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Periodic Research

Harmonic Elimination by Shunt Active Power Filter

Abstract

In this paper, three phase shunt active power filter is given for compensating multiple non-linear loads . The circuit models a standard shunt AHF with IGBT inverter and series inductor on the AC side and DC capacitor energization. The AHF uses a PLL to generate a reference sinusoidal source current which is in-phase and has the same RMS gain as the load current. Current control is implemented through feedback modulation of a dynamic hysteresis band PWM controller. The shunt line current tracks the reference current within a hysteresis band. By comparing the reference currents calculated by the controller with the measured values of compensation currents, the command signals for the inverter semiconductor switches can be produced.

Keyword: Shunt AHF, IGBT inverter, Series Inductor

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Introduction

Nonlinear loads cause voltage and current waveforms distortion in the ac power network. It results in harmonic related problems including substantially higher transformer and line losses, reactive power and resonance problems, over-voltages, over-heating, Electro Magnetic Interference (EMI) problems, and other undesirable effects. The result is reducing system stability [1]-[3]. Passive filters alone have been traditionally used to eliminate the harmonics in utilities due to their low cost and high efficiency. Shunt-connected passive filters, tuned to show low impedances at different dominant harmonic frequencies, are widely used. However, these filters have multiple drawbacks including that at fundamental frequency they generate fixed quantity of reactive power affecting sometimes the voltage regulation at the PCC. Active filters were developed to mitigate problems of passive filters. They are more effective in harmonic compensation and improved system performance. But using only active filters is a very expensive solution because it requires comparatively high power converter ratings. Hybrid Active Filter (HAF) topologies which combine the advantages of both active and passive filters [4]-[6] is more appealing in terms of cost and performance. They are cost-effective by reducing the KVA rating of the active filter as much as possible while offering harmonic isolation and voltage regulation [5].

Two kinds of hybrid active filters have been developed: a hybrid series active filter and a shunt hybrid active filter. To compensate for both current and voltage system harmonics, a shunt and series active filter configuration must be used respectively. Integrating this filter serves to eliminate load harmonics whilst ensuring the supply remains fundamental. For harmonic elimination, active filter can be classified on the basis of various control technique- open loop system & closed loop system. Open-loop systems sense the load current and the harmonics it contains. They inject a fixed amount of power in the form of current (mainly reactive) into the system, which may compensate for most of the harmonics and/or reactive power available. No reference current is required for this type Closed loop control systems incorporate a feedback loop providing greater accuracy of current injection for harmonic compensation as well as reactive power reduction well over open loop system [7]-[10]. There is reference variable to check the performance and accuracy of the filter.[11-18]

Active harmonic filter

Proposed methodology uses a combination of a grid current forcing shunt APF with a series reactor installed at the Point of Common Coupling (PCC) to handle the harmonic and unbalance problems from mixed loads.[20] The three-phase shunt active power filter is a three-phase current controlled “voltage-source inverter” (CC-VSI) with a mid-point earthed, split capacitor in the dc bus and inductors in the ac output (It is essentially three independent single phase inverters with a common dc bus).

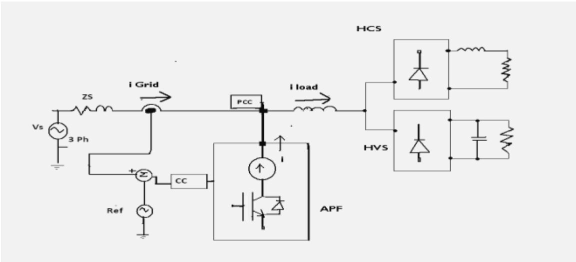

Figure1.
Proposed Active Power Filter Configuration

The circuit models a shunt AHF with IGBT inverter and series inductor on the AC side and DC capacitor energization. The load consists of two diode rectifiers which are phase-shifted by 30 degrees. The Delta-Y connected rectifier is connected after 10 cycles to change the load from 6-pulse to 12-pulse.

