Simulink Model of Shunt Active Filter Based on Synchoronous Reference Frame Theory

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Abstract— Power quality is a cruisal issue for modern electrical power system. With wide use of non linear load such as electrical drives, computers at industrial, commercial, residential electrical load there is a great challenge for power engineers relating to power quality. One of such problem is generation of current and voltage harmonics. Traditionally it was suppress by passive filters. After a lot of technical researches there are so many newly developed ways for harmonic suppression. Active filters are one of universal way for harmonic mitigation. Active filters are comparatively superior to conventional passive filters. In this paper the active shunt filter MATLAB/SIMULINK model is presented. Simulation result indicates that proposed active shunt filter can effectively reduce harmonic distortion level.

Keywords: Harmonic, Non Linear Loads, Shunt Active Filter, Synchronous Reference Frame

I. INTRODUCTION

The numerous power quality problem is due to increased use of of non linear load such as fan regulator,UPS,VFD[1][3].These types of equipments draws a harmonic current from electricity distribution network. Major effects include overheating, capacitor failure, vibration, resonance problem low power factor, overloading, communication interference and power fluctuation. [1][2]. So it is very necessary to concentrate towards power quality. Several power quality standards have been defined in order to keep harmonic distortion in limit like IEEE-519-1992/IEC 6100[4].Several options including passive filters are available for improving power quality are available The drawback of huge size, resonance problem, rigidity and fixed compensation [5]. Active filter is widely accepted and implemented as a more flexible and dynamics means of power conditioning. Shunt active power filter (SAPF) in which a reference current is generated to remove distortion from the harmonic currents. Shunt active power filter continuously monitor the harmonics current and reactive power flow in the network and generate reference current from distorted current waveform.[2]. SAPF can be used with different current control strategy such as d-q method, fuzzy logic controller, p-q method, neural networks etc. which is helpful in removing effective harmonic from power system.[5]

Simulation is a proper verification technique. Simulink, developed by Mathwork is a commercial tool for modeling and analyzing. This paper proposes a model of 3 phase 3 wire shunt active filter. The control strategy utilized is Synchronous Reference Frame (SRF).The model is simulated on MATLAB/SIMULINK and results are analyzed on Total Harmonic Distortion(THD) basis[6].

II. BASIC PRINCIPLE OF SHUNT ACTIVE FILTER

The below fig.1 shows the basic compensating principle of Shunt Active Power Filter(SAPF)

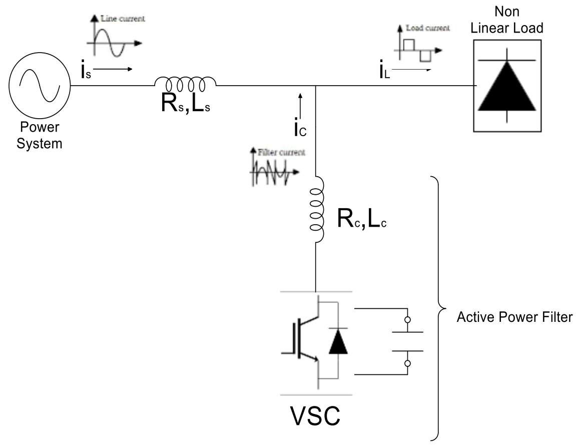

Fig.1 Basic Principle of shunt active filter

Due to harmonics in load current i_L, the wave shape of line current i_S has been distorted. The shunt active filter inject/draw a compensating current in power system to make the line current pure sinusoidal. The VSC (Voltage Source Converter) is the heart of the shunt active filter. [4][6]

III. DERIVATION OF COMPENSATING SIGNAL

One of the key points for a proper implementation of an active filter is to use optimized techniques for current/voltage reference generation. There exist many implementations supported by different strategies based on (1) Frequency-domain harmonic detection methods (2) Time-domain harmonic detection methods. Control methods of the APFs in the time domain are based on instantaneous derivation of compensating commands in the form of either voltage or current signals from distorted and harmonic-polluted voltage or current signals. There are a large number of control strategies in the time domain. Synchronous Reference frame (d-q) *control* strategy is one of effective control strategy [5][11][13]

