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CURRENT HARMONICS REDUCTION USING SHUNT ACTIVE FILTER

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Abstract- The excessive use of power electronics elements in power distribution system creates the power quality problems because of its own non-linear (V-I) characteristics and switching instants. That quality of power can be improved by usage of the compensators and active power filters. This paper gives the Simulink model of shunt active power filter for improvement of quality of power. Harmonic currents produced by non linear loads are compensated by shunt active filter and maintain the source current sinusoidal. In this proposed methodology shunt active power filter is acts as a current source and eliminates the harmonics by injecting equal but opposite current harmonics components at the Point of Common Coupling (PCC). The operation of shunt active power filter explained using instantaneous reactive power (IRP) theory with Hysteresis Band current controller (HBCC) and PI controller. The simulation results of the shunt active power filter using instantaneous reactive power (IRP) theory is simulated by MATLAB/SIMULATION tool box.

Keywords — Shunt Active Filter (SAF), Hysteresis Band current controller (HBCC), PI controller, Instantaneous Reactive Power (IRP) theory.

I. INTRODUCTION

Harmonic parameter is one component of periodic wave form consists of frequency with multiple integrals of fundamental frequency. Harmonics are produced by the modern power electronics devices. The usage of the power electronics devices [1] at the load side as well as the source side is increases because of the tremendous changes in the semiconductor technology. The more use of power electronics components gives the problems like generation of harmonic components, efficiency of the system is low, reactive power disturbance , less power factor and disturbance the other consumer etc. This problem increases in future years also; hence need to mitigate such type of problems as early as possible.

Basically two approaches are there for the mitigation of such power quality issues, the first approach is the condition of load, the load is having less immune harmonics. Those Equipments are made less sensitive, practically first approach is not possible. The second approach is power line conditioning. This approach gives power line conditioning system is installed at the Point of Common Coupling (PCC) that counteracts or suppresses the undesirable result produced by non linear loads. Traditionally passive filters deal harmonic generation and reactive power disturbance problems. But it has given lot of disadvantages like fixed compensation characteristics, large size resonance problem etc. so the solution given by traditionally passive filters are less attractive. To overcome these disadvantages shunt active filters (SAF) are used. Shunt active power filters allows the harmonics currents compensation, compensation of unbalance conditions, and correction of power factor. Shunt active power filters gives better solution than the traditionally passive filters. SAF is operated as current source and produces the harmonics currents which is equal and opposite phase components than harmonic currents produced by the power electronics devices or by nonlinear loads. The simulation implementation of a shunt active filter is proposed in this, with instantaneous reactive power theory.

II. SHUNT ACTIVE POWER FILTER

The Shunt Active Filter (SAF) is connected in parallel with the nonlinear load. The connection diagram of shunt active filter in Power System is shown in Fig. 1[2]. In The shunt active filter, Voltage Source Converter (VSC) is implemented and DC-link capacitor is connected to VSC. The function of DC-link capacitor is to provide the reactive power imbalance and needed to compensate the harmonics components. The basic operation of shunt Active Power Filter is required voltage sensors and current sensors for sensing Alternating voltage and Alternating current flow on DC-link capacitor voltage at the inverter terminals and from source to load. Based on The control strategy, the control theory calculates the harmonic current. The switching devices in voltage source converter switches according to and inject equal but opposite compensating harmonic current components. The compensated harmonic component is calculated by the IRP theory controller. An inductor is connected in series with the active power filter to reduce the ripple currents.

