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Shunt Active Power Filter for Harmonics and Reactive Power Compensation

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Abstract

This paper presents the enhancement of power quality for a power system at distribution level using Shunt active power filter. The main objective of this paper is to identify a suitable pulse generation technique for obtaining a better compensation capability of shunt active power filter. The compensation capability of the device is mainly depends on the regulation of DC link capacitor voltage. Conventionally fixed hysteresis current control technique has been used. To raise the performance of shunt active power filter, an adaptive hysteresis current control technique has been proposed here. The performance of proposed technique has been verified for different operating condition in the platform of MA TLAB/SIMULINK model.

Keywords- Power quality (PQ), Shunt active power Filter(SAPF), Total harmonic distortion (THD).

I. INTRODUCTION

There are generally three types of APFs, they are series APF, shunt APF and UPQC (Unified Power Quality Conditioner). Series APF is gives compensation for voltage related problems like voltage sag, swell, flicker and unbalances. Shunt APF is a device which is used to compensate the current related problems like harmonics, inter harmonics and reactive power consumption. UPQC is the combination of series and shunt APF. So that it will provide both voltage and current related compensation [10], [12]. This paper deals with the application of shunt APF to the distribution system to mitigate the current related issues and provide a satisfaction to the customer by delivering good electrical power. The operation of shunt APF can be identified by using the control technique [2]. There are different control strategies provided by different authors. In this paper Unit Vector Template Generation is described. Among the different pulse generation techniques, here Adaptive hysteresis current control technique is chosen because of its simplicity and easy to implementation. In section 2, the concept of microgrid has been described, shunt APF was discussed in section 3, section 4 comprises of control technique for shunt APF, section 5 includes adaptive HCC technique, and mathematical formulation was described in section 6. The section 7 holds the results obtained from MA TLAB/SIMULINK model and its discussions. The final section incorporates conclusion part.

II Problem Definition

The present power system scenario mainly focused on the issue of power quality problems. The major research topic in the power distribution system is to improve the quality of power [1]-[3]. The primary cause for poor power quality is the arrival of power electronics based devices and non-linear loads in industries as well as commercial applications. The ideal power system has balanced, pure sinusoidal phase supply, the loads operating with unity power factor and zero harmonics. But practically this is not possible because the system comprises of linear and non-linear loads. Due to these complex loads there will be a change in the system parameters such as voltage, current and frequency together they are termed as 'Power quality issues'. The poor power quality results malfunction of devices and equipment, voltage and current harmonics and unbalances, low power factor and reactive power consumption. Among these harmonics is the primary index for poor power quality. Hence it is necessary to mitigate these power quality issues and maintains the % THD within certain limits as per IEEE standards. Due to the development in the field of power electronics and the digitalized control technology the entry of custom power devices is encouraged. A most widely used custom power device is called shunt active power filters (SAPF).

The Shunt active power filter (SAPF) is device to eliminate harmonics from power system, also help to compensate part of reactive power requirement of load, thus improving load end power factor. This helps to avoid electrical losses due to excessive current that flows in power system to fulfill the reactive power requirement of load.

III LITERATURE BACKGROUND

(Enjeti et al., 1992), entitled "Analysis and design of an active power filter to cancel harmonic currents in low voltage electric power distribution systems", presents active power filter design considerations used for improving current quality in low voltage electric power distribution systems. Among various types of filters, shunt active filter is used for current harmonics removal and improves the power quality in electric power distribution system.

(Adil M. Al, -Zamil.,**2001),** entitled "The unified power quality conditioners: the integration of series active and shunt-active filters", In this paper the main purpose of a UPQC is to compensate for voltage flicker/imbalance, reactive power, negative sequence current, and harmonics. In other words, the UPQC has the capability of improving power quality at the point of installation on power distribution systems or industrial power systems. This paper discusses the control strategy of the UPQC, with a focus on the flow of instantaneous active and reactive powers inside the UPQC.

(Singh, Bhim Al-Haddad et al., 1999), entitled "Harmonic elimination, reactive power compensation and load balancing in three-phase, four-wire electric distribution systems supplying non-linear loads" In this paper, a new control scheme of a three-phase active power filter (APF) is proposed to eliminate harmonics, to compensate reactive power and neutral currents and to remedy system unbalance, in a three-phase four-wire electric power distribution system, with unbalanced non-linear loads. The APF is realized using three single phase IGBT based PWM-VSI bridges with a common dc bus capacitor.

(Bhimsingh et al., 1999), entitled " A review of active filters for power quality improvements", presents in this paper presents a comprehensive review of active filter (AF) 21configurations, control strategies, selection of components, other related economic and technical considerations, and their selection for specific applications. It is aimed at providing a broad perspective on the status of AF technology to researchers and application engineers dealing with power quality issues.

