IMPACT OF POWER ELECTRONIC LOADS IN A GRID CONNECTED HYBRID POWER SYSTEM

PROJECT REPORT

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE OF

BACHELOR OF TECHNOLOGY

(Electrical & Electronics Engineering)

OF

MAHATMA GANDHI UNIVERSITY

SUBMITTED BY

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CERTIFICATE

This is to certify that the project report entitled ***Impact of Power Electronic Loads in a Grid Connected Hybrid Power System is*** *an authentic report of the project work carried out by* ***A J Francis Vijith, Anandhu Appukuttan, Asif Muhammed, Kiran Kumar B*** *in partial fulfillment of the requirement for the award of the degree of Bachelor of Technology in* ***Electrical and Electronics Engineering*** *by the Mahatma Gandhi University.*

Mr. Bobin K Mathew	Mr. Shinosh Mathew/ Mr. Anumod D M
Assistant Professor	Assistant Professors
Dept. of EEE	Dept. of EEE
(Guide)	**(Project Coordinators)**

Dr. P. C. Thomas
Head of the Department
Electrical and Electronics Engg.

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We are thankful to and fortunate enough to obtain constant encouragement, support and guidance from all the faculty members of the department who helped us in the successful completion of our project work. We would also like to extend our sincere regards to all the technical staff of the Department for their timely support.

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Mr. Kiran Kumar B.

Abstract

Now a days the major power systems are hybrid in nature. The hybrid configuration have better advantages than non hybrid configurations like greater reliability, reduced pollution and flexibility. The electrical power system of Amal Jyothi College of Engineering (AJCE) is a hybrid system. The AJCE power system consists of power sources such as KSEB, Diesel generators and solar PV which makes it a hybrid one. The hybrid power systems have enormous advantages like improved reliability, reduced production cost, etc. Practical Hybrid systems are beset with power quality issues. Increased use of power electronics in power systems is the major cause of this power quality issues. The problem is shared by the AJCE power system. UPS forms a major load in the AJCE system. In this project work, the main aim is to study the effects of power electronic loads in the AJCE power system. The objective steers towards the problem identification and its solution. For that, the connected loads are listed out using the single line diagram and the extra loads accounted by performing load survey. The connected loads from the each VDB (vertical distribution board) and each phase to the blocks are to be checked and any unbalance in the loads is summarized. A study regarding the behaviour of UPS with various loads, generation combinations and also perform its power quality measurements using power quality analyzer.

Key Words : Power system, Harmonics, Phase imbalance, THD

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Abbreviations

PE	Power Electronic
AHF	Active Harmonic Filter
GEC	Government Engineering College
PDU	Power Distribution Unit
PLL	Programmable Logic Loop
RMS	Root Mean Square
THD	Total Harmonic Distortion
UPS	Uninterruptible Power Source
IGBT	Insulated Gate Bipolar Transistor
SAPF	Shunt Active Power Filter

Chapter 1

Introduction

1.1 General Background

This report is based upon a case study conducted to investigate the impacts of power electronic loads, mainly UPS loads which are used to supply power for the computer system loads of divisional block A in Amaljyothi College of Engineering, Kanjirapally. A UPS acts as an auxiliary power source for computer loads.The power system of the campus comprises of grid connection, generator supply and PV panel system making it a hybrid power system. Details are listed in fig 1.1.

