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A NOVEL METHOD OF SYNCHRONOUS REFERENCE FRAME THEORY FOR REAL TIME CONTROL OF THREE-PHASE SHUNT ACTIVE POWER FILTER (SAPF)

Mr.Sachin B Dahule[1],Dr.Hari Kumar Naidu[2]
[1](PG Student Electrical Department,TGPCETNagpur), [2](HOD Of Electrical Department,TGPCETNagpur)
[1]sachindahule@gmail.com,[2]hod.electrical@tgpcet.com

ABSTRACT :

In recent years various harmonic disturbances occur in power lines, mainly due to the nonlinear loads such as electrical machines, static power converters, and electric arc furnaces. Due to wide application of non-linear loads and electronic equipment's in distribution system, the problem of power quality has become serious. Thisequipment can cause high disturbances in the power supply system. Effect of harmonic current and voltages in the power system affects the instruments connected to same power system. 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.In this paper we concentrate on design of Shunt Active Power Filter (SAPF) by using STF method to mitigate the harmonics. Here we use MATLAB/Simulink to obtain the result.

Index Terms: **Shunt Active Power Filter (SAPF), Total harmonic Distortion (THD), STF method,Power quality (PQ),MATLAB/Simulink**

I.INTRODUCTION

In recent years, there has been an increased emphasis and concern for the quality of power delivered to factories, commercial establishments, and residences. This is due to the increasing usage of harmonic-creating non-linear loads such as adjustable-speed drives, switched mode power supplies, arc furnaces, and electronicfluoresce lamp. This mainly lead to harmonic disturbances in power lines. Also power electronic equipment's for human comfort plays major role in it. Although these power electronic equipment's make our life convenient, it injects lot of harmonic current to the supply system and affects power factor. 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.

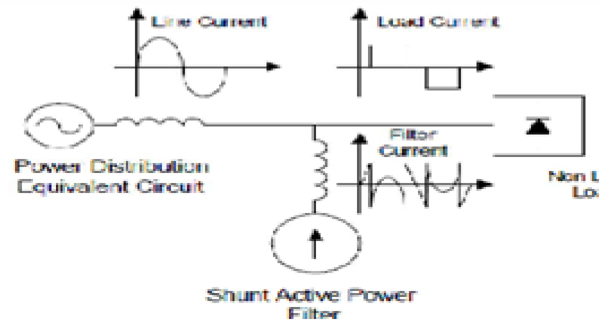


Figure 1. Basic structure of SAPF

In this paper to mitigate harmonics created due to non-linear load a reference current generation using STF method is presented. Finally simulation results are presented.

II.CONTROL TECHINIQUE

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.

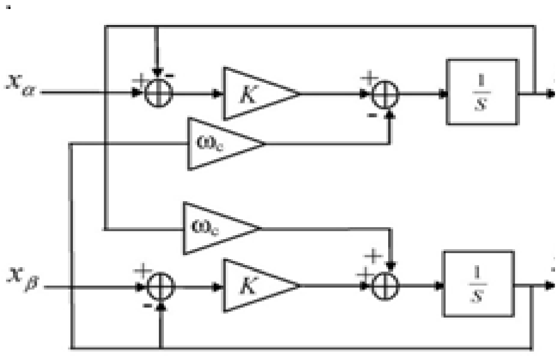


Figure 2. Control strategy of SAPF

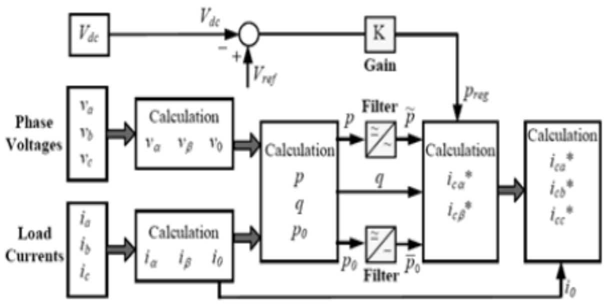


Figure 3. Reference current generation

This theory is useful while working with distorted supply voltage. It is a modified version of the classical p–q theory. The STF is dedicated to extract the fundamental component directly from electrical signals (distorted voltage and current) in α-β referenceframe.

