Analysis of Shunt Active Filter using Nonlinear Load for Harmonic Reduction

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***Abstract*—** An Active Filter is controlled current or voltage power electronics converter that facilitates its performance in different modes like current harmonics compensation, reactive power compensation, power factor correction and load balancing in the distribution system. The compensation process uses different control approaches to extract the reference current but they all share a common objective i.e. imposing sinusoidal currents in the grid, eventually with unity power factor and load balancing. The main aim of the research work is to enhance the power quality using Active Filters. In this thesis three phase three wire voltage source Shunt Active Filter has been implemented. It mainly deals with improvement of major power quality issues like harmonic elimination, reactive power compensation, power factor correction and load balancing due to nonlinear load. The thesis provides a complete framework for the analysis of power quality issues.

Keywords— Active Filter, Passive Filter, IGBT switch, Power Converters.

I. INTRODUCTION

Within the world of electrical engineering where silicon chips hold trillions of transistors and billions of people depend on the function of computers there are countless ways that the basic principles of electricity have been applied to human life. Deep within that realm of engineering lives the study of energy transfer, transduction, transmission, and perhaps most importantly – control. Electricity provided to the masses in a common 50 hertz or 60 hertz waveform at some voltage is certainly a blessing to the world of electronics, but not all devices can work with such an input. When there is some device or application that desires a lower/higher voltage, current, frequency, or even a DC characteristic there has to be a change within that device rather than the entire utility grid. This is, in short, part of the job of power electronics. Power electronics includes anything that works to change or control a certain input to attain some different output for the use of a device.

When working within large or small scale power systems however the control of electricity and power flow is no simple feat. Resistors are linear and easy to work with, but most devices contain more complicated non-linear, non-ideal components that by themselves can be difficult to control. Worse still however, are the underlying effects of non-linear components such as diode bridges that can create, what are called harmonics? These harmonics exist at frequencies at multiplies of the fundamental or desired frequency with decreasing magnitude as they increase in order. This means that these additional harmonics are added to the original waveform and create some form of undesired distortion. The last harmonic which has a noticeable impact on the original waveform would be the 19th harmonic.

In the world of macro power, where the utility has many homes, schools, hospitals, police stations, libraries, and other large buildings to supply it clearly has many connections. All of these buildings are considered non-linear, non-ideal loads which mean they will create harmonics. These harmonics, due to the loads, will feed into the line current and may be "passed down the chain" increasing the distortion. Power electronics involves the study of various ways of rectifying this situation.

Usually it is the responsibility of the consumer, based upon IEEE standard 519, to monitor and reduce the harmonic production of some loads. That production is greater for some than others, but with the correct knowledge it can be filtered. The filtering process depends on the application, but a popular form of filtering is utilizing active filters instead of passive filters to adjust to the changing harmonics to keep consistent filtering. This is important because each time a new consumer is added the harmonics on the line can change and affect what would need to be filtered somewhere else. Passive filters are set to filter a certain type and frequency of waveform (to a certain order of harmonic), while active filters can be made to adapt.

These active filters work based off of a thorough understanding of the frequency and time domains and their relations. This is important since most things that consumers are concerned with can be explained simply in the time domain, while the more intensive concerns of the utility and providers are best handed in the frequency domain. This is because, as previously stated, the harmonic distortion can be seen on the load lines, but are added to the fundamental. The ability to separate the harmonics from the fundamental exists much more appropriately in the frequency domain than in the time domain since harmonics occur at the same time but different frequencies than the fundamental or desired waveform.

In this paper the study of a pure active filter, one without passive components, is centered around the idea that one can filter out harmonics of a non-linear load by understanding the difference between the line current (including harmonics) and what the ideal current would be. If this is the case then an active filter that responds to any change in the line current should be able to filter any change and always result in a clean, clear output waveform.

II. TYPES OF FILTER

Mitigation or cancellation of harmonics can be done by using passive or active filters. Passive filters have been used for harmonic mitigation purposes for long time ago. They consist of capacitors, inductors, and resistors. The filter is unable to adapt to the changing system conditions. Passive filters can be divided into four categories which are low pass, band-pass, high-pass, and tuned filters. Nowadays, passive filters are used to cancel the switching frequency of active filters and high frequencies.

Based on topology, there are two kinds of active filters which are current source and voltage source active filters. Current source active filters (CSAFs) employ an inductor as the DC energy storage device. In voltage source active filters (VSAFs), a capacitor acts as the energy storage element. VSAFs are less expensive, lighter, and easier to control compared to CSAFs

The most dominant type of active filter is voltage source inverter-type active filter, and shunt active filter is one type of VSI filter.

