Current Control Technique for Three Phase Shunt Active Power Filter by Using Adaptive Hysteresis Current Controller

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Abstract- In today's scenario due to market competition there is wide spread use of power electronic equipments in power system but these devises poses non-linear characteristics and fast switching action causes harmonics in the system. Harmonics is predominant power quality issue and generation of harmonics have adverse effect on sensitive equipments. These equipments will continue polluting the system more and more due to built-in compensation and sometimes for the lack of enforced regulations. Power quality issues are of biggest concern because poor power quality result in loss of reliability, increased cost and poor efficiency. Active power filters have been developed over There are different types of active power filters available among which shunt active power filter is extensively considered to eliminate the load current harmonics and reactive power compensation.

In this work performance improvement of three-phase shunt active power filter to compensate harmonics current and reactive power to improve power quality is explained for three-phase systems. The insulated gate bipolar transistor based voltage source inverter with DC capacitor is used as active power filter. The shunt active filter employs instantaneous PQ theory for reference current generation. Adaptive hysteresis current controller is used for voltage source inverter switching signal generation and tuning of shunt active power filter which maintain the switching frequency the years to solve these problems to improve power quality by Harmonic Reduction. constant, hence overcoming the drawbacks of hysteresis band current controller. The shunt active power filter generates compensating signal which reduces the harmonic component of the system.

Keywords *Harmonic, Adaptive Hysteresis Current Control (AHCC), Shunt Active Power Filter (SAPF), Total Harmonic Distortion (THD), Voltage Source Inverter (VSI).*

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I. INTRODUCTION

The main objective of the electric utility is to deliver sinusoidal voltage at fairly constant magnitude throughout their system but it is difficult to obtain fairly constant sinusoidal voltage due to the presence of non linear loads on the system which are the source of harmonic currents. These currents result in distorted voltages and currents that can adversely impact the system performance in different ways. As the number of harmonic producing loads has increased over the years, it has become increasingly necessary to address their influence when making any additions or changes to an installation. To fully appreciate the impact of these phenomena, there are two important concepts to bear in mind with regard to power system harmonics. The first is the nature of harmonic-current producing loads (non-linear loads) and the second is the way in which harmonic currents flow and how the resulting harmonic voltages develop.

The intensive use of power electronic converters and non linear loads resulted in the deterioration of power quality which ultimately causes economical losses. Non linear loads pose harmonics into the power system which deviate the sinusoidal voltage and current waveform. In three phase system they could also cause unbalance and draw excessive neutral currents. The injected harmonics, reactive power burden, unbalance and excessive neutral currents cause low system efficiency and poor power factor. They also cause disturbance to the other consumers and interference in nearby communication networks.

In present scenario prime importance is given by the engineers to develop a method which reduces the harmonic distortion. In earlier days simple and conservative power system has less problem of harmonics distortion but now a day complex designs of industry result in increased harmonic distortion.

This paper explains the effects of Harmonics in the Power System and method to overcome the effects of Harmonics. The armonic distortion is one of the most important problems associated with power quality concern and how it creates several disturbances to the Power System.

II.SYSTEM CONFIGURATION

The recent advances in power semiconductor devices have resulted in the development of Active Power Filters (APF) for harmonic suppression. Various topologies of active filters have been proposed for harmonic mitigation. The shunt APF based on Voltage Source Inverter (VSI) structure is an attractive solution to harmonic current problems. The shunt active filter is a pulse width modulated (PWM) voltage source inverter (VSI) that is connected in parallel with the load. It has the capability to inject harmonic current into the AC system with the same amplitude but opposite phase than that of the load to cancels reactive and harmonic currents from non linear load. The resulting total current drawn from the ac mains is sinusoidal.

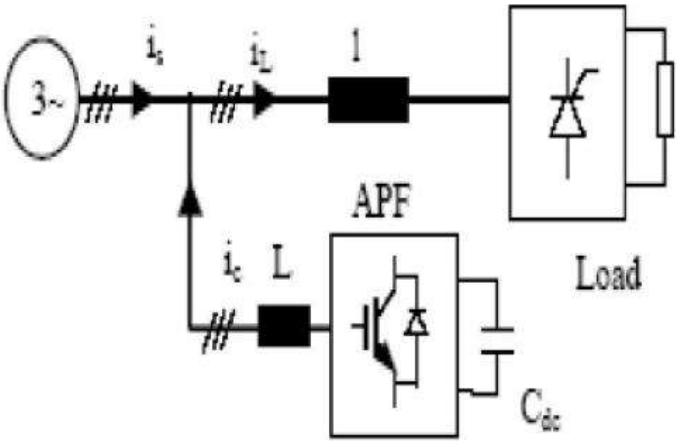


Figure1: Basic system with Non-Linear Load and Shunt Active Filter

The current wave form for cancelling harmonics is achieved with the voltage source inverter in the current controlled mode and an interfacing filter. The filter provides smoothing and isolation for high frequency components. The desired current waveform is obtained by accurately controlling the switching of the insulated gate bipolar transistors (IGBT's) in the inverter. Control of the current wave shape is limited by the switching frequency of the inverter and by the available driving voltage across the interfacing inductance. There are two major approaches that have emerged for reference current.

