Performance Analysis of Shunt Active Power Filter With Matlab Simulation

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Abstract: **This paper presents the analysis and simulation using Matlab/Simulink of a Shunt Active Power Filter (SAPF) for reducing the harmonics current generated by nonlinear loads. Due to increasing the usage of power electronics equipment with linear load, the increase of the harmonics disturbance in the ac mains currents has became a major concern due to the adverse effects on all equipment mostly capacitors, transformers, and motors, causing additional losses, overloading, malfunctioning and overheating and interferences. Shunt Active Power filter is used to compensate the harmonics due to nonlinear load by injecting equal but opposite harmonic compensating current which gives pure sinusoidal wave [1].**

Keywords: **Power System, Harmonic Distortion, Shunt Active Power Filter, Non-Linear Loads, Total Harmonic Distortion, PI controller.**

1. INTRODUCTION

The main objective of the power system is generation of electrical energy to transmit and distribute to the end-user. Many power system are internally connected into a network. If a fault exists in any one of the network, it should affect the whole power system.[2] Transients, sagging, variations in voltage, harmonics are the some of disturbances affecting power system. The aim of this paper is to suggest a method to reduce the current harmonics. Basically, AC electrical power system mainly uses non-linear loads. For these types of loads, the load current and voltages are non-sinusoidal. So it is necessary to compensate the voltage and current harmonics. Non-linear loads are mainly used in adjustable-speed drives, switch mode power supply (SMPS), and unintertable power supply (UPS). These types of loads will cause harmonic voltage drop across the network impedance, resulting in distorted voltage. Harmonics are one of the major concern in a power system. Harmonics are the non-integer multiples of the fundamental frequency. It is generated in a power system by means of non-linear loads. In order to reduce the harmonic distortion two types of filters can be used. 1) active filter 2) passive filter. A passive filter is composed of only passive elements inductor, capacitor and resistor. The passive filters are inexpensive. Since they are ineffective due to the inability to adapt to network characteristic variations, therefore the active filters are used. An active filter is implemented when orders of harmonic currents are varying. It use active components such as MOSFET, IGBT-transistors etc. Its structure may be either of the series or shunt type. Shunt active power filters are widely used for mitigating current harmonics. Series active filters are widely used for mitigating voltage harmonics. Drawbacks of series active filter are, they have to handle high load currents, which increase their current rating and increasing I^2R losses. It is mainly used at the load because non-linear loads inject current harmonics.[3] It injects equal compensating currents, opposite in phase, to cancel harmonics and/or reactive currents of the non-linear load current at the point of connection. Recently, voltage source inverter or current source inverter based active power filter is used. They have many advantages as compared to the previously used methods, which include potential size, weight and cost reduction ,small size and light weight, low power losses, tracking of the power system frequency change, fast dynamic response to load changes and reduction of resonance problems. In addition, APF can provide other conditioning functions such as reactive power control, load balancing and flicker mitigation.[4] selective harmonic compensation can be used to reduce the harmonics chosen by the designer. Many theories have been developed for instantaneous current

harmonics detection in active power filter such as FFT (fast Fourier technique) technique, neural network, instantaneous p-q theory(instantaneous reactive power theory), synchronous d-q reference frame theory or by using suitable analog or digital electronic filters separating successive harmonic components, PLL with fuzzy logic controller, neural network etc. This paper basically deals with the modeling and simulation of shunt active filter with PI controller. study for THD.[5].

2. SHUNT ACTIVE POWER FILTER WITH NON LINEAR LOAD

Shunt active filter is used in the load side of the system. Because non-linear loads is to generate harmonics in the current waveform.

1. Basic concept of active power filter:

Fig.1shows the configuration of active power filter with non-linear load. The basic operating principle of active power filter is that a non sinusoidal waveform at a bus can be corrected to sinusoidal by injecting current of proper magnitude and waveform. Fig.1 shows the Basic concept shunt active filter The basic concept of APF is explained below

IL = IS + IF……………… (1)

The load current having fundamental and harmonic content, and IF is the harmonic compensating current.

IL + IH = IS + IH………...(2)

Filter provide harmonic requirement of the load

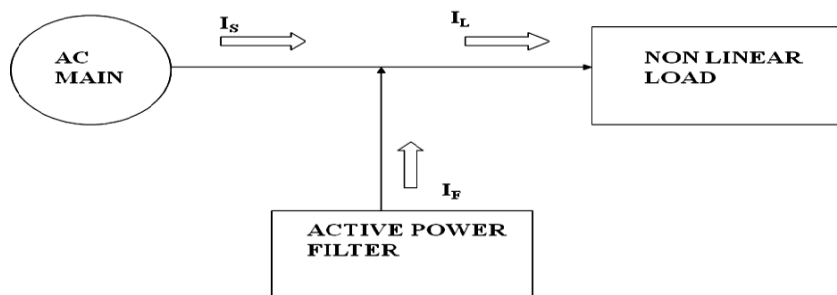IL + IH = IS + IH……….. (3)