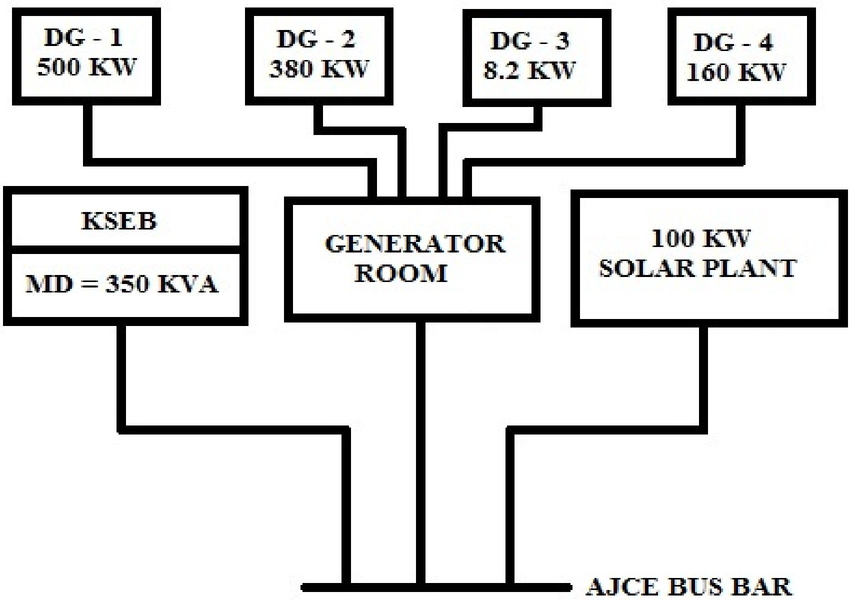

Figure 1.1 Hybrid Power System

Divisional block A comprises of two departments i.e. information technology department and computer science department. Thus the loads mainly come under the group of UPS loads to supply power during power cuts. During the power loss from the grid, a diesel generator is installed to support the loads in progress. As there is a infinitesimal delay between the instant of the grid power cut and the starting of the diesel generator, the computer loads may become affected. So to reduce this effect, the computer systems are connected via UPS. As these UPS loads comprises of power electronic components and FACT devices, it will produce a considerable effect in the power system in form of harmonics and phase imbalance. The analysis of these loads are discussed in this report. Usually, a power system comprising of UPS produces different types of problems. It may affect other devices connected to the power system. So, a method to analyse and detect the problems are essential in an educational institution like AJCE. In this report, major problems faced by the power system with UPS loads and its impact on it are presented.

The bulk use of power electronic devices such as an UPS in an educational institute like produces sources of harmonic distortion, phase imbalance and exceeding standard limits. The main sources of harmonics are computers, uninterruptible power supply, power converters and solid-state drives. The inefficiency in the connection of loads to the three phase supply also produce adverse effects on the power system. It can cause severe phase imbalance and high neutral current. Several measures are put forth in this report for the mitigation of the effects of above said UPS loads on the power system.

1.2 Objectives

(i)To study the impacts of Power Electronic Loads in a grid connected hybrid power system.
(ii)To identify the major issues in the system and suggest the remedial action for them.

1.3 Layout of Report

Chapter 1 emphasizes the relevance of the project and its details. Chapter 2 provides a brief description about the past studies executed in same field. Chapter 3 deals with the description of the method adopted for the completion of the study. Chapter 4 gives the details about the measurements and analysis of the work done. Chapter 5 explains the working of a shunt active power filter for mitigating the effects of harmonics. Chapter 6 concludes the report.

Chapter 2

Literature Survey

2.1 Introduction

The past study about the power quality analysis about an educational power system has brought many conclusions especially for power electronic loads like UPS systems. The literature work is mainly focussed on the harmonics mitigation and phase imbalance of UPS loads.

2.2 Harmonics mitigation

Harmonic analysis at GEC(Government Engineering College, Thrissur) discusses the harmonics found in the power system due to the UPS systems and its mitigation by using an active power filter. Power quality measurements are done using a power quality analyzer. The power quality analyzer used in this thesis work is FLUKE 435 series II power quality and energy analyzer. It is capable of detecting the presence of voltage and current harmonics and measuring their characteristics. Fig 2.1 gives a MATLAB simulink model of an active power filter[2].

