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Stability Improvement of a Bus System Using Shunt Active Filter under Different Loads

S.Sindhuja[#1], Assistant Professor
[#]Department of EEE, Anna University
Bharathiyar Institute of Engineering Women, Deviyakurichi -636 112
[1]lathasindhuja@gmail.com

***Abstract*—The stability of the bus system is enhanced by using the shunt active filters. Shunt active power filters are designed to reduce the harmonic content in the power system which is caused by nonlinear loads .Nonlinear loads contains harmonics which is provides the non sinusoidal waveforms. The harmonic content presented in the system are suppressed and the sinusoidal waveforms of current and voltage are restored by passing the compensating current at a bus system using shunt active filter. Active filter consists of a three phase current controlled voltage source inverter with a DC link capacitor across it. Synchronous Reference Frame (SRF) algorithm is used to generate the reference current. Hysteresis current control technique is worn for the generation of firing pulses to the inverter. This system is simulated using MATLAB/Simulink and the results are presented.**

***Index Terms*— Shunt Active Filter, Synchronous Reference Frame (SRF), stability, Hysteresis current control.**

I INTRODUCTION

Power system stability is defined as the ability of power system to preserve its steady stability or recover the initial steady state after any deviation of the system's operation. Now a day's power systems are being operated nearer to their stability limits due to economic and environmental reasons. Stability and operation of a power system is now becoming a very important and challenging issue. The stability of the system gets affected by faults, transient, harmonics, distortion in the voltage and voltage.

Now a day's power electronics devices and non-linear elements are used widely in rectification and switchgear applied to various areas of power system. A power system has the levels of harmonics which cannot be ignored by engineers, planners, energy conservationists and economists due to the existence of non-linear loads.

In addition, power electronic based devices are commonly used for inversion, rectification and other applications. However the Power electronics devices are more efficient, they generate harmonics in the power system. Power systems efficiency consider only distortion-free waveforms,(the voltage and current waveforms should be sinusoidal}. A harmonic is an integral multiple of the fundamental frequency. The major sources of harmonics are the converter used as rectifiers, adjustable speed drives, switched-mode supplies, frequency changers for induction heating in Power systems. As nonlinear loads correspond to an ever-increasing percentage of the total load of an power system, harmonic studies have become an essential part in power systems.

Most of the system prefers nonlinear loads. This result in the reduction of power factor, reduces the efficiency and reduces the system performs. The remedy for these distortions different types of filters is used. Passive filter has some disadvantage such as it produce some resonance problem, it provide only fixed compensation and increased in size. To overcome these drawbacks active filter is used. Active filter is used to compensate the harmonics and increases the total harmonic distortion. It uses active components such as MOSFET, IGBT-transistors etc. both the shunt and series active filter is used. The main aim of this paper is to reduce the current and improve the system stability by used shunt active filter to compensate the harmonic current. Thus the harmonic component present in the waveforms is eliminated and the current waveforms are sinusoidal. Thus the losses in the system are reduced and the reactive power is compensated.

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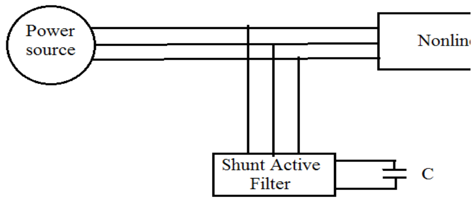

Figure 1: Block diagram of Active Filter

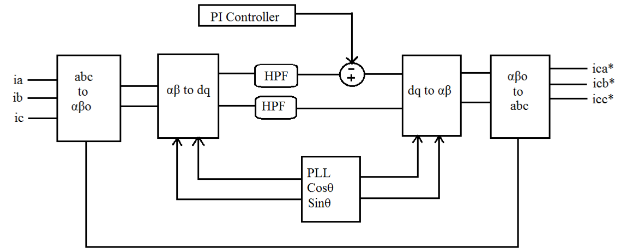

Figure 3: Model of SRF.

