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Performance of Shunt Active Power Filter based SRF Algorithm under Non Linear Load

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***Abstract*— Now a day's numbers of power system equipment contain power electronic based controller to get smooth operation, better reliability & efficiency in the operation. These power electronic based controller contains Non-Linear components which is responsible to produce harmonics in the source current & hence in the source voltage at the point of common coupling (PCC). These harmonics creates the disturbance in normal operation, excessive heating in the equipments etc. so it is necessary to mitigate these harmonics problems. So, various types of filters such as Passive filter & active filters are introduced. But due to problem of Passive filter like bulky in size, resonance problem & it compensate only tuned harmonics frequencies they are comparatively less in use. So alternative filtering used as active filtering.**

Currently Shunt active filter with various control techniques are used. In this paper shunt active filter is designed with synchronous reference frame algorithm to compensate the harmonic current of a three phase Non- Linear load. In these, load current, DC bus voltage& source voltage are sensed to compute the reference current of shunt active power filter. Driving signal for shunt active filter are produced by feeding reference by feeding reference & actual Output current to hysteresis band current controller. It s found that under this condition SAPF is very effective solution for current harmonics. MATLAB Simulation @ power system toolbox is used to simulate the proposed system.

***Index Terms*— Shunt Active Filter, Synchronous Reference Frame Algorithm, Hysteresis current control, harmonics etc.**

I. INTRODUCTION

Now a day, power system uses large numbers of power electronics devices to control the power system equipments. Due to use of these devices harmonics are produced in the power system which pollutes the entire power system. Even if the power electronics devices have advantages to system reliability & fast response, but these non linear devices are the main source of harmonics in the power system [1].

These harmonics reduces the quality of power. Also cause to low efficiency, low power factor and produces the disturbance in the power system & communication interference. It also produces excessive heating of measuring equipments in power system. Hence to overcome these problems of harmonics conventionally passive filter have been used. But due to disadvantages, namely they only filter frequencies for which they tuned, limited operation cannot be possible to certain load, resonance problems introduced due to interaction between the passive filter and other loads, bulkiness and fixed compensation etc.

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To overcome these disadvantages, active power filter have been developed. The active power filter is based on power electronics topology. It is possible solution for power conditioning system [2]. Active power filter differs from passive filters in that they condition the harmonics current rather than divert & block them. Active filter consist bridge (inverter or rectifier) configuration for harmonics filter. They inject the counter harmonics current to cancel out harmonics current generated by non linear load.

Active filter is classified as series active filter and Shunt active filters. Series filter is consist capacitor and inductor connected in parallel with each other but in series with the load. This types of filter provides high impedance to the harmonics currents and allow to pass them reaching the power supply, but allows the fundamental frequency of 60 Hz current to pass through. But these types of filters have a drawback of carry of full load current. Shunt active filter consist of capacitor and inductor connected in series but parallel with load. This filter provides low impedance path for harmonics current and divert the harmonics to ground. Shunt filter is common and less expensive because they don't have to carry the full load current [3].

Here shunt active power filter is used with voltage source inverter to mitigate the harmonics produced by Non linear load. It injects the compensating harmonics current (in 180^0) phase shift to harmonics current) in to the power lines. In these shunt active power filter main theme is to design these filter with synchronous reference frame control theory which is signal processing based. Hysteresis band current controller is used to generate the switching signal to the voltage source inverter [4][5]. The basic diagram for three phase SRF based shunt active filter is shown in fig. 1 [5].