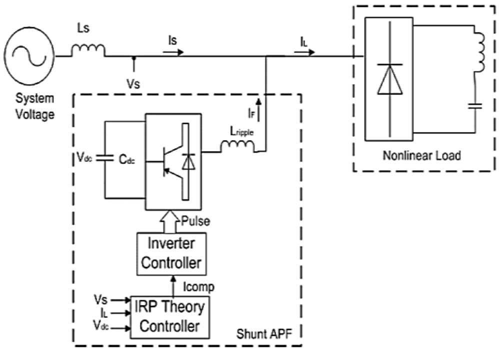

Figure 1: Block diagram of SAF

III. INSTANTANEOUS POWER THEORY

Akagi proposed Instantaneous reactive power Theory [3-4]. This theory is based on the transformation of three phase quantities (a-b-c) into two phase quantities in α-β frame and the Instantaneous active and reactive power is calculated in this frame. Sensed source voltages V_{sa} ,V_{sb} and V_{sc} and Sensed load currents i_{La} ,i_{Lb} and i_{Lc} are given to the controller. These parameters are processed and to generate the reference current signals (i^*_{fa}, i^*_{fb}, i^*_{fc}) again which are given to a hysteresis based PWM current controller to generate gate pulses (g_1,g_2, g_3, g_4, g_5 and g_6) for SAF.

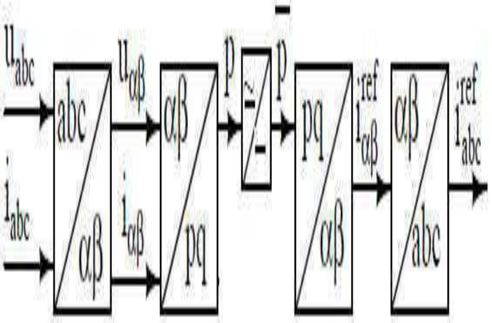

Figure 2: Block diagram of reference current signal generation

In instantaneous reactive power theory [5], the instantaneous quantities three-phase currents and three-phase voltages are calculated and converted into the α–β orthogonal coordinates.

$$\begin{bmatrix}V_\alpha\\ V_\beta\end{bmatrix}=\sqrt{\frac{2}{3}}\begin{bmatrix}1 & -1/2 & -1/2\\ 0 & \sqrt{3}/2 & -\sqrt{3}/2\end{bmatrix}\begin{bmatrix}V_{sa}\\ V_{sb}\\ V_{sc}\end{bmatrix}$$

(1)

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

(2
)

Consider three-phase three-wire system, the three-phase currents can be expressed in terms of harmonic zero sequence, positive sequence, and negative sequence currents. Three-phase conventional instantaneous power is calculated as follows:

$$P = V_\alpha I_\alpha + V_\beta I_\beta$$

(3)

The instantaneous real power (p) is

$$p = V_{sa}I_{sa} + V_{sb}I_{sb} + V_{sc}I_{sc}$$

(4)

The instantaneous imaginary power (q) is

$$q = V_\beta I_\alpha - V_\alpha I_\beta$$

(5)

Instantaneous real and imaginary powers can be written as (5)

$$\begin{bmatrix}p\\ q\end{bmatrix}=\begin{bmatrix}V_\alpha & V_\beta\\ V_\beta & -V_\alpha\end{bmatrix}\begin{bmatrix}i_\alpha\\ i\beta\end{bmatrix}$$

(6)

In Equation (6), V_α I_α and V_β $I_\beta$are instantaneous real (p) and imaginary (q) powers. Since these equations are products of instantaneous currents and voltages in the same axis. In three-phase circuits, instantaneous real power is p and its unit is watt. In contrast V_α I_β and V_β I_α are not instantaneous powers. Since these are products of instantaneous current and voltages in two orthogonal axes, q is not conventional electric unit like W or Var.qis instantaneous imaginary power and its unit is Imaginer Volt Ampere (IVA).

These power quantities given above for an electrical system represented in a–b–c coordinates and have the following physical meaning.