Frequency domain methods - The frequency domain methods include, Discrete Fourier Transform (DFT), Fast Fourier Transform (FFT), and Recursive Discrete Fourier Transform (RDFT) based methods. The frequency domain methods require large memory, computation power and the results provided during the transient condition may be imprecise.

Time domain method - The time domain methods require less calculations and are widely followed for computing the reference current. The two mostly used time domain methods are synchronous reference (d-q-0) theory and instantaneous real-reactive power (p-q) theory.

Current controller techniques

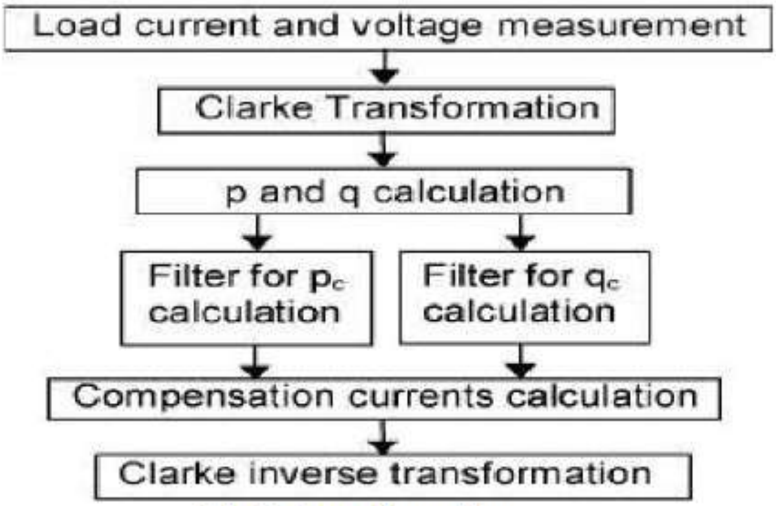
There are several current control strategies proposed in the literature namely, PI control, Average Current Mode Control (ACMC), Sliding Mode Control (SMC) and hysteresis control.

The PI controller based approach requires precise linear mathematical model which is difficult to obtain. Also, it fails to perform satisfactorily under parameter variations, non-linearity, and load disturbances. Average Current Mode Control (ACMC) scheme does not provide immediate switch current limit as in the case of peak current control. In Sliding Mode Control (SMC) there is problem of chattering occur.

Among the various current control techniques, hysteresis control is the most popular one for active power filter applications. Hysteresis current control is a method of controlling a voltage source inverter so that the output current is generated which follows a reference current waveform. The current control with a fixed hysteresis band has the disadvantage that the switching frequency varies within a band because peak - to - peak current ripple is required to be controlled at all points of the fundamental frequency wave. The adaptive hysteresis band controller changes the hysteresis bandwidth as a function of reference compensator current variation to optimize switching frequency and THD of supply current.

III. PROPOSED CONTROL ALGORITHM

The p-q theory consists of an algebraic transformation (Clarke transformation) of the three-phase voltages and currents in the a-b-c coordinates to the α-β-0 coordinates, followed by the calculation of the p-q theory instantaneous power components. The relation of the transformation between each component of the three phase power system and the orthogonal coordinates are expressed in space vectors shown by the following equations in terms of voltage and current as shown in equation 1.



Clarke transformation

$$\begin{bmatrix} V_\alpha \\ V_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} \quad \text{..........(1)}$$

$$\begin{bmatrix} I_\alpha \\ I_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix}$$

Since in a balanced three-phase three wire system neutral current is zero, the zero sequence current does not exist. The power components p and q are related to the same α-β voltages and currents, and can be written together as given below,

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} V_\alpha & V_\beta \\ -V_\beta & V_\alpha \end{bmatrix} \begin{bmatrix} I_\alpha \\ I_\beta \end{bmatrix} \quad \text{.........(2)}$$

where p is the instantaneous real power and q is the instantaneous imaginary power. The alternated value of instantaneous real power is calculated back to a-b-c frame which represent the harmonic distortion, given as reference for the current controller. The mean value of the instantaneous real power is usually the only desirable power component. The other quantities can be compensated using a shunt active filter.