Many types of control schemes and controllers are existing. Here SRF algorithm is used for the reference current extraction from the distorted source current. The switching pulses for the power circuit is generated using the Hysteresis Current Control technique and is found to be very effective.

II. IMPLEMENTATION

A. PI CONTROLLER

The combinations of proportional and integral controller are the PI controller. PI controller is essential to increase the speed of the response and to mitigate the steady state error.

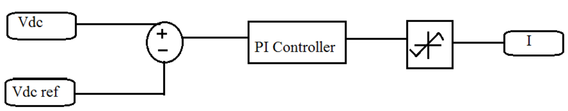

Figure 2: Model of PI controller

To reduce the forced oscillations and to get the maximum value of the reference current PI controller is used. PI controller gives a maximum overshoot and settling time. The above figure shows that the PI controller compares the reference voltage with the actual voltage of the system.

B. SYNCHRONOUS REFERENCE FRAME TECHNIQUE

Synchronous reference frame theory is used to generate the reference current which is based on time domain. This theory is used for its simplicity and it uses only the algebraic calculation, achieve the fast and accurate harmonic extraction from the system. **T**he three-phase reference currents (ica*, icb*,icc*) used by the active power filters is extracted by using Synchronous theory . Figure 3 shows the block diagram which explains three-phase SRF-theory which is used to extract the harmonic components.

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

$$\begin{bmatrix} i_\alpha \\ i_\beta \\ i_o \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/_2 & -1/_2 \\ 0 & \sqrt{3}/_2 & -\sqrt{3}/_2 \\ 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \rightarrow (1)$$

Now, the two phase current quantities iα and iβ of stationary αβ-axes are transformed into active and reactive components of synchronous 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). The phase-locked loop system provides cosθ and sinθ for synchronism.

$$\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \rightarrow (2)$$

High pass filter is used to eliminate the harmonic content present in the system. The d-axis current is a combination of active fundamental current (id dc) and the load harmonic current (ih). The reference current is obtained from PI controller. By subtracting id dc part from the total d-axis current (id), which leaves behind the harmonic component present in the load current AC component can be obtained. The q-axis current is used to calculate the reference compensation currents.

Now the active and reactive current components are changed into two stationary frame components using inverse transformation using equation (3).

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

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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.

$$\begin{bmatrix} i_{ca}^* \\ i_{cb}^* \\ i_{cc}^* \end{bmatrix} = [T_{abc}] \begin{bmatrix} i_\alpha \\ i_\beta \\ i_o \end{bmatrix} \rightarrow (4)$$

Where,

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

C. HYSTERISIS CURRENT CONTROL TECHNIQUE

The filter current Ifabc and the reference current Iabc* from the synchronous reference frame theory are compared to acquire the switching pulse for the inverters is done using hysteresis current control. The hysteresis current control method is used due to its good stability, a fast response, good accuracy and simple operation. The error signal is then given to the hysteresis band to attain the switching pulses for the inverter.

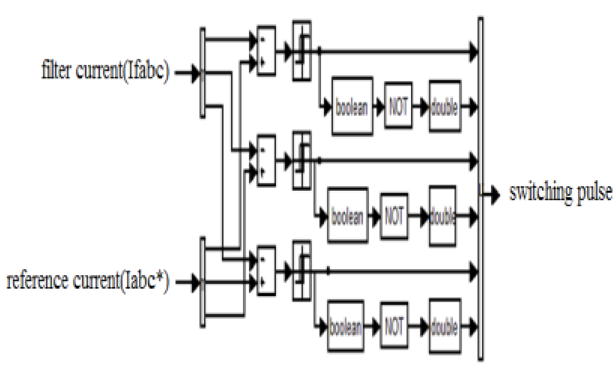

Fig. 4.Hysteresis Current Control

The operation of APF depends on the sequence of pulse generated by the controller. The position between the generated error signals is hysteresis band. When the error signal crosses the upper band, the output voltage changes with decreasing the input current and when the signal crosses the lower band, the output voltage changes with increase the input current. As the result, switching signals are generated.

