Power Quality Improvement using DQ0 Shunt Active Power Filter

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Abstract - Using SAPFS Power Quality difficulties can be taken up. A simulation model of the three-phase shunt active filter has been implemented on the basis of mathematical modeling of the system where we can detect considerable improvement insource current in the forms of Total Harmonic distortion (THD) of source current. We can also notice the corrected power factor (PFC).It corrects the problems of harmonic current in power system and also reimburse reactive power and balances load on three phase (if load is unbalanced).Its measures load current, and then transforms this to DQ0 coordinate system. Preliminary the position of d axis has chosen in such a way that active part of current is given by d axis. Oscillating part of d and q axis both component of the load current should be inserted to eliminate harmonics.Non-oscillating part of q axis component must be inserted to compensation of reactive power. Zero sequence components should be inserted to balancing the loads. In this way, current that should be inserted has been calculated in DQ0 coordinate system. It is being converted in to abc coordinate system. This is the reference compensating current.Using of hysteresis band current control method the compensating current is injecting to the network though thethree phase inverter. In this Method, harmonic and reactive component of load isbeing supplied by this shunt active power filter.This thesis discuss and implement the same concept by using DQ0 theory and find its Total Harmonics Distortion. So the work is novel and finds its improvement while comparing it with PQ approach

Keywords -Shunt active power filter (SAPFs), Hysteresis current controller (HCC), Proportional integral (PI) and Total harmonic distortion (THD). Single Phase, Three Phase, Switching, High Voltage, Simulation Model.

I. INTRODUCTION

1.1 Introduction

As most of loads are non linear which causes harmonics in distribution structure creates power quality problems for power engineers.The use of power electronic devices at the user end for reactive power compensation and for different purpose isvery frequent due to advancement in semiconductor technology. This is a major source for generation of harmonics. Now a days generation of harmonics is serious concern because it is related to the power quality.

Power quality has given major attention. The reason is that the intensive use of nonlinear loads, ex. Power electronic controlled application. The use of nonlinear loads increasing rapidly because it consumes less power and give some other benefits. Although these power electronic equipment's make our life easy, they inject harmonics into power system which leads to bad power quality.

There are two methods for the extenuation of power quality problems. The first is done by load conditioning, which ensures that load is resistant of harmonics. Equipment’s made less sensitive towards harmonics and power disturbance, but it is impossible practically. The one solution is power line conditioning. In this theline conditioning system is installed at point of common couplingwhichsuppresses or neutralize theadverse effect produced by nonlinear harmonic producing loads.

1.2 Waveform Distortion

Waveform distortion is defined as a steady-state deviation from an ideal sinusoidal wave of power frequency primarily it is characterized by the spectral content of the deviation. The several types of wave form distortion are given below.

1.2.1 DC Offset

The presence of a dc voltage or current in an ac power system is known as dc offset.

1.2.2 Harmonics

Harmonics are sinusoidal voltages or currents having frequencies that are integral multiple of the frequency at which the supply system has designed to operate. The harmonic distortion initiates in the nonlinear characteristics of devices and also on loads which connected to the power system

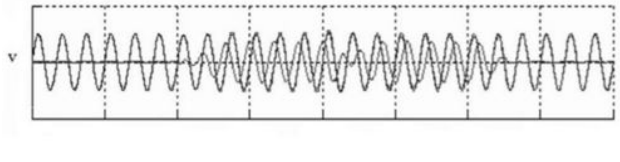

Figure 1.1: Harmonic Distortion

Harmonic distortion levels determined by computing total harmonic distortion which determines the entire harmonic spectrum with magnitudes and phase angles of each harmonics component. THD is represented as the square-root of the sum of the squares of each harmonic. [2].

1.3 Short Duration Voltage Variations

Depending on the system conditions and the location of fault location, the fault can create either temporary voltage drops (sags), voltage rises (swells), or a loss of voltage (interruptions). The duration of voltage variation is less than 1 minute termed as short voltage variation. These variations are due to fault conditions, the energization of large loads which requires high starting currents, or discontinuity loose connections in power wiring.

1.4 Long –Duration Voltage Variations

Long-duration variations can be classified as over voltages, under voltages or sustained interruptions any of above is possible.