IV. SYNCHRONOUS REFERENCE FRAME (D-Q)

A. Theory:

The synchronous reference frame theory is employed for the control of three-phase three-leg VSC of the APF. A block diagram of the control scheme is shown in Figure2.The load currents (i_{La}, i_{Lb}, i_{Lc}), the PCC voltages (v_{sa}, v_{sb}, v_{sc}), and the DC bus voltage (v_{DC}) of the APF are sensed as feedback signal [6][7][12].

$$\begin{bmatrix} i_{Ld} \\ i_{Lq} \\ i_{L0} \end{bmatrix} = \frac{2}{3}\begin{bmatrix} cos\theta & sin\theta & \frac{1}{2} \\ \cos(\theta - \frac{2\pi}{3}) & -\sin(\theta - \frac{2\pi}{3}) & \frac{1}{2} \\ \cos(\theta + \frac{2\pi}{3}) & \sin(\theta - \frac{2\pi}{3}) & \frac{1}{2} \end{bmatrix}\begin{bmatrix} i_{La} \\ i_{Lb} \\ i_{Lc} \end{bmatrix}$$

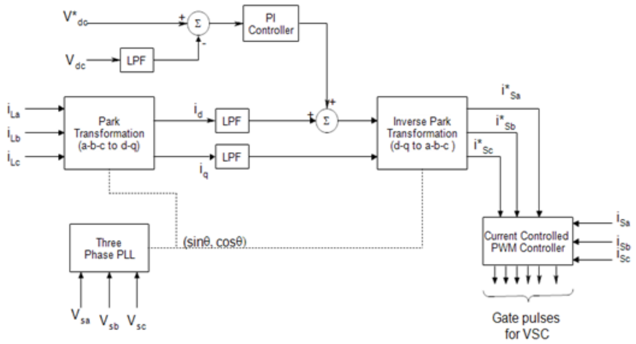

Fig. 2: Block diagram of synchronous reference frame

A three-phase PLL (phase locked loop) is used to synchronize these signals with the PCC voltages. These d–q current components are then passed through low-pass filters (LPFs) to extract the fundamental (DC components) of i_{Ld} and i_{Lq}. The d-axis and q-axis currents consist of fundamental and harmonic components as

$$i_{Ld} = i_{dDC} + i_{dAC}$$

$$i_{Lq} = i_{qDC} + i_{qAC}$$

SRF controller extracts DC quantities by a LPF and hence the non-DC quantities (harmonics) are separated from the reference signals. after considering switching loss the reference direct-axis supply current is

$$i_d^* = i_{dDC} + i_{loss}$$

The reference source current obtained by the following reverse Park's transformation

$$\begin{bmatrix} i_{sa}^* \\ i_{sb}^* \\ i_{sc}^* \end{bmatrix} = \begin{bmatrix} cos\theta & sin\theta & 1 \\ \cos(\theta - \frac{2\pi}{3}) & -\sin(\theta - \frac{2\pi}{3}) & 1 \\ \cos(\theta + \frac{2\pi}{3}) & \sin(\theta - \frac{2\pi}{3}) & 1 \end{bmatrix}\begin{bmatrix} i_d^* \\ i_q^* \\ i_0^* \end{bmatrix}$$

V. MATLAB/SIMULINK MODEL

As per SRF control strategy the proposed system uses two control loop (1)inner loop which ensures the current supplied by VSI follows the referenced current generated from samples of load current.(2)Outer loop controls the dc voltage[6]. On behalf of we can represent model in following blocks:

A. Mains Supply:

The main supply is three phase balanced wye connected with grounded power supply.

Its value is 127 volt rms (line to line), 50Hz.

