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Simulation Analysis of Harmonic Eliminator using PQ Theory

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Abstract: The harmonic eliminator deals with the compensation of odd harmonics, reduces the THD and improve power quality compared to the other filters. This device is connected at the power grid to improve the power quality. This report is intended to provide a method to filter the harmonics and improve the power factor. By this by switching the suitable PWM modulator pulse we can reduce the any no. of harmonics. Mostly 3rd harmonics are present in the power system. Simulation results are also shown which shows that elimination of harmonics can be done with this method.
Keywords: Shunt active power filter, PQ theory, Hysteresis current Controller.

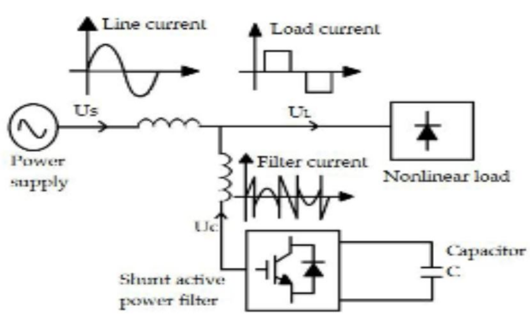
I. INTRODUCTION

Electric power system has a three functional blocks - Transmission, Generation and Distribution. Generation of harmonics from non linear loads, such as switch mode power converters and adjustable speed drives as well as other unbalanced loads in distribution network deteriorate power quality in power transmission and distribution system. Non linear loss increases losses and produce harmonics distortion in the grid as a consequence poor power quality cause a various problem in both the power grid and connected equipment. This harmonics distortion can be mitigated using passive filters. However, the use of traditional compensation with capacitor banks and passive filters produce harmonic propagation and harmonic voltage amplification, due to possible resonance between line inductance and shunt capacitors. Thus, passive filters cannot always offer complete compensation solution. As an alternative different active filter solution have been continuously analyzed in recent years. A conventional (APF) is typically composed of three single phase inverters and pulse width modulation (PWM) and can be attached to the load either in parallel or in series. Many harmonics-suppression methods based on the technique of power electronics have been developed to solve harmonics problems. One of them is the Harmonic Eliminator.

The purpose of harmonic eliminator is to eliminate the harmonic contents present in the power system. This improves the filtering performance and also cost effective.

II. SYSTEM DESCRIPTION

Harmonic eliminator is a device that is connected in parallel to and cancels the reactive and harmonic currents from non linear loads. Resulting total current drawn from the ac main is sinusoidal. Harmonic Eliminator has one voltage source inverter which is used to generate compensating currents which are 180 degree out of phase with the original harmonic currents. Non linear load is responsible for generating disturbances at supply side and voltage source inverter is responsible for nullifying that disturbances. To generate compensating currents the PQ theory is used. By using PQ theory the alpha and beta (voltage, current) reference frames are generated which are used to generate active and reactive power waveforms. Active power waveforms are passed through low pass filter to separate dc component of the active power from which the total active power is subtracted and this will give negative oscillating component of active power(-Pac). To compensate the total reactive power present in the power system, the reactive power is multiplied with the negative gain (-Q). By using (-Pac) and (-Q) compensating harmonic currents are generated. Now, the hysteresis current controller is used to generate pulses which are given to the voltage source inverter for generating compensating currents.



III. DESCRIPTION OF PQ THEORY

The PQ theory uses Clarke transformation i.e. α-β-0 transformation. Clarke transformation convert three phase voltage and circuit into stationary reference frame by using real matrix are as follows;

$$\begin{bmatrix} v_0 \\ v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix}$$

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

After getting Valpha, Vbeta and Ialpha, Ibeta calculate active power and reactive power by following equations.

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

Active power waveforms are passed through low pass filter to separate dc component of the active power from which the total active power is subtracted and this will give negative oscillating component of active power(-Pac). To compensate the total reactive power present in the power system, the reactive power is multiplied with the negative gain (-Q).

