Harmonic Compensation Using Shunt Active Power Filter with Fuzzy Logic Controller

Moolchandra Patel[1], Dr. G. P. Rathore[2]

[1]*M. Tech. (Power Electronics),* [2]*Asst. Prof.*

Electrical & Electronics Department TIT-S, Bhopal (M.P.)

Abstract- Now a day due to the increasing presence on the network of nonlinear loads; they constitute a harmonic pollution source of to the network, which generate many disturbances, and disturb the optimal operation of electrical equipments. In this work, we propose a solution to eliminate the harmonics introduced by the nonlinear loads. In this work we presents the analysis of a three-phase active power filter (APF) compensating the harmonics and reactive power created by nonlinear balanced and unbalanced low power loads in steady state and in transients. In this work the troubles formed by non linear load as well as the solutions having been applied so far are briefly reviewed. A new simple and effective reference current generation method of a shunt active filter is proposed In this paper we developed MATLAB model of a typical power supply system with a nonlinear load and shunt active power filter is carried out and the results are presented which imply a better dynamic performance of the proposed scheme compared to the fuzzy logic controller for controlling voltage source inverter.

Keywords: Active Power Filters, Harmonics, fuzzy logic controller, Inverters, Matlab-Simulink Software, Pulse Width Modulation (PWM).

I. INTRODUCTION

Electrical power is the most efficient and popular form of energy and the recent society is heavily needy on the electric give. The existence cannot be predictable devoid of the delivery of electricity. The same time quality of the electric power supplied is also very vital for the efficient functioning of the end consumer apparatus. The expression power superiority becomes the largest part main in the power sector and both the electric power supply company and the end user are worried about it. The quality of power delivered to the patrons depends on the voltage and frequency ranges of the power. If there is any variation in the voltage and frequency of the electric power delivered from that of the standard values after than the quality of power delivered is artificial.

At the present time with the spread in technology there is a dire improvement in the semi-conductor campaign. With the large number of power electronics based equipment come the real problem of harmonic distortion [2]. Through this development and compensation, the semi-conductor campaign got a permanent place in the power sector helping to ease the control of in general system, so nearly all of the loads are also semi-conductor base equipment. But the semi-conductor devices are non-linear in natural world and draws non-linear current commencing the source [1]. Also the semi-conductor devices are concerned in power conversion, which is either AC to DC, from DC to AC. This power conversion contains lot of switch operations which may bring in discontinuity in the current. Since of this discontinuity and non-linearity, harmonics are present which have an effect on the power quality delivered to the end consumer in sort to maintain the power quality delivered, the harmonics should be filtered out. Traditionally passive filters have been used to attenuate the harmonic distortion and compensate the reactive power [12].

There are lots of filter topologies in the literature like active, passive and hybrid. In this development the use of hybrid power filters for the upgrading of electric power quality is studied and study.

II. LITERATURE REVIEW

[1] A.Priyadharshini, N.Devarajan, AR.Uma saranya, R.Anitt, This paper presents a new adaptive hysteresis band controller for three phase shunt active power filters implemented using the Fuzzy logic. The simulations were carried using Matlab Sim Power Systems and Fuzzy logic toolboxes under two load configurations, balanced and unbalanced. The results are found quite satisfactory in order to keep the switching frequency constant, and to compensate the current harmonics, unbalance and reactive power in three phase electrical systems.

[2] George Adam, Alina Georgiana Stan (Baciu), Gheorghe Livinţ, Harmonic Distortions are the major cause for power quality problems. For this analyzing the harmonics present in non linear loads is significant. Here a survey is made to show details of harmonics present in various non linear loads.

[3] **Hideaki Fujitaand Hirofumi Akagi,** This paper discusses the control strategy of the UPQC, with a focus on the flow of instantaneous active and reactive powers inside the UPQC. Experimental results obtained from a laboratory model of 20 kVA, along with a theoretical analysis, are shown to verify the viability and effectiveness of the UPQC.

