

Simulation and Analysis of Single Phase Shunt Active Filter Based on PQ Theory

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Abstract— This paper deals with the analysis and simulation of single phase shunt active filter based on PQ theory. Normally PQ theory is used for 3 phases 3 wires and 3 phases 4 wire system but here it is used for single phase system as well. This paper also concentrates on reduction of THD of load current [1]. Since the system has only single phase signal for both voltage and current, thus the dummy signal with a phase shift of 120 ° different angles must be generated for providing the input for p-q theory. During simulation the six pulses will be generated for switching of IGBT but only two will be used. MATLAB tool is used to simulate the proposed scheme.

Index Terms— Shunt active filter, THD (Total harmonic distortion), PQ theory.

I. INTRODUCTION

The Power Electronic converters and loads are the sources of harmonics and reactive power which greatly affect the performance of the power system network[1].To overcome the problem of power quality, recent efforts have been made on development of better filtering technique. The active filters gathered more concentration because of excellent performance to overcome the harmonic and reactive power problems. But the performance of the active filters depends upon shunt active power filter with controlling done over Instantaneous active and reactive power (P-Q) theory has been purposed to verify its capability and ability to reduce the harmonics [3]. The advantage of p-q theory is that it is instantaneous and it performs in time domain system. The shunt active filter connected to AC distribution system in the presence of different shares of Electronic loads [1] is analyzed. It has been investigated through simulations that even under unbalanced and distorted states of distribution supply voltage and unbalanced loading, shunt active filter is able to mitigate the harmonics (THD) specified by power quality standards the control theory that is employed to formulate the control strategy of the active filter [2].

Due to excessive use of power converters and other non-linear loads in industry it is observed that the power systems voltage and current waveforms gets deteriorates. Static power converters such as single phase and three phase rectifiers, Thyristor converters and maximum number of power electronic device are nonlinear loads which produce considerable large disturbances in the supply and distribution system. Mostly voltage harmonics and power distribution issues are arise due to current harmonics generated by nonlinear load [5]. when nonlinear currents flow in the electrical system and the distribution-transmission lines, supplementary voltage distortion produce due to the impedance present in the electrical network. Due to the presence of harmonics in the power system various power losses occurs in distribution, interference problem in communication system and, sometimes result in operation failure of electronic device which are more sensitive because it contains controller systems, which can work with low energy levels [6]. It has been observed that non-sinusoidal current results in many problems for the utility power supply company, such as low energy efficiency, electromagnetic interference (EMI) and distortion of line voltage etc.

II. PRINCIPLE OF SHUNT ACTIVE POWER FILTER

The shunt active power filter with dc bus which use to get adjust itself has a topology similar to that of a static compensator (STATCOM) which is basically used for reactive power compensation in transmission systems. Shunt active power filters compensate harmonics by inserting equal- but opposite compensating current into the system. During this process the active filter works as a current source injecting the harmonic components generated by the load but phase- shifted by 180°. Fig 2 shows the basic compensation principle of a shunt active power filter. The load current, the desired mains current and compensating current injected by the active filter are containing the all harmonic components to make mains current sinusoidal. The shunt active filter adds the compensating current in the load current to provide the sinusoidal current.

