Performance Analysis of a Control Scheme for Shunt Active Filter as Reactive Power Compensator

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ABSTRACT

This article presents a performance analysis of a basic control method for a three-phase voltage source converter (VSC) used as an active filter to compensate for reactive power in a grid-integrated system, with the goal of improving power quality. The majority of electrical systems are comprised of power electronic-based reactive loads, which can lead to power quality problems such as current harmonics, undesirable power factor, and reactive power burden in the distribution system. Reactive power demand is a significant power quality concern, and power researchers are focused on maintaining it at the optimal level. This article discusses the implementation of the P-Q Control Strategy to generate gate signals that activate a shunt connected active filter. The purpose of this filter is to reduce current harmonics in the projected system. The specified control mechanism is modeled and simulated in the Simulink environment to assess its effectiveness in the study.

Index Terms – Voltage Source Converter (VSC), Reactive Power, Current harmonics, Active Power, Power Factor, Power Quality, Reactive power management, Active Filter.

NOMENCLATURE

Vabc	Main grid source voltage
Iabc	Main grid source current
VSC	Voltage source converter
VLL	PCC line-line voltage
PCC	Point of common coupling
SAF	Shunt connected Active Filter
Vdc	DC capacitor voltage
i_{La},i_{Lb},i_{Lc}	Phase-a,b,c load Currents
$\bar{q}$	average reactive power, VAR
$\tilde{q}$	Oscillatory reactive power, VAR
i^*_{sabc}	Reference currents for Statcom
i_α, i_β	Currents in αβco-ordinates

1.0 INTRODUCTION

Due to increased utilization of power electronic loads like uninterrupted power suppliers, electric arc furnaces, Adjustable Speed Drives (ASD) and etc. has resulted severe power issues in the projected system. The non-linear loads effects on the system`s performance and efficiency by injecting the harmonics into the system. the IEEE 519-1992 describes the harmonic limitations in the distribution system [4]. The major consequences of current harmonics are excessive neutral current, Transformer overheating, Distortion of feeder voltage, Malfunction of sensitive equipment like energy meter and computers, poor power factor and etc. [1]. Because of reactive components the distribution system absorbs the reactive power (Q), which enhances the VAr demand in power distribution system, which effects on power factor; hence the compensation of reactive power is the main task for researchers to obtain efficient and effective outcomes from the projected system.

The custom power devices are playing vital role for the diminution of quality issues in distribution system. Among the various FACTS devices the shunt active filters are responsible one for mitigation of both reactive demand and current harmonics. The control strategy called instantaneous reactive power strategy and also known as P-Q Theory, generating the required gate signals, which activates the operation of VSC (Voltage Source Converter) based shunt connected filter for diminution of quality issues in grid tie projected test system.

This article managed as follows, the section II demonstrates need for reactive power compensation, section III depicts about description of proposed system and IV, V and VI sections demonstrates control strategy, result analysis and conclusion respectively.

2.0 NECESSITY OF REACTIVE POWER COMPENSATION

The main grid source will generate the required amount of reactive power for proper operation of electric equipment. The generated VAR power will be stored in system`s reactor or in a capacitor during quarter of a cycle. During forthcoming quarter of a cycle it will be feedback to the grid source. Hence the reactive power is circulating between the reactor and main grid source. To overcome this particular circulation of VAR power issue from reactor to source, the compensation strategies are required in the power system. On the other hand the control or compensation of reactive power in the test model results improvement of the power quality such as

- Proper voltage control or Voltage regulation
- Power Factor enrichment
- Diminution of current harmonics
- Load balancing in the projected system

In this research work the control or compensation of reactive power can be implemented with the help of active involvement of mentioned control strategy for Active Filter for magnification of power quality in grid tie projected system.

3.0 PROPOSED SYSTEM DESCRIPTION

The Fig.1 indicates the detailed description of the test model. The performance analysis of proposed control strategy is analyzed for proposed grid tie system for enrichment of power quality.