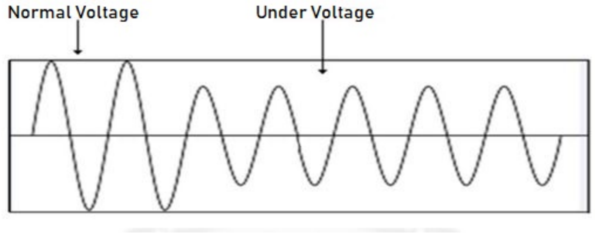

Figure 1.2 : Under Voltage

1.5 Solution for Harmonic Suppression

The presence of non-linear loads such as industrial and office equipment, domestic devices, power inverters etc. generates harmonic rich currents which also spread into the electrical grid system. This current harmonics in the transformers and grid results in voltage harmonics in the feeder connected to that grid. It is known that the conductor impedance increases with the high frequencies of the harmonics currents pass through it and different impedance appear for each range of current harmonics. The harmonic current of range will be created through the impedance harmonic voltage in that circuit. All the loads connected to the same point will be fed with the equal disturbed voltage.

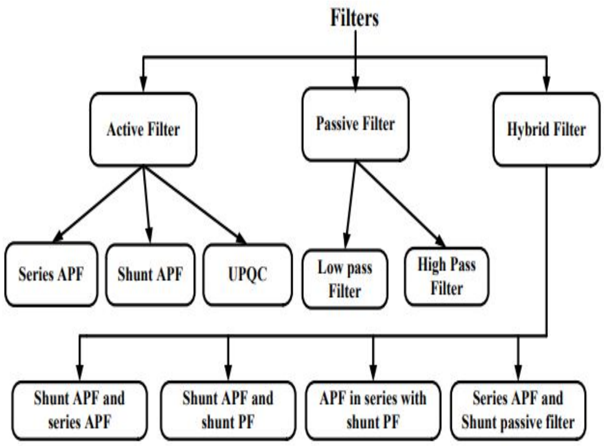

Figure 1.3: Classification of filter

2.1Literature Review

The present day systems are powered by non-ideal sources whose output impedance cannot be neglected, besides most of the loads are non-linear in nature. These non-ideal and non-linear characteristics contribute to waveform distortion in driving systems. The analysis of harmonic components present is an inevitable part of the study, to meet out the Standard requirements of system. Numerical techniques offering a good representation of the non-characteristic waveform distortion is generated. Methods do not provide an analytical insight required to the optimal design; besides frequency dependencies cannot be accurately modeled. An alternative method for the calculating the harmonic currents present of a power systems uses the Fourier series analysis and the switching function. With the frequency domain model, the closed loop frequency responses has been established, which will facilitate the analysis of the system stability and designed optimization. Also the frequency domain modeling is more significant for power electronic circuits, which offers a good and faster response.

II. LITERATURE REVIEW

Facilitate the analysis of the system stability and designed optimization

Balaga UdayaSri et. al. [1], "Improvement of power Quality Power Quality using PQ shunt active power filters"difficulties can be overcome using SAPFS. A simulation model of the three-phase shunt active filter has been implemented on the basis of the mathematical modeling of the system where we can note the considerable improvements in the source current in the norms of Total Harmonic distortion of the source current. We can also note the correction in the power factor by doing this.

Camila Barreto Fernandes et al. [2], "Power Management Strategy based upon the PQ- Theory applied to a Cascaded Modular Converter to Fuel Cell Vehicle Application" They Discuss the new power management strategy based on PQ-Theory for fuel cell and electric vehicle applications. Using the modular cascaded converter topology, more thanOne power source could be combined with the capacitors for supply active and reactive power in an efficient manner to the electric motors. The control approach to separate mean and oscillating active power and reactive power and the capacitors voltage regulation control, are described. Simulation results are shown for validate the control approach.