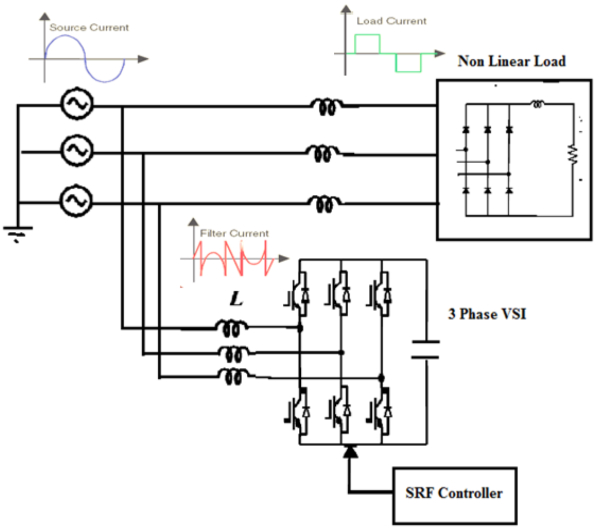

Fig.1 Three Phase SRF based SAPF

II. SYNCHRONOUS REFERENCE THEORY

Synchronous Reference Frame theory depends on the transformation of stationary three phase to rotating two phase. In these transformation coordinates from three phase stationary a-b-c coordinates system to 0-d-q rotating coordinates [6]. The following figure shows the transformation of three phase stationary to rotating two phase.

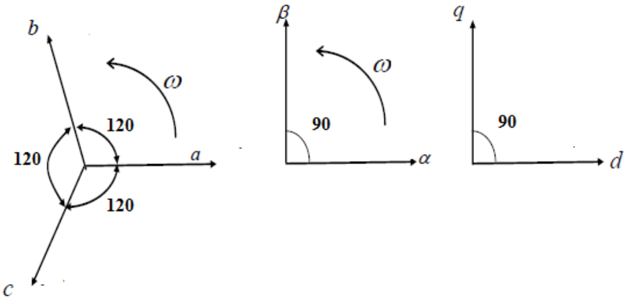

Fig.2 Reference Frame Transformation

In Synchronous Frame Reference theory park transformation is used for the conversion.

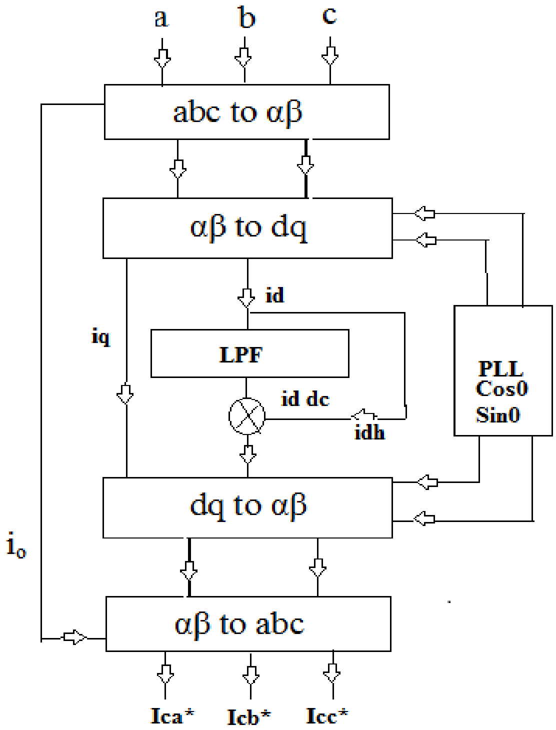

Fig. 3 Park Transformation algorithm

Here, the source currents (ia, ib, ic) from three pahse supply a,b,c are first identified and transformed into stationary two-phase frame (αβ-*0*) from the three-phase stationary frame (a-b-c), as per equation (1).

$$\begin{bmatrix} i_\alpha \\ i_\beta \\ i_0 \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \qquad (1)$$

Here two direct and inverse parks transformation is used which allows the evaluation of specific harmonic component of the input signals and a low pass filtering stage LPF. After conversion of stationary three phase to stationary two phase axis the two phase current quantities iα and iβ of stationary αβ-axes are transformed into two-phase rotating synchronous frame (d-q-axes) using equation (2), in this equation Cosθ and Sinθ represents the synchronous unit vectors which can be generated using phase-locked loop system (PLL).

$$\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \begin{bmatrix} \cos\vartheta & \sin\vartheta \\ -\sin\vartheta & \cos\vartheta \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\alpha \end{bmatrix} \qquad (2)$$