IV POWER SYSTEMS AND POLLUTION

Electric systems and grids are complex dynamic systems. These systems suffer usually from unexpected or sudden changes of the currents and voltages. These changes are due mainly to the different types of linear and non-linear loads to which they are connected. In addition, to different types of accidents which can intervener into the grid [31]. With the increasing use of power semiconductors in the most of industrial and domestic procedures, the electric grids are polluted with different harmonic currents and voltages. These harmonics affect the normal function of the most of the grid connected devices; in addition to considerable economic losses. Many classic and modern solutions have been proposed in the literary for the harmonic problems. In this chapter, the harmonic problem as one of the most common power quality problems will be presented. The different modern and traditional solutions will then be discussed.

Power Systems Distortion and Problems

In power systems, different voltage and current problems can be faced. The main voltage problems can be summarized in short duration variations, voltage interruption, frequency variation, voltage dips, and harmonics. Harmonics represent the main problem of currents of power systems.

Voltage Variation for Short Duration

The short duration voltage variation is the result of the problems in the function of some systems or the start of many electric loads at the same time. The defaults can increase or decrease the amplitude of the voltage or even cancel it during a short period of time [31]. The increase of voltage is a variation between 10-90% of the nominal voltage. It can hold from half of a period to 1 minute according to the IEEE 1159-1995. According to the same reference, the increase in voltage is defined when the amplitude of the voltage is about 110-180% of its nominal value.

Voltage Interruption

The cutoff of the voltage happens when the load voltage decreases until less than 10% of its nominal value for a short period of time less than 1 minute. The voltage interruption can be the effect of defaults in the electrical system, defaults in the connected equipment's, or bad control systems. The main characteristic of the voltage interruption is the period over which it happens.

Frequency Variations

In the normal conditions the frequency of the distribution grid must be within the interval 50±1 Hz. The variations of the frequency of the grid can appears to the clients who are using auxiliary electric source (solar system, thermal station…etc). These variations are rare and happen in the case of exceptional conditions like the defaults in the turbines.

Unbalance in Three Phase Systems

The three phase system is unbalanced when the currents and voltages are not identical in amplitude; or when the phase angle between each two phases is not 120°. In the ideal conditions, the three phase system is balanced with identical loads. In reality, the loads are not identical, in addition to the problems of the distribution grids which can interfere.

Voltage Dips (Sags)

The voltage dips are periodic perturbations. They appear as a natural effect of the switching of the transistors. They are due also to the start of big loads like motors. Lifts, lights, heaters…etc. this phenomena causes bad functioning of the protection equipment's.

Harmonics

Power systems are designed to operate at frequencies of 50 or 60 Hz. However, certain types of loads produces currents and voltages with frequencies that are integer multiples of the 50 or 60 Hz fundamental frequency. Harmonics are familiar to the musicians as the overtones from an instrument. They are the integer multiples of the instrument's fundamental or natural frequency that are produced by a series of standing waves of higher and higher order. Electrical pollution known as harmonic distortion. Synchronous harmonics are sinusoids with frequencies which are multiples of the fundamental frequency. The multiplication factor is often referred to as the harmonic number. The synchronous harmonics can be subdivided into two categories.