[4] Konstantin Borisov, Herbert L. Ginn III and Andrzej M. Trzynadlowski, Shunt active power filters are used to eliminate the current harmonics and to improve the power factor in systems with non-linear loads. At the present time, different methods exist to control active power filters. Some of them are based on instantaneous reactive power theory [1] and others are based on the synchronous reference frame using Park's transformation [2]. The purpose of this paper is to present a new control method of shunt active power filters in unbalanced systems, both in load currents, and in AC supply voltage, with a high contents of harmonics. The method is based on the time domain analysis carried out by P. Filipski. With this control method one can make that the set formed by the nonlinear load and the shunt power filter behaves every time like a resistance, UPF (with unity power factor), or that the current absorbed by the set is perfectly sinusoidal, by simply acting on a switch. The system has been simulated for different load and line conditions. Waveforms of the line currents are shown, with their harmonic distortion contents.

[5] Victor Ciirdenas, Luis Moriin, Arturo Bahamonded, Juan Dion, A comparison of three different techniques used for the generation of the current reference signal in shunt active power filters. The three different techniques are evaluated and compared in terms of compensation performance under steady state and transient operating conditions, implementations requirements, and compensation in four wire power distribution systems, with unbalanced single phase nonlinear loads. The three techniques analyzed are the Instantaneous Reactive Power Theory (PQ Theory), the Synchronous Reference Frame Theory (SRF) and Peak Detection Method (PDM). The technical evaluation is done by considering the robustness for the operation with unbalanced and distorted supply voltages, unbalanced load currents, control signals conditioning and processing delays introduced by the. The comparison is based on theoretical analysis and simulated results obtained with Matlab.

[6] TingQian, Brad Lehman, Anindita Bhattacharya, Herb Ginn, Marshall Molen, Modern navy electric ship, the application of multiple shunt active power filters (SAPF) has become an attractive choice to mitigate the current distortion of the nonlinear loads. Multiple SAPF has the advantage of high power capacity and high reliability. Based on the introduction of SAPF, this paper analyzes the importance of paralleling SAPF in electric ship systems.

III. HARMONICS AND SHUNT ACTIVE FILTER

3.1 Introduction

Harmonics are cause if one of the main issues in a power system. Harmonics supply distortion in current and voltage waveforms consequential into corrosion of the whole power system. The first step for harmonic assessment is the harmonics from non-linear loads. The result of such analysis is compound more than many years; much significance is given to the method of study and control of harmonics. Harmonics present in power system too has non-integer multiples of the essential frequency and have a intermittent waveform. The harmonics are generating in a power system from two types of loads. [1]

One is labeled as linear loads. The linear time-invariant loads are characterized such that application of sinusoidal voltage outcome in sinusoidal flow of current. A regular steady-impedance is showed from these loads during the functional sinusoidal voltage. As the voltage and current are comparative to each other, if voltage is increased it will also product into increase in the current.

Active harmonic filters are electronic devices that eliminate the undesirable harmonics on the network by insert harmful harmonics into the network. The active filters are usually presented for low voltage network.

3.2 Causes

Sinusoidal waveforms which are non ideal were created by synchronous generators in the past; on the other hand new generators are far more advanced. Generators these days have brilliant control systems which allocate them to produce close to perfect sinusoidal waveforms. Nevertheless transformer saturation is still a cause of harmonics on systems while the main cause of harmonics is non-linear loads. This is due their trend to draw a current that is far from being sinusoidal. With advances in power electronics, harmonics is a problem that is becoming quite severe in almost every power system. Common causes of harmonics are:

1. Fluorescent Lighting
2. Arc Furnace
3. Power Supplies and Converters
4. Adjustable Speed Drives
5. Cycloconverters
6. Rectifiers
7. Personal Computers
8. Television
9. Semiconductors Switches

3.2.1 Rectifiers

Rectifiers are the basic load employed in every system [1]. Rectifiers are used to convert AC to DC current, while converting due to the involvement of thyristors (non linear load) produces harmonics. It consume the current in the circuit and which at last will have dc output with ac components (i.e. harmonics).This distorted current also lead to distortion in line voltage. Total harmonic distortion in line current in single phase rectifier is 88.82 %. But, three phase diode rectifier has total harmonic distortion of 52.84% [16]. Comparison of the line-current waveforms shows that the line current in a single-phase rectifier contains significantly more distortions when compared to a three- phase rectifier.

