



Performance of Control Algorithms for Shunt Active Filter

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Abstract-Problems caused by power quality have great adverse economical impact on the utilities and customers. Current harmonics are one of the most common power quality problems and are usually resolved by the use of shunt active filters (SAFs). This paper Deals with simple but effective evaluation of various control algorithms for shunt active filters, which eliminates current harmonics and compensates the reactive power of the load. The majority of shunt active power filter control methods which have been presented require a complex and sophisticated mathematical model.

In this paper, the three-phase shunt active filtering algorithms in time-domain have been compared with frequency domain for a non-linear load. The comparison of the simulation results show the effectiveness of both the algorithms although the time domain current detection modified algorithm is more complex in terms of its implementation aspects.

Keywords:-Power Quality, Harmonics, Shunt Active Filter, Time domain, Frequency Domain

1. INTRODUCTION

Active power filters are advanced devices in the field of applied power electronics. They exploit the latest generation of power semiconductor devices, as well as modern digital signal processor technology. The growing number of power electronics base equipment has produced an important impact on the quality of electric power supply. Both high power industrial loads and domestic loads cause harmonics in the network voltages [2]-[4].

Many standards organizations have been increasing their efforts to establish standards limiting the harmonic pollution in electric power systems. As a precondition, a unique set of power definitions valid for generic voltage and current waveforms should be universally accepted for all.

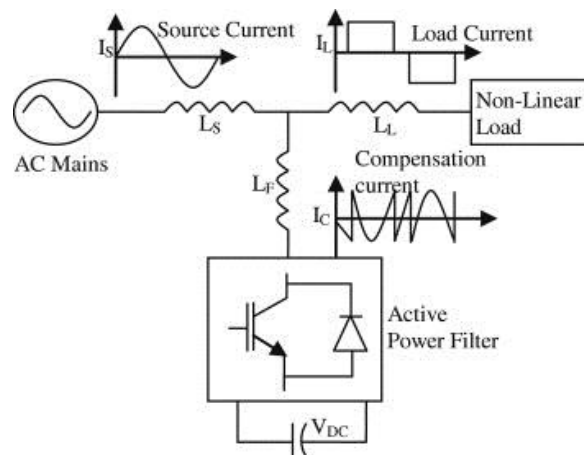


FIG .1 BASIC PRINCIPLE OF ACTIVE POWER FILTER

2. PROBLEM DEFINITION

Primarily non-linear loads which, are mainly power electronics loads cause power system harmonics. Injected current harmonics in to the power system lead to distorted voltages at the point of common coupling (PCC.) harmonic filtering is one of the potential solutions. With a certain limitation of passive filtering, active filtering techniques have come to the front end. The shunt APF is used to eliminate current harmonics, whereas series compensation does the same job for voltage harmonics. The shunt active filtering principle was first introduced by Gyugyi and Strycula. [1]. Figure 1 explains the basic principle of operation. Three major area are to be considered for the shunt type APF. First is to estimate the compensating current [4, 5], [8]. Second is look for possible power converter technologies along with PWM generation techniques and third is to prepare control techniques/ algorithms for generation of reference current [11]-[17]. Traditional reference current generation techniques may be broadly classified as time domain and frequency domain approaches. Recent additions are the adaptive filtering and soft computation based methods.

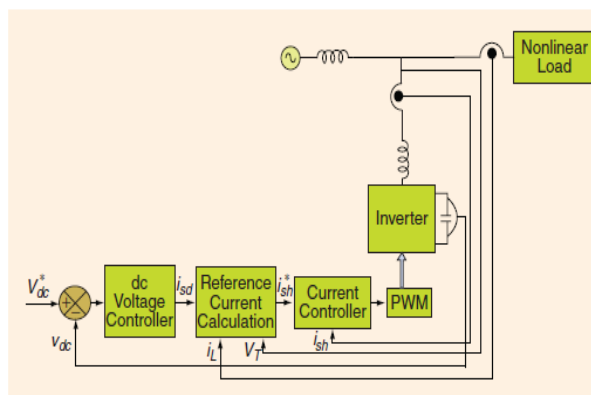


FIG .2 CONTROL BLOCK DIAGRAM OF SHUNT ACTIVE FILTER

3. CONTROL STRATEGIES

Shunt active filter uses mainly two compensation methods. First one is the frequency and another is time domain method, which are described in following section. Each method has its own advantages and disadvantages.

