International Journal of Modern Trends in Engineering and Research
www.ijmter.com
e-ISSN No.:2349-9745, Date: 2-4 July, 2015

Harmonics Reduction by Using SRF Based Shunt Active Power Filter

Mr. K. L. Deshmukh[1], Mr. S. M. Shembekar[2],

[1]*Electrical Engineering Department, S.S.B.T's COET Bambhori, Jalgaon, deshmukh_kalpesh@ymail.com*
[2]*Electrical Engineering Department, S.S.B.T's COET Bambhori, Jalgaon, smshembekar@gmail.com*

Abstract – Now days, due to use of non linear load and wide spread use of power electronics devices harmonics are introduce in source currents and hence in source voltages at the point of Common coupling (PCC) and hence may damage the system equipment. So importance is being given to the development of Active Power Filters to solve these problems to improve power quality among which shunt active power filter is used to eliminate voltage and load current harmonics and for reactive power compensation. The shunt active power filters have been developed based on Synchronous Reference Frame Algorithm Method. Synchronous Reference Frame (SRF) Algorithm is used to extract the harmonics components. Hysteresis band current control (HBCC) technique is used for the generation of firing pulses to the inverter. This system is simulated using MATLAB and results are observed and these results are compared with p-q theory based shunt active power filter.

Keywords – Shunt Active Power Filter, harmonics, Synchronous Reference Frame Algorithm, Hysteresis Current Control, Compensation Current.

I. INTRODUCTION

In recent years, the increasing use of power semi-conductor technology and non linear loads, have introduce the harmonics in the system, which affect power quality in power systems [1]. Therefore, to mitigate these harmonics to improve power quality in electrical power systems conventionally passive L-C filters were employed to reduce harmonics and capacitors were used to improve the power factor of the loads. But passive filters have the demerits of fixed compensation, large size and resonance. Also, in practical applications, the amplitude and the harmonic content of the load current can vary randomly; under such conditions the conventional solution becomes ineffective [2].

The Active Power Filter (APF) based on power electronics technology is a viable solution for power conditioning to suppress the harmonics in the power system. With recent developments in power electronic switches, the Active Power Filters (APFs) have been applied to mitigate the problems created by non-linear loads. One of the most commonly used active filters is the Shunt Active Filter (SAF) which is used to eliminate the unwanted harmonics and compensate reactive power consumed by non-linear loads [3].

The Shunt Active Power Filter is connected in parallel with the line through a coupling inductor. Its main power circuit consists of a three phase three-leg current controlled voltage source inverter with a

DC link capacitor. An active power filter operates by generating a compensating current with 180 degree phase opposition and injects it back to the line so as to cancel out the current harmonics introduced by the nonlinear load. This will thus suppress the harmonic content present in the line and make the current waveform sinusoidal. So the process comprises of detecting the harmonic component present in the line current, generating the reference current, producing the switching pulses for the power circuit, generating a compensating current and injecting it back to the line. [4-7]

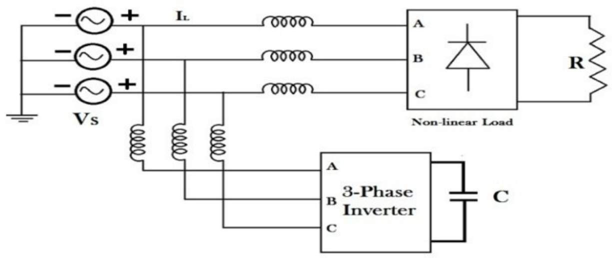
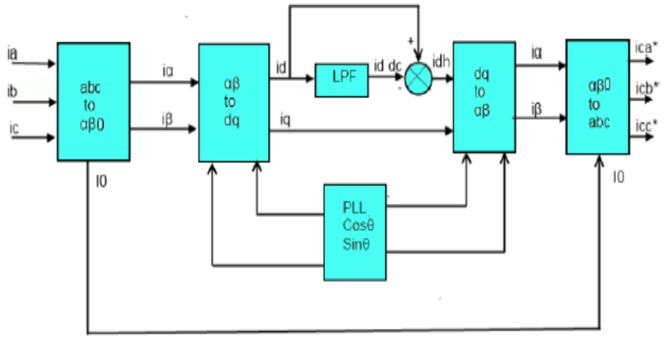


Figure.1 Three phase shunt active power filter

II. SYSTEM DESIGN

2.1 Synchronous Reference Frame Algorithm

Number of control strategies being used for the determination of reference currents in shunt active power filters namely Instantaneous Reactive Power Theory (p-q theory), sliding mode control strategy, Unity Power Factor method, One Cycle Control, Fast Fourier Technique etc. Here, SRF theory is used to evaluate the three-phase reference 3currents (i_{ca}*, i_{cb}*, i_{cc}*) by the active power used filters by targeting the source (i_{ca}, i_{cb}, i_{cc}) current Fig.2 shows the block diagram which explains three-phase SRF-theory, used for harmonic component extraction.



