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SELF TUNING FILTER METHOD FOR REAL TIME CONTROL OF THREE-PHASE SHUNT ACTIVE POWER FILTER (SAPF)

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ABSTRACT

Due to a large amount of non-linear loadsand power electronic equipments, impact and fluctuating loads (such as that of arc furnace, heavy merchant mill and electric locomotive, etc), problems of power quality have become more and more serious with each passing day which injects harmonic currents in supply system. These harmonics creates power quality issue. Shunt Active Power Filter (SAPF) is the popular and efficient solution to reduce these harmonics. SAPF can overcome voltage sag, eliminate harmonics and improves power factor. SAPF reduces total harmonic distortion (THD) to acceptable level. Reference current generation is the heart of APF. Reference current generation using self Tuning Filter (STF) method is presented in this paper. STF method is widely used to control active power filters (APFs). Modeling of this technique is implemented in MATLAB/simulink.

KEYWORDS: SAPF, Power quality, STF method, THD, MATLAB/simulink..

INTRODUCTION

Power quality issue is becoming very serious now-a-days. This is because non linear loads such as electrical machines, static power converters, electric arc furnaces, etc. which mainly lead to harmonic disturbances in power lines. Also power electronic equipments for human comfort plays major role in it. Although these power electronic equipments make our life convenient, it injects lot of harmonic current to the supply system and affects power factor [1]. Conventionally, passive LC filters have been used to eliminate line current harmonics and thereby increase the load power factor. Tuned passive filters are very effective for the elimination of specific harmonic components but has some drawbacks, such as

- Fixed Compensation,
- Resonance,
- huge size
- voltage regulation

They may cause series and load resonances in the system Also its performance depends on load, it gets affected significantly due to the variation in the filter component values, filter component tolerance, source impedance and frequency of ac source [1]. Shunt Active Power Filter (SAPF) is the effective solution to these problems. Active Filters can be designed to achieve following goals [2]:

- Harmonic Compensation
- Harmonic Isolation
- Reactive power compensation
- Voltage regulation

Out of three system based configurations of APF; here we are interested in Shunt Active Power Filter (SAPF). The Active filters overcome the problem occurring in the passive filter. Major Advantage of Active Filter over Passive Filter is that it can be controlled to compensate harmonics such that Total Harmonic Distortion (THD) lower than 5% at the PCC can effectively be achieved. SAPF is shown in fig 1. The reference current generation is like heart for APF.

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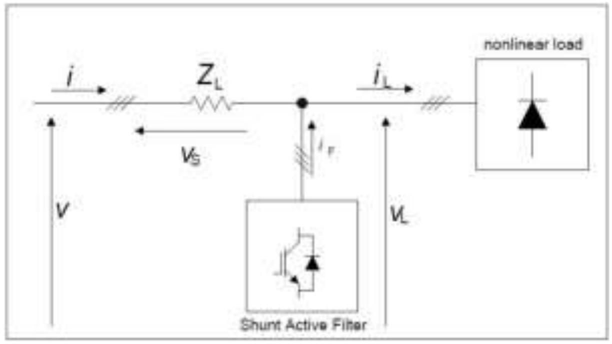

Figure 1. ***Basic structure of SAPF***

In this paper reference current generation using STF method is presented. Finally simulation results are presented.

CONTROL STRATEGY

Key factor for successful implementation of SAPF is strategy Controls. Block diagram of control strategy is shown in figure 2 below. In this paper SAPF is controlled using Self Tuning Filter (STF) method. Using STF method , reference current will be generated. These reference currents will be further used to generate gate pulses for inverter. The basic principle of reference current generation is shown in figure 3 below.

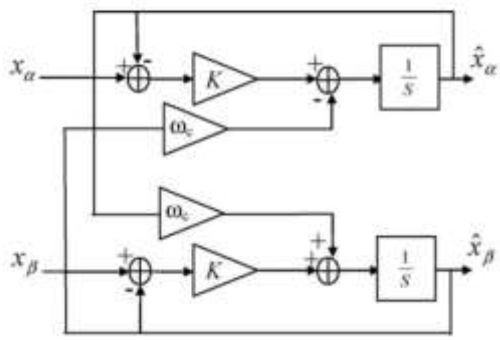

Figure 2. ***Control strategy of SAPF***

Figure 3.