Yoash Levron et al. [3], "Observable Canonical Forms of Multi-Machine Power Systems by the use of DQ0 Signals" Discuss a dynamic model of large symmetric power networks which is presented in ***s***-domain and uses the DQ0 reference frame. The model is constructed to symmetric networks based on the network admittance matrix, and including the analytic expressions to the proper transfer functions. Further, on the basis of developed model we derive the observable state space realizations, which may contribute towards stability analysis of large multi-machine power system

Gibson H.M.Sianipar et al. [4], "Transient Short circuit current Calculation by the use of Reduced and decoupled DQ0 network"Discuss the new method for calculating transient short circuit current in the large multi machine power system that is numerically very efficient accurate and stable the proposed methodology is based upon network reduction that find the minimally equivalent network retaining buses where the machines and the fault are located on which the simulation is being carried out with the much reduced network the computation speedup is huge.

Subham Sahooet al. [5], "Dynamic Performance of the DQ0-frame Deadbeat Controller for VSC based HVDC System"Discuss the DQ0-frame deadbeat (DB) controller which is used in a voltage source converter (VSC) based on high voltage direct current (HVDC) system to incorporate the robust controller behavior during sudden transient disturbances in grid. Furthermore, stability analysis along with controller response for tracking objectives and parameter uncertainties has been discussed. Finally, a comparative analysis with the proportional-integral (PI) controller.

Hao Yu et al. [6], this study introduces the power quality state space representation for describing continuous Power Quality issues. A tolerance boundary has designed to characterize the integrated disturbances tolerance of all equipment connected to electric power network and uncertainty of the integrated disturbance tolerance is described withthe cloud model. Electromagnetic compatibility and incompatibility degree indices are proposed to reflect severity of the Power Quality disturbances affecting equipments. The influence degree index has defined to quantify the severity and impact scope of Power Quality (PQ) disturbances.

Anurag H. Ukande et al. [7], "Generalize PQ Theory with SPWM to Single Phase Shunt Active Sower Filter Applications" the current control method has used for reference signal generation for the voltage base Pulse Width Modulation that is SPWM. Voltage source inverter (VSI) by the help of generalized PQ theory is implemented to shunt active Power filter applications. Two methods are used for generate the compensated current. Current is further converted into voltage just as reference signal and it is fed to the inverter's sinusoidal pulse width modulation technique. This inverter is generating the injected current by all possible modification to the conventional single phase shunt active Power filter.

Ali Chebabhi et al. [8],a 3- level NPC four leg inverter has used as a shunt active Power filter andThree level 3- D Space Vector Modulation technique in the αβ0 axes to Generate the Switching signal of this Shunt Active Filter to power quality (PQ) improvements under balanced and unbalanced loads has proposed. In order to improving the fix switching frequency, output forms ofthe voltage, lower switching losses, minimizing the harmonics of source current, reducing magnitude of neutral current, eliminating the zero-sequence currents, and to compensating reactive power to the four–wire distribution network, and for a good dynamic the synchronous reference frame (SRF) theory to the DQ0-axes for generating and extracting the reference currents which should be injected by Three level four leg inverter is presented.

P. Miranda et al. [9], "A new full PQ control of the wind turbine trapezoidal emf permanent magnet synchronous generator (PMSG)" a complete new control strategy of the grid connected permanent magnet synchronous generator for the wind turbines based upon the Instantaneous Power Theory has proposed. Given the permanent magnet synchronous generator trapezoidal electromotive force to the proposed Power Quality control is advantageous over those based upon the Park transformation because it reduces the electromagnetic torque ripples and removes calculation of sinusoidal functions.

Rajeswari R et al. [10], "Analysis of DQ0 Based Fuzzy Logic Controller in DVR for the Voltage Sag and Harmonic Mitigation" They found that Voltage sag and harmonics are major reason that affects the power quality thereby causes the severe damage to customer equipment's. These power quality issues can be mitigated effectively using DVR. This is proposed two control approaches first Proportional Integral controller and other is Fuzzy Logic Controller with DQ0 transformation for DVR.

III.PROBLEM FORMULATION AND OBJECTIVES

3.1 Problem Formulation

From literature review, it has been observed that the wide range of scheme which is based on different types of technique has developed till date but their application has restricted to a few reduce the overall reliability, increases total harmonic distortion and efficiency of power system. The performance of currently available Shunt Active Power Factor scheme is increasing reliability, efficiency, and decreasing the Total harmonic distortion of the system.

