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Harmonic Mitigation using Shunt Active Power Filter Controlled by Constant Power Control & Synchronous Reference Frame based Technique

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Abstract— Increasing use of nonlinear devices for purpose of the controlling the machines is common now a days. These circuits are based on power semiconductor switching devices which are for most of harmonic source in network. Due to negative effect of harmonics, the filtration of it is must require. The active power filter is most superior solution in eliminating unwanted harmonics. Here 3-phase 3-wire shunt active power filter is used for harmonic mitigation of non-linear load. Control technique used here are constant power control and synchronous reference frame theory based. Results are shown with and without use of SAPF. MATLAB/Simulink software is used for analysis & simulation purpose.

Key words: SAPF, Constant Power Control (CPC), Synchronous Reference Frame (SRF) Theory, Total Harmonic Distortion (THD)

I. INTRODUCTION

In today's scenario it is very difficult and also challenging for Electrical Engineers to meet rising expectation of getting high quality of power. This can be achieved by mitigation of harmonics in power system caused by non-linear loads. Point of Common Coupling (PCC) must be considered as an important factor while designing the harmonic compensators. The shunt active filters are a conceivable substitute to minimalize the effects of non-linear loads on the power network [1][2].

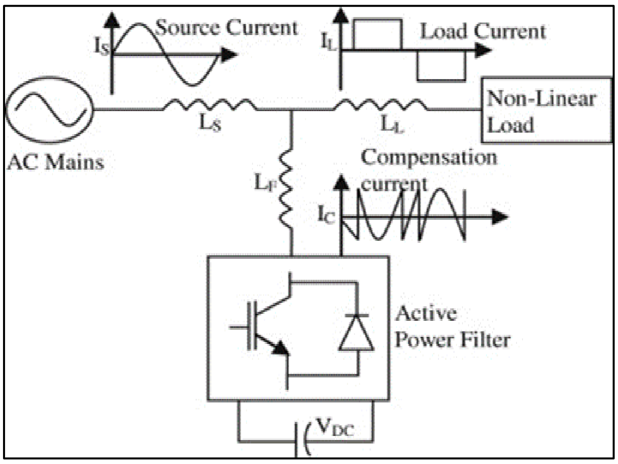


Fig. 1: Block Diagram SAPF

Generally SAPF works in a closed loop method. It sense current that flows through load (i,), and computes the instant values of the compensating current reference value (ic*) for converter section(PWM).Either voltage fed converter (VSC) or current fed converter (CSC) can be used in shunt active filter. In additional exchange of average energy should remain zero among the power filter and the power system [6].

II. CONSTANT POWER CONTROL TECHNIQUE

This techniques is based on p-q theory, which was first introduced by H. Akagi [5]. As the name suggest, the active power drawn from the source supply should be constant and other power should be supplied by active filter. Firstly the three phases a-b-c are converted to α-β reference frame using Clark's transformation and by Inverse Clark's transformation for sake of simplicity. The instantaneous active and reactive power can be described in form of α-β components [4].

$$p = v_\alpha i_\alpha + v_\beta i_\beta \qquad (1)$$

$$q = v_\beta i_\alpha - v_\alpha i_\beta \qquad (2)$$

These active and reactive power both categorized in two different component named average powers and oscillating powers.

$$p = \overline{p} + \tilde{p} \qquad (3)$$

$$q = \overline{q} + \tilde{q} \qquad (4)$$

The reference current is generated from the compensating components of the instantaneous powers by using the α-β components of the voltages which is shown in below equation, than the inverse Clark's transformation is applied to get back abc coordinates.

$$\begin{pmatrix} i_{c\alpha} \\ i_{c\beta} \end{pmatrix} = 1/(v^2_\alpha + v^2_\beta) * \begin{pmatrix} v_\alpha & v_\beta \\ v_\beta & v_\alpha \end{pmatrix} \begin{pmatrix} p_{loss} - \overline{p} \\ -q \end{pmatrix} \qquad (5)$$

III. SYNCHRONOUS REFERENCE FRAME

A. *Technique*

In this method, the source currents (ia, ib, ic) are first detected and transformed into two-phase stationary frame (*αβ*) from the three-phase stationary frame (*abc*). Now, the two phase current quantities iα and iβ of stationary αβ-axes are transformed into two-phase synchronous (or rotating) frame (d-q-axes) using equation, where cosθ and sinθ represents the synchronous unit vectors which can be generated using phase-locked loop system (PLL) [7].