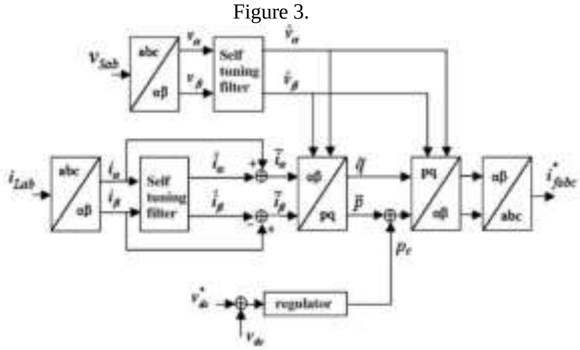

Figure 4. ***Reference current generation***

Figure 5.

As shown in above figure 3, 3-phase voltage and currents will be first converted into two phases which are inputs to the STF blocks. The outputs of STF blocks are used to generate reference currents. Reference currents generated using STF are used to generate switching pulses for inverter. From inverter compensating/filter currents are injected to system to reduce harmonics.

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HARMONIC ISOLATOR USING STF

The load currents, iLa, iLb and iLc of the three-phase three-wire system are transformed into the αβ axis (see Fig. 3) as follows by using equation

$$\begin{bmatrix} I\alpha \\ I\beta \end{bmatrix} = \sqrt{2/3} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \cdot \begin{bmatrix} iLa \\ iLb \\ iLc \end{bmatrix}$$

As known, the currents in the α-β axis can be respectively decomposed into DC and AC components by using equations (1) and (2)

$$i\alpha = \hat{i}\alpha + \tilde{i}\alpha \quad (1)$$

$$i\beta = \hat{i}\beta + \tilde{i}\beta \quad (2)$$

Then, the STF extracts the fundamental components at the pulsation ωc directly from the currents in the α-βaxis. After that, the α-β harmonic components of the load currents are computed by subtracting the STF input signals from the corresponding outputs(see Fig. 3). The resulting signals are the AC components ĩα and ĩβ, which correspond to the harmonic components of the load currents iLa, iLb and iLc in the stationary reference frame. For the source voltage, the three voltages Vsa, Vsb and Vsc are transformed to the α-β reference frame as following equation (3):

$$\begin{bmatrix} V\alpha \\ V\beta \end{bmatrix} = \sqrt{2/3} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \cdot \begin{bmatrix} Vsa \\ Vsb \\ Vsc \end{bmatrix} \quad (3)$$

Then, we applied self-tuning filtering to these α-β voltage components. This filter allows suppressing of any harmonic component of the distorted mains voltages and consequently leads to improve the harmonic isolator performance. After computation of the fundamental component $\tilde{v}\alpha\beta$and the harmonic currents îαβ, we calculate the p and q powers as follows:

$$p = v\alpha \cdot i\alpha + v\beta \cdot i\beta 3. \quad (4)$$
$$q = v\alpha \cdot i\beta - i\alpha \cdot v\beta 3. \quad (5)$$

Where, p = Instantaneous Active Power = $\hat{p} + \tilde{p}$
q = Instantaneous Reactive Power = $\hat{q} + \tilde{q}$

Where $\hat{p}, \hat{q}$ are fundamental components &$\tilde{p}, \tilde{q}$ are alternative components. The power components $\tilde{p}$ *and* $\tilde{q}$ are related to the same α-β voltages and currents can be written as follows in equation

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} V\alpha & V\beta \\ -V\beta & V\alpha \end{bmatrix} \cdot \begin{bmatrix} i\alpha \\ i\beta \end{bmatrix} \quad (6)$$