The AHF uses a PLL to generate a reference sinusoidal source current which is in-phase and has the same RMS gain as the load current. The current error between the load current and the reference current is generated by the IGBT Bridge through hysteresis switching. The AHF aims to inject this current error at the point of common coupling in order to match the source current as closely as possible with the reference current.

PLL (Phase Locked Loop)

Three different types of harmonic detection strategies used to determine the current reference for the active filter. These are-

1. Measuring the load harmonic current to be compensated and using this as a reference command;
2. Measuring source harmonic current and controlling the filter to minimize it; and
3. Measuring harmonic voltage at the active filter point of common coupling (PCC) and controlling the filter to minimize the voltage distortion.

Proposed methodology involves measurement of the load current and subsequent extraction of its harmonic content. The harmonic components, so extracted, are adjusted for polarity and used as reference commands for the current controller. For estimation of reference current various techniques are used- High pass filter method, Low pass filter method, Time domain approaches- Instantaneous reactive power algorithm, Synchronous detection algorithm, Constant active power algorithm, Constant power factor algorithm, Fictitious power compensation algorithm, Synchronous frame based algorithm, Synchronous flux detection algorithm, Frequency domain approaches- Conventional Fourier and FFT algorithms Sine multiplication technique, Modified Fourier series techniques.

Proposed methodology uses PLL (phase Locked loop) and hysteresis switching for estimation of reference current.[12]

Let the load current, input frequency and terminal voltage be the input to the PLL. Three phase distorted supply voltages are sensed and given to the PLL which generates sine terms. The sensed supply voltage is multiplied with a suitable value of gain before being given as an input to the PLL. Here K=1…N, be the gain value assigned for controlling.

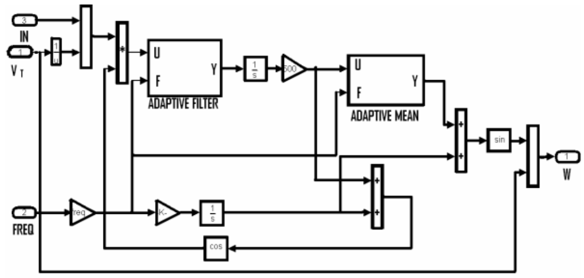

Figure 2: Proposed reference signal generation (PLL)

Here IL is the load current VT is the load voltage, ω is the output signal of the adaptive detecting circuit; and f is the fundamental reference frequency which is in phase with ac source voltage. As the input sinusoidal reference signal, i.e. the fundamental component of the system voltage has the same frequency and in phase with the desired fundamental components of load current and load voltage, the dc component of the output of integrator will tune accordingly until they are equal in magnitude. The corresponding fundamental real components of the current and voltage are then extracted from the sampled load current and load voltage.

The output signal of the adaptive detecting current and voltage are just the reactive power and harmonic components of the nonlinear load voltage and current.

Hysteresis Switching

Current control is implemented through feedback modulation of a dynamic hysteresis band PWM controller. The shunt line current tracks the reference current within a hysteresis band. By comparing the reference currents calculated by the controller with the measured values of compensation currents, the command signals for the inverter semiconductor switches can be produced.

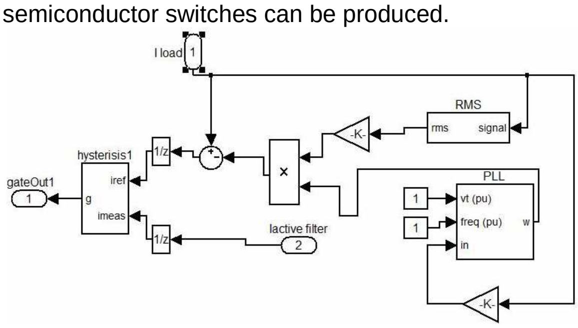

Figure 3: Proposed hysteresis controller

In proposed methodology, the load current, and the current of active filter be the input to the shunt firing unit. The gate signal obtained from this unit is the input to the IGBT. Thus obtaining gate signal by means of hysteresis current controlling technique is performed. The gate signal is obtained by means of using hysteresis current controlling technique. To detect the current to be compensated, reference current should be obtained. PLL value is improved by means of RMS value of load current.