3.2 Objectives

In order to overcome this shortage of passive filter, new technical alternatives are available for improve power quality. Among these, APF have proved to be the significant and lithe alternative to compensating harmonics in power systems. This filter does not resonate with the power system and they work independently with respect to system impedance characteristics.

The work upon Shunt Active Power Filters with the following main objectives.

- ➢ To Study about the issues in the power system and types of filter for using to reduce the harmonics
- ➢ To create a MATLAB SIMULINK model DQ0 theory which is based on the shunt active power filters.
- ➢ To Design the MATLAB SIMULINK model with Voltage source inverter
- ➢ To improve the Total Harmonic Distortion of power System with using DQ0 Theory

Objective of the thesis was to study power conditioning capabilities of Shunt Active Filter. Synchronous Reference Frame control strategy executed and studied for harmonic cancellation, for reducing the THD of source current, load balancing and power factor improvement.

IV- METHODOLOGY

The model has developed in a MALAB / SIMULINK environment. It is a high-level matrix / matrix language with instructions, functions, data structures, input / output functions and the object-oriented programming function. It hasfollowing main features:

- High level language for the scientific and technical computer science
- Desktop environment optimized to exploring, designing and solving iterative problems
- Graphs for displaying data and tools to create custom graphics
- Curve adjustment, data classification, signal analysis, control system setting and many more tasks
- Complementary toolboxes for use of various technical and scientific applications
- Tools for creating custom applications for the user interface
- Provisioning options to sharing MATLAB programs with end users.

4.2 Modeling DQ0 Based Shunt Active Power Filter

In the electrical engineering *d-q* transformation is a mathematical based transformation used for simplifying the analysis of 3-phase circuits. For balanced three-phase circuits application of the DQ0 transform reduces three AC quantities in to two DC quantities obviously in the terms of current. Simplified calculation can further be carried out on these imaginary DC quantities before performing the inverse transform for recover the actual 3-phase AC results.

Over again it is often used in order to simplifying the analysis of 3-phase synchronous machines or to simplifying calculations to the control for three-phase inverters. Formula for ABC to DQ transformation [4].

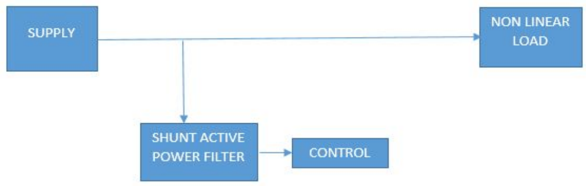

Figure 4.1: Flow diagram of shunt active power based system

It solves the problems to the harmonic current present in power system. It also compensates reactive power and balances the load present on three phase (if load is unbalanced). It uses Clarke transformations for calculation value of 0, *d* and *q* axis filters out of constant part of d and thus finding the compensating part of 0, *d* and *q* axis. Then, it calculates compensating current with the help of inverse-Clarke transformation. The compensating current is being injected to the network via 3- phase inverter with using hysteresis band current control (HBCC) method. In this way, harmonic and reactive component to the load is supplied by this shunt active power filter. Also, compensating zero means balancing load present on three phase.

4.2.1 DQ0 Reference Theory

Reference frame transformations refer to the transformation from a-b-c in to *d-q*-0 axes. Coordinates from a three-phase a-b-c stationery coordinate system in to the *d-q*-0 rotating coordinate system as shown in Fig.4.2 below Here first transformation is from a-b-c in to alpha-beta co-ordinates and then further in to *d-q*-0 coordinates. Two different transformation matrix need to be required for Clarks Transformation and parks transformation. [4].

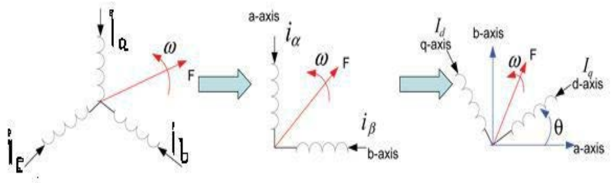

Figure 4.2: Reference Frame Transformations

V. SIMULATION AND RESULTS

5.1 Comparison for Total Harmonic Distortion

The proposed DQ0 based Shunt Active Power Filter technique has Improve the Total Harmonic Distortion 2.18% from 3.76%. The proposed DQ0 based SAPF technique is

Improves the Total Harmonic Distortion 41.61% from the previous algorithm.