$$\begin{pmatrix} i_d \\ i_q \end{pmatrix} = \begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} i_\alpha \\ i_\beta \end{pmatrix} \qquad (6)$$

The d-q currents thus obtained comprises of AC and DC parts. The fundamental component of current is represented by the fixed DC part and the AC part represents the harmonic component. This harmonic component can be easily extracted using a high pass filter (HPF). Now inverse

Transformation is performed to transform the currents from two phase synchronous frame dq into two-phase stationary frame αβ. Finally the current from two phase stationary frame αβ is transformed back into three-phase stationary frame abc and the compensation reference currents ica*, icb* and icc* are obtained [2][5].

IV. SIMULATION & RESULTS

Three phase three wire distribution network is taken into consideration for simulation and analysis of CPC & SRF technique on sinusoidal and non-sinusoidal voltage source having 415 V phase to phase voltage and 50 Hz. The load is simple diode rectifier with dc side R=60 Ω, L=10 mH and line parameters are r = 0.1234 Ω, l = 0.045 mH.

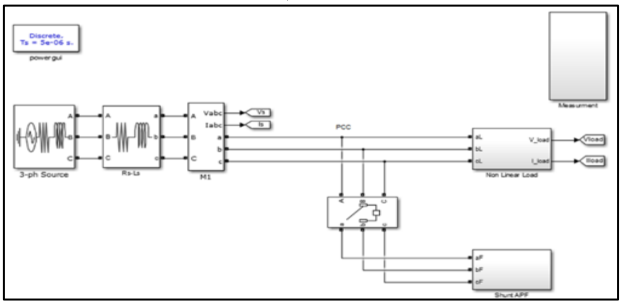


Fig. 2: Model of SAPF with Non-Linear Load

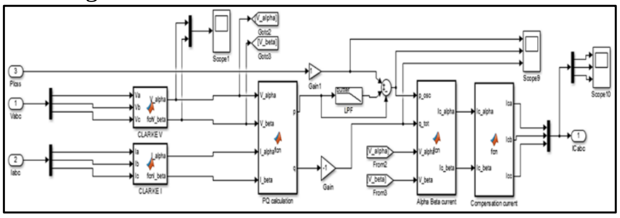


Fig. 3: Constant Power Control Based Technique Block Diagram

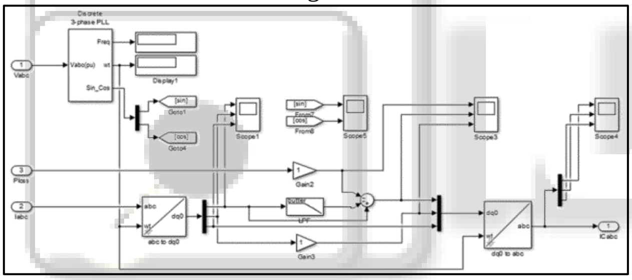
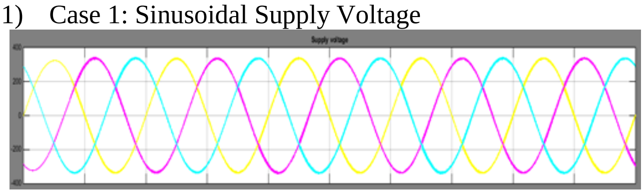
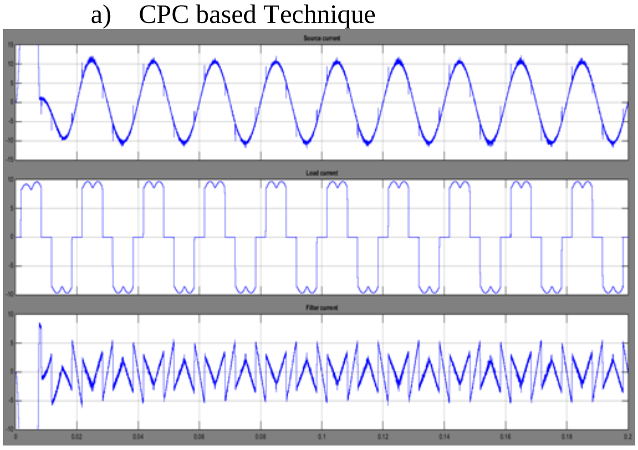