A 3 phase, six pulse (per cycle) converter also produces the 5th, 7th, 11th, 13th, 17th, etc., and contains no harmonic lower than the 5th; for a 12-pulse converter the lowest is the 11th harmonic.

3.3 Shunt Active Power Filter

The basic compensation principle of the shunt active power filter. It is controlled to draw or supply a compensating current i_c from or to the utility, so that it cancel current harmonics on the ac side.. In this manner a shunt active power filter can be used to eliminate current harmonics and reactive power compensation.

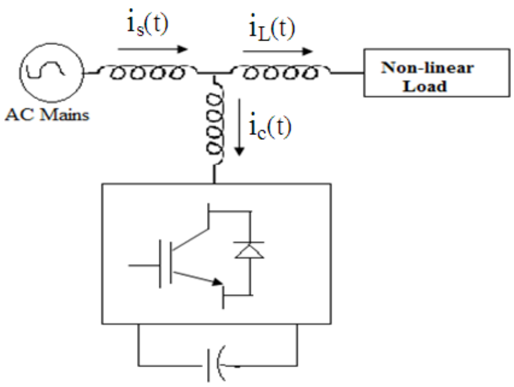

Figure 3.1 Shunt Active Filters

3.4 Estimation Of Reference Source Current

The peak value of the reference current I_{sp} can be estimated by controlling the dc side capacitor voltage. The ideal compensation requires the main current to be sinusoidal and in phase with the source voltage irrespective of the load's current nature. The desired source currents after compensation can be given as

$isa = Isp \sin \acute{\omega}t, \quad (3.12)$

$isb = Isp \sin(\acute{\omega}t - 120°), \quad (3.13)$

$isc = Isp \sin(\acute{\omega}t + 120°), \quad (3.14)$

Where $I_{sp} = I_1 \cos \phi_1 + I_{sL}$ is the amplitude of the desired source current, while the phase angles can be obtained from the source voltages? Hence, the waveform and phases of the source currents are known only the magnitude of the source currents needs to be determined.

IV. FUZZY SET THEORY

In modern days, the integer and variety of applications of fuzzy logic have increased to a large extent. The applications range from user products such as cameras, camcorders, washing machines, also microwave ovens to industrial system control, medical instrumentation, decision-support setup, and portfolio selection.

Fuzzy logic needs to be understood, to understand why usage of fuzzy logic has grown. Fuzzy logic has too many meanings. In a precise sense, fuzzy logic is a logical process, which is an extension of multivalve logic. However, in a wider sense fuzzy logic (FL) is almost identical with the theory of fuzzy sets, a theory which relates to collection of objects with unsharp boundaries in which membership is a matter of degree. In this overview, fuzzy logic in its narrow sense is a branch of FL. Even in its more precise definition, fuzzy logic differs both in view and substance from traditional multi valued logical process. In Fuzzy Logic Toolbox software, fuzzy logic should be explained as FL, that is, fuzzy logic in its wide sensibility.

4.2 Fuzzy Set

If *U* is a collection of objects denoted generally by *x*, then a fuzzy set *A* in *U* is defined as a set of prearranged pairs. A algebraic expression for this mapping is given in.

$$A=\{x,u{\sim}_{A}(x)|\ x \text{ € } U\}$$

IV. FUZZY SET THEORY

4.1 Introduction

In modern days, the integer and variety of applications of fuzzy logic have increased to a large extent. The applications range from user products such as cameras, camcorders, washing machines, also microwave ovens to industrial system control, medical instrumentation, decision-support setup, and portfolio selection.

Fuzzy logic needs to be understood, to understand why usage of fuzzy logic has grown. Fuzzy logic has too many meanings. In a precise sense, fuzzy logic is a logical process, which is an extension of multivalve logic. However, in a wider sense fuzzy logic (FL) is almost identical with the theory of fuzzy sets, a theory which relates to collection of objects with unsharp boundaries in which membership is a matter of degree. In this overview, fuzzy logic in its narrow sense is a branch of FL. Even in its more precise definition, fuzzy logic differs both in view and substance from traditional multi valued logical process. In Fuzzy Logic Toolbox software, fuzzy logic should be explained as FL, that is, fuzzy logic in its wide sensibility.