IL= IS………………………. (4)

Fig.1: Active shunt filter with non linear load

Thus the supply current represents the fundamental waveform input output harmonics. Fig.2. shows the configuration of active shunt filter with non-linear load and the full bridge converter. which is almost widely used to eliminate current harmonics, reactive power compensation and balancing the unbalanced currents.[6] Fig
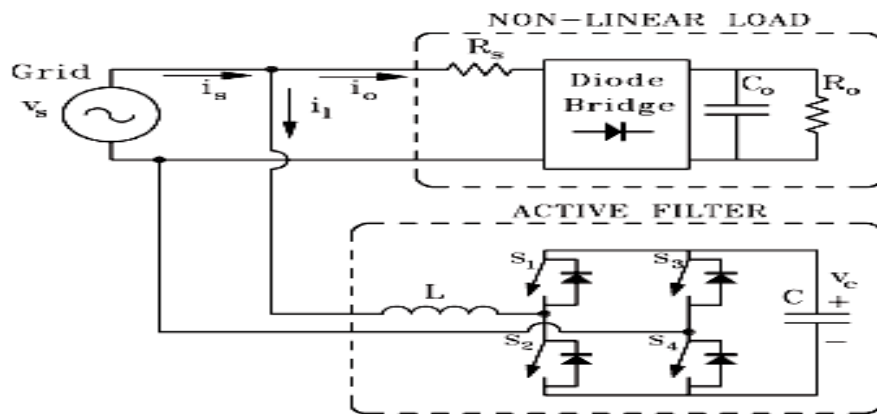

Fig.2: Shunt APF with non-linear load and the full-bridge controller

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Nonlinear load - Non-linear loads are considered as the second category of loads. The application of sinusoidal voltage does not result in a sinusoidal flow applied sinusoidal voltage for a non-linear devices. In this system the nonlinear load consists of a diode diode bridge, a series resistance (Rs), a load resistance (Ro)and a load capacitance (Co), Induction motor load, and DC motor.[7]

3. PI CONTROLLER LOOP

This section reviews the, indirect current control method, based on the outer voltage loop and inner current loop.

1. Design of the outer voltage loop-For an indirect current control method, outer voltage loop is mainly used for capacitor voltage regulation. The capacitor is mainly used at the load side. For the design of outer voltage loop cut off frequency and phase margin is essential. Its value should be 2.5Hz to 56^0 based on the small signal model analysis.

2. Design of the inner control loop-For this linear current control scheme inne current loop is used for reference error current is compensated by PI controller.[8]
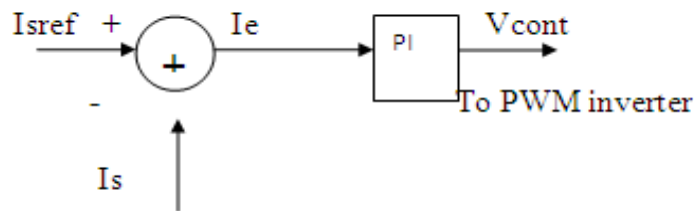

Fig.3: Inner current loop

4. SAPF WITH PI CONTROLLER

The main drawback of using repetitive current control is, there is no control action, to avoid the distortion from the grid voltage. In-order to overcome this drawback, it needs some additional algoritham. The PI controller operation with shunt active filter is shown in figure.4.source voltage and source current values are given to the reference generator. It will produce Iref and given to PI controller. Using PI controller error should be compensated.[9]
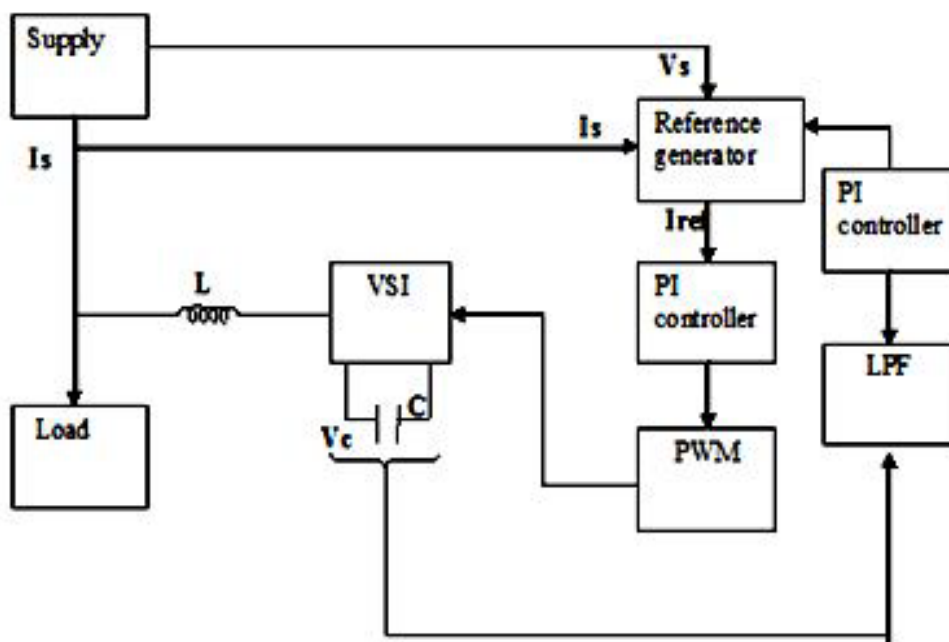