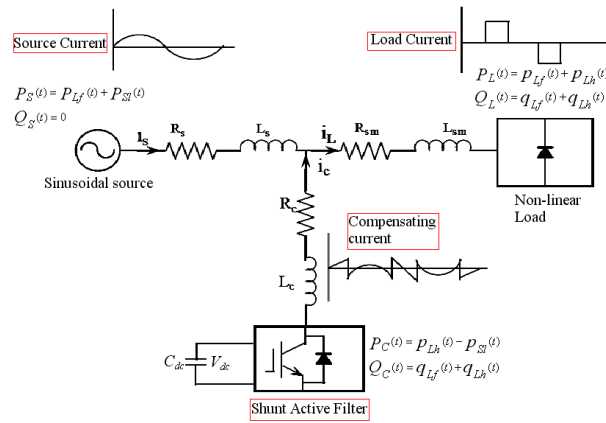


Fig. 1: Principle of single phase shunt active power filter

III. MATHEMATICAL MODEL

In this method algebra transformation which is most popularly known as Clarke transforms [2] is used for three phase voltage and current. These three phase voltage and current are then converted into α - β coordinate. According to this theory three current and three voltage signals are used but it also can be used for single phase active filter by making the two dummy current and voltage signal with 120° angle of shifting. During this procedure separation in mean and oscillating values takes place. Consider load current of single phase load as phase “a” and others phase (phase “b” and phase “c”) are generated by duplicating technique. The load current is assumed as phase “a” current and with be expressed mathematically as shows in eq. (1). By assuming that eq. (1) as phase “a” load current, load current for phase “b” and “c” can be represented as in eq. (2) and eq. (3).

$$i_a = \sum_{i=0}^n \sqrt{2} I_i \sin(\omega_i + \theta_i) \tag{1}$$

$$i_b = \sum_{i=0}^n \sqrt{2} I_i \sin(\omega_i + \theta_i - 120^\circ) \tag{2}$$

$$i_c = \sum_{i=0}^n \sqrt{2} I_i \sin(\omega_i + \theta_i + 120^\circ) \tag{3}$$

Equation (1), (2) and (3) can be transformed in matrix form as shown in (4) and (5) for load current and load voltage respectively:

$$\begin{pmatrix} i_a \\ i_b \\ i_c \end{pmatrix} = \begin{pmatrix} 1 \angle 0^\circ \\ 1 \angle 120^\circ \\ 1 \angle 240^\circ \end{pmatrix} [i_a] \tag{4}$$

$$\begin{pmatrix} v_a \\ v_b \\ v_c \end{pmatrix} = \begin{pmatrix} 1 \angle 0^\circ \\ 1 \angle 120^\circ \\ 1 \angle 240^\circ \end{pmatrix} [v_a] \tag{5}$$

The α and β reference current are obtained using algebra transformation and shown with the help of eq (6) for load current and in eq (7) for load voltage.

$$\begin{pmatrix} i_\alpha \\ i_\beta \\ i_o \end{pmatrix} = \begin{pmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{pmatrix} \begin{pmatrix} i_a \\ i_b \\ i_c \end{pmatrix} \tag{6}$$

$$\begin{pmatrix} v_\alpha \\ v_\beta \\ v_o \end{pmatrix} = \begin{pmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{pmatrix} \begin{pmatrix} v_a \\ v_b \\ v_c \end{pmatrix} \quad (7)$$

The equation for the active and reactive power can be obtained as [1]:

$$p = v_\alpha i_\alpha + v_\beta i_\beta + v_o i_o \quad (8)$$

$$q = v_\alpha i_\alpha - v_\beta i_\beta \quad (9)$$

$$\begin{pmatrix} p \\ q \end{pmatrix} = \begin{pmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{pmatrix} \begin{pmatrix} i_\alpha \\ i_\beta \end{pmatrix} \quad (10)$$

Active power and reactive power consist of two part which are average part and oscillating part also known as DC part and AC part. The equations of active power and reactive power can be given as:

$$p = \bar{p} + \hat{p} \quad (11)$$

$$q = \bar{q} + \hat{q} \quad (12)$$

The DC part can be calculated by using low-pass filter, which use to extract the high frequency signal and provides the fundamental component (DC part). From the DC part active power and reactive power. The α - β component of the current can be represented as in equation (13).

$$i_{\alpha\beta} = \frac{1}{v_\alpha + v_\beta} \begin{pmatrix} v_\alpha & v_\beta \\ v_\beta & -v_\alpha \end{pmatrix} \begin{pmatrix} i_\alpha \\ i_\beta \end{pmatrix} \quad (13)$$