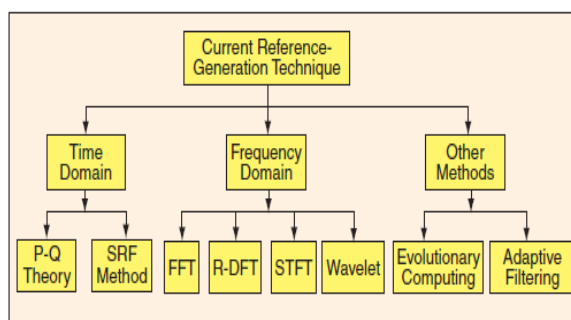


FIG.3 CLASSIFICATION OF REFERENCE GENERATION TECHNIQUES

3.1 Frequency Domain Methods

Three widely used reference-generation techniques are discussed: fast Fourier Transform (FFT), recursive discrete Fourier transform (RDFT), and wavelet-based approach. This frequency-domain method mainly utilizes the principle of Fourier analysis and can estimate the harmonics very fast if a regular pattern of current is available. The fast Fourier transform algorithm (FFT) takes the sampled load current for one period and calculates the magnitudand

phase of the frequency components. Figure 4(a) shows the time domain sample used as the input to the FFT and Figure 4(b) shows the FFT output.

Each element in the frequency plot is a harmonic since the spacing is 50 Hz. The number of harmonics that can be resolved are given by half the number of samples used. Therefore the higher the number of samples in each cycles of current, the higher the value of $f_{\max}$.

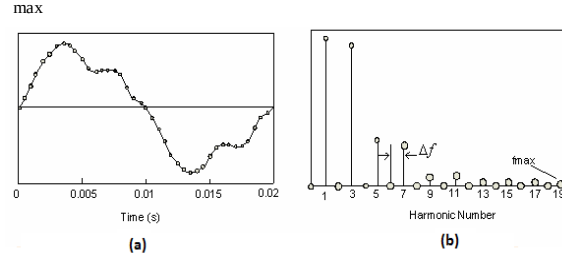


FIG 4. (a) INPUT WAVEFORM OF LOAD CURRENT WITH 40 SAMPLES WITHIN ONE CYCLE. (b) HARMONIC SPECTRUM OF THE INPUT WAVEFORM.

Note that short-time Fourier transform (STFT) can also be applied for fast harmonic compensation. It's easily implementable but requires at least one cycle to estimate the reference current. RDFT uses the same principle as that of DFT but introduces the concepts of a sliding window. In this reference-generation technique, a spectrum update is implemented in one step, larger than one sampling period to avoid oversampling. RDFT technique comes with the benefit of lower computational burden when compared with FFT or DFT. its advantages is computational delay is less than FFT. But failed to estimate reference current if the current samples are corrupted with noise or transient.

Wavelets may be used for the extraction of fundamental component of load current [18], [19]. Different types of mother wavelets are used. The cutoff frequency of the multi resolution analysis (MRA) filters needs to be selected properly to reduce the sensitivity to power frequency variation. The advantages of wavelet-based reference-generation technique are fast and accurate estimation of the fundamental and can be made insensitive to power frequency variation. Disadvantage is performance of the system totally depends on the design of the mother wavelet.

3.2 Time Domain Methods

So far, most commercial APF's have been designed on the basis of reactive power theory to calculate reference for harmonic compensation. The instantaneous reactive power theory was introduced by Akagi et al. in 1984 [4]. This theory proposes the control of active filters in three-phase power systems called "Generalized Theory of the Instantaneous reactive power in three-phase circuits", also known as "Theory of Instantaneous Power", or simply as "p-q Theory". The theory was initially developed for three-phase three-wire systems, with a brief mention to systems with neutral wire. Later, Watanabe et al. [12] and Aredes et al. [13] extended it to three-phase four-wire systems. Since the p-q Theory is based on the time domain, it is valid both for steady state and transient operation, as well as for generic voltage and current waveforms, allowing the control of the active filters in real-time. Another advantage of this theory is the simplicity of its calculations, since only algebraic operations are required.

Drawbacks of this method is it s require large number of voltage and current transducers and this method is poor in compensation of harmonic current if source Voltages are not symmetrical.