4.2 Fuzzy Set

If U is a collection of objects denoted generally by x, then a fuzzy set A in U is defined as a set of prearranged pairs. A algebraic expression for this mapping is given in

$$A=\{x,u{\sim}A(x)|\ x \text{ € } U\}$$

Where { u~A(x)} is called a membership function for the fuzzy set A. The membership function maps every element of U to a membership grade between 0 and 1.

An α-cut of fuzzy set A is determine by the crisp set including all elements x having a membership degree not inferior to α and obtained from A for each α [0, 1]. That is,

Aα= {x : u~A(x)> α and | x € U}

4.3 Membership Functions

Fuzziness in a fuzzy set is characterized by its membership functions. It classifies the element in the set, whether it is discrete or regular. The membership functions can also be formed by graphical representations. The graphical image may include various shapes. There are certain restrictions respecting the shapes used. The rules composed to represent the fuzziness in a request are also fuzzy. The "shape" of the membership function is an main criterion that has to be considered. There are various methods to form membership functions. This chapter confers on the features and the different methods of inward membership functions.

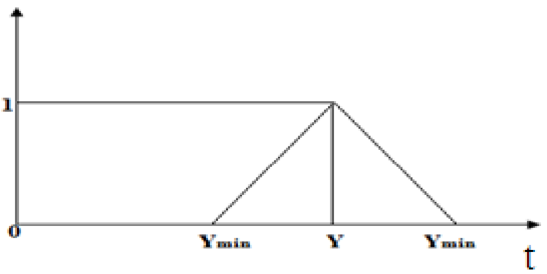

Figure 4.1 Triangular membership functions

V. INVERTER THEORY

5.1 Introduction

Inverters are use to make reversal by change a direct current into an alternating current. When the output of a circuit is AC in that condition depending on the input i.e. either DC or AC, the devices are identified as AC-AC cyclo-converters or DC-AC inverters. DC to AC inverters is a device that's AC output has magnitude and frequency which is whichever fixed or variable. For that of DC to AC inverters the output AC voltage can be also single phase or three phases. As well, the magnitude of the AC voltage is from the range of 110-380V AC while the frequencies are 400 Hz, 60Hz or 50Hz.

5.2 Types of Inverters

There are two types of inverters

5.2.1 Single Phase Inverters

5.2.3 Three Phase Inverters

5.3 Methods for Harmonic Reduction in Inverters

As explained earlier, one of the most significant aspects of a system is the reduction of harmonics that are present in the system. In case of an inverter, it is essential to remove the harmonics from the ac output.

The harmonics present in a dc to ac inverter are very much clear compared to the harmonics that can be present in an ac to dc converter. This is because of the result of dc to ac inverter as ac. As a result, the filters that are used in dc to ac inverter have different designs matched to the filters used in ac to dc converters. In situation of ac to dc converters, the main objective is to develop the output voltage ripple.

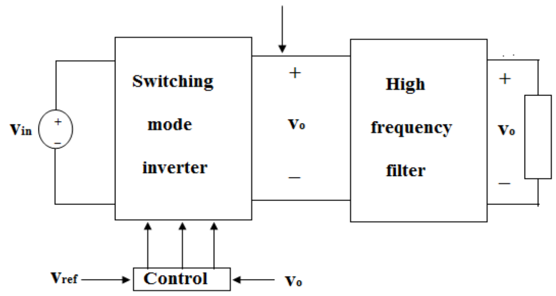

Figure 5.1: Single Phase Inverter with Filter

VI. PROBLEM FORMULATION

6.1 Power Quality Problems Solutions

The way out for some of the more conventional power quality troubles can be achieved by using the following devices or equipments:-

1. The UPSs (Uninterruptable Power Supplies) or urgent situation generators are the only resolution for extended interruptions in the electrical power supply [3].

2. Transitory electrical energy heave Suppress bolster protection beside transient phenomena which source voltage spikes in the lines.

3. The electromagnetic intrusion filters assurance that polluting equipment does not spread the high frequency noise to the electrical grid [10].