V PROPOSED METHODOLOGY

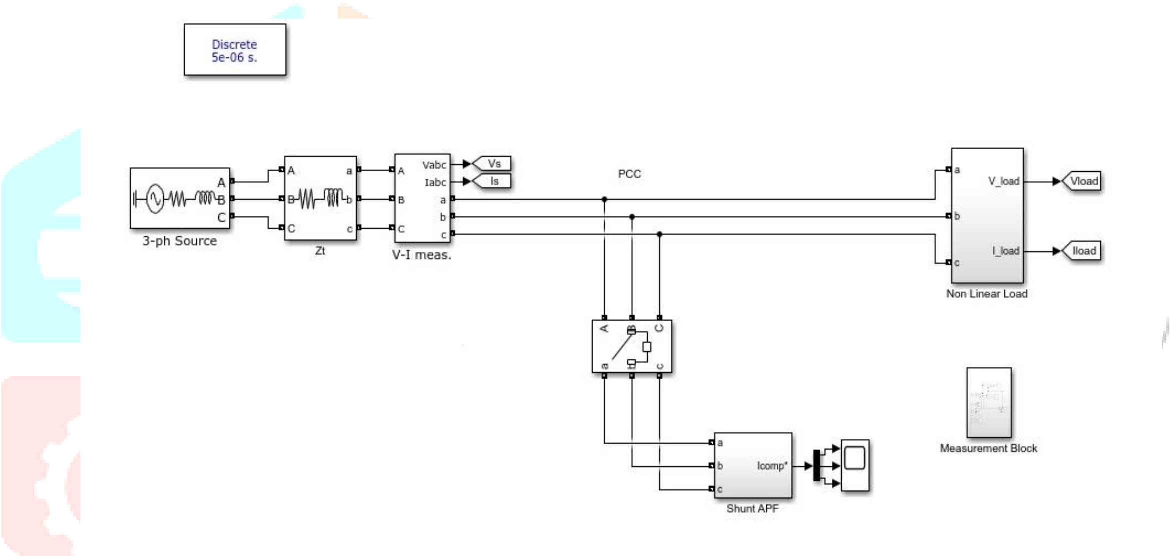
The work include simulation of harmonic generating load and its compensation by shunt active power filter. A RL load fed by three phase uncontrolled rectifier is considered as non linear load as source of harmonics. The harmonics generated by the load are mitigated by shunt active power filter. The overall model is developed in MATLAB/Simulink platform. This paper also includes the analysis, the review on the information and data of the harmonic distortion and its impact on the industrial and also to find the main source of how the harmonic has been generated. Design a three phase shunt power active filter and do a simulation using MATLAB/Simulink to obtain the answer, solve the problem and also achieves all of the objectives for this project. Represent the nonlinear load with RL load, and analysis as the distorted source current waveform drawn by the nonlinear load. The objective of the study is to develop a Shunt Active Power Filter based on PQ theory and to obtain results. The work will include harmonic mitigation of load harmonics due to two different types of load, i.e. pure resistive load and a RL load fed from full bridge uncontrolled rectifier. Also To study behavior of Shunt Active Power Filter to addition of load. The active filter injects the harmonic current spectrum in opposite phase to the measured distorting harmonics currents. The original harmonics are there by cancelled. The harmonic current on the ac bus generated by active filter have opposite phase to the harmonic current present in the ac system. The control of an active filter in combination with the active generation of the compensating current allows for a concept that the active filter may not be overloaded and thus current exciding the capacity of active filter will remain on the network but the filter will operate and eliminate all harmonic currents up to its capacity.

VI SIMULATION

Simulation time 0.5 sec

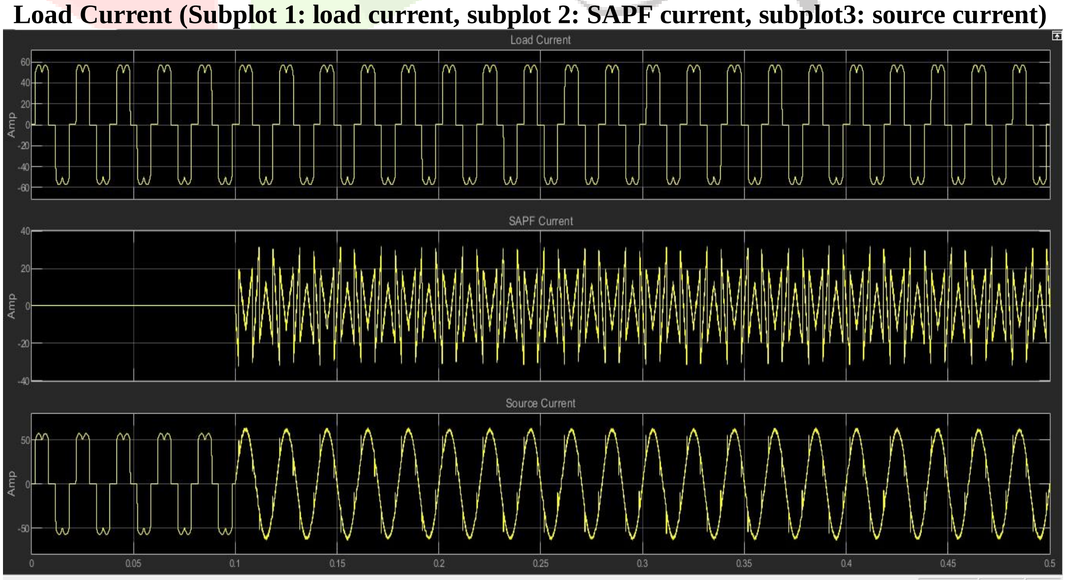
Shunt Active power filter switched on at **0.1 sec**