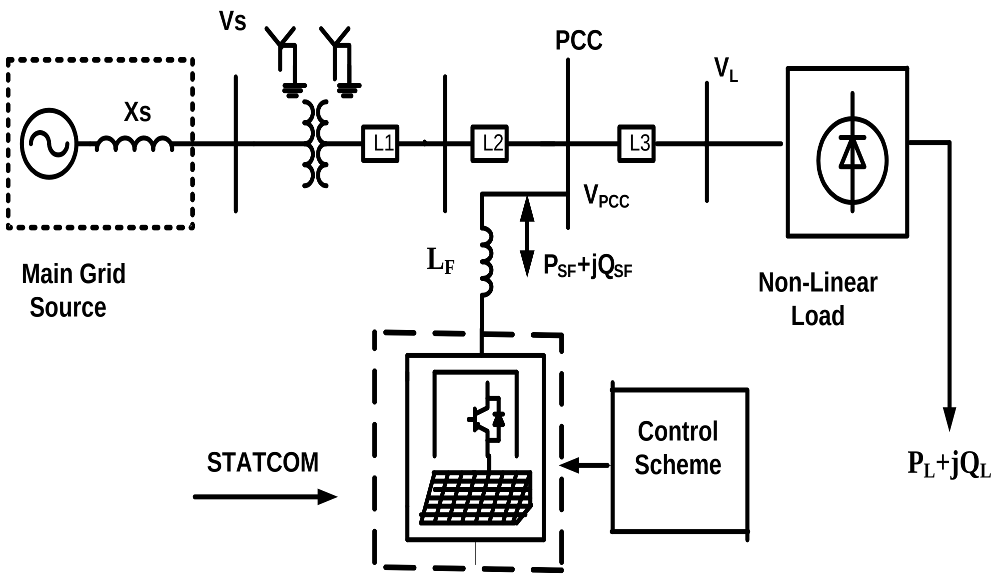

Fig.1 Single line diagram for proposed test model

This fragment principally describes the arrangement of the present test model for the attenuation of power quality complications like voltage variations, wave form distortions (Current harmonics), VAR power demand etc., in grid tie system. The VSC based Shunt Active Filter is associated in shunt with grid for injection of sufficient real and reactive powers for stable operation of power system. The 3-Phase, 3-Wire diode rectifier power electronic based linear load is energized by major grid source as depicted in Fig.1. The active filter connected in shunt with the grid tie system has been utilized to manage the reactive power and current harmonics (current distortions) at PCC in the power system for diminution of power quality hitches generated by the sensitive loads in the projected system.

The complete operation of shunt connected filter as volt ampere reactive power compensator is analyzed. The Fig.2 demonstrates the complete DC voltage control loop of proposed system to for nullification of quality issues in the test model.

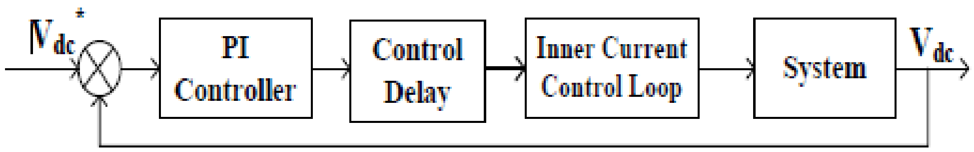

Fig.2 Representation of DC voltage control loop.

4.0 CONTROL SCHEME

The control strategy called IPRT (Instantaneous Reactive Power Theory is perfectly utilized to produce gate current signals to activate the electronic valves of active filter. The switching signals (Gate signals) are extracted with the assist of proposed control theory as follows [4]

The source voltages are

$$V_a = V_m Sin(\omega t) \quad (1)$$

$$V_b = V_m Sin\left(\omega t - \frac{2\pi}{3}\right) \quad (2)$$

$$V_c = V_m Sin\left(\omega t - \frac{4\pi}{3}\right) \quad (3)$$

And load current are given as

$$i_{La} = \sum I_{Lan} Sin\{n(\omega t) - \theta_{an}\} \quad (4)$$

$$i_{Lb} = \sum I_{Lbn} Sin\left\{n\left(\omega t - \frac{2\pi}{3}\right) - \theta_{bn}\right\} \quad (5)$$

$$i_{Lc} = \sum I_{Lcn} Sin\left\{n\left(\omega t - \frac{4\pi}{3}\right) - \theta_{cn}\right\} \quad (6)$$

As per Clarke`s transformation (abc → αβ0) the grid voltages and currents in the stationary frame will be represented as follows

$$\begin{bmatrix} V_\alpha \\ V_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} \quad (7)$$

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i_{La} \\ i_{Lb} \\ i_{Lc} \end{bmatrix} \quad (8)$$