4. Separation transformers with electrostatic shield propose not only galvanic isolation, but also keep away from the propagation of voltage spikes to the secondary winding.

5. Ferro-resonant transformers formulate certain voltage regulation, since resolve overvoltage troubles.

6. Voltage regulation can also be making confident by means of transformers with more than a few outputs, linked with a commutation electronic scheme by thyristors.

VII. SIMULINK MODEL AND RESULTS

6.1 Three Phase circuit with linear load

It is Matlab Simulink model of three phase circuit with linear load, it gives the source side and load side voltage and current waveform which follow the Ohm's law and purely sinusoidal in nature.

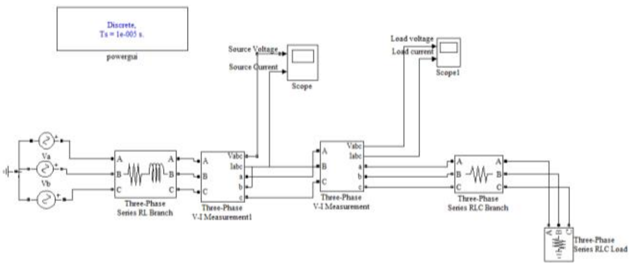

Figure 6.1 MATLAB simulink model of three phase circuit with linear load

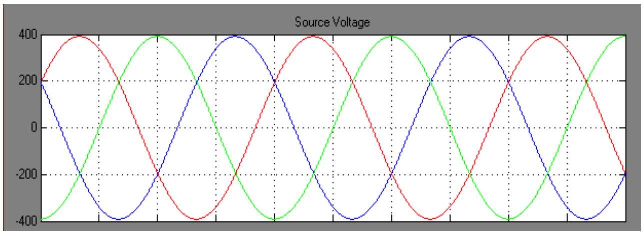

Figure 6.2 Source side voltage waveform of linear load circuit

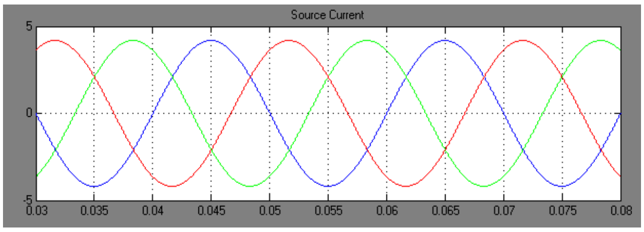

Figure 6.3 Source side current waveform of linear load circuit

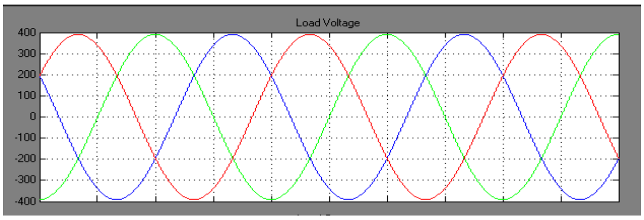

Figure 6.4 Load side voltage waveform of linear load circuit

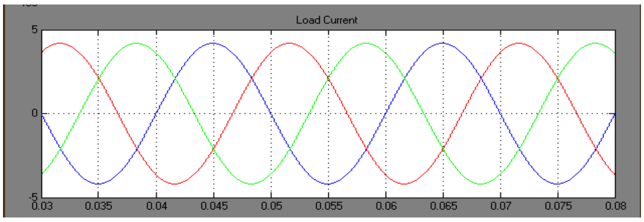

Figure 6.5 Load side current waveform of Linear load circuit

6.1.1 FFT analysis of current waveform of linear load circuit

It is the Fast Fourier Transform analysis of the current waveform of linear load which give the total harmonics distortion of current 0.00% it means there is no harmonics presents. When we use linear load. It is also shown in figure 6.3 that current is linear (Sinusoidal).