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2} \begin{bmatrix} v_\alpha & v_\beta \\ v_\beta & -v_\alpha \end{bmatrix} \begin{bmatrix} p \\ q \end{bmatrix}$$

$$\begin{bmatrix} i_{Ca}^* \\ i_{Cb}^* \\ i_{Cc}^* \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & 1 & 0 \\ \frac{1}{\sqrt{2}} & -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} -i_0 \\ i_{C\alpha} \\ i_{C\beta} \end{bmatrix}$$

IV. HYSTERESIS CURRENT CONTROLLER

Among all current control techniques the hysteresis current control is a extensively used because of its simplicity of implementation and fast response current loop. It has also the disadvantage that is the variation of switching frequency during load parameter variation of fundamental period. The working of hysteresis current controller is represented by the figure below. In working techniques the measured load currents are compared with reference using hysteresis comparators. The comparator determines the switching state of corresponding inverter leg such that the load current is forced to within the hysteresis band.

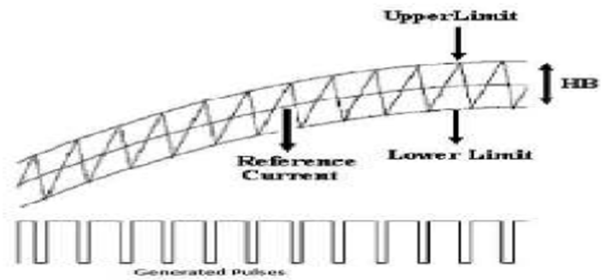


Fig.1 Basic block diagram of hysteresis controller

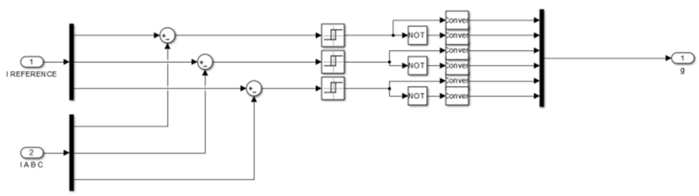


Fig.2 Hysteresis Current Control

V. SIMULATION RESULTS

This chapter deals with the simulation results of Harmonic Eliminator Configuration. The system built in Simulink for Harmonic Eliminator configuration has been tested with non linear load using hysteresis current control.