B. Non Linear Load:

A three phase diode rectifier supplying R-L load is taken as non linear load

C. Reference current Calculation by SRF Theory:

As discussed in section IV a three phase load current in a-b-c frame is converted into d-q-0 frame by Park's transformation. By using low pass filter (LPF) D axis current i_{Ld} is filtered out and assigned for inverse Park transformation. Same way i_{Lq} is applied for reactive power compensation.i_{L0} must be used if input voltages are distorted and unbalanced[7][8]

D. SRF Phase Locked Loop:

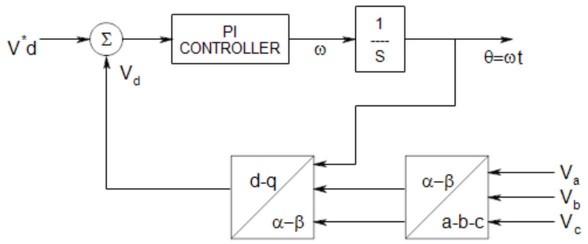

Fig. 3: Basic structure for SRF based PLL structure

Fig.3 shows basic structure for SRF based PLL structure. To obtain phase information, the three phase voltage V_a, Vb, Vc are transferred into stationary two phase systems V_α & V_β and further transferred to V_d andV_q. Now phase angle θ can be obtained by reference voltage v_d^* equal to zero.The PI controller (Kp.$\frac{1+s\tau}{s\tau}$) is used to regulate this d component and the output of this PI controller is the grid frequency.After the integration of this grid frequency, the utility voltage angle is obtained.[12]

E. Dc Bus Voltage Control:

As explained in section IV capacitor provides a reactive power requirement and the reactive transfer between load and APF(due to charging and discharging of capacitor),the average DC bus voltage can be maintained constant. However due to switching losses in VSI power distribution source must supply active power requirement of load and additional power requirement of inverter. This task is fulfilled by PI controller.[6][8]

F. Voltage Source Inverter:

It is the heart of Active Shunt filter. Capacitor supplies energy and VSI generates high frequency switching signal which cancels the harmonic from load current. Control of current wave shape is limited by switching frequency and by available driving voltage across interface reactor. Switching is done according to gating signals from hysteresis current controller. Capacitor voltage is continuously measured and applied to PI controller.[2][5][8]

G. Hysteresis Band Current Controller:

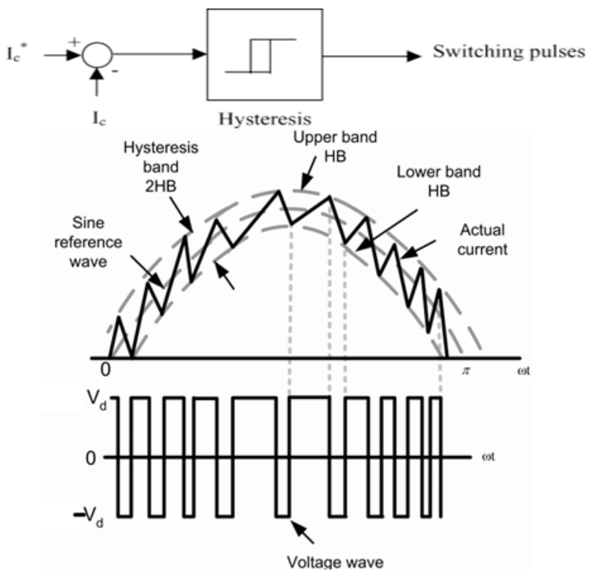

Fig. 4: Voltage and Current waveforms with hysteresis control

As shown in fig 4 when the actual current exceeds the upper or lower hysteresis limit, the associated witching of the VSI will force the current to get back to the hysteresis band limit [8]. The error of the reference current and the actual current determines the turn on/off time of the switch. When the actual current exceeds the upper hysteresis limit, a negative voltage switching function is turned on and causes the actual current to decrease. On the other hand, when the actual current is smaller than hysteresis limit, a positive voltage switching function is turned on and causes the actual current to increase. When actual line current tries to leave the respective band suitable IGBT (+ OR -) turns ON [9][10].