III. METHODOLOGY

This section will describe the method that will be used for this project in order to achieve the desire objectives. This project development is divided into various parts. The entire project is described below which will be helpful in project modeling and simulation.

Shunt Active Filter

An understanding of the requirements of the system was necessary before commencing with the design process for the active power filter. The active power filter design contains four major components: input source, non-linear load, active power filter, and a control system. The input source needs to be an AC signal, which is meant to simulate the signal found in a power system. If the necessary AC input voltage is less than the wall outlet voltage of 850 volts, then a variance could be used to scale down the voltage to a more reasonable level for testing purposes. The AC input voltage source is paired with an input inductance, so that there cannot be any instantaneous changes in the system current. The non-linear load needs to be able to produce a distorted input current, which will be added to the input current. In order for the load to be nonlinear, the current drawn by the load needs to be non-sinusoidal as the applied voltage on the load varies. Therefore the load should contain different configurations of at least one energy storage element, such as an inductor or a capacitor, and linear elements, such as a resistor. The active power filter has a couple possible design options, including the full-bridge implementation. The full-bridge implementation utilizes six transistors in an diagonally configuration. The purpose of the DC capacitor or DC voltage supply in the active power filter is to serve as a DC voltage energy source, which can help to produce increasing current levels seen in the compensation current.

The control system component is the most open-ended because there a number of different design options to choose from. The requirement of the control system is to be able to provide the gates of the transistors in the active power filter with the proper control signals. The high-side transistors are driven with signals with duty cycles which are the inverse of the duty cycles used for the signals driving the low-side transistors. For this application, the choice was made to apply a digital control instead of an analog control, so there need to be digital blocks which sample the input current, determine the frequency, phase, and magnitude of the input current, determine the proper duty cycles for the drive signals, and produce the signals to drive the gates of the transistors in the active power filter.

Active Power Filter Design

As can be seen in Figure 1, the proposed system functional block design consists of combination of analog and digital components which work together to correctly compensate for the harmonic distortion produced by the non-linear load. The main system consists of analog components, such as the Universal switches IGBT Gate Drivers, Active Power Filter, Non-linear Load, and Duty Cycle Algorithm and PWM Generation. The digital control system is composed of a DSP chip, which contains software/hardware code to implement a Sliding Window FFT and a method to calculate the Ideal and Harmonic Distortion Waveforms. Some of the key concepts considered when designing the project were phase matching, frequency matching, and a modulation method for driving the gates of the transistors in the active power filter to produce the proper compensation current.

V RESULT

MATLAB SIMULINK MODELING OF SHUNT

APF SYSTEM: This section presents the simulation results of shunt APF system which

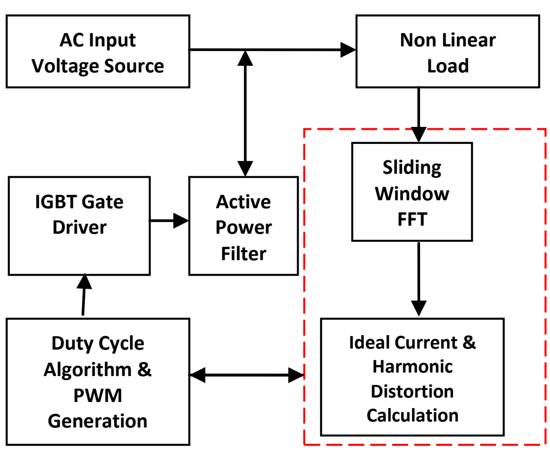


Figure 1 Active Power Filter Design

maintain sinusoidal AC current and ripple free constant dc-link voltage. The parameters used for the simulation study is given in Table-I. The SIMULINK model is shown in Figure.2

TABLE -I: SIMULATION PARAMETERS

Parameter	values
3-Phase AC source voltage Vs	400 V
Source Impedance Rs; Ls	0.01Ω; 100uH
Input frequency	50 Hz
DC Capacitor(SAPF)	20 uF
Constant DC voltage	850 V
Simulation time	0.2 second
Filter Impedance Lf	1.2mH
Load Resistor	10Ω