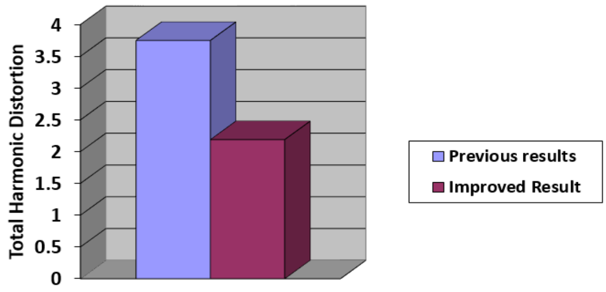

Figure 5.1: Comparison between previous and proposed work

5.2 Result for Source Voltage

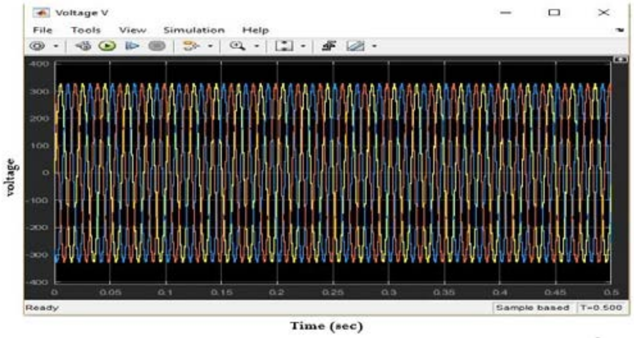

Figure 5.2: Output waveform of Source Voltage

Voltage is range of the output voltage of the continuous current power supply. Over which the load being regulation is within certain limits. The source adjusts the output voltage so that provide the desired amount of current to the load side.

5.3 Result for Source Voltage

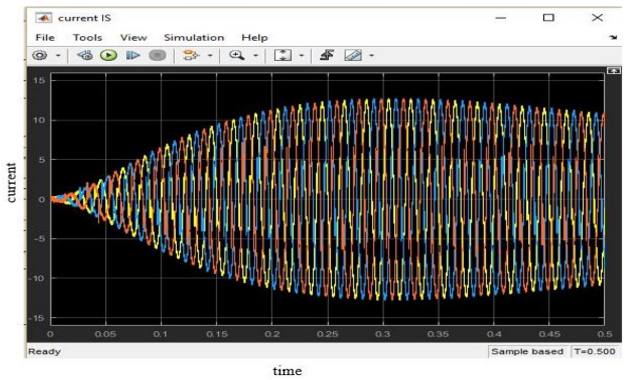

Figure 5.3: Output waveform of Source current

A current source is the electronic circuit that absorbs or delivers an electric current which is independent to the voltage across the load. A current source is dual of a voltage source. The term current sink is sometimes used for the sources that fed from the negative voltage supply of system.

5.4 Result for Capacitor Current

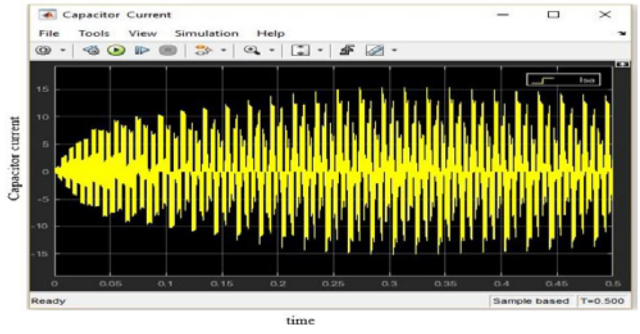

Figure 5.4: Output waveform of Capacitor current

Flow of the charges in to capacitor plates such that the inside and outside of the membrane is being referred to as the current flow through capacitor. If the rate of change of the voltage is zero then the capacitive current is zero and only the ionic current flows.