The generated switching pulses are given to the power circuit which consists of switching devices with a DC link capacitor. According to the switching pulse induced into the inverter, it generates the compensating current signal. The harmonic current in the line suppressed by giving back the compensating current into the power line.

V .SIMULATION RESULT

5.1. Simulation without Filter

The simulink model of the bus system is shown in the figure 6. The total harmonic distortion present in this system is 10.23%. The supply current is shown in the figure 7.

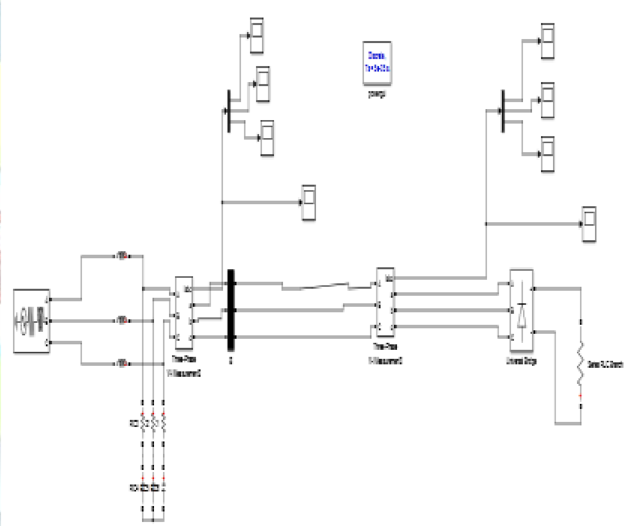

Figure 5: Simulink diagram

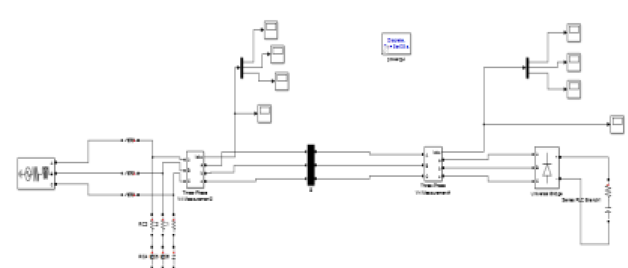

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Figure 6: Simulink diagram

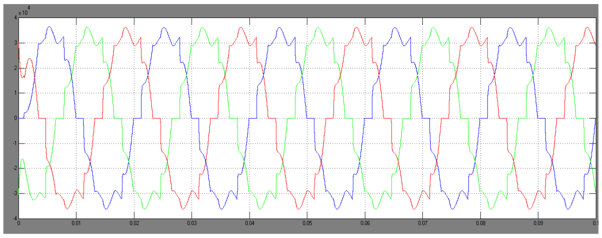

Figure 7: Analysis of supply current.

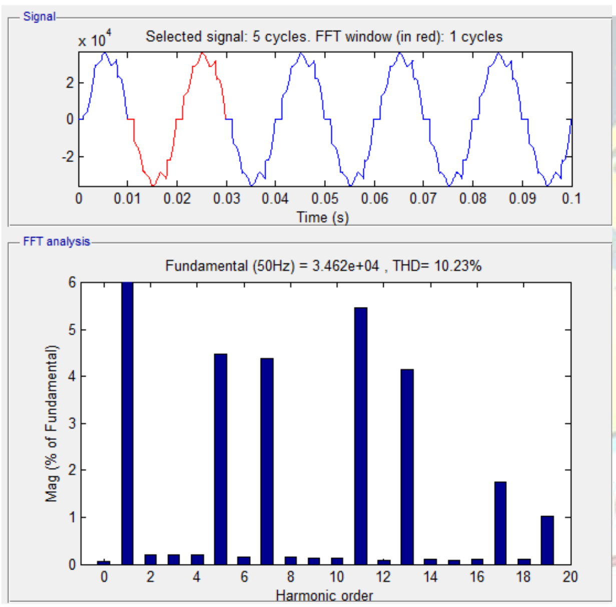

Figure 7: THD analysis.