Simulation Results

Simulation is carried out on a Matlab /Simulink software.[19] Figure 4 represents the simulation model. Harmonics generated by non-linear loads is removed by PLL based Shunt Active Power Filter. Proposed model not only considers the harmonics due to non-linear load but it also considers the disturbance occurs in supply. In this simulation the input current wave shape is non-sinusoidal which represents unbalanced supply. Simulation time is 0.25 seconds. Figure 5 shows the Simulation Results. Table 1 shows experimental & simulation parameters.

Table 1

SAPF Experimental and Simulation Parameters

S.No.	Parameters		Value
Source	Voltage	Vabc	4160*sqrt(2)/sqrt(3)
	Frequency	F	50Hz
Load	Two Diode Rectifiers	Resistance	$1*10^{-3}$ ohms
		Snubber Resistance	$1x10^{3}$ohms
		Snubber Capacitance	$1x10^{-6}$ohms

Conclusion

This project proposes the implementation of a three-phase active power filter together with a decoupling reactor in series with the load operated to directly control the ac grid current to be sinusoidal and in phase with the grid voltage. From the simulation results, this system provides unity power factor operation of non-linear loads with harmonic current sources, harmonic voltage sources, reactive, and unbalanced components

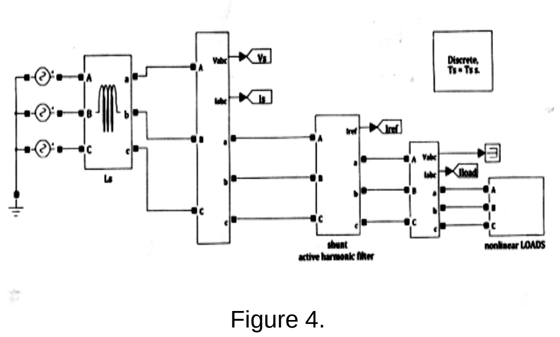

Figure 4.
Simulation Model of Shunt Power Active Filter

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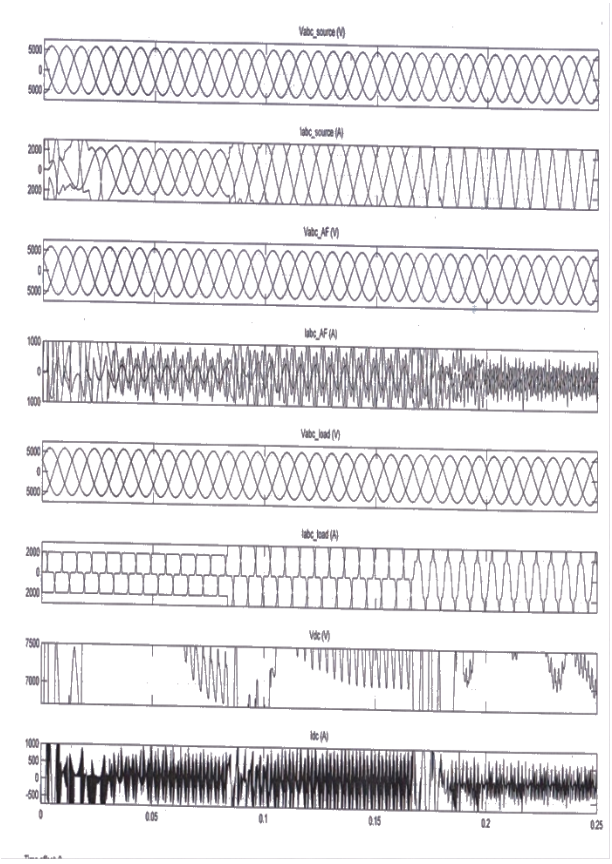

Figure 5. Simulation Results

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