5.5 Result for Capacitor Voltage

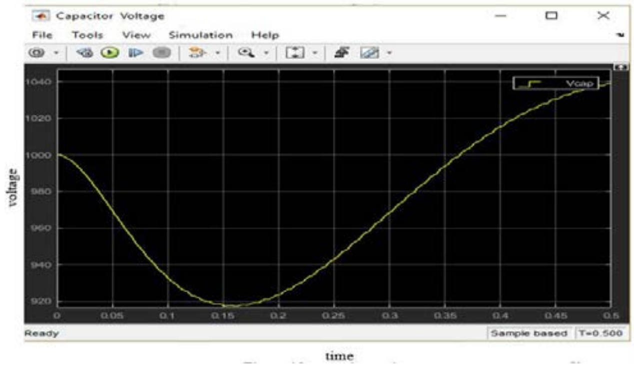

Figure 5.5: Output waveform of Capacitor Voltage (C_V)

The voltage rating to a capacitor is maximum extent of voltage that the capacitor can safely be exposed to and can store. Because you may need different voltages to a circuit depending upon what circuit you are dealing with. Remember that the capacitors supply voltage to the circuit just like a battery .

5.6 Result for Zero Axis Current

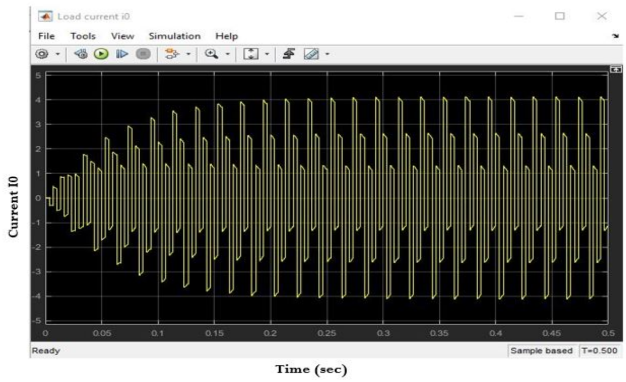

Figure 5.6: Output waveform of current I_0

A zero-axis current estimator is which helps increase the control approach. This zero-axis current estimator is which consists of an all pass filter design to peak values of zero-axis signal, and calculation to angles of zero-axis. This method separates the zero-axis signal into the dc signal. The control parameter of this system is very simple to design.

5.7 Result for Direct Axis Current

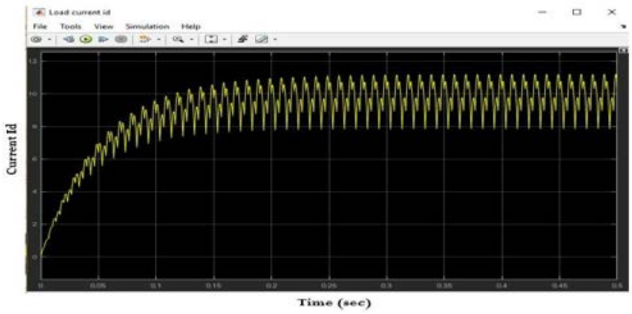

Figure 5.7: Output waveform of current I_d

The axis of field winding in the direction to the DC field is called the rotor d-axis or direct axis. 90 degrees later to the direct-axis is the *q*- axis.A stator current into the magnetic field-generating part for control stator current in such a way that generates the *d*-axis current into the machine has desired.

5.8 Result for Quardrature Axis Current

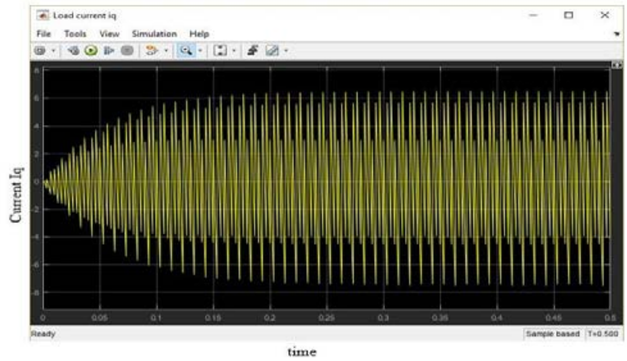

Figure 5.8: Output waveform of current I_q

It is revealed that gain of the transfer function from feedback component of voltage phase angle to actual *q*-axis current is increased to the high frequency region which is close to the resonant frequency. It is discovered that the ratio of *d*-axis and the *q*-axis stator windings linkage flux should be considered to the stable operation because it affects *q*-axis current control performance.