To calculate the reference compensation currents in the α-β coordinates, the expression (2) is inverted as below

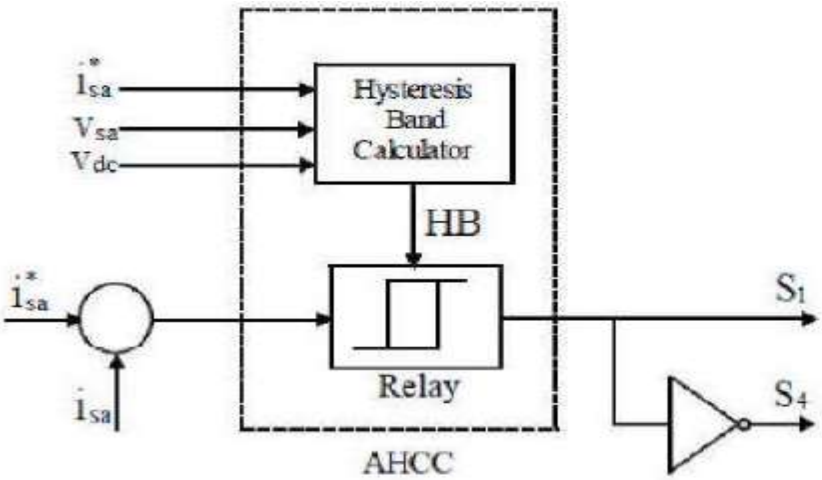
$$\begin{bmatrix} i_{c\alpha}^{*} \\ i_{c\beta}^{*} \end{bmatrix} = \begin{bmatrix} V_\alpha & -V_\beta \\ V_\beta & V_\beta \end{bmatrix} \begin{bmatrix} \tilde{p} \\ q \end{bmatrix}$$

where *p~* is the alternated value of the instantaneous real power. It is the energy per time unity that is exchanged between the power supply and the load, through a-b-c coordinates. *q* is the instantaneous imaginary power corresponds to the power that is exchanged between the phases of the load but is responsible for the existence of undesirable currents, which circulate between the system phases. In order to obtain the reference compensation currents in the a-b-c coordinates the inverse of the transformation given in expression (1) is applied.

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

V.ADAPTIVE HYSTERESIS BAND CURRENT CONTROLLER

To overcome the drawbacks of HBC with fixed hysteresis band an Adaptive Hysteresis Band Current Controller (AHCC) is used, which maintains the switching frequency nearly constant, by changing the hysteresis band according to system parameters (reference current, source voltage & dc capacitor voltage).



The current and voltage waveform for phase 'a' is shown here where I_{sa*} is the desired reference source current and I_{sa} is the actual source current. When the source current tries to leave the hysteresis band appropriate switch is turned ON or OFF to force the ramping of the current within the hysteresis band.

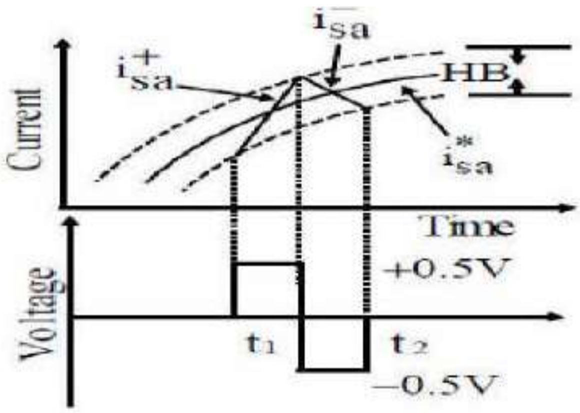


Figure.2 phase current and voltage waveform

V. IMPLEMENTATION OF THE PROPOSED METHOD

To develop and simulate result using MATLAB/SIMULINK power system toolbox demonstrating effectiveness of using hysteresis control technique for shunt active power filter. The implementation of the control strategy will be

done in three steps. In the first step, the required load current and source voltage signals are measured to know the exact information about the system studied. In the second step, by using instantaneous p-q theory the reference compensating currents are obtained. In the third step, by using hysteresis-based current control technique the required gating signals for the solid-state devices are generated. The Adaptive Hysteresis Band (HB) value was calculated using this block and given to the Active Power Filter (APF). Using this method, variable hysteresis bandwidth is calculated instantaneously, which leads to reducing the switching frequency variation. The calculated instantaneous value can be given to the shunt active filter pulse generation block by using MATLAB command h='band'. Results of simulation studies on the performances of HCC and AHCC are included to demonstrate the effectiveness of using adaptive hysteresis band.

VI.RESULTS

This section presents the details of the simulation carried out to demonstrate the effectiveness of the proposed control strategy for the active filter to reduce the harmonics. The test system consists of a three phase voltage source, and a three phase diode bridge rectifier with R load. The active filter is connected to the test system through an inductor L. MATLAB/SIMULINK is used to simulate the test system and the proposed shunt active filter.

VII. CONCLUSION

An Adaptive Hysteresis current controller strategy is used to generate firing pulse for IGBT in SAPF. To improve the dynamic behavior of shunt active filter and make it robust under wide range of load variations, the value of load current, the reference source current and the calculated Hysteresis Band Width (HB) is considered as inputs of current controller. The AHCC results in reducing the high-frequency components of source current and switching losses. For power quality control, an AHCC model giving comparatively better harmonic reduction than the fixed HCC. The simulation result will shows the effectiveness of the proposed AHCC which reduces harmonic distortion below the IEEE519 standard.

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