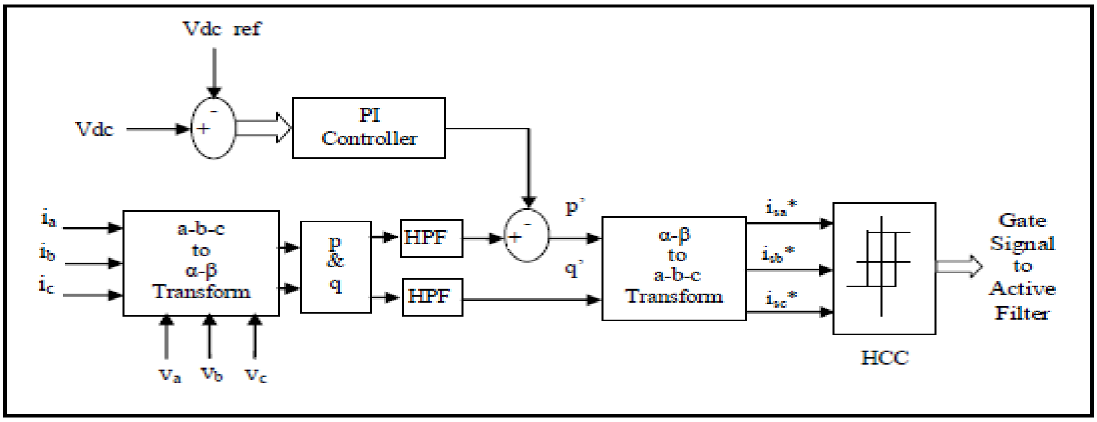

Fig. 3 Schematic diagram of p-q control scheme.

The various powers are computed as follows

$$p = v_\alpha i_\alpha + v_\beta i_\beta (9)$$

$$q = -v_\beta i_\alpha + v_\alpha i_\beta (10)$$

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \tag{11}$$

The i_α and i_β can be obtained as follows

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \frac{1}{\Delta} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} p \\ q \end{bmatrix} \tag{12}$$

Where $\Delta = v_\alpha^2 + v_\beta^2$

$$p = \bar{p} + \tilde{p} \tag{13}$$

$$q = \bar{q} + \tilde{q} \tag{14}$$

Where $\bar{p}$ is average active power and $\bar{q}$ is average reactive power and $\tilde{p}$, $\tilde{q}$are oscillatory powers.The gate currents in the stationary reference frame will be calculated with the assistance of inverse Clarke`s technique as follows

$$\begin{bmatrix} i_{sa}^* \\ i_{sb}^* \\ i_{sc}^* \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1/\sqrt{2} & 1 & 0 \\ 1/\sqrt{2} & -1/2 & \sqrt{3}/2 \\ 1/\sqrt{2} & -1/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i_0^* \\ i_{s\alpha}^* \\ i_{s\beta}^* \end{bmatrix} \tag{15}$$

5.0 RESULT ANALYSIS

The power electronics based nonlinear inductive loads are connected at point of common coupling (PCC) and supplied by main grid source.