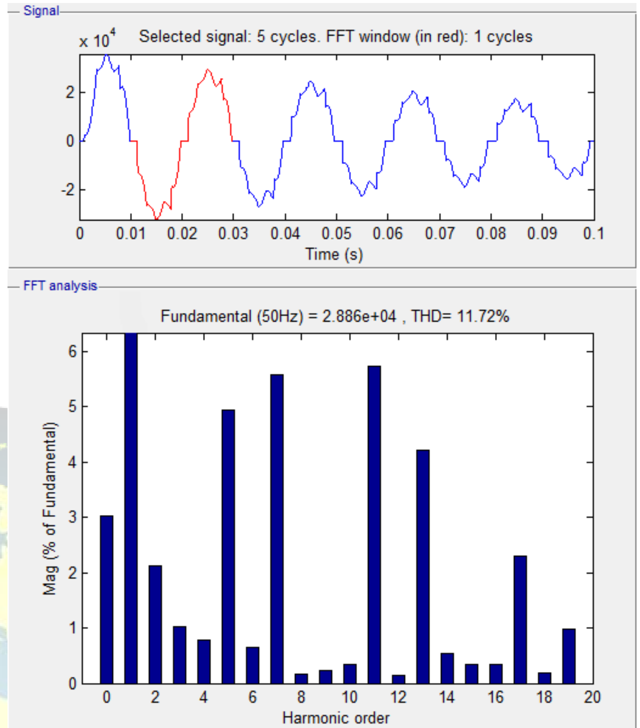

Figure 8: THD analysis.

5.2. Simulation with Filter

The simulink model of the bus system with shunt active filter is shown in the figure 9. The total harmonic distortion of this system is 6.08%. The supply current is shown in the figure 10.

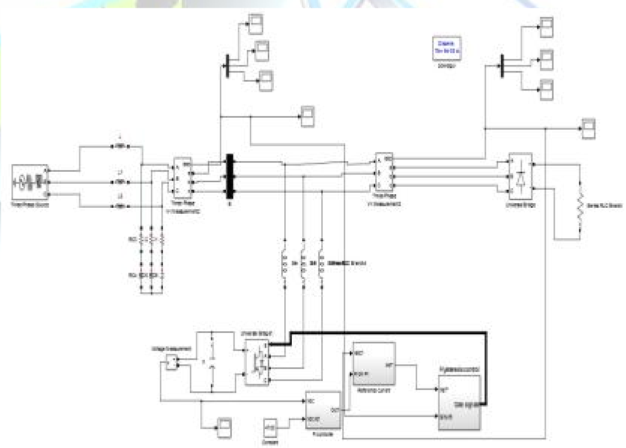

Figure 9: Simulink Model.

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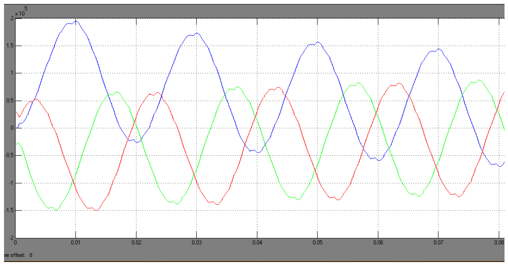

Figure 10: Analysis of supply current.