The three phase reference current of active power filter shown in eq (14) before the signal will subtracted from load current. The subtracted three phases current will be used to generate PWM signal using hysteresis band. Hysteresis band will produce six PWM signals and for single phase active filter only two are used as input.

$$i_{abc}^* = \sqrt{\frac{2}{3}} \begin{pmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{pmatrix} i_{\alpha\beta}^* \quad (14)$$

IV. SINGLE PHASE SHUNT ACTIVE FILTER

Fig 2 a system configuration of a single-phase or three-phase shunt active filter for harmonic-current filtering of a 1-phase or 3-phase diode rectifier with a capacitive dc load. The active filter is one of the most basic system configurations among various forms of pure and hybrid active filters [4]. The dc load may be taken as an ac motor driven by a voltage-source PWM inverter in many cases. This shunt active filter is normally connected with the transformer is connected in parallel with the harmonic-producing load. The active filter can be controlled on the basis of the following "feed forward" manner [5].

1. The controller measures the instantaneous load current.
2. It extracts the harmonic current from the measured load current by means of digital signal processing.
- 3 The active power filters draw the compensating current from the supply so that it can cancel out the harmonic current [6].

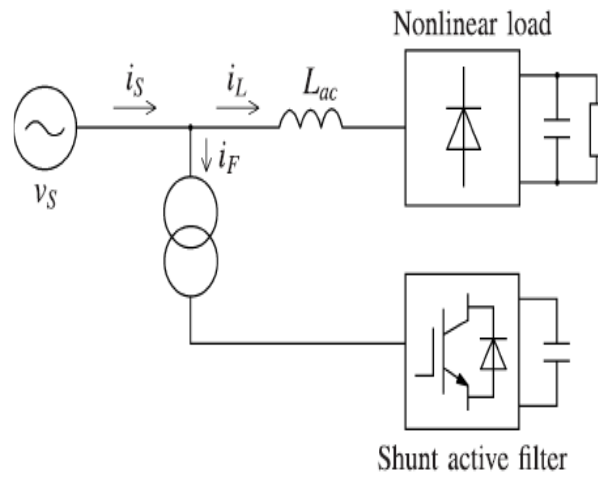


Fig. 2: Single phase shunt active filter

The block diagram shown in figure 3 shows the control strategy based on p-q theory which is used to generate the PWM signal.

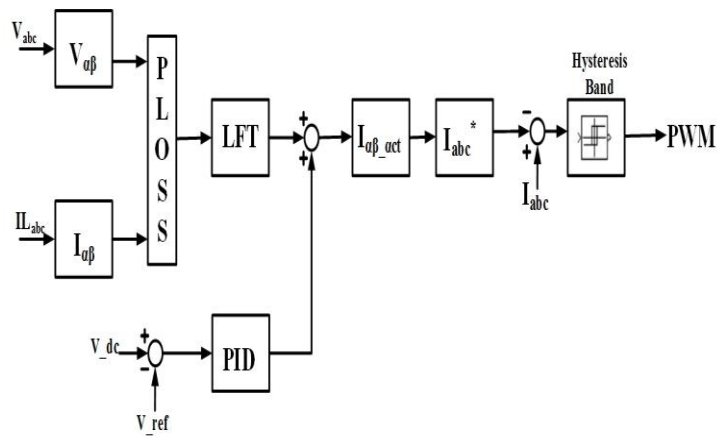


Fig. 3: Control strategy of p-q theory

V. ALGORITHM OF APPLIED CONTROL STRATEGY

From literature survey it can be conclude that shunt active filter is a useful device for compensation of current harmonics due to nonlinear loads. The THD due to nonlinear loads can be brought to limits according to IEEE standards by using shunt active filter.