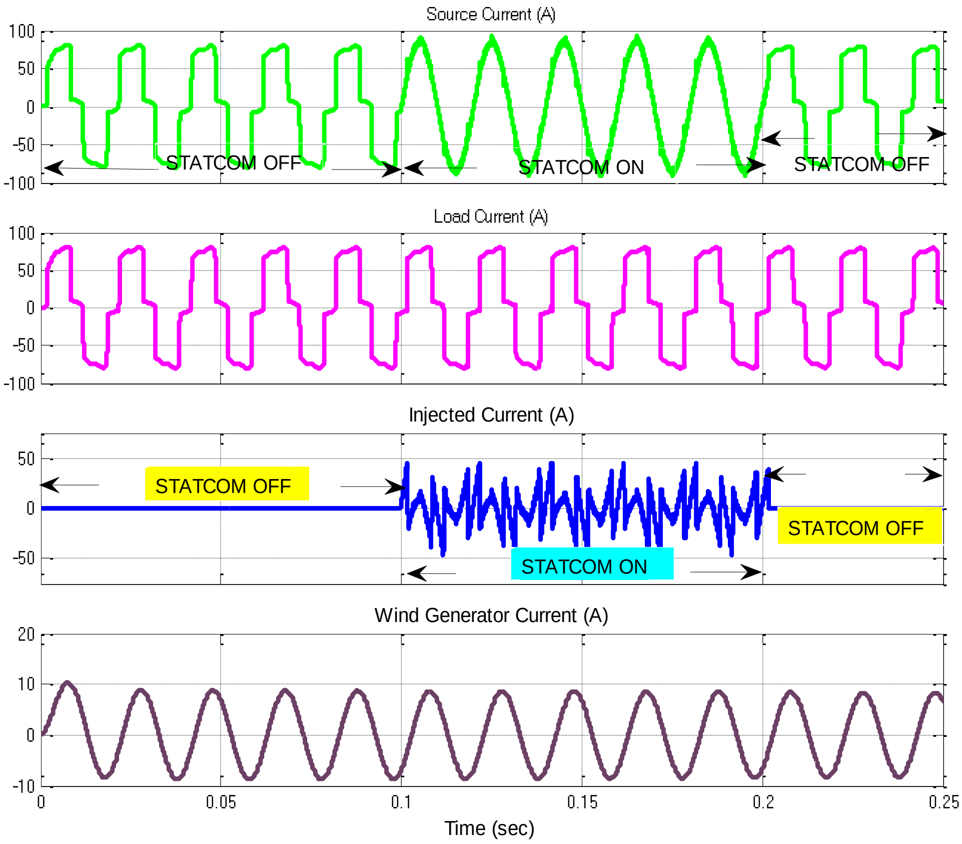

Fig.4 (a)Source current (b)Load current (c) Active Filter injected current (d)Wind Generator current

The distorting loads always drawing harmonic currents from main source, which results in the distortion of supply current at Point of Common Coupling. The distorted current value always depends on main grid source impedance. In this MATLAB simulation model the diode bridge rectifier are connected in Delta configuration as presented in the Fig.1. The Simulation waves for the projected test system demonstrate the performance of proposed control strategy for SAPF as volt ampere reactive power compensator for attenuation of power quality concerns in the system.

From Fig.4(a) it is clear that before 0.1s (Active Filter OFF mode) the source current is get polluted with harmonic currents generated by non-linear load. The SAPF is injecting the required amount of current with desired phase and magnitude so that the current harmonics are completely mitigated from source current from 0.1s to 0.2s, because in this time period the Shunt Active Filter is allowed to operate as presented in fig.4(c).

The Fig.5 represents the reactive power management with Active Filter as reactive power compensator. It is clear that in the time span before 0.1s and after 0.2s (Active Filter OFF mode) the volt ampere reactive power demand is more in the system and it is completely compensated by shun active filter from 0.1s to 0.2s (Active filter ON mode) with the help of active operation of SAPF in proposed grid integrated system.