The instantaneous active and reactive power includes ac and dc values and can be expressed as follows:

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

(7)

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

Equation (6) can be written as Equation (8):

$$\begin{bmatrix}i_\alpha\\ i_\beta\end{bmatrix}=\begin{bmatrix}V_\alpha & V_\beta\\ -V_\beta & V_\alpha\end{bmatrix}^{-1}\begin{bmatrix}p\\ q\end{bmatrix}$$

(8)

From Equation (8), in order to compensate harmonics and reactive power instantaneous compensating currents (icα and icβ) on α and β coordinates are calculated by using $\widetilde{-P}$ and −q as given below

$$\begin{bmatrix}i_{c\alpha}\\ i_{c\beta}\end{bmatrix}=\begin{bmatrix}V_\alpha & V_\beta\\ -V_\beta & V_\alpha\end{bmatrix}^{-1}\begin{bmatrix}-\tilde{p}\\ -q\end{bmatrix}$$

(9)

In order to obtain the reference compensation currents [6] in the a–b–c coordinates the inverse of the transformation given in expression (10) is applied:

$$\begin{bmatrix}i_{ca}^*\\ i_{cb}^*\\ i_{cc}^*\end{bmatrix}=\sqrt{\frac{2}{3}}\begin{bmatrix}1 & 0\\ \frac{-1}{2} & \frac{\sqrt{3}}{2}\\ \frac{-1}{2} & \frac{-\sqrt{3}}{2}\end{bmatrix}\begin{bmatrix}i_{c\alpha}\\ i_{c\beta}\end{bmatrix}$$

(10)

IV. HYSTERESIS CURRENT CONTROL TECHNIQUE

The generated reference current signal i_c^* is taken as the reference of the active power filter and actual source currents are i_c . The hysteresis band current controller compares the current signals and deiced to generate the switching pulses for active power filter. The logic of switching is formulated as follows:

If $i_{ca} < (i^*_{ca} - HB)$ upper switch is OFF and lower switch is ON for leg-a (S_A = 1).

If $i_{ca} < (i^*_{ca} + HB)$ upper switch is ON and lower switch is OFF for leg -a (S_A = 0).

The switching functions of S_B and S_C for leg —"b" and —"c" are determined similarly, using corresponding reference and measured currents and hysteresis bandwidth (HB).

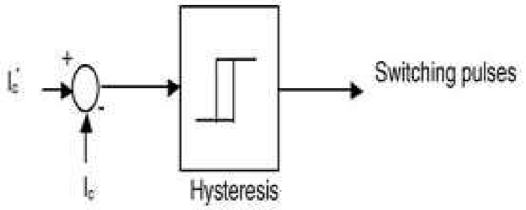

Figure 3: Generation of switching of pulses

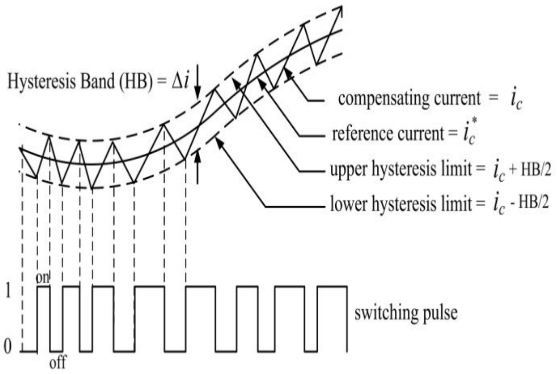

Figure 4: Block diagram of hysteresis band current controller

V. SIMULATION RESULTS

Simulation block diagram of SAF is shown in figure connected parallel to nonlinear load at point of common coupling (PCC).SAF injects the compensating currents at PCC and protects the source current.

CASE 1: BEFORE COMPENSATION

Before the compensation means SAF is not connected is shown in figure 5 [7].The effect of load is directly applied on the source side. So source side current parameter is disturbed. The disturbed source current waveform and source phase currents are presented. In this case both source and load current THD also presented.