From the above equation The d-q axis currents (i_q and i_d) are determined which comprises of AC and DC parts. The fixed DC part consist fundamental component of current and the harmonic components are represented by AC part. This harmonic component can be easily extracted using a high pass filter (HPF). The d-axis current is a combination of active fundamental current (i_d dc) and the load harmonic current (i_h). The fundamental component of current rotates in synchronism with the rotating frame and thus can be considered as dc. By filtering i_d, the current is obtained, which represents the fundamental component of the load current in the synchronous frame. Thus, the AC component i_{dh} can be obtained by subtracting i_d dc part from the total d-axis current (i_d), which leaves behind the harmonic component present in the load current. In the rotating frame the q-axis current (i_q) represents the sum of the fundamental reactive load currents and part of the load harmonic currents. So the q-axis current can be totally used to calculate the reference compensation currents.

After this inverse transformation is used to transform the currents from two phase synchronous frame d-q into two-phase stationary frame α-β as per equation (3).

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \begin{bmatrix} \cos\vartheta & -\sin\vartheta \\ \sin\vartheta & \cos\vartheta \end{bmatrix} \begin{bmatrix} i_d \\ i_q \end{bmatrix} \qquad (3)$$

Finally the current from two phase stationary frame αβ0 is transformed back into three-phase stationary frame abc as per equation (4) and the compensation reference currents ica*, icb* and icc* are obtained

$$\begin{bmatrix} i_{ca}* \\ i_{cb}* \\ i_{cc}* \end{bmatrix} = \left[T_{abc}\right] \begin{bmatrix} i_\alpha \\ i_\beta \\ i_0 \end{bmatrix} \qquad (4)$$

Where,

$$\left[T_{abc}\right] = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 & \frac{1}{\sqrt{2}} \\ \frac{-1}{2} & \frac{\sqrt{3}}{2} & \frac{1}{\sqrt{2}} \\ \frac{-1}{2} & \frac{-\sqrt{3}}{2} & \frac{1}{\sqrt{2}} \end{bmatrix}$$

The simulation of park transformation (SRF) is as shown below.

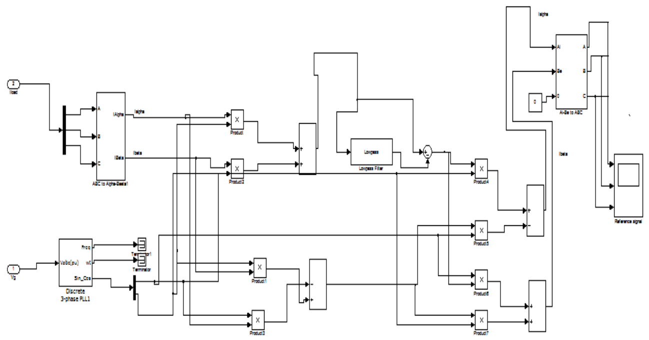

Fig.4 Simulation of park transformation (SRF)

III. HYSTERESIS BAND CURRENT CONTROLLER

The hysteresis band current control (HBCC) technique is used for pulse generation in current controlled Voltage Source Inverters. This method has advantage of good stability, very fast response, good accuracy and has simple operation. The HBCC technique employed in an active power filter for the control of line current. It consists of a hysteresis band surrounding the generated error current. The current error is obtained by subtracting the actual filter current from the reference current. The reference current is obtained by the SRF method which is represented as Iabc*. The actual filter current is represented as I_f abc. The error signal is then fed to the relay with the desired hysteresis band to obtain the switching pulses for the inverter. The operation of APF depends on the sequence of pulse generated by the controller. Fig. 5 shows the simulation diagram of the hysteresis current controller.

