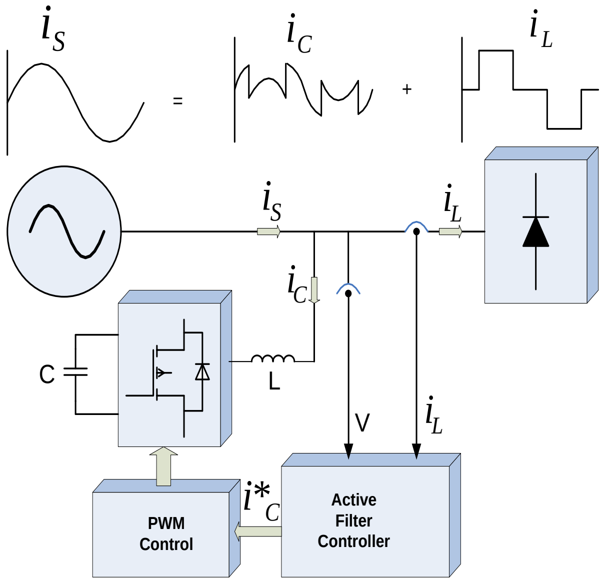

Fig. 2 Basic configuration of a Shunt Active Filter

The Fig. 3 shows the simulation circuit of three-phase, three-wire Active Power Filter using the control strategy based on the p-q Theory. The software used for this is MATLAB 7.1.

Simulation parameters selected in circuit of three-phase, three-wire APF with RL Load of Fig. 3 are given below:

Voltage (Vs) = 200 (V peak value)

Current (I) = 15 Amp (peak value)

Frequency(f) = 50 Hz

Load Resistance (R) = 25Ω

Load Inductance (L) = 200 mH

DC Link Capacitor (C) =5000 µF

Filter Inductor = 2.5 mH

Sampling time = 2 µS

Simulation solver = ode45

Similarly for RC load shown in Fig. 4 the value of R=25Ω and C=200 µF, other parameters are same as RL load.

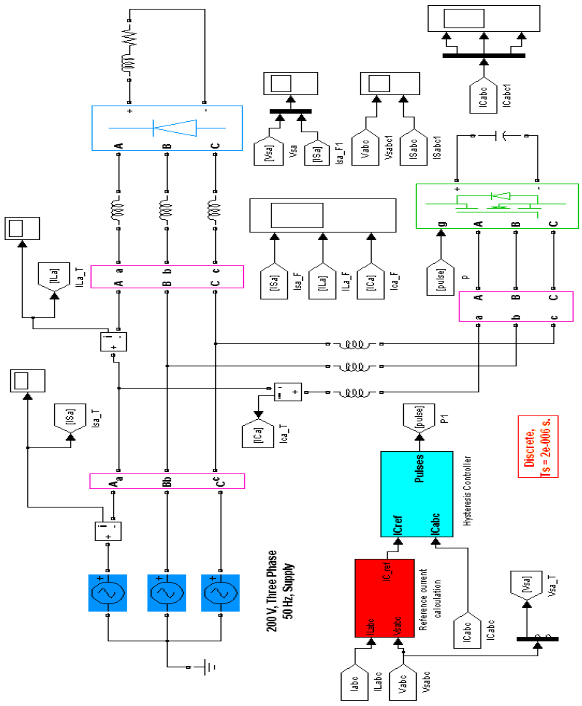

Fig. 3 Simulation circuit of three-phase, three-wire APF with RL load

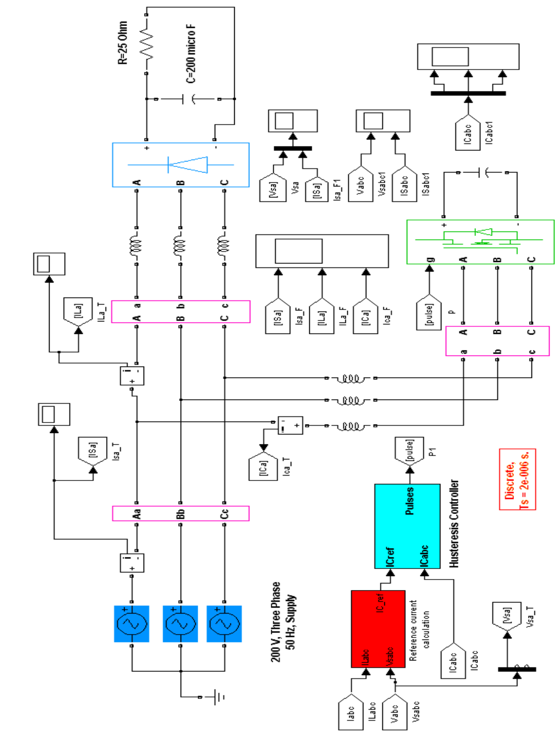

Fig. 4 Simulation circuit of three-phase, three-wire APF with RC load

IV. DISCUSSION OF SIMULATION RESULTS

In previous section detailed information of three-phase, three-wire shunt active filter is discussed and also their simulations with control based on *p-q* Theory are shown. Simulation results for following types of load are presented.