The proposed simulink model is as shown in fig. The data values are as below:

Source Voltage	127v rms line to line
System Frequency	60Hz
DC side capacitance C_{DC}	1500μF
AC side inductance	1.0mH
AC side resistance	0.1Ω
Inverter DC voltage	450V
Proportional K_p	0.25
Integral constant K_i	0.005

Table 1:

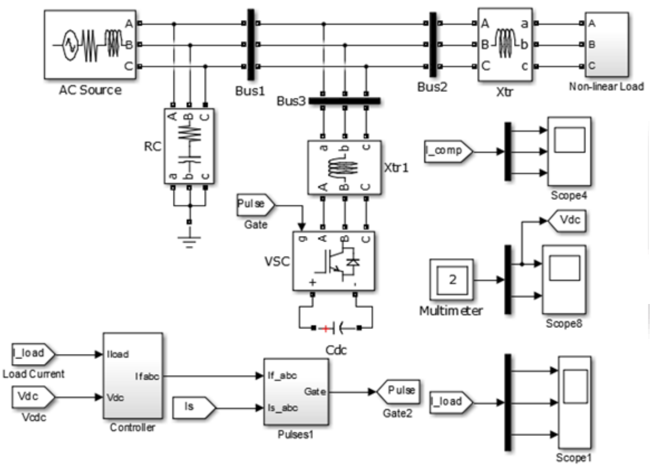

Fig. 5: Simulink model of SAPF

VI. Simulation Result

A. *Source Current I_s:*

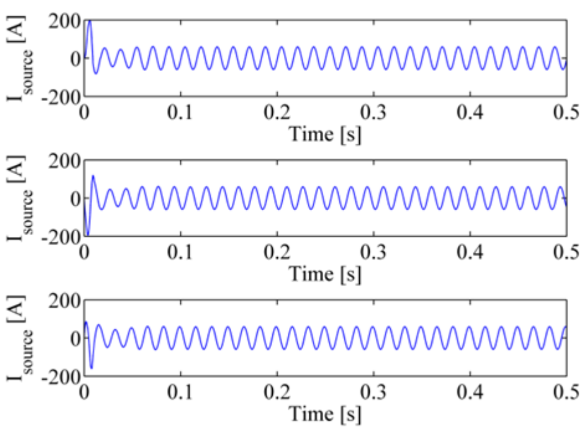

Fig. 6: Simulation of source current

B. *Compensating Current:*

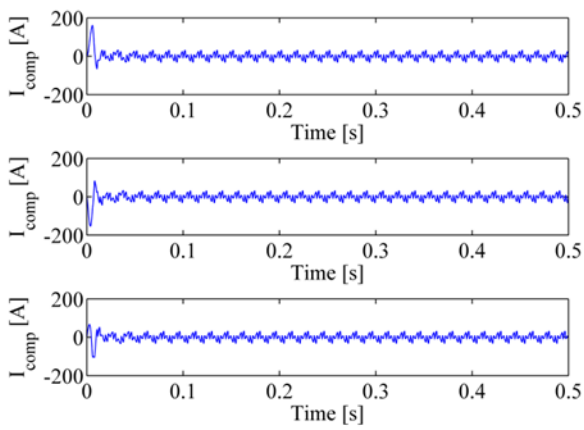

Fig. 7: Simulation of Compensating Current

THD before compensation	THD after compensation
19.12%	0.86%

Table 2: THD Result

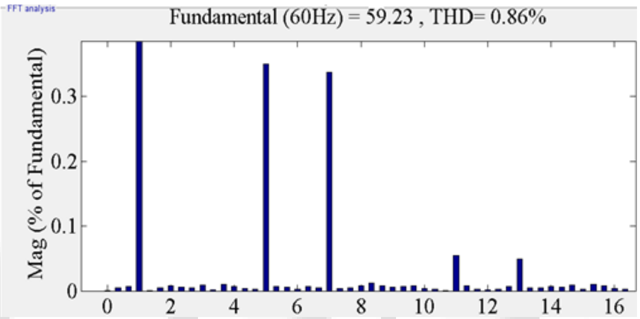

Fig. 8: FFT Analysis

VII. Conclusion

Simulation result indicates there is a considerable reduction in THD after active filter compensation. Results indicates that SRF based APF can be used for elimination of harmonic for three phase three wire power system

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