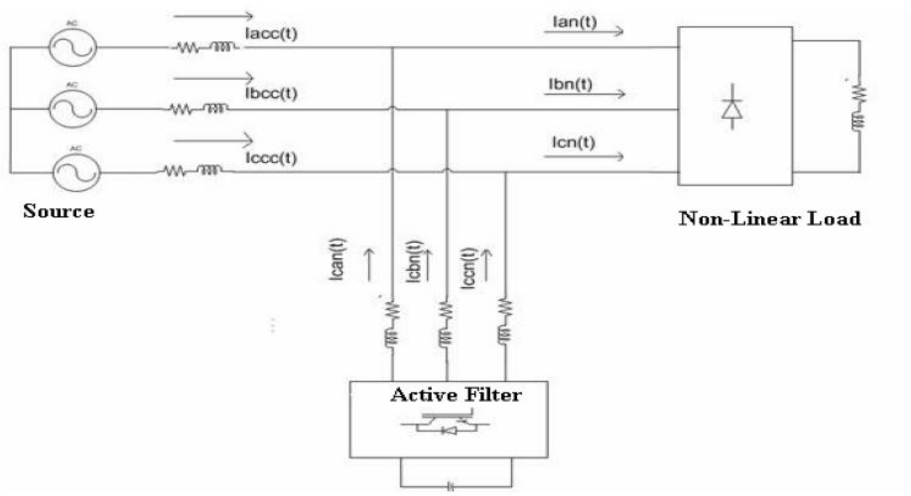

Figure 2.1 Active Power Filter[2]

For designing an active power filter, synchronous detection method is used here. Compensating currents are calculated using this method while the three phase source is feeding a highly non-linear load. The equal current distribution method of synchronous detection theory is used here to calculate the three phase compensating currents to be provided by the active filter. Synchronous detection theory can work effectively under balanced as well as unbalanced source and load conditions because the compensating currents are calculated taking into account the magnitudes of per phase voltages[2].

UPS load of capacity 5 KVA is simulated as the load. At the time of measurement the UPS is 70% loaded. The measured load current THD is 71%. Fig 2.2 and Fig 2.3 show the voltage and current waveforms when an unbalanced load is compensated with an active power filter. The analysis of results shows that due to the filter the harmonics are reduced to the extent that the THD has decreased to 5% even if there is a phase imbalance[2].

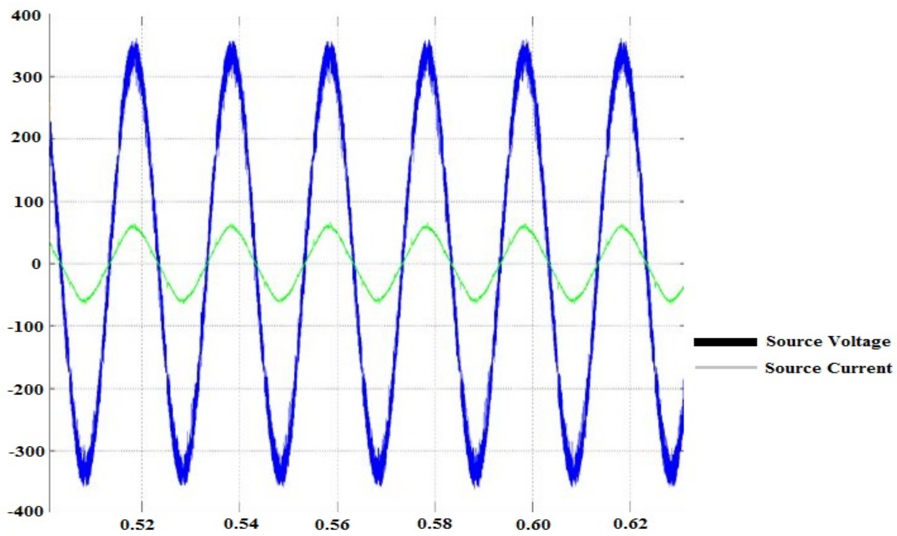

Figure 2.2 Source Current and Source Voltage[2]

In this section harmonic analysis are taken for nonlinear loads in GEC campus and it is found that these loads have distorted the voltage and current to a great extent. The total harmonic distortion exceeds the standard limit of voltage and current THD. Voltage THD limit is 5% and current THD limit is 20%[6]. A shunt active filter is designed by the Synchronous detection method using equal current division technique to compensate for reactive and harmonic currents under unbalanced load conditions[2].