After adding the active power *Pc* required for regulating DC bus voltage to the alternative component of the instantaneous real power $\tilde{p}$, the current references in the α-β reference frame $i^*_{\alpha\beta}$ are calculated by following equations

$$i_\alpha^* = \tilde{i}_\alpha + \frac{\hat{V}\alpha}{\hat{V}_\alpha^2 + \hat{V}_\beta^2} Pc \quad (7)$$

$$i_\beta^* = \tilde{i}_\beta + \frac{\hat{V}_\beta}{\hat{V}_\alpha^2 + \hat{V}_\beta^2} Pc \quad (8)$$

Current references obtained from equations (7) and (8) include two terms, the first term contains the harmonic current components and the second one is a fundamental current component in phase with the supply voltage. Consequently, a small amount of active power is absorbed from or released to the DC capacitor so as to regulate the DC bus voltage. Then, the filter reference currents in the a–b–c coordinates are defined by following equation (9)

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$$\begin{bmatrix} i_{fa}^* \\ i_{fb}^* \\ i_{fc}^* \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ \frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} . \begin{bmatrix} i_\alpha^* \\ i_\beta^* \end{bmatrix} \qquad (9)$$

This how reference currents are obtained using Self Tuning Filter Method. These reference currents further used for PWM pulses generation.

SIMULATION BLOCK DIAGRAM FOR STF METHOD

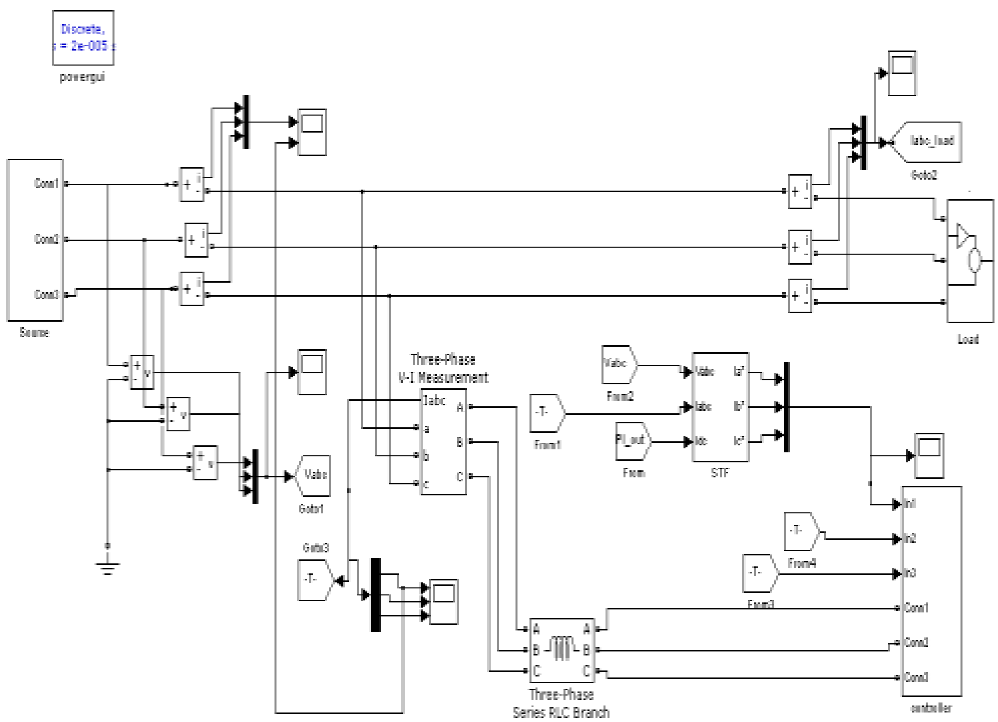

Figure 6. ***Simulation block diagram***

SIMULATION RESULTS

The proposed system is simulated in MATLAB/simulink along with the control technique proposed in figure 2 and 3. The system is simulated in MATLAB/ simulink having phase to phase 400v, and frequency of 50 Hz. along with control technique, non linear load and gate pulse generation. SAPF is connected to supply system through very small coupling inductor. The simulation is performed on three phase balanced non linear load; as a result of this following results are obtained.