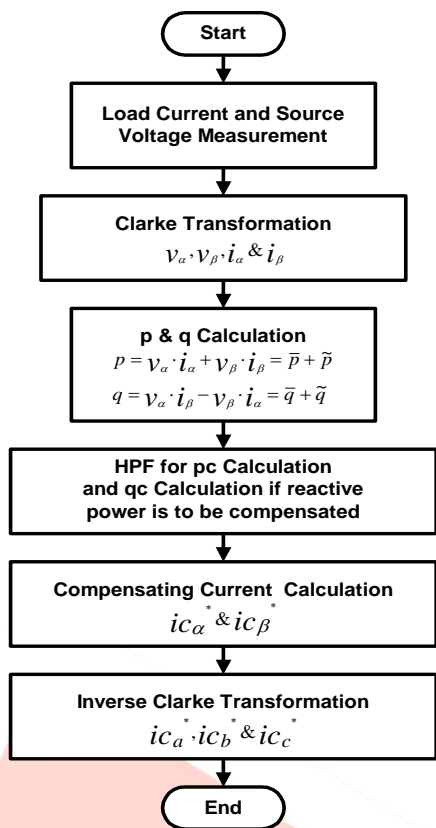


Fig. 4: Flowchart for the calculation of compensating current

VI. SIMULATION OF 1-PHASE SHUNT ACTIVE FILTER BASED ON PQ THEORY

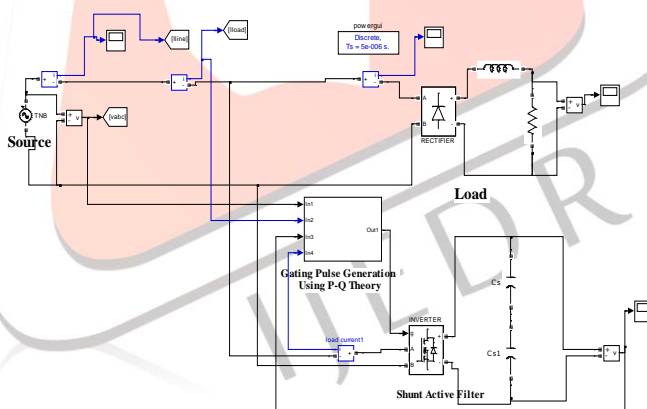


Fig. 5: Simulink model of shunt active filter

The modeling of p-q theory which consists of single to three phase block, algebra transformation[10] of p-q theory three phase to two phase, two phase to three phase transformation and hysteresis band is shown in figure 6. Hysteresis band will produce six signals PWM and for single phase active filter only use two signals to control the single phase active filter[8].