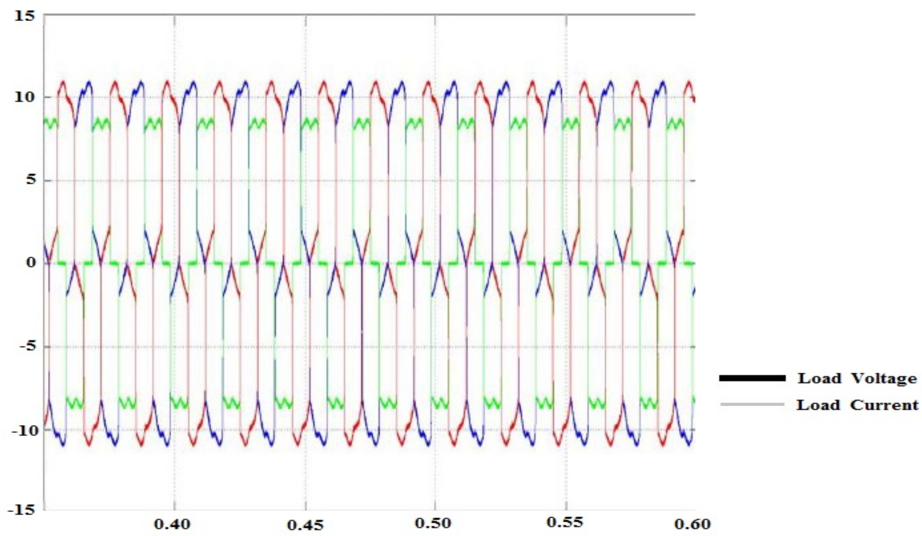

Figure 2.3 Load Current and Load Voltage[2]

2.3 Phase Imbalance

This section deals with the neutral harmonic currents based problems in an electrical distribution system of a 6 floored building. There are several offices in this building one of which is a bank. For this reason almost all the loads in this building are harmonic sources. The power demand is supplied by a 34.5/0.4 kV 630 kVA Delta/Star (grounded) connected power transformer. No measures are taken for mitigating harmonics. Harmonic and neutral current measurements were taken in the electrical distribution system. Fig 2.4 represents the single line diagram of the office building[3].

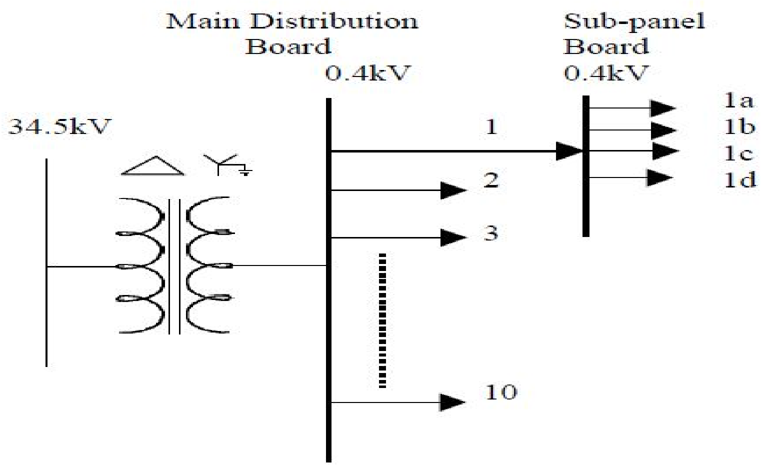

Figure 2.4 Single Line Diagram[3]

The incoming feeder supplies power to a delta-star transformer. The secondary winding of the transformer is connected to the main distribution board. A sub panel board is connected supplying power to the entrance floor of the bank. Neutral current and harmonics are measured for the analysis of harmonic based power losses, overloading and power quality. A high amount of neutral current was identified and it was concluded that the neutral conductor size must be increased for the given power system[3].

From the measurements it was concluded that the neutral conductor carried high current and third harmonics in the system. A filter must be used for the triplen harmonics on the neutral line to reduce the neutral-ground voltage, overloading of neutral line and power losses on neutral line. One proposed method of dealing with the potentially high neutral currents involves using full-sized neutral wiring and monitoring the neutral current[3]. All neutral components, including neutral terminals, and neutral bus bars, should be sized for the additional neutral current. Excessive imbalance in a three phase load has various undesirable effects[1]. In this way, neutral current in excess of the triple harmonic current is minimized. A separate neutral conductor for each phase in the three-phase circuit that serves single-phase nonlinear loads should be installed, increasing neutral conductor rating and doubling the neutral conductor will reduce the effects of phase imbalance[3].