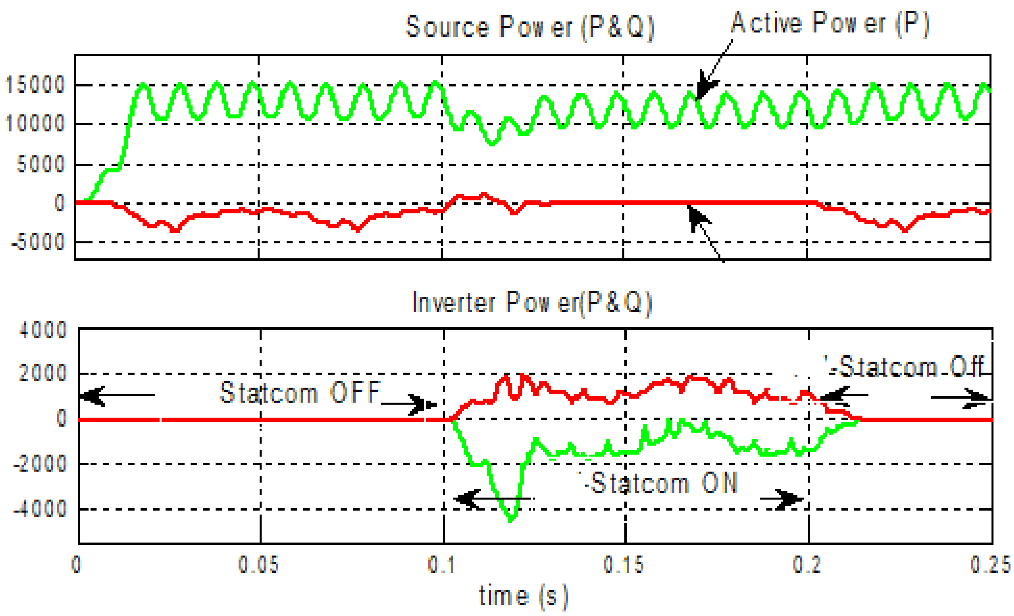

Fig.5 (a)Source Power (b) Active Filter injected Power

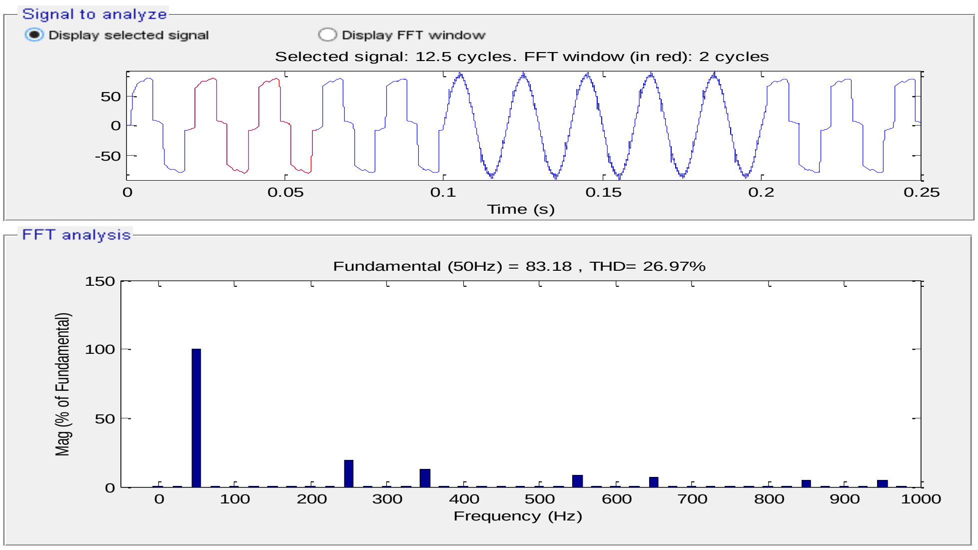

Fig.6 Source Current FFT analysis without SAPF.

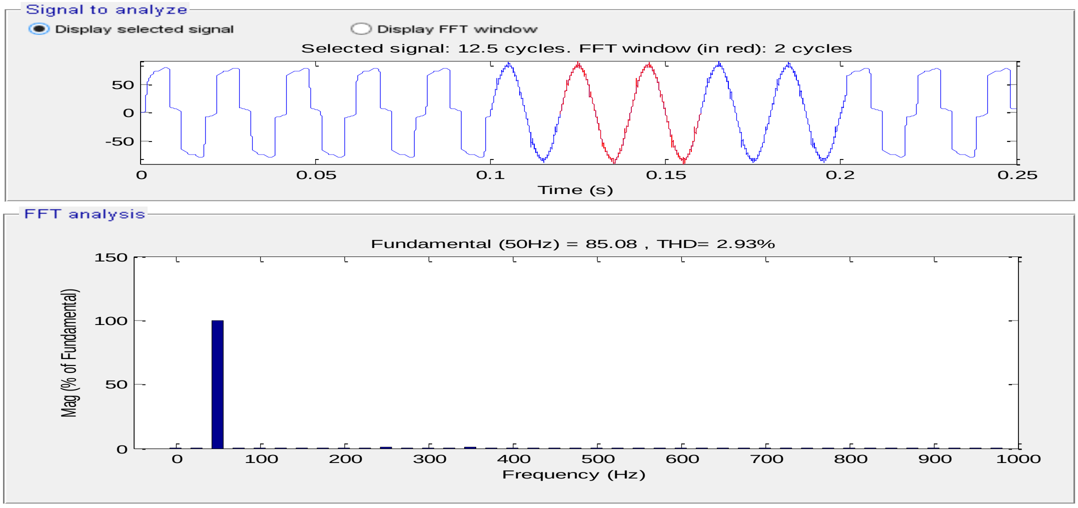

Fig.7 Source Current FFT analysis with SAPF.

The Fig.6 indicates the FFT analysis of source current without Shunt active filter and Fig.7 indicates the FFT analysis of source current with shunt active filter. From Fig.6 and Fig.7 it is clear that the THD value is reduced from 26.97% to 2.92%, which is within the acceptable limit of IEEE standard.

6.0 CONCLUSION

The performance analysis of A control strategy called instantaneous reactive power theory for voltage source converter based Shunt Active Power Filter reactive power compensator was presented and analyzed with the help of active operation of SAPF the volt ampere reactive power is compensated and current harmonics are completely mitigated and power factor is improved from logging mode two leading case. The reactive power compensation and current harmonic mitigations results are simulated using MATLAB simulink block set. The THD value of source current was found within the accepted limit of IEEE standard.

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