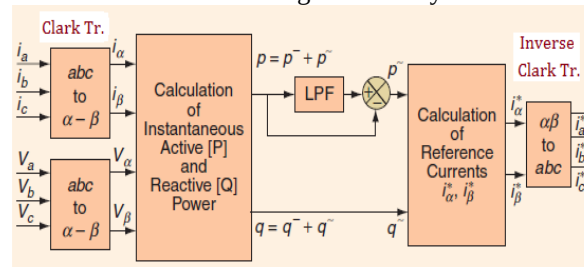


FIG 5. BLOCK DIAGRAM OF SHUNT ACTIVE POWER FILTER CONTROLLER FOR GENERATION OF REFERENCE COMPENSATING CURRENT BASED ON PQ THEORY.

Second technique is Synchronous Reference Frame method. Among the several methods presented in the literature, the (SRF) is one of the most common and probably it is widely used method. Also known as d-q theory.

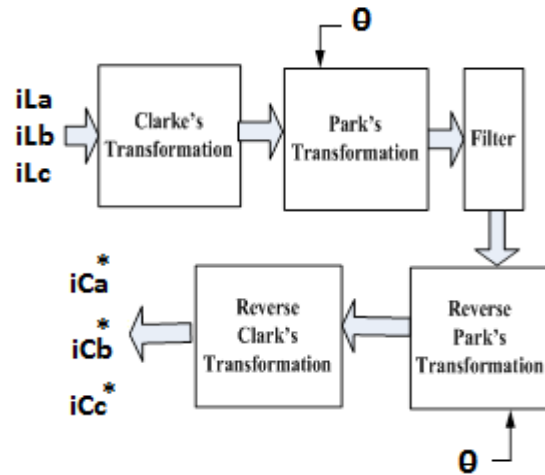


FIG 6. BLOCK DIAGRAM OF SHUNT ACTIVE POWER FILTER CONTROLLER FOR GENERATION OF REFERENCE COMPENSATING CURRENT BASED ON SRF THEORY.

It is based on the fact that harmonics change their frequency in a rotating reference frame, and so they are better isolated with high pass filters. In the SRF [8,9], [10], the load current signals are transformed into the conventional rotating frame d-q. If θ is the transformation angle, the transformation is defined by

$$\begin{bmatrix} x_d \\ x_q \\ x_0 \end{bmatrix} = \frac{\sqrt{2}}{3} \begin{bmatrix} \cos \theta & \cos\left(\theta - \frac{2\pi}{3}\right) & \cos\left(\theta - \frac{4\pi}{3}\right) \\ -\sin \theta & \sin\left(\theta - \frac{2\pi}{3}\right) & -\sin\left(\theta - \frac{4\pi}{3}\right) \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} x_a \\ x_b \\ x_c \end{bmatrix} \quad \dots\dots\dots(1)$$

Where x denotes voltages or currents. In the SRF θ is a time varying angle that represents the angular position of the reference frame which is rotating at constant speed in synchronism with the three-phase ac voltages. To implement the SRF method some kind of synchronizing system should be used. In [9] phase-locked loop (PLL) is used for the implementation of this method.

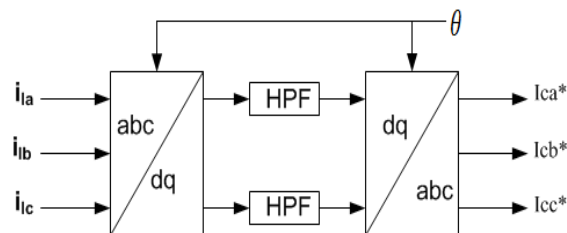


FIG.7 BLOCK DIAGRAM OF REALISATION OF COMPENSATOR

Harmonic isolation of the d-q transformed signal is achieved by removing the dc offset. This is accomplished using high pass filters (HPF). In spite of a high pass filter, a low pass filter is used as AHPF (alternate HPF) to obtain the reference source current in d-q coordinates. Fig. 3 illustrates a configuration of the SRF method. There is no need to supply voltage waveform for a SRF based controller. However the phase position angle must be determined using voltage information.