2.4 Summary

Different types of power quality assessment approaches have been reviewed in this chapter. The need for an active power filter is necessary in every power system with non linear loads. High neutral current must be compensated by using adequate quality of neutral conductors.

2.5 Problem Identification

(i)The phase imbalance due to inefficient workload scheduling of UPS load are studied.

(ii)The various harmonic content in the power system was identified. Various corrective measures were taken.

Chapter 3

Adopted Methodology

3.1 Introduction

As stated earlier in the report, the main considerations are on to the phase imbalances and harmonics mitigation. A number of measurement are taken from the subject block i.e. the divisional block A and from the main feeder. The studies conducted in this report is based on these measurements. The measuring equipment used is FLUKE 435 series II power quality and energy analyzer VO5.00.

3.2 Divisional Block A

The divisional block A is comprised mainly of UPS loads supplying power to computer systems and network servers. The other loads are A/C loads and light loads like lighting, fan and power plugs. It represents the connection of each UPS in the four labs and the connections are identical in each lab. The measurements are taken on the input side of the power distribution boards where all the effects of each UPS loads are summed up.
The table 3.1 gives the details about the IT department section in divisional block A.

TABLE 3.1 DB Layout - IT Dept.

Floor	Distribution board	Room
3	PDB1	Programming Lab
	PDB2	Server room 1
	PDB3	Project lab
2	PDB4	Database lab
	PDB5	Server room 2
	PDB6	Internet and Multimedia lab
1	PDB7	Staff Room, library and HODs room

3.3 Methodology

The adopted methodology comprises of measuring the basic parameters of a power system. For attaining a practise in measurement, a prior familiarization of the power quality analyzer was done. A single line diagram is shown in Fig 3.1. Power analyzer was connected at the input feeder of machines lab and various measurements were taken. As the next step the power quality analyzer was connected at the input of the three phase supply to a single floor of the IT lab section. Various readings at different load conditions were then measured for a specific time period and the measured data is transferred to a power logger software for analysis and interpretation.

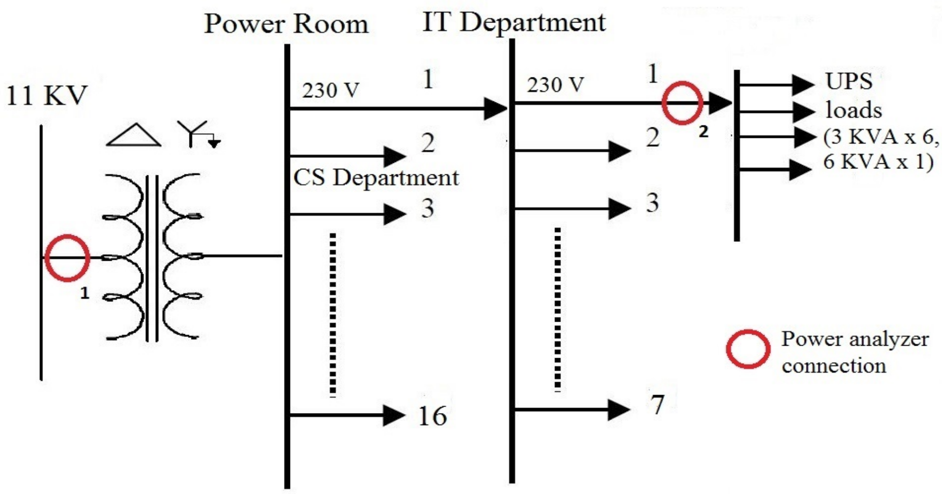

Figure 3.1 Single Line Diagram

As shown in Fig 3.1, the power analyzer was connected at the points 1 and 2 for measuring the various parameters to obtain the performance of the power system. For studying the basic levels of harmonic parameters in the whole power system, an experiment to check for the harmonic levels at no load condition of the whole power system was conducted by connecting power analyzer at the input feeder of the main power room when most of the loads were inactive. Then various load condition were achieved and recorded for a specific time period. Different types of abnormalities are detected owing to changing load conditions.