Fig.4: SAPF with PI controller

5.   INSTANTANEOUS CURRENT METHOD (D-Q METHOD)

This method, also called instantaneous current i_d, i_q, the load current are transformed from three phase frame reference abc into synchronous in order to separate the harmonic contents from the fundamentals. It gives better performance even in the case where the three phase voltage is not ideal.fig 4 presents the diagram block of this extraction method.
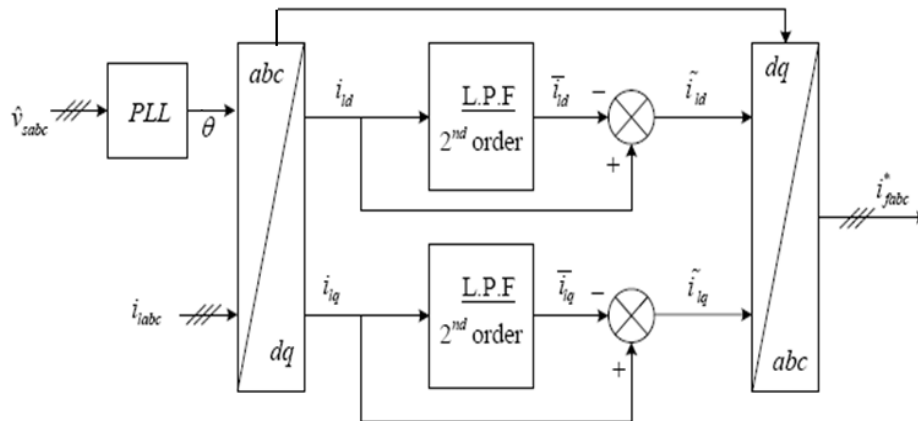
the load currents are transformed from three phase frame reference *abc* into synchronous reference d-q coordinate by using parks transform in order to separate the harmonic contents from the fundamentals

$$\begin{bmatrix} i_{ld} \\ i_{lq} \\ i_{l0} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \cos\theta & \cos(\theta - \frac{2\pi}{3}) & \cos(\theta + \frac{2\pi}{3}) \\ -\sin\theta & -\sin(\theta - \frac{2\pi}{3}) & -\sin(\theta + \frac{2\pi}{3}) \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} i_{la} \\ i_{lb} \\ i_{lc} \end{bmatrix}$$

Where, θ is the angular position of the synchronous reference. This is a linear function of the fundamental frequency. The harmonic reference current can be extracted from the load currents using a simple LPF with feed-forward effect.The currents in the synchronous reference can be decomposed into two terms as:

$$\begin{cases} i_{ld} = \overline{i_{ld}} + \tilde{i}_{ld} \\ i_{lq} = \overline{i_{lq}} + \tilde{i}_{lq} \end{cases}$$

$$\text{...... (10)}$$

Only the alternating terms -which are related to the harmonic contents - will be seen at the output of the extraction system. The APF reference currents will be then:

$$\begin{bmatrix} i_{fd}^* \\ i_{fq}^* \end{bmatrix} = \begin{bmatrix} \tilde{i}_{ld} \\ \tilde{i}_{lq} \end{bmatrix}$$

$$\text{.......(11)}$$

In order to find the APF currents in three phase system, the inverse Park transform can be used as follow:

$$\begin{bmatrix} i_{fa}^* \\ i_{fb}^* \\ i_{fc}^* \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \cos\theta & -\sin\theta \\ \cos(\theta - \frac{2\pi}{3}) & -\sin(\theta - \frac{2\pi}{3}) \\ \cos(\theta + \frac{2\pi}{3}) & \sin(\theta + \frac{2\pi}{3}) \end{bmatrix} \begin{bmatrix} i_{fd}^* \\ i_{fq}^* \end{bmatrix}$$

$$\text{…. (12)}$$

6. EXPECTED OUTCOME

Initially we will design a filter with nonlinear load, without shunt active filter and then it will simulated in MATLAB. Next we will design a filter with DQ method and simulate it in MATLAB. Now we calculate, analyse and compare both the result. Comparing the result we will find that total harmonic distortion is reduced when we will modelling the filter with shunt active filter method.

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