Fig. 4: Synchronous Reference Frame Based Technique Block Diagram

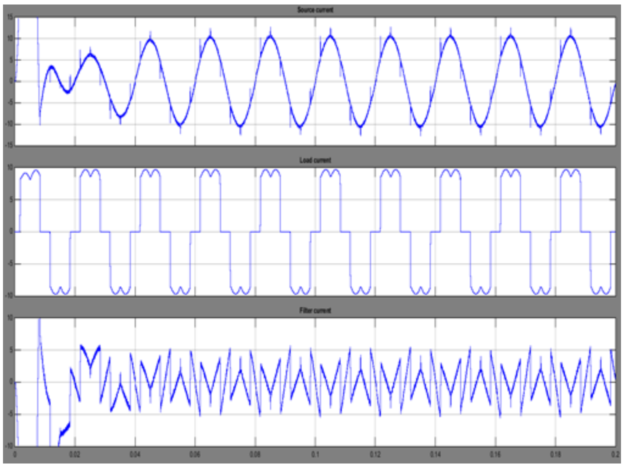
1) Case 1: Sinusoidal Supply Voltage



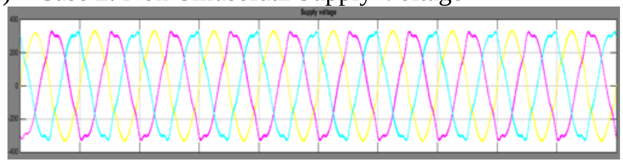
a) CPC based Technique



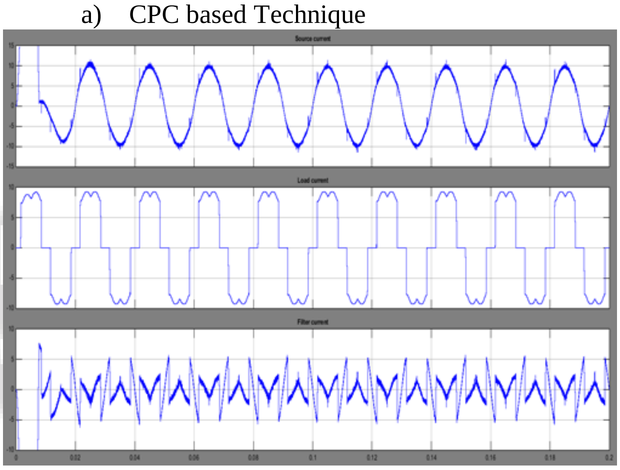
b) SRF based Technique



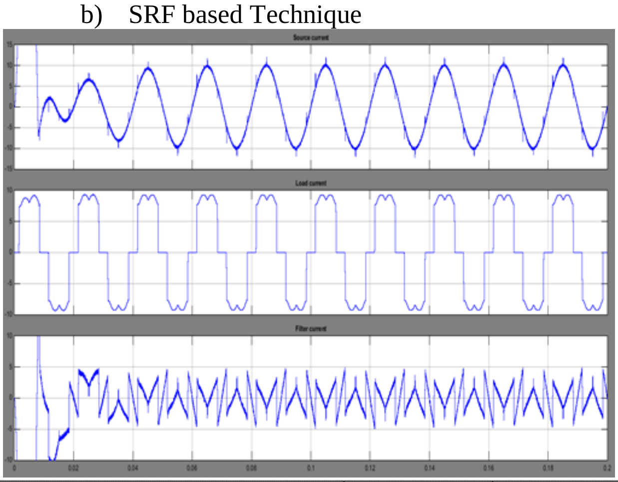
2) Case 2: Non-Sinusoidal Supply Voltage



a) CPC based Technique



b) SRF based Technique



Type of 3-Phase Supply	CPC Method THD %		SRF Method THD%	
	Without SAPF	With SAPF	Without SAPF	With SAPF
1) Sinusoidal Supply Voltage	30.17%	5.01%	30.17%	6.33%
2) Non-Sinusoidal Supply Voltage	26.24%	7.05%	26.24%	4.47%

Table 1: Comparison Table Showing THD % Values

V. CONCLUSION

From the above table we can conclude that under both cases THD values differs. In case of sinusoidal supply voltage CPC technique shows better results while in case of non-sinusoidal supply voltage SRF technique shows good results. In both the case we can see that after the use of power filter THD value is much reduced and harmonics are eliminated. As per the standards of IEEE-519-2014, the both limits are easily satisfied by SAPF.

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