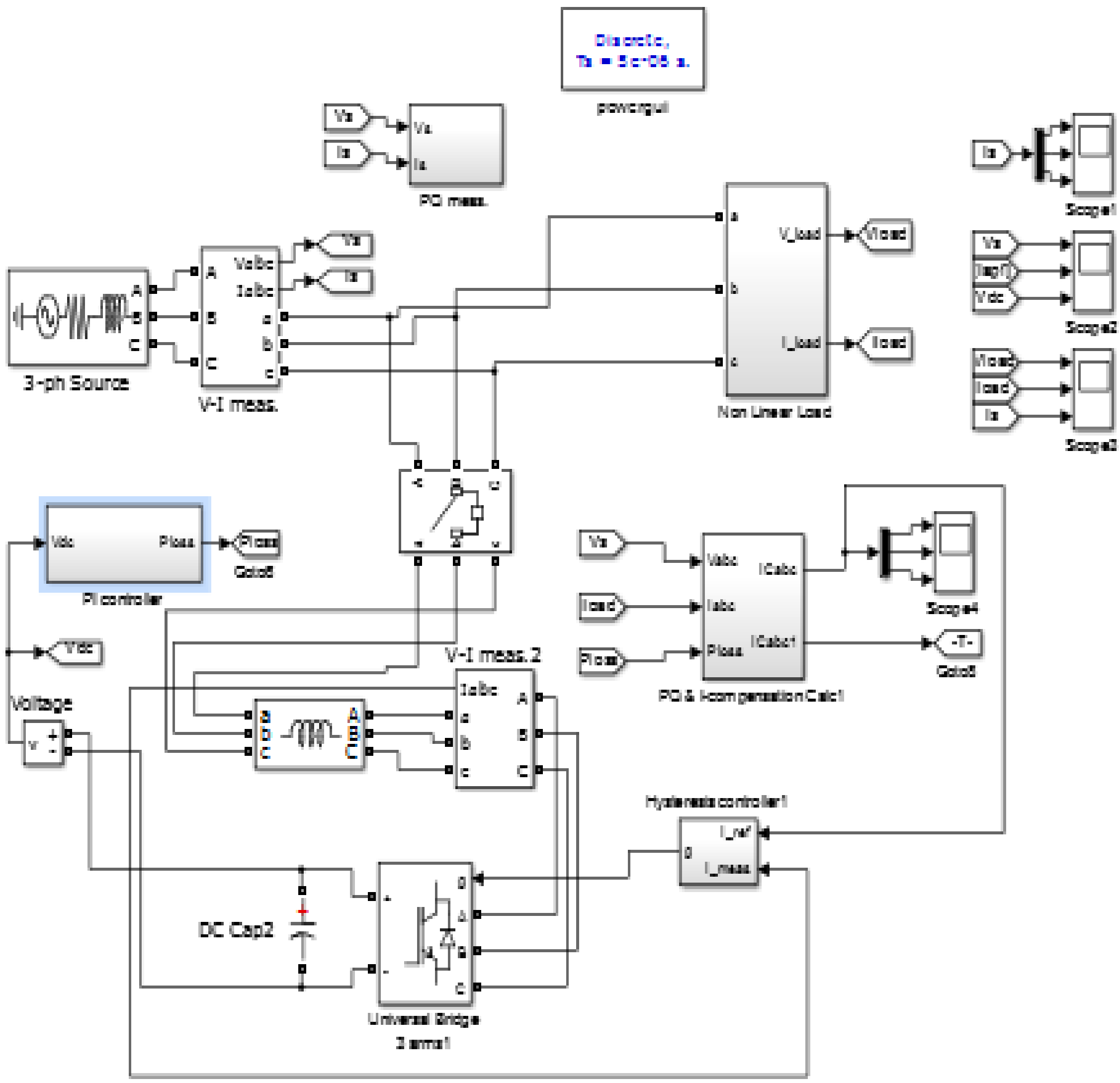
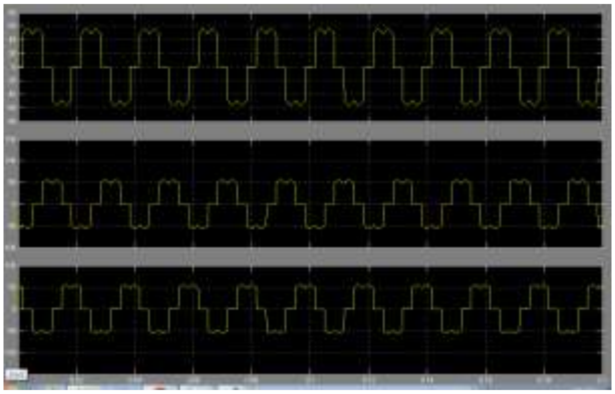


Figure-2 Simulation Model Shunt Active Power Filter in Presence of Non Liner Load