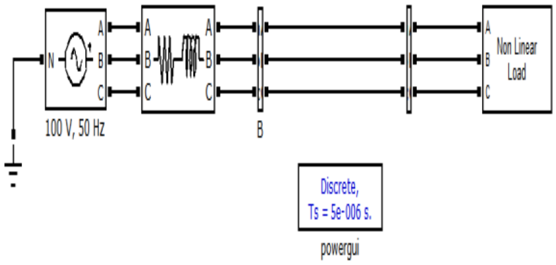

Figure 5: Simulink model of system without SAF

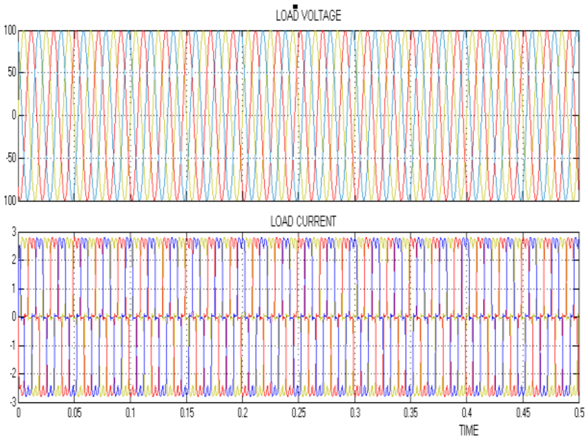

Figure 6: waveform of load voltage and current

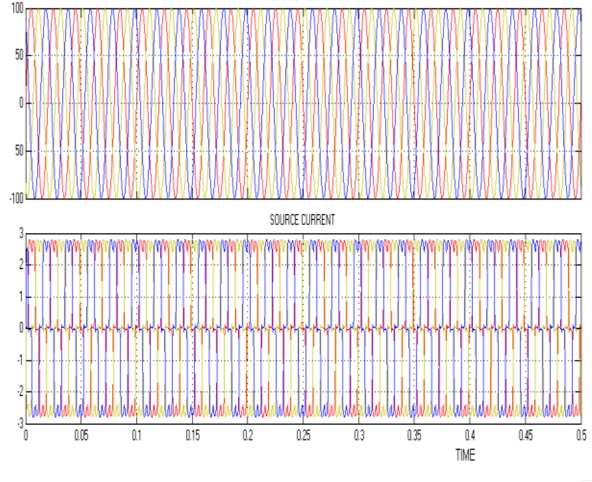

Figure 7: waveform of source voltage and current

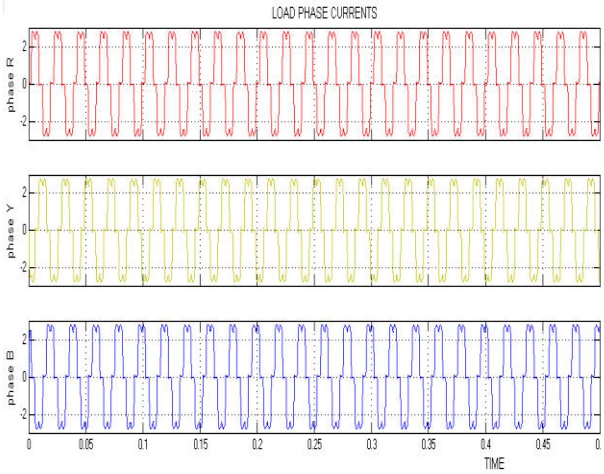

Figure 8: waveform of load phase currents

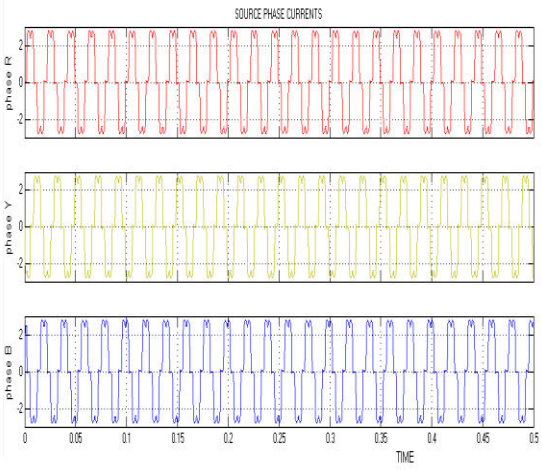

Figure 9: waveform of source phase currents

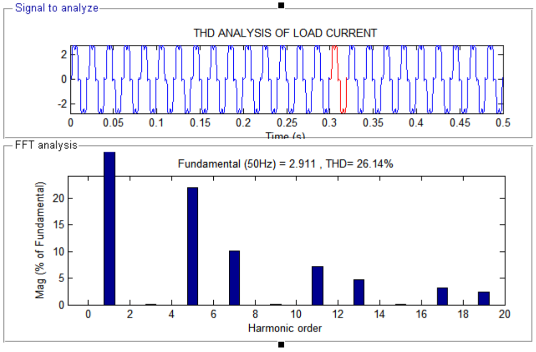

Figure 10: THD analysis of load current

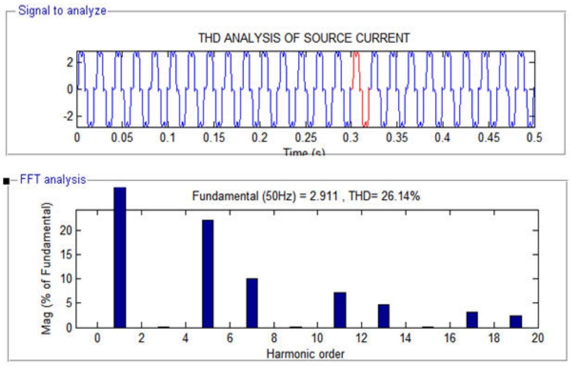

Figure 11: THD analysis of source current

CASE 2: AFTER COMPENSATION

At t=0.1sec instant switch is closed. SAF is connected parallel to nonlinear load is shown in figure 12. When the switch is closed SAF is injects the harmonic currents at PCC and make source current sinusoidal. The source current waveform and source phase currents are presented. In this case both source and load current THD also presented.