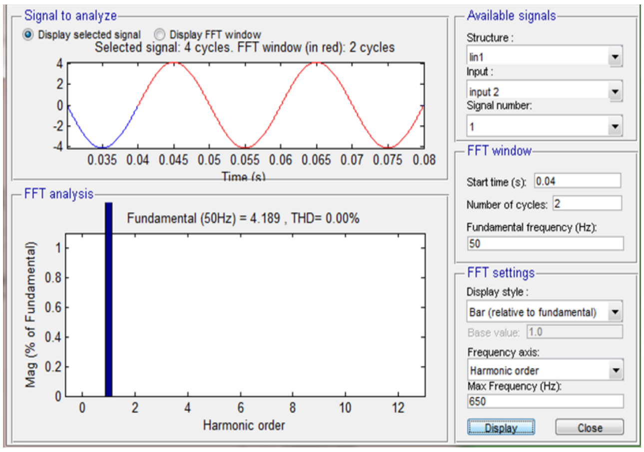

Figure 6.6 FFT analysis of current waveform

6.2 Three Phase circuit with nonlinear load

It is MATLAB Simulink model of three phase circuit with Non linear load, it gives the source side and load side voltage and current waveform which do not follow the Ohm's law and waveform of current is distorted in nature.

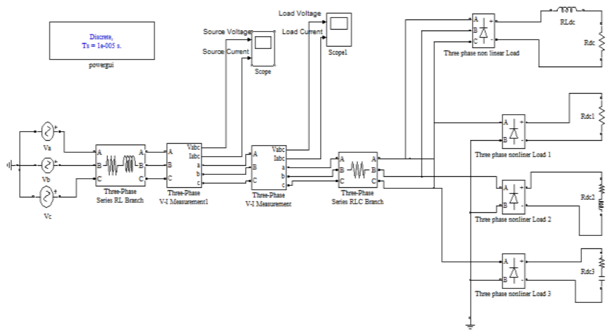

Figure 6.7 MATLAB simulink model of three phase circuit with nonlinear load

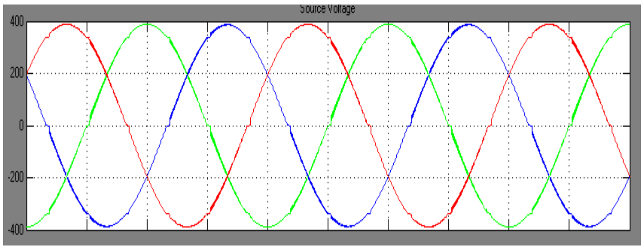

Figure 6.8 Source side voltage waveform of Non linear load circuit

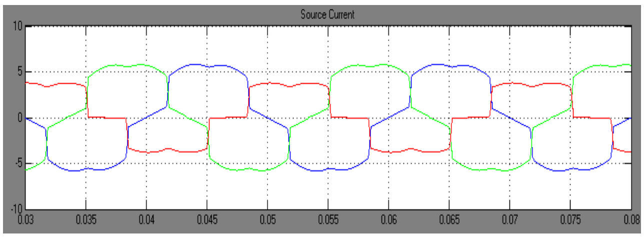

Figure 6.9 Source side current waveform of Non linear load circuit

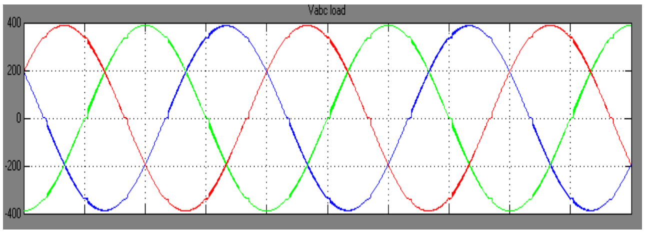

Figure 6.10 Load side voltage waveform of Non linear load circuit

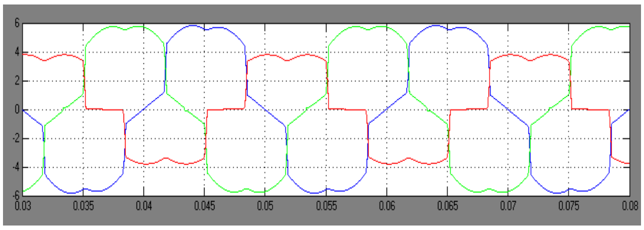

Figure 6.11 Load side current waveform of non-linear load circuit

6.2.1 FFT analysis of current waveform of Non linear load circuit:-

It is the Fast Fourier Transform analysis of the current waveform of Non Linear load which give the total harmonics distortion of current 18.50 % it means there is harmonics presents. when we use Non linear load. It is also shown in figure 6.9 that current is distorted.