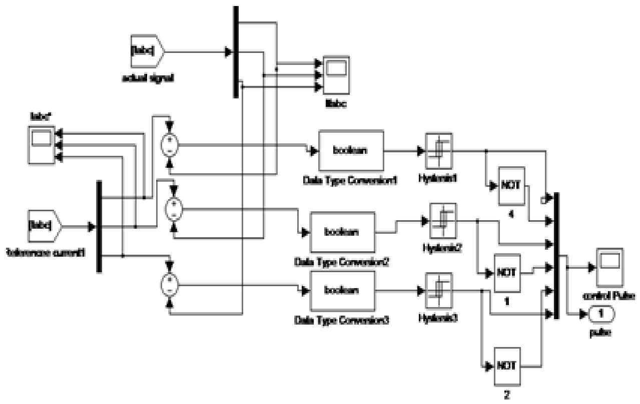

Fig. 5 Simulation diagram of hysteresis current control

IV. SIMULATION AND RESULTS

In this paper simulation of SRF algorithm using park transformation has been done. The overall simulation diagram is shown in fig.6. By doing this the reference signal I_{abc}* is produced from SRF algorithm which is shown in fig 7. Then this reference current is compared with actual current signal from which error signal is developed shown in fig 8. This is fed to the hysteresis band control harmonic current. This developed the pulse signal for VSI shown in fig 9.when the harmonics produces in the system the control signal is provided to the VSI fed filter which provide the 180 phase shift compensating current to compensate the harmonic current produced by Non Linear Load.