3.4 Power Quality and Energy Analyzer

The sole equipment used in our experiments is FLUKE 435 series II power quality and energy analyzer. It is equipped with advanced power quality functions. It is an ideal portable, power quality tool to efficiently troubleshoot motors and generators, discover the source of intermittent power problems or perform energy studies. It can also monetize the cost of energy waste due to poor power quality. The wide range of measurement functions and measurement methods in the Fluke 435-II make it an ideal tool for both power quality troubleshooting and discovering energy savings. Wrapped in a lightweight, rugged package, the Fluke 435 II Energy Analyzer, shown in fig 3.2 is the ideal portable power quality instrument for our project providing advanced power quality functionality and energy analysis capabilities.

Figure 3.2 FLUKE 435 series II Power Quality And Energy

3.5 Summary

The divisional block A containing mainly UPS loads which produces enough harmonics and imbalances in the power system is studied by adopting a suitable methodology of observing variations in the basic parameters of a power system under various load conditions.

Chapter 4

Measurements and Analysis

4.1 Introduction

Using the power analyzer mentioned earlier, measurements were taken from different blocks on different load conditions. Then the performance of the power system is analysed through power logger software.

4.2 Familiarization of Measurements

The power analyzer is a device giving a large number of data and information. To know about the measurement procedures and sorting of values in the power analyzer, a well familiarization of the device was essential. Therefore the power analyzer was connected at the input feeder of electrical machines lab. Although this experiment was conducted with the aim of familiarization of the analyzer, the standard limits of the parameters of the power system were also checked. The fig 4.1 relates the characteristics of the current in each phase with time. The behaviour of the neutral current during imbalance and balance loads can also be seen.

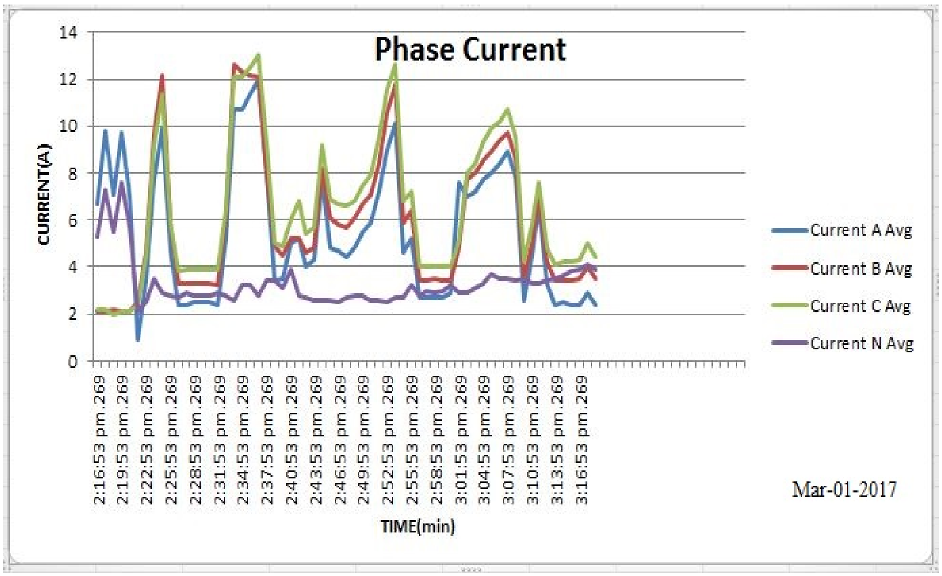

Figure 4.1 Phase Current Vs Time Characteristic

The harmonics limits are also plotted to study about its behaviour. Fig 4.2 shows that the voltage THD is within the safe limit of 5%[6]. It is the standard limit for a power system in the subject field.