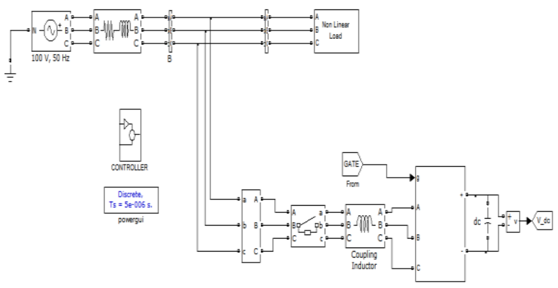

Figure 12: Simulink model of system with SAF

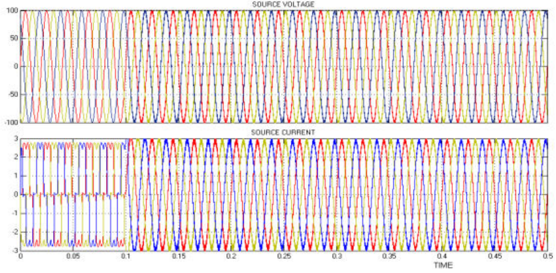

Figure 3: waveform of source voltage and current

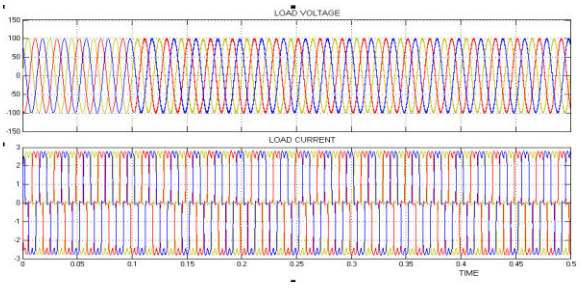

Figure 13: waveform of load voltage and current

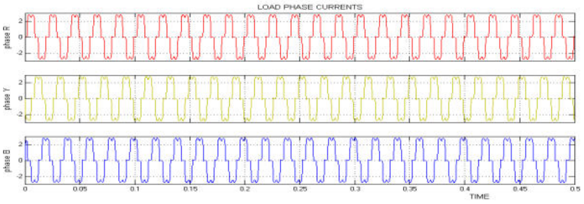

Figure 14: waveform of load phase currents

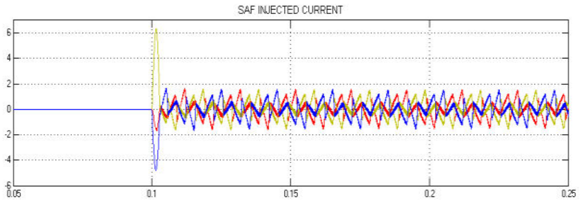

Figure 15: SAF injected currents at PCC

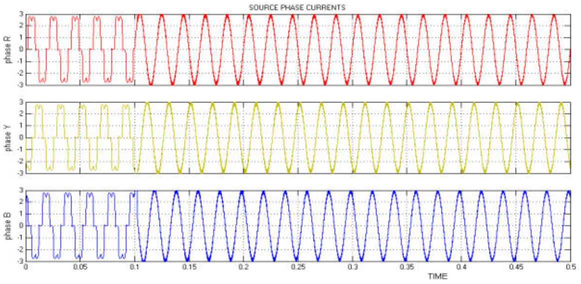

Figure 16: waveform of source phase currents

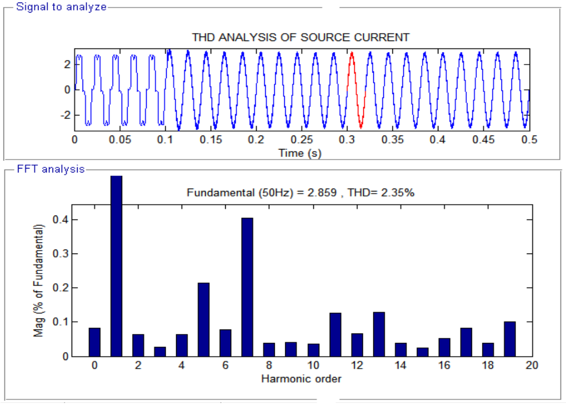

Figure 17: THD analysis of source current

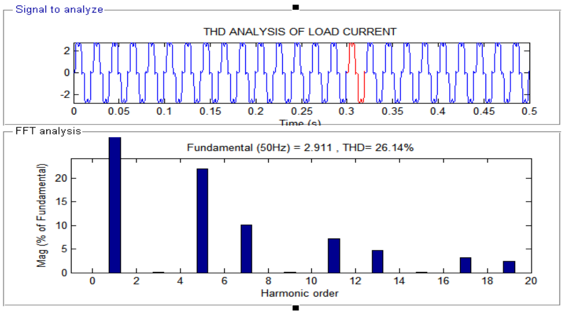

Figure 18: THD analysis of load current

Table 1: COMPARISION THD analysis

S.No	THD parameter	Before	After
1	SOURCE CURRENT	26.14%	2.35%

VI. CONCLUSION

This paper gives the idea on improvement of power quality using shunt active filer. Firstly, we calculated the reference currents Signals using Instantaneous active and reactive current (I_d-I_q) method and instantaneous active and reactive power (p-q) method with the help of proportional integral (PI) controller. Now hysteresis band current controller compares the reference currents signals and source currents. Compared result is given to inverter in the form of switching pulses and inverter generates the required amount of compensating currents. These compensating currents are injected at PCC through the three legs SAF. SAF with Hysteresis current controller is simulated in Simulink /MATLAB toolbox. Simulation results shows the better operation of shunt active power filter for current harmonic elimination in distorted source current and using FFT analysis calculated Total Harmonic Distortion (THD) of source current and load current. THD is more for SAF without controller (26.14%) than with controller (2.35%).

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