4. SIMULATION RESULTS

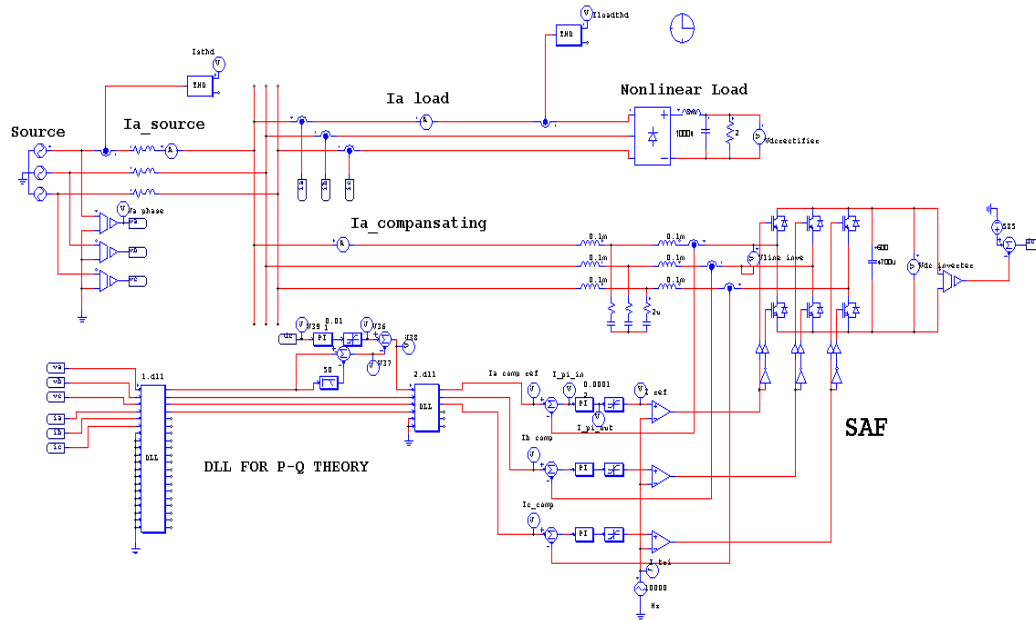


FIG.8 SIMULATION BLOCK DIAGRAM OF SHUNT ACTIVE FILTER BASED ON PQ THEORY

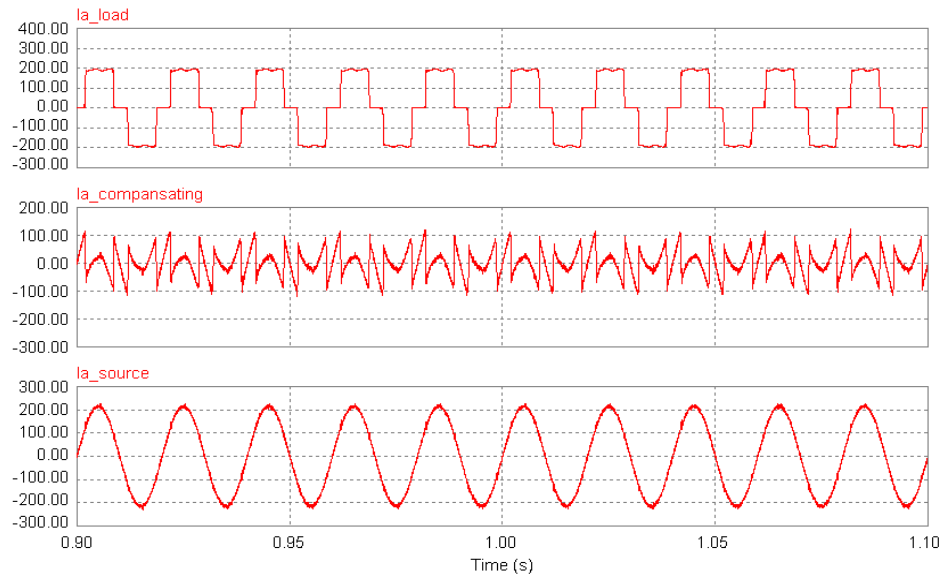


FIG 9: WAVEFORMS OF PHASE-A (a) NONLINEAR LOAD CURRENT (b) COMPENSATING CURRENT (c) SOURCE CURRENT.