(1) RL Load

(2) RC load

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Simulation Result of RL Load

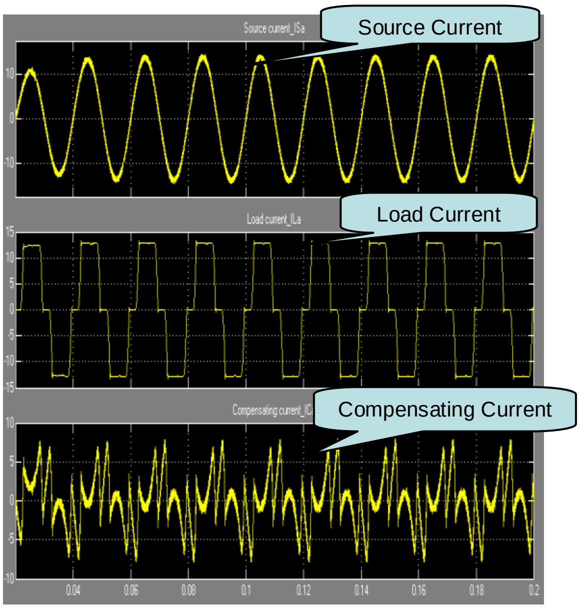

Fig. 5 Simulation waveform of source, load and compensation current for RL load

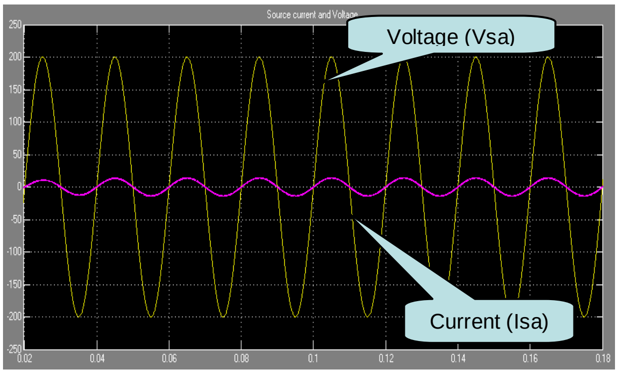

Fig. 6 Simulation waveform of source voltage and source current for RL load

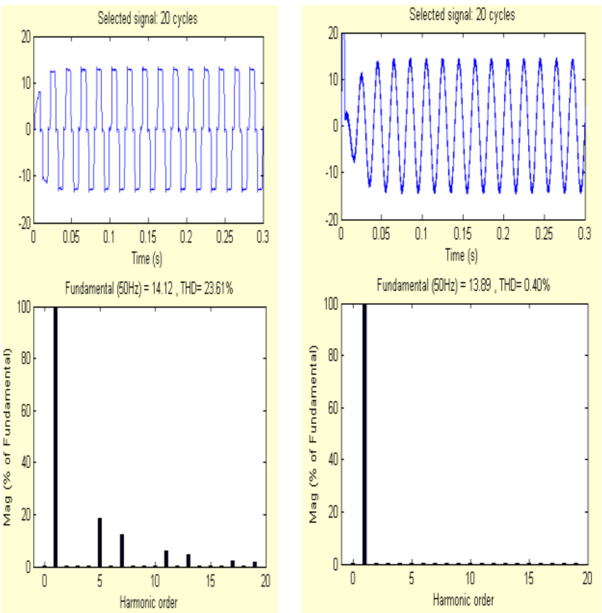

Fig. 7 Harmonic spectrum of source current

Fig. 5 indicate waveform of source current, load current and compensator current for a single phase say ‘a-phase’. Here the waveform of source current is sinusoidal nature but load current and compensator current waveform are non- sinusoidal.

Fig. 6 shows simulation waveform of source voltage and source current in a phase for RL load where source voltage and source current are in one phase. This indicates power factor improvement on supply side.

Fig. 7 shows FFT analysis of source current. Where the total harmonic distortion of source current without APF is 23.61%. Application of *p-q* Theory to APF reduces the THD to 0.40% [8].