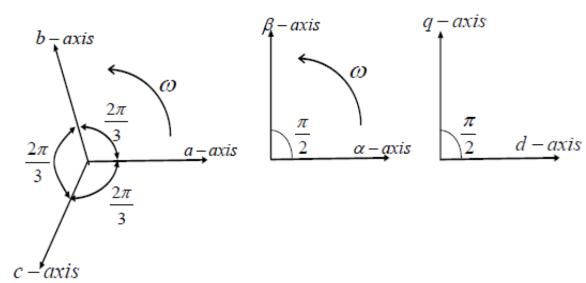


Figure.2 Block diagram of SRF based algorithm Figure.3 Reference Frame Transformation

In this method, the source currents (i_a, i_b, i_c) are first detected and transformed into two-phase stationary frame (αβ-*0*) from the three-phase stationary frame (a-b-c), as per equation (1).

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

(1)

Here two directand inverse parks transformation is used which allows the evaluation of specific harmonic component of the input signals and a low pass filtering stage LPF. Now, the two phase current quantities i_α and i_β of stationary αβ-axes are transformed into two-phase synchronous (or rotating) frame (d-q-axes) using equation (2), where Cosθ and Sinθ represents the synchronous unit vectors which can be generated using phase-locked loop system (PLL).

$$\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix}$$

(2)

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), as implemented in Fig 2. The d-axis current is a combination of active fundamental current (id dc) and the load harmonic current (ih). The fundamental component of current rotates in synchronism with the rotating frame and thus can be considered as dc. By filtering id, the current is obtained, which represents the fundamental component of the load current in the synchronous frame. Thus, the AC component id_h can be obtained by subtracting id dc part from the total d-axis current (id), which leaves behind the harmonic component present in the load current. In the rotating frame the q-axis current (iq) 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.
Now inverse transformation is performed to transform the currents from two phase synchronous frame d-q into two-phase stationary frame α-β as per equation (3).

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} i_{dh} \\ i_q \end{bmatrix}$$

(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.

$$\begin{bmatrix} i_{ca}^* \\ i_{cb}^* \\ i_{cc}^* \end{bmatrix} = [T_{abc}] \begin{bmatrix} i_\alpha \\ i_\beta \\ i_0 \end{bmatrix}$$

(4)

Where,

$$[T_{abc}] = \sqrt{\frac{2}{3}}\begin{bmatrix} 1 & 0 & \frac{1}{\sqrt{2}} \\ \frac{-1}{2} & \frac{\sqrt{3}}{2} & \frac{1}{\sqrt{2}} \\ \frac{-1}{2} & \frac{-\sqrt{3}}{2} & \frac{1}{\sqrt{2}} \end{bmatrix} \quad (5)$$

2.2 Hysterisis Band Current Control

The hysteresis band current control (HBCC) technique is used for pulse generation in current controlled VSIs. The control method offers good stability, gives a very fast response, provides good accuracy and has got a simple operation. The HBCC technique employed in an active power filter for the control of line current is shown in Figure 4. 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 used here is obtained by the SRF method as discussed earlier 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.

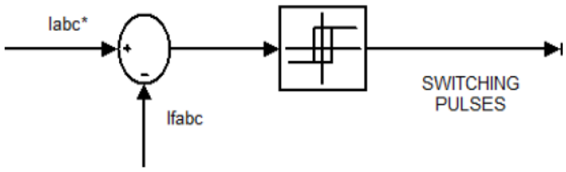


Figure.4 Hysteresis Band Current Controller

The operation of APF depends on the sequence of pulse generated by the controller. Figure 4 shows the simulation diagram of the hysteresis current controller. A band is set above and below the generated error signal. Whenever this signal crosses the upper band, the output voltage changes so as to decrease the input current and whenever the signal crosses the lower band, the output voltage changes to increase the input current. Accordingly switching signals are generated.

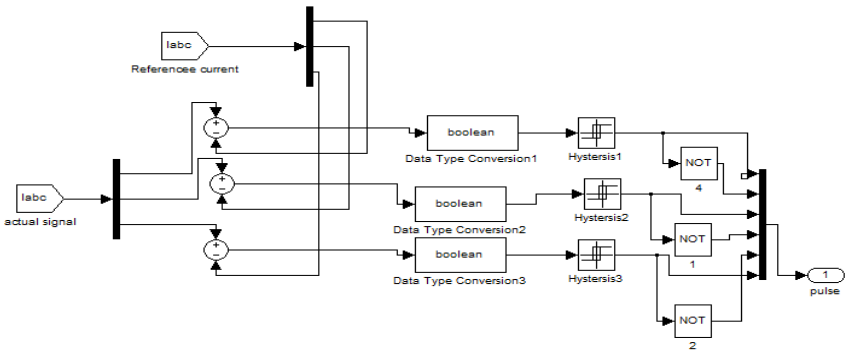


Figure.5 Simulation diagram of hysteresis current control

The switching signals thus generated are fed to the power circuit which comprises of a three phase three leg VSI with a DC link capacitor across it. Based on these switching signals the inverter generates compensating current in phase opposition to the line current. The compensating current is injected back into the power line at the PCC and thus suppressing the current harmonics present in the line. The overall simulation block diagram is shown in Figure 6.