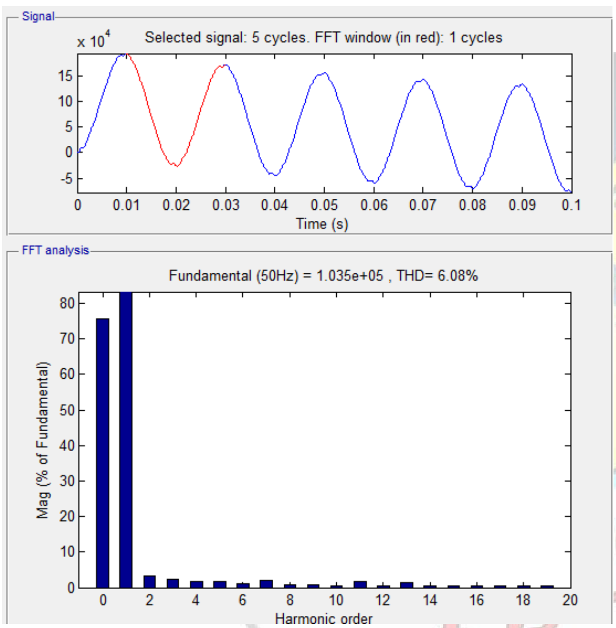

Figure 11: THD analysis

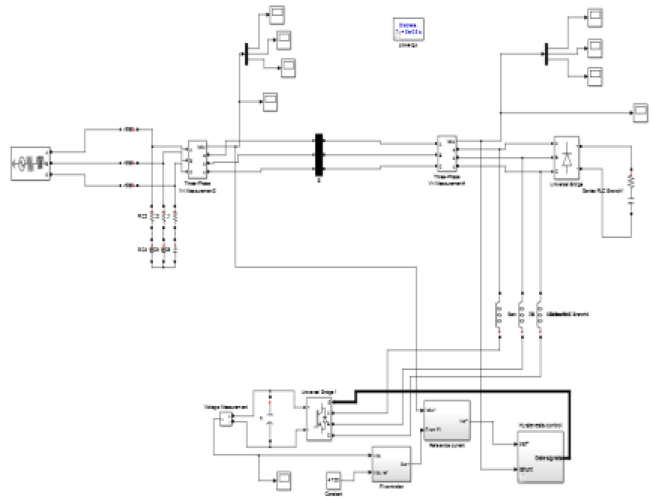

Figure 12: Simulink Model.

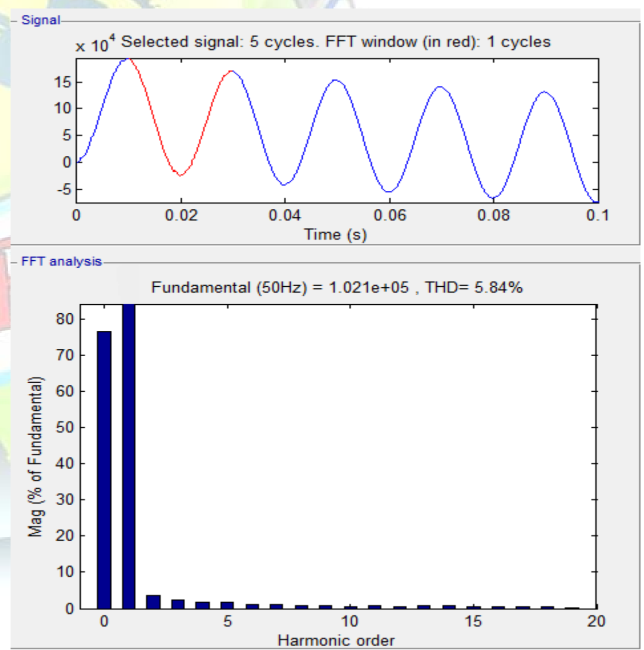

Figure 13: THD analysis

5.3. Performance comparison

NON LINEAR LOADS	WITHOUT FILTER(THD)	WITH FLTER(THD)

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A	10.23%	6.08%
B	11.72%	5.84%

VI. CONCLUSION

The shunt active filter was designed to eliminate the harmonic content produced by the nonlinear load and produces the sinusoidal. The control techniques such as synchronous reference frame theory and the hysteresis current control techniques were found to be very effective. Then the total harmonic distortion without filter and with filter was compared. The active filter with the control techniques are simulated using MATLAB. Finally the system performance, stability of the system and reduction of harmonic components were achieved.

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