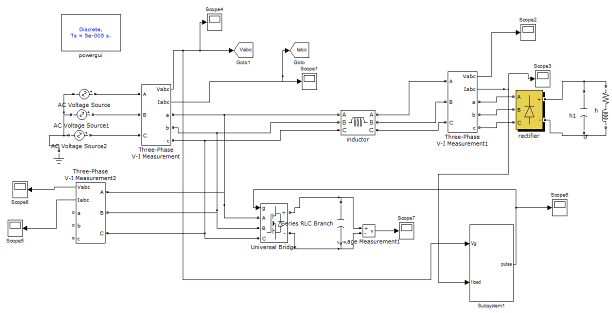

Fig.6 Overall Simulation diagram

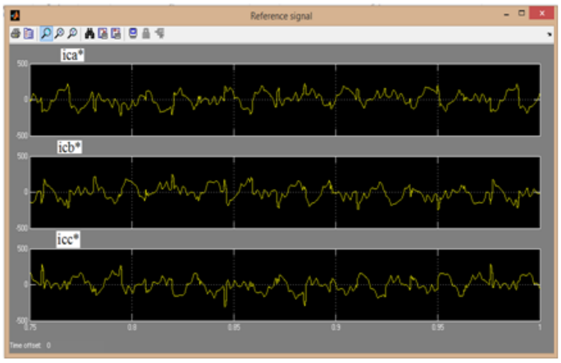

Fig.7 Reference Signal

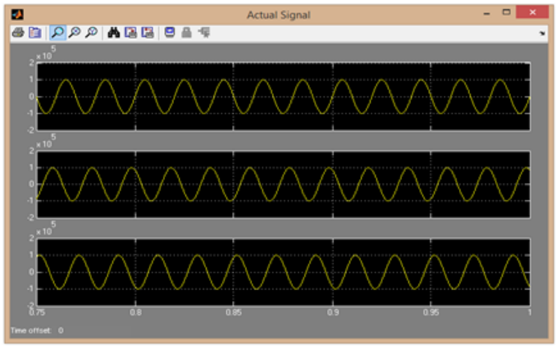

Fig.8 Error Signal

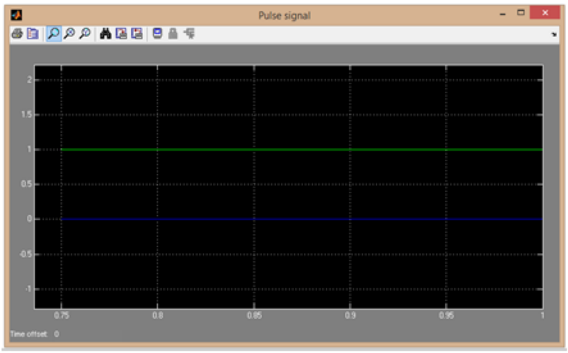

Fig.9 Control Pulse from HBCC

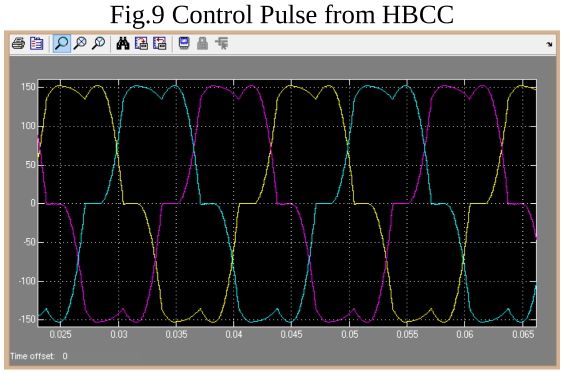

Fig.10 Source current without SAPF

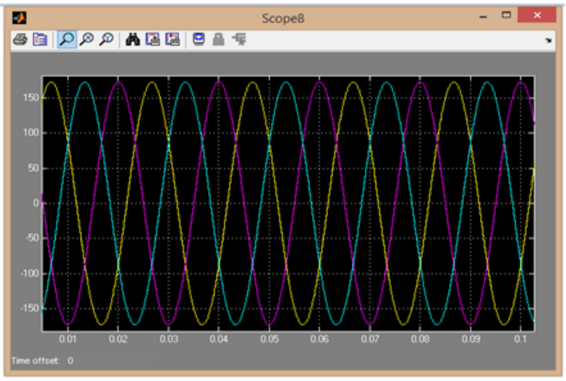

Fig.11 Source Current with SAPF

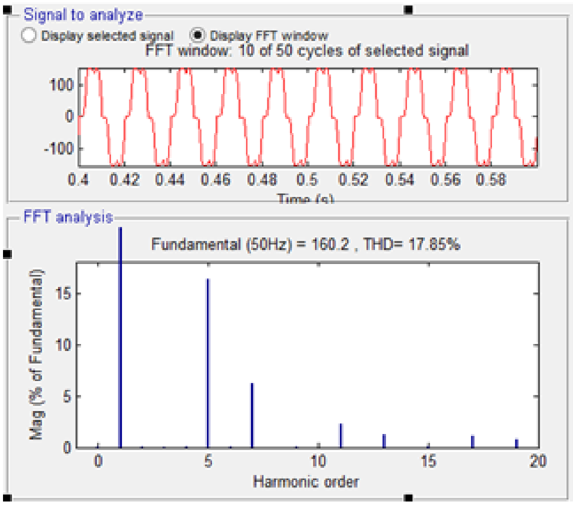

Fig.12 THD spectrum without SAPF

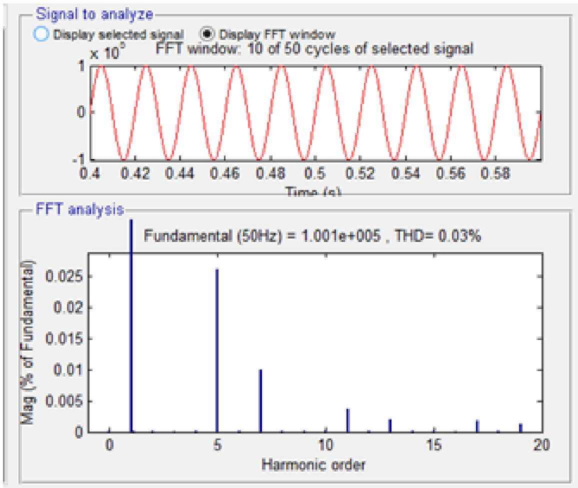

Fig.13 THD spectrum with SAPF

V. CONCLUSION

This paper describes Performance of Shunt active power filter with SRF controller. Using Synchronous Reference Frame Algorithm three phase reference current is generated, this is compared with the actual filter current and resultant signal is given to the HBCC, it provides control signal to three phase voltage source inverter. HBCC technique used for the switching pulse generation is found more effective and gives fast response. In this simulation it is found that the THD level is obtain below 5% as per the IEEE std for distribution system. In this paper THD obtained within the permissible limits of IEEE std for distribution system.

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