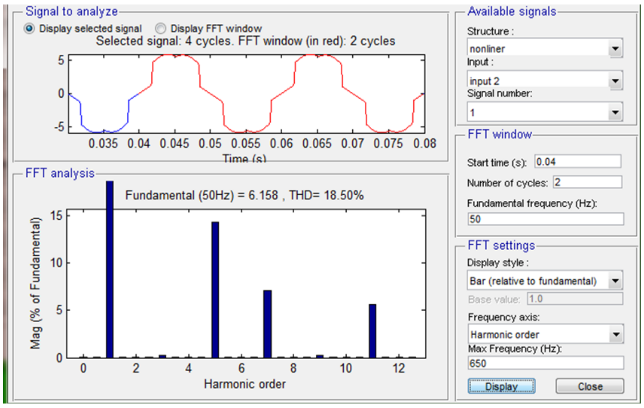

Figure 6.12 FFT analysis of current waveform of non liner load circuit

TABLE 6.1 Comparisons of All Three Cases:-

Comparison	Case-1 (Linear Load)	Case-2 (Non- Linear Load)	Case-3 (Non Linear load with Shunt active Filter)
Ohm's Law	Applicable	Not Applicable	Not Applicable
Crest Factor	1.41	Could be 3 to 4	Could be 3 to 4
Source Side Current Waveform Shape	Pure Sinusoidal	Distorted	Sinusoidal
Total Harmonics Distortion	0%	18.50%	0.68%
Load Type	Capacitive and Inductive load	Power Electronics Devices(Diode and Thyristor etc)	Non-Liner load With Active power Filter with Fuzzy Logic controller

CONCLUSION

1. This thesis presents the harmonics of power system. Inverter circuit and shunt active power filter.

2. In this thesis we explained the application of the fuzzy logic controller to control the compensating voltage.

3. Fuzzy logic Controller for the three-phase circuit is pretend and the THD calculated verify the lessening of harmonics base shunt active filter.

4. We use the MATLAB/Simulink software to suggest the shunt active power filter base model.

5. The SAPF is capable to recompense unbalanced nonlinear load currents of a three-phase system.

6. We evaluate three case of MATLAB/Simulink model and results of THD of different cases.

7. Though various optimization techniques are present, research is being done for the best eliminated results of THD.

8. In this thesis proposes a technique to reduce the converter losses in the shunt active power filter.

FUTURE SCOPE

Practical analysis can be done on shunt active power filter by designing a model in the laboratory to demonstrate the simulation outcome for balanced and unbalanced non-linear loads under indistinct source voltage situation with fuzzy-Nero controller. The future shunt active power filter can pay compensation on insist the harmonic current as well as the THD.

REFERENCES

[1] A.Priyadharshini, N.Devarajan, AR.Uma saranya, R.Anitt , "Survey of Harmonics in Non Linear Loads" , International Journal of Recent Technology and Engineering (IJRTE), pp. 2277-3878, April 2012.

[2] George Adam, Alina Georgiana Stan (Baciu), Gheorghe Livinţ , "An Adaptive Hysteresis Band Current Control For Three Phase Shunt Active Power Filter Using Fuzzy Logic" ,IEEE EPE , pp.324-329 ,25-27 October,2012.

[3] Hideaki Fujitaand Hirofumi Akagi, "The Unified Power Quality Conditioner: The Integration of Series- and Shunt-Active Filters," IEEE Transaction on Power Electronics, vol.13, pp .315-322, 1998.

[4] Konstantin Borisov, Herbert L. Ginn III and Andrzej M. Trzynadlowski, “Attenuation of Electromagnetic Interference in a Shunt Active Power Filter”, IEEE TRANSACTIONS ON POWER ELECTRONICS,VOL. 22, NO 5, pp.1912-1918, SEPTEMBER 2007.

[5] Victor Ciirdenas, Luis Moriin, Arturo Bahamonded, Juan Dion, “Comparative Analysis of Real Time Reference Generation Techniques for Four-Wire Shunt Active Power Filters,” IEEE, pp.791-796, 2003.