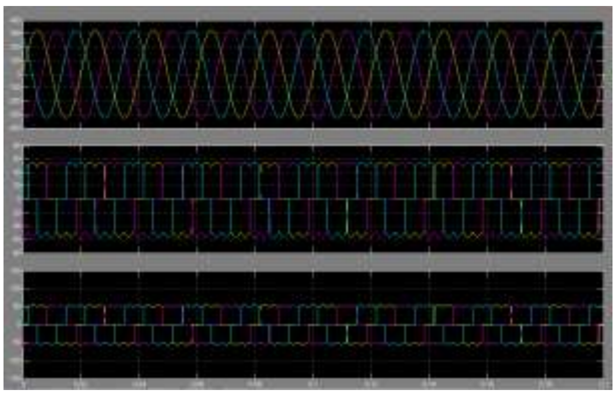
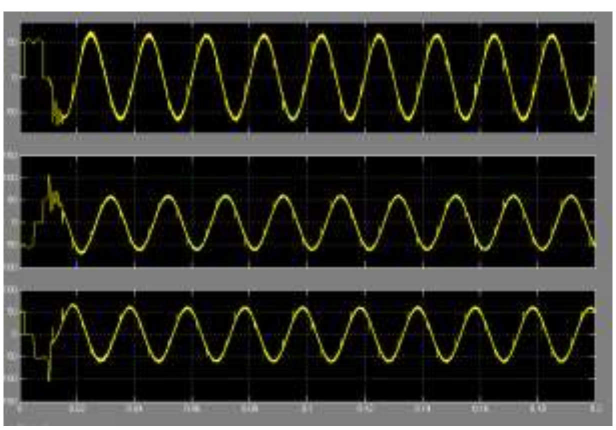


Figure-3 Input voltage &current and load current in presence of unbalancing load without APF



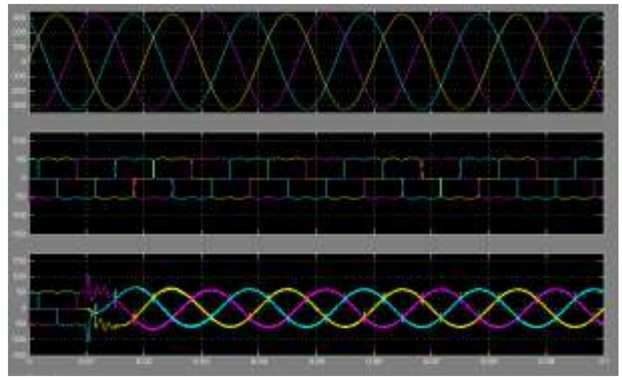


Figure-4 Input voltage &current and load current in presence of unbalancing load with APF

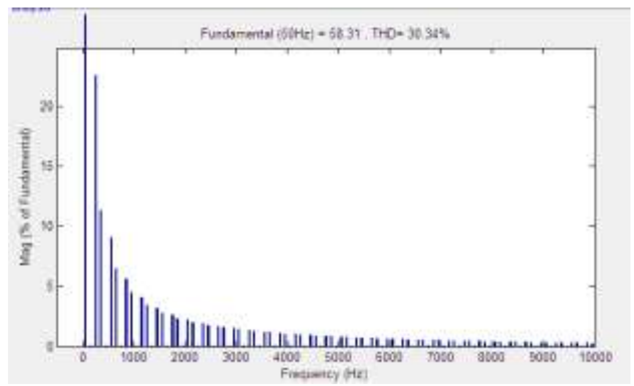


Figure-5 FFT Analysis of supply current when Unbalancing load presence without APF

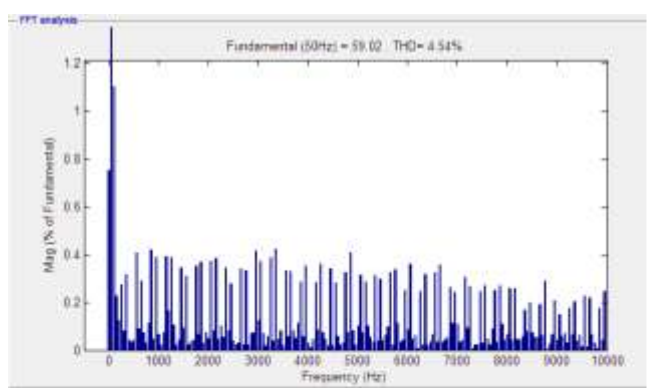


Figure-6 FFT Analysis of supply current when Unbalancing load presence with APF

TABLE -II: Output FFT Result

Control Schemes	Source Current THD (%)
Without APF	30.34%
With APF	4.54%

VI CONCLUSIONS

The power electronic equipments lead to an increasing harmonic contamination in power transmission or distribution systems. Many researchers from the field of the power systems and automation have searched for different approaches to solve the problem. One way was open by introducing the harmonic compensation by using Shunt active filters. With the development of power electronics technology, people have paid more attentions to harmonics. Using active Power filter is an effective method to suppress harmonics. This paper has studied the simulation of three phase shunt active power filter. Using our Shunt Active Power Filter, we have reduced the THD remarkably from 30.34% to 4.54% on the simulated power systems circuit.

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