Simulation Result of RC Load

Fig. 8 indicate various waveform of source current, load current and compensating current under RC load condition.

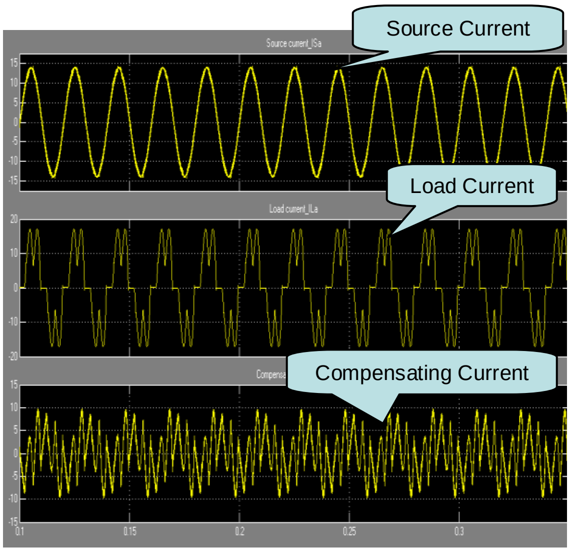

Fig. 8 Simulation waveform of source, load and compensation current for RC load

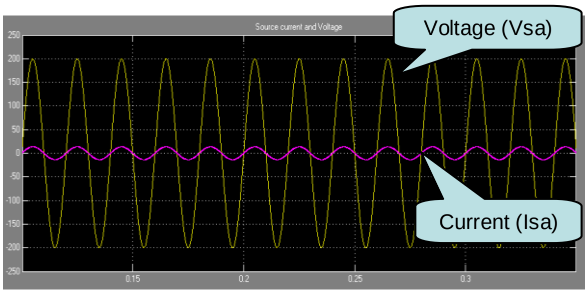

Fig. 9 Simulation waveform of source voltage and source current for RC load

Fig. 9 shows simulation waveform of source voltage and source current in a phase for RC load where source voltage and source current are in same phase. This indicates power factor improvement on supply side.

Simulation result of RC load in Fig. 10 shows that the total harmonic distortion of source current using APF is improved from 37.12 % to 1.14%.

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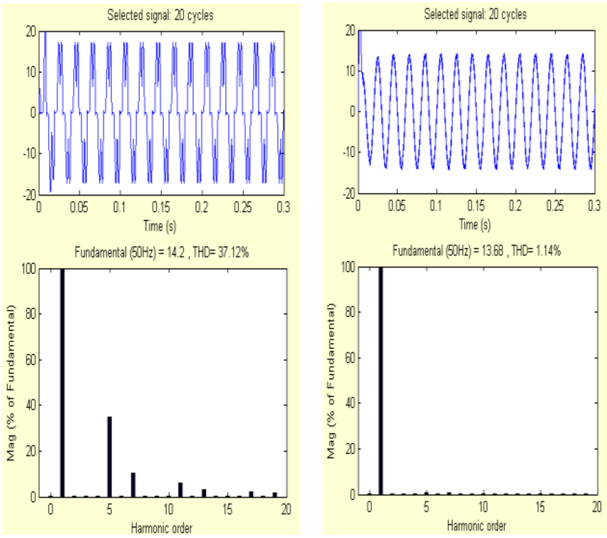

Fig. 10 Harmonic spectrum of source current for RC load

V.CONCLUSION

In this paper simulation of three-phase, three-wire shunt active filter with control strategy based on *p-q* theory with two different types of loads are shown. Application of *p-q* theory to APF gives significant reduced in THD and also improvement in power factor. Moreover it has been seen from the FFT analysis of the source current, after connecting the active power filter, the THD has been reduced from 23.62% to 0.40% for RL load and 37.12% to 1.14% for RC load which successfully fulfill the criteria of IEEE 519 standard for harmonic compensation. From the waveform of source voltage and source current it concludes that both are in phase so the power factor of the system is improved significantly.

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BIOGRAPHIES

Pradeep Kumar, born in India in 1985. He received the B.E.(Electrical Engg) from GEC Bilaspur, India and M.Tech. (Electrical Engg) with specialization of Control System from COEP, Pune, India in 2008 and 2010 respectively. Currently, he is pursuing his Ph.D. Degree in Electrical Engg.Department, NIT Jamshedpur , India. He joined NIT Sikkim as a assistant professor. His main research interests are control system, renewable energy system and power quality.

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