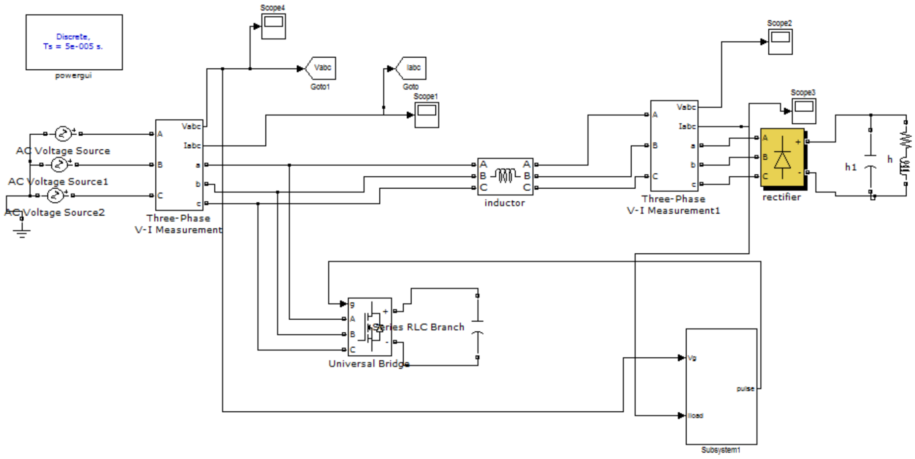
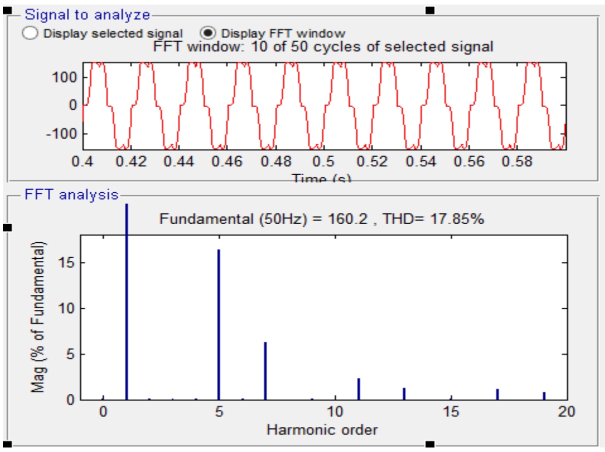


Figure.6 Overall simulation diagram.

III. SIMULATION RESULTS AND DISCUSSION



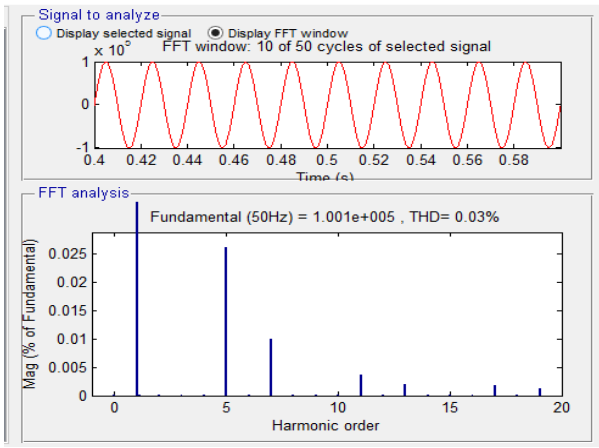


Figure.7 Source current and THD spectrum without SAF Figure.8 Source current and THD Spectrum with SAF

After simulation of three phase transmission line having non linear load with SRF based shunt active filter the harmonic current is compensated within a permissible limits of IEEE standard. In this the source current waveform without filter in a-phase is shown in Figure 7. when filter is not connected in the system the harmonics are produces due to non linear load. These harmonics distort the source current as shown in figure.7. Also if the THD is cheked, then Total Harmonic Distortion (THD) spectrum in the system without filter is shown in Figure.7, which indicate a THD of 17.85% These compensating current is produced by the filter when we are injecting this compensating current we get the source current with minimum harmonics. The source current after the injection of compensating current is shown in Figure 8. The THD with active power filter included is observed to be 0.03% which is within the allowable harmonic limit. Figure.8 shows the THD spectrum with active power filter in the circuit.

IV. CONCLUSIONS

The SAPF explained in this paper compensate the line current harmonics generated due to the nonlinear loads in the system. HBCC technique used for the switching pulse generation was found to be effective and its validity is proved based on simulation results. Thus SRF based SAPF has been proved to be effective to keep the harmonic content in power lines within the permissible limit of IEEE standards i.e. THD is 0.03%.

V. REFERENCES

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