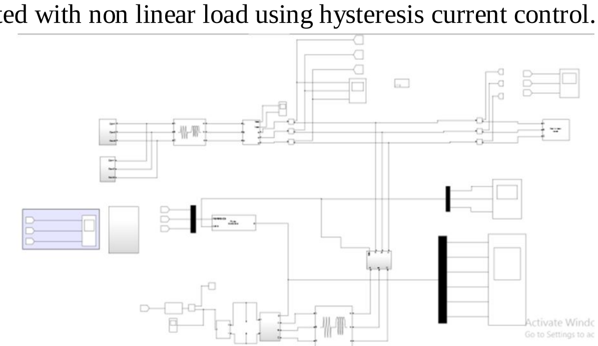


Fig.3 Simulink model of Harmonic Eliminator

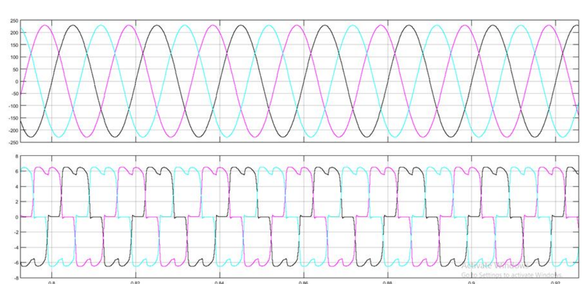


Fig.4 Source voltage and current waveforms before compensation

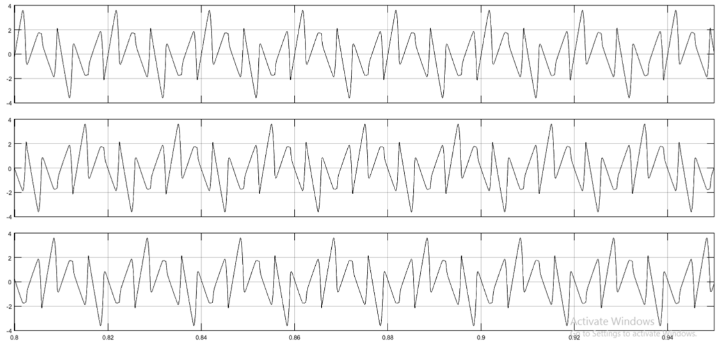


Fig.5 Compensation current produced by controller

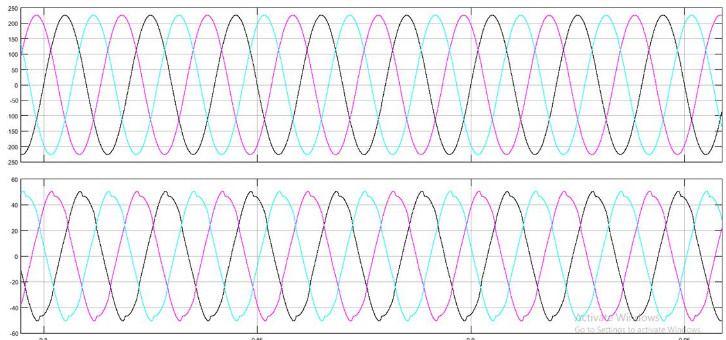


Fig.6 Source voltage and current waveforms after compensation

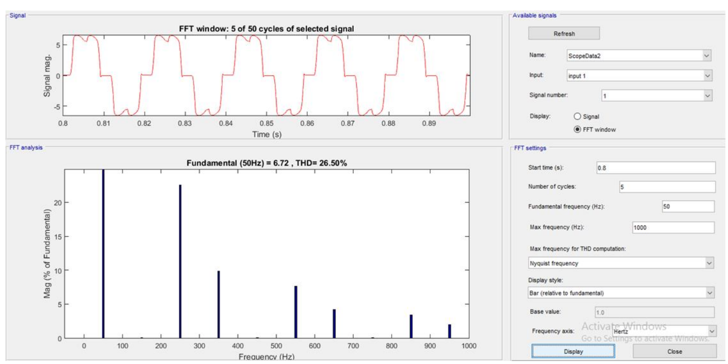


Fig.7 FFT waveforms analysis before compensation (THD=26.50%)

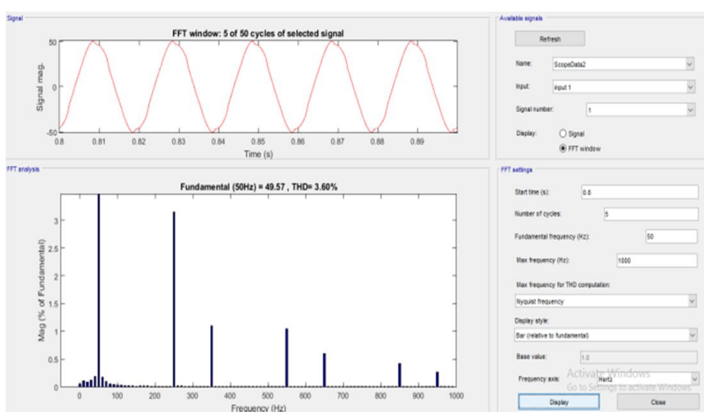


Fig.8 FFT waveforms analysis after compensation (THD=3.60%)

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VI. CONCLUSION

The instantaneous real power theory based shunt active power filter has been proposed to improve the power quality by compensating harmonics and reactive power requirement of the nonlinear load. In this paper we are trying to compensate the reactive power of the power system by eliminating harmonics but as the THD decreases value of supply current increases so there is a compromise between the value of supply current and THD of supply current.

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