[6] TingQian, Brad Lehman, Anindita Bhattacharya, Herb Ginn, Marshall Molen, “Parallel Operation of Shunt Active Power Filters for Damping of Harmonic Propagation in Electric Shipboard Power Systems”, IEEE Electric Ship Technologies Symposium, pp. 248-254, 2005.

[7] A. Koochaki ,S.H. Fathi, and M.Divandari, “Single Phase Application of Space Vector Pulse Width Modulation for Shunt Active Power Filter,” IEEE, pp. 611-616, 2007.

[8] WanchakLenwari and MilijanaOdavic, “A Comparative Study of Two High Performance Current Control Techniques for Three-Phase Shunt Active Power Filters,” PEDS, pp.962-966, 2009.

[9] Antonio Abellan, Gabriel Garcera, Jose M. Benavent, “ A New Control Method for Obtaining Reference Currents of Shunt Active Power Filters in Unbalanced and Non Sinusoidal Conditions,” IEEE ISIE’99 - Bled, Slovenia,pp.831-836,1999.

[10] S. J. CHIANG and J. M. CHANG National Lien Ho Institute of Technology Taiwan, “Parallel Operation of Shunt Active Power Filters with Capacity Limitation Control” ,IEEE TRANSACTIONS ON AEROSPACE AND ELECTRONIC SYSTEMS,VOL. 37, NO. 4, pp.1312-1320, 2001.

[11] Wang Jianze, PengFenghua, Wu Qitao, JiYanchao, Member, and Yaping Du, “ A Novel Control Method for Shunt Active Power Filters Using SVPW”, IAS,IEEE, pp.129-134, 2004.

[12] Hongyu Li, Fang Zhuo, LonghuiWu,Wanjun Lei, Jinjun Liu, Zhaoan Wang, “ A Novel Current Detection Algorithm for Shunt Active Power Filters in Harmonic Elimination, Reactive Power Compensation and Three-phase Balancing”, IEEE Power Electronics Specinlisrs Conference ,pp.1017-1023,2004.

[13] AbdelazizZouidi , FarhatFnaiechand Kamal AL-Haddad, “Voltage source Inverter Based three-phase shunt active Power Filter Topology, Modeling and Control Strategies”, IEEE ISIE , Montreal, Quebec, Canada, PP.785-790,2006.

[14] E. C. dos Santos Jr., C. B. Jacobina, A. M. Maciel , “ Parallel Connection of Two Shunt Active Power Filters with Losses Optimization” IEEE Trans. Power Electr , pp.1191 – 1196 , 2010.

[15] P. García-González, A. García-Cerrada and O. Pinzón-Ardila, “Control of a shunt active power filter based on a three-leg four-wire electronic converte,”, Compatibility and PowerEelectronics , pp.292-297, 2009.

[16] Parimala V1, Ganeshkumar D2, Benazir Hajira A3, “Harmonic Reduction Using Shunt Active Power Filter With Pi Controller”, International Journal of Scientific Engineering and Research , Volume 2 Issue 4, pp. 85- 90, April 2014.

[17] A. Dell’Aquila, G. Delvino, M. Liserre, P. Zanchetta, A new fuzzy logic strategy for active power filter, in: Proc. Eighth Int. Conf. on Power Electronics and Variable Speed Drives, pp. 392–397 (IEEConf. Publ. No. 475), September 2000.

[18] S. Fan, Y.Wang, Fuzzy model predictive control for active power filter, in:Proc. IEEE Int. Conf. on Electric Utility Deregulation, Restructuring and Power Technologies (DRPT 2004), vol. 1, pp. 295–300, April 2004.

[19] S.K. Jain, P. Agrawal, H.O. Gupta, Fuzzy logic controlled shunt active power filter for power quality improvement, IEE Proc. Electr. Power Appl.149, pp. 317–328 , September (2002).

[20] D. Chen, S. Xie, Review of the control strategies applied to active power filters, in: Proc. IEEE Int. Conf. on Electric Utility Deregulation, Restructuring and Power Technologies (DRPT-2004), Hong Kong, , pp. 666–670 April, 2004.