In Following figure 5 graph 1, 2, 3, 4 shows source voltage, source current after compensation, source current before compensation and reference currents respectively. Also filter current for phase A is obtained as fallows in figure 6, THD of the given system shown in figure 7 below, THD is found to be 4.89%

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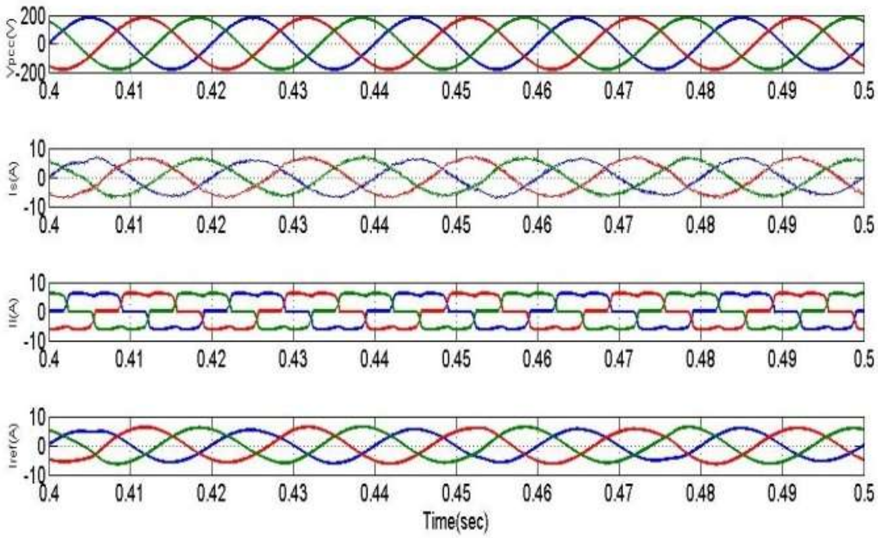

Figure 7. ***Results obtained by STF method***

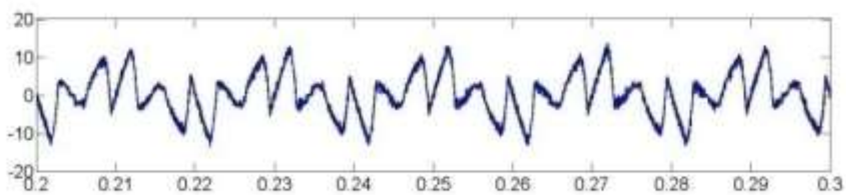

Figure 8. ***Filter current for phase A***

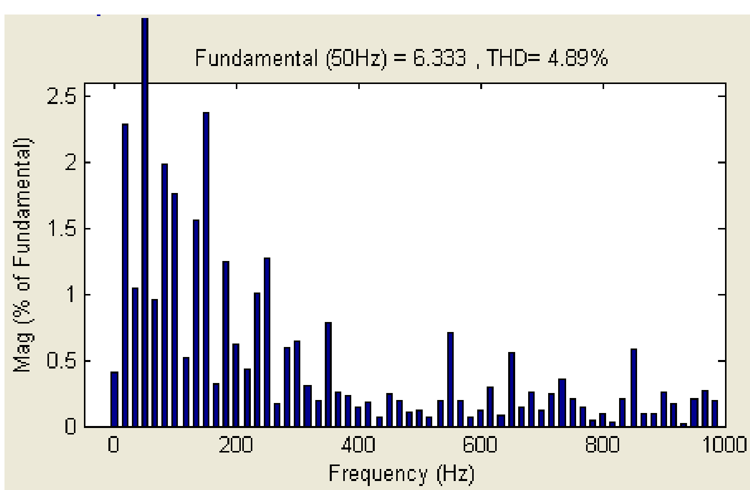

Figure 9. ***THD of system***

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CONCLUSION

Reference current is the key factor for successful performance of SAPF. The reference current using self tuning filter method is presented in this paper. Further these reference currents are used to generate switching pulses for inverter. THD can be maintained to acceptable level using SAPF. The simulation results using MATLAB/simulink verifies that. The advantages of STF method are that Operating adequately in steady state and transient condition, No phase delay and unity gain at the fundamental frequency, No PLL required, Easy to implement in digital or analogue control system.

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