5.9 Results for Neutral Current

As neutral point of the electrical supply system is often connected to the earth ground and neutral current are very precisely related. Under the certain conditions, a conductor used for connect to a system neutral is also used for grounding to structures and equipment.

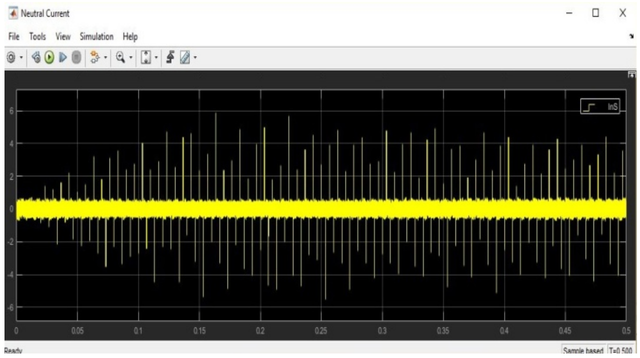

Figure 5.9: Output waveform of neutral current

5.10 Result for Load Current

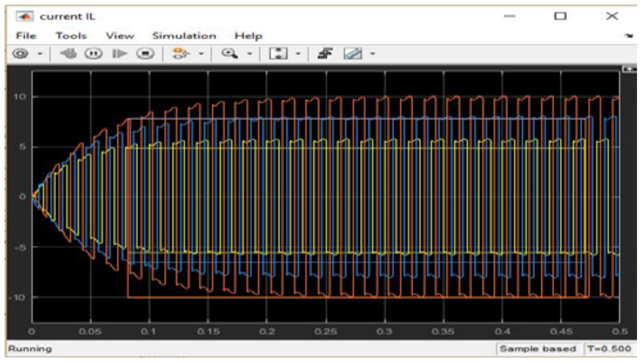

Figure 5.10: Output waveform of load current

Load current in this context is purely current flow though the wire. As you say, a load consumes power and that power is delivered electrically, which means it is product ofcurrent and voltage.

VI. CONCLUSION & FUTURE SCOPE

6.1 Conclusions

The main objective of work was for investigate the power conditioning capabilities to the Hybrid Active Filter and Shunt Active Filter. Synchronous Reference Frame control approach has been executed and investigated to the harmonic cancellation, for reducing the Total Harmonic Distortion of the source current, reactive power compensation, load balancing and the power factor improvements. To achieve these objectives DC capacitor voltage to the inverter has been controlled with several Artificial Intelligence Techniques keeping the fixed reactive power compensation. The Active Filter has implemented with the hysteresis band and current controller because of the easiness of implementation. Also beyond the fast reaction current loop, the methods do not need any knowledge of the load parameters. The performance of Shunt Active Power Filter has evaluated through MATLAB / SIMULINK environment by Sim power Systems toolbox.

The proposed DQ0 based SAPF technique decreases THD by 2.18% for three levels fromthe 3.76% to PQ based SAPF technique. The proposed DQ0 based SAPF technique is 41.61% THD improvement to previous algorithm.

6.2 Future Scope

The thesis presented here concern to the development for the several techniques and their validation to different conditions to the enhancement of power quality by using Active Filters. This research work has been extended to a Series Active Power Filters to power Quality Improvement. Three phase three wire system can be extended for three phase four wire system with having different conditions like considering to the zero sequence voltage existent in system. FPGA based controller to Active Power Filters can be developed for reducing the hardware requirements of the system. For sustainable growth in the power system, recently Renewable and the Non-Renewable Energy source are gaining a lot of attention. Hence such energy sources feeding to the nonlinear loads can be investigated to further work in the field for power quality improvement.

Further enhancing coordinated control of the proposed Distributed Active Power Filters incorporates the design of adaptive gains can also be implemented. Another attractive aspect that can be investigated has the finding the explanations for power quality problems by the other emerging Evolutionary algorithm like the Anti Colony Optimization and bacteria forging technique. Thus, the power quality of networks can be expressively enhanced, and the high reliability can be provided.

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