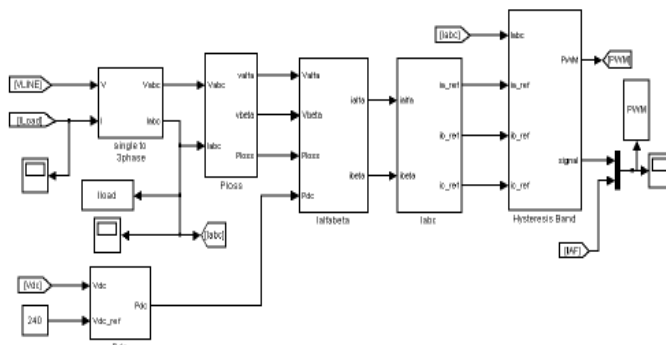


Fig. 6: Modeling of p-q theory

VII. VARIOUS WAVEFORMS OF LOAD CURRENT & SHUNT ACTIVE FILTER

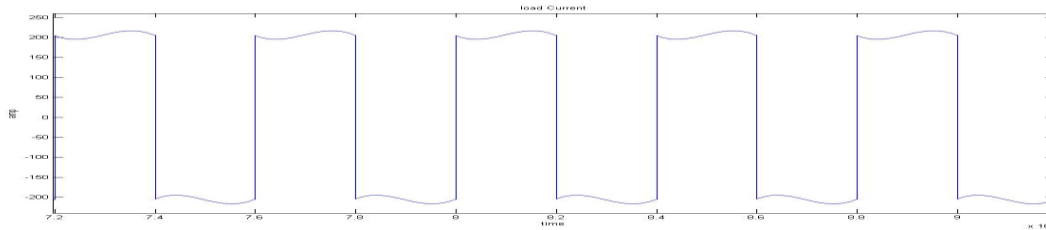


Fig 7. (A) LOAD CURRENT

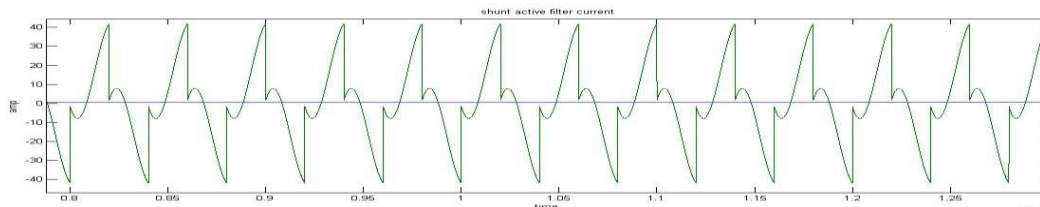


Fig 7 (B) ACTIVE FILTERS CURRENT

The effected non-linear load of the system will make the THD of load current increase up to 47.822% as shown in Fig. 8. By injecting the active filter current the THD offline current will reduce to 0.85% as shown in Fig 9

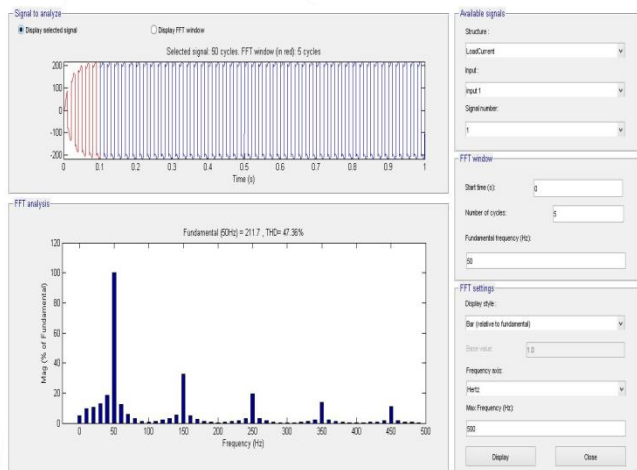


Fig 8 THD of load current

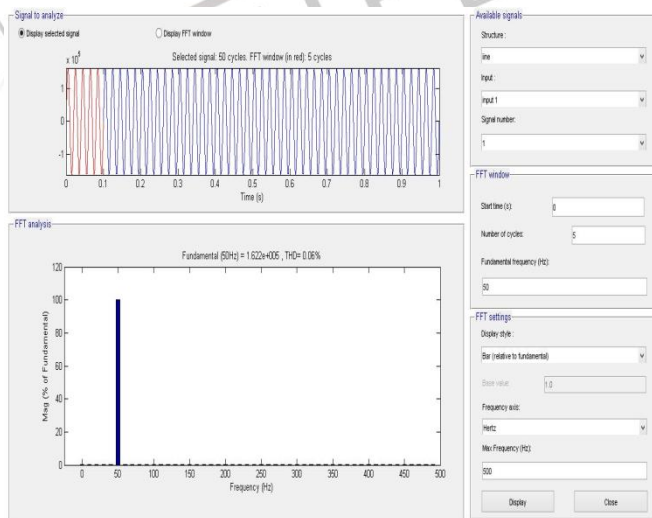


Fig 9 THD of line current

VIII CONCLUSION

A program has been developed to simulate PQ theory in MATLAB tool. It is found from simulation results that shunt active power filter improves power quality of the power system by eliminating harmonics which makes the load current sinusoidal and in phase with the source voltage. A model has been developed and simulated to verify the results. The PQ theory based shunt active power filter has better performance to the other controlling methods and it is time domain method as well.

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