III.REFERENCE CURRENT GENERATION USING SRF

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 $\tilde{i}\alpha$ and $\tilde{i}\beta$, 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):

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

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:

$$p = v\alpha \cdot i\alpha + v\beta \cdot i\beta 3. \qquad (4)$$

$$q = v\alpha \cdot i\beta - i\alpha \cdot v\beta 3. \qquad (5)$$

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

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

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

Current references obtained from equations (7) and (8) include two terms, the first term contains the harmonic currentcomponents and thesecond one is a fundamental current component in phasewith thesupply 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)

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

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

IV.SIMULATION BLOCK DIAGRAM FOR SRF METHOD

The figure 4 shown below gives the shunt active power filter system simulated in MATLAB/Simulink. This system is consist of three phase balanced source supplying diode bridge rectifier feeding R-L load. This load draws a highly nonlinear current rich in harmonics with a substantial reactive power requirement. A three phase, VSI-based shunt AF is connected to the system for reactive power compensation and harmonics elimination.. This SAPF model is simulated with the above described *IRP (p-q),SRF and PF* based theories. Simulation models for these theories that are inconsistent with the control schemes are describe here

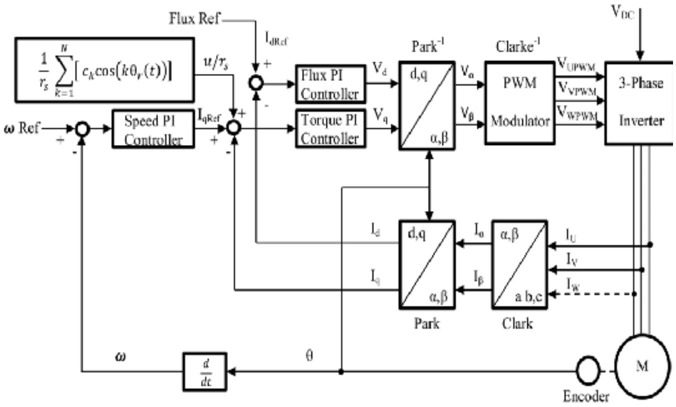


Fig-4 Simulation Block diagram for SRF

V.SIMULATION RESULT

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, nonlinear load and gate pulse generation. SAPF is connected to supply system through very small coupling inductor. The simulation is performed on three phase balanced nonlinear load; as a result of this following results are obtained.

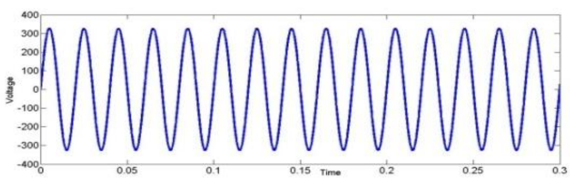


Fig-4 Source voltage of phase A

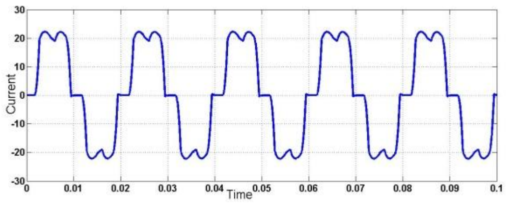


Fig-6Source current before compensation

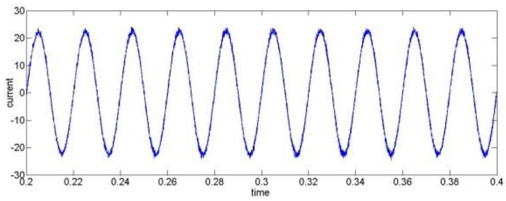


Fig-8Source current after compensation

The load current for phase A is obtained as fallows in figure 8. Also filter current for phase A is obtained as fallows in figure 10,

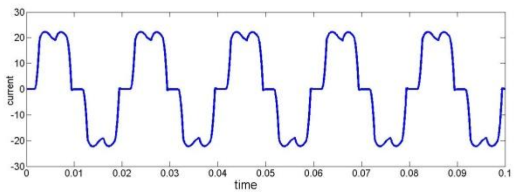


Fig-9Load Current for phase A

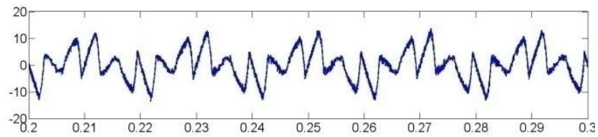
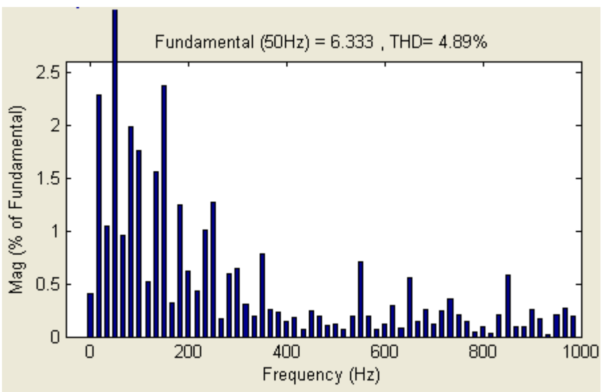


Fig-10Filter current for phase A

THD of the given system shown in figure 9 below, THD is found to be 4.89%



THD of system

VI.CONCLUSION

Reference current is the key factor for successful performance of SAPF. The reference current using SRF 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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