1) Model

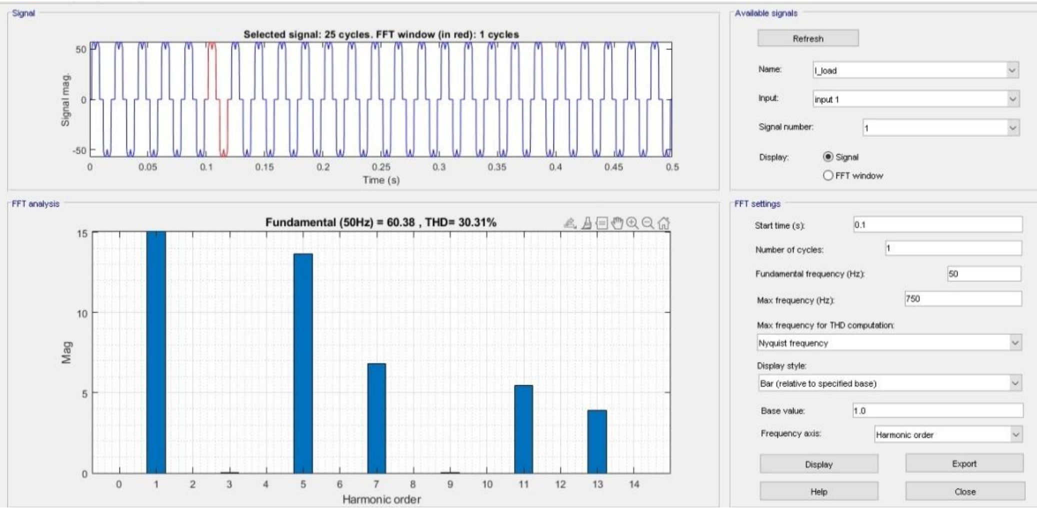


2)Simulation Result

Load Current (Subplot 1: load current, subplot 2: SAPF current, subplot3: source current)

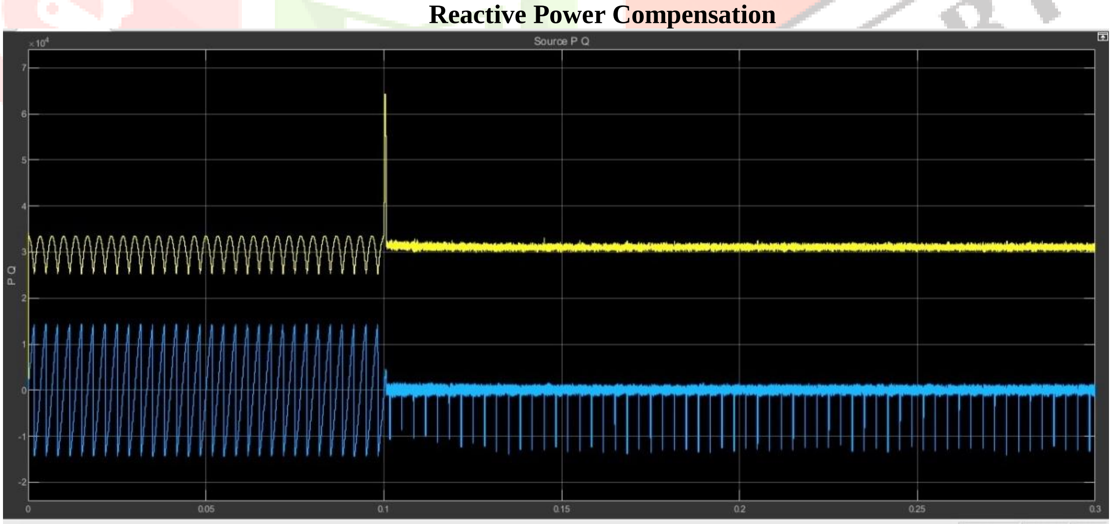


FFT Analysis of Load Current (THD=30.31%) (Magnitude Vs Harmonic Order)



FFT Analysis of Source Current (THD=1.26%) (After compensation by SAPF)

Reactive Power Compensation



CONCLUSION

We have observed that Harmonics and reactive power requirements of nonlinear loads are becoming a serious problem, causing power quality pollution. So for harmonic compensation a 3 phase SAPF is developed. Simulations have been carried out to study the performance of the system with and without active shunt filter. The developed shunt active filter is able to reduce the THD of the source current from 30.31% to 1.26%. From results of Active & Reactive Power Waveforms, it is also concluded that when filter is connected to the system, it is clearly seen that initially when the Shunt Active Power Filter is not operational up to 13.5 kVAr, at 0.1 sec, the Shunt Active Power Filter become operational. The reactive power drawn from source is reduced to 2.5 kVAr. Thus the Shunt Active Power Filter also provide reactive power compensation to great extent.

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