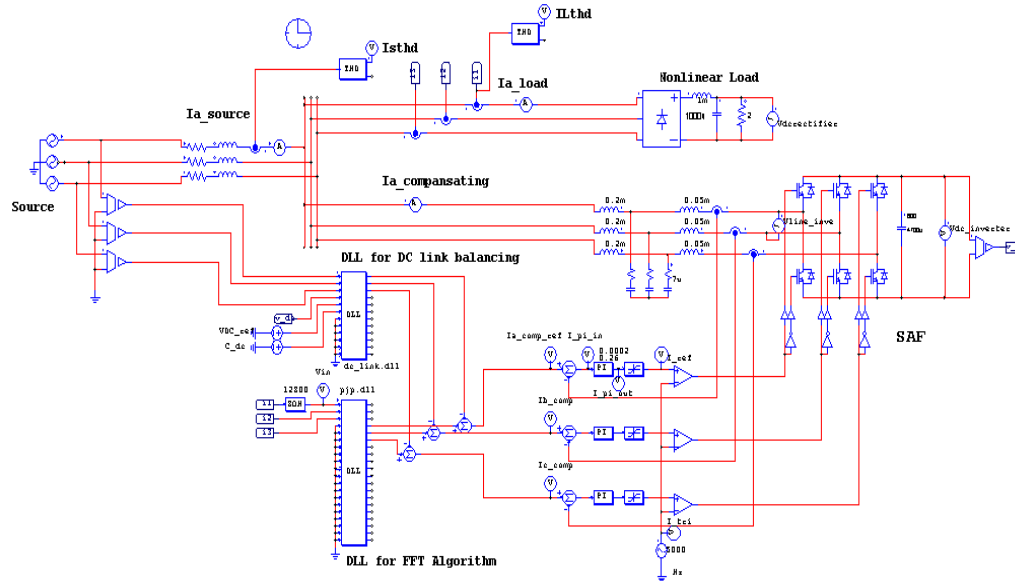


FIG 10: SIMULATION BLOCK DIAGRAM OF SHUNT ACTIVE FILTER BASED ON FFT ALGORITHM

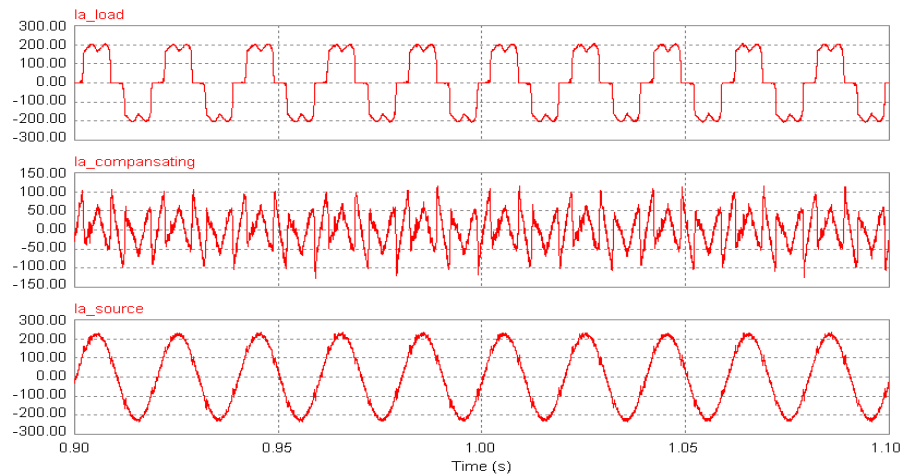


FIG 11: WAVEFORMS OF PHASE-A (a) LOAD CURRENT (b) COMPENSATING CURRENT (c) SOURCE CURRENT

5. CONCLUSION

This article has discussed some of the important techniques used to generate the reference current for the shunt-type APF. From the simulation of shunt active power filter working on PQ Theory and FFT algorithm the following results have been obtained. In the steady state condition when the supply voltage is balanced and the load is constant both control strategies P-Q theory and FFT algorithm are effectively eliminating the harmonic distortion from the system. The drawbacks of time domain method is delay in compensation, uses large number of voltage and current transducers additionally compensation is poor in case of distorted supply voltage and the limitations of the frequency-domain approaches are that the designer has to consider the effect of aliasing. The antialiasing filter used for this purpose is required to be very accurate. The adaptive filtering technique can be effectively used for reference generation of shunt APF [20]. The adaptive filter-based reference-generation technique makes sine and cosine functions from load current Sample, and no assumption is made on the harmonic content of the voltage signal. The advantage of this method of estimation also provides satisfactory result for distorted source voltages and disadvantage is that the method is sensitive to variation in supply frequency.

6. FUTURE WORK

Recently, there has been an increased effort to apply soft-computation-based techniques. With the availability of low cost and high-speed processors, such computationally extensive methods are expected to be popular in the future for eliminating all types of problem for getting desired results.

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