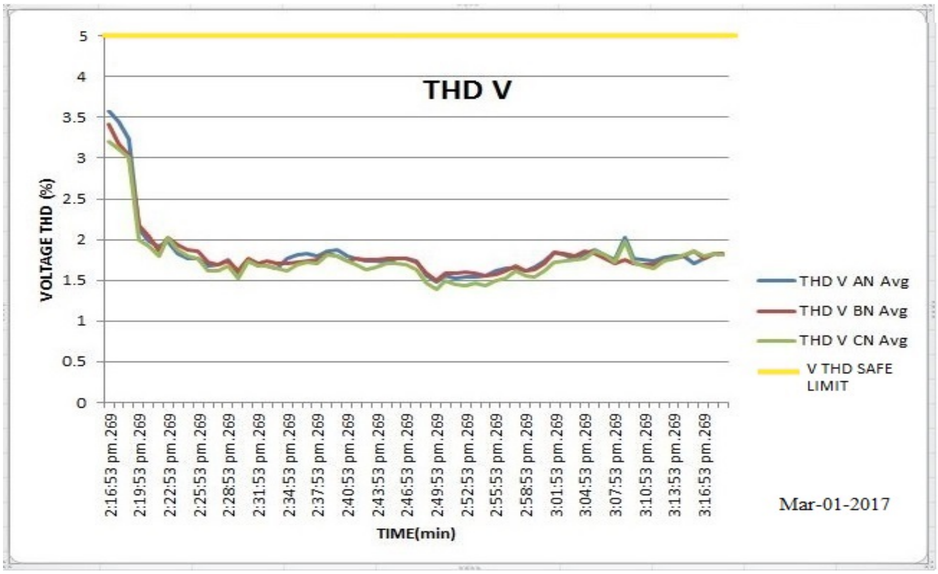

Figure 4.2 Voltage THD Vs Time Characteristic

While in the case of current THD, as shown in fig 4.3, the safe limit is 20% for this power system[6]. But it reaches upto 46% which is not an appreciable value. So this helps to realize that the possibility of wide current harmonics in loads like motors and generators is high.

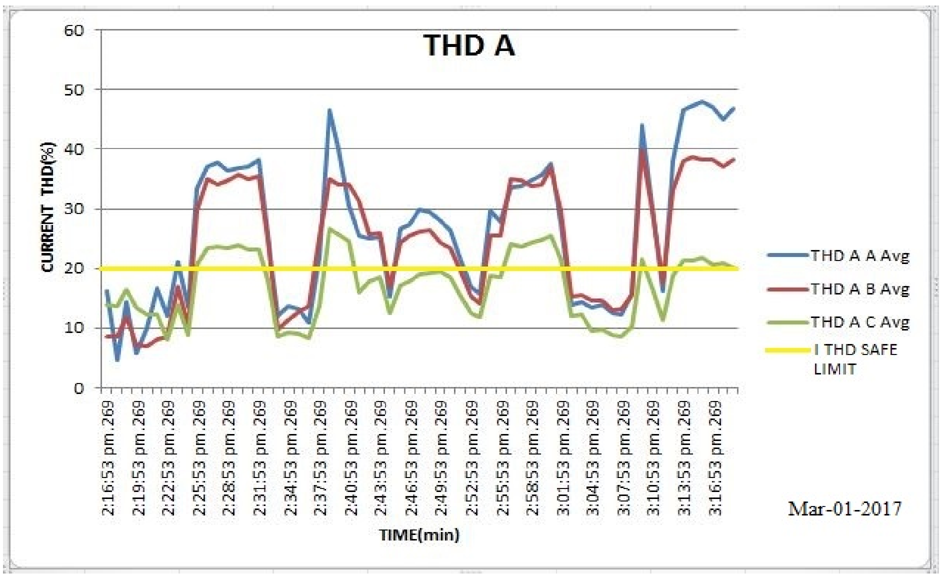

Figure 4.3 Current THD Vs Time Characteristic

4.3 UPS Loads

For studying the behaviour and characteristics of the UPS loads connected in the divisional block A, the power analyzer was connected at the input of the three phase supply to the programming lab of the IT department. Different load patterns were formulated with respect to time for one hour continuously. The loads were normally supplied from KSEB grid. The different load patterns according to time is formulated in table 4.1

TABLE 4.1 UPS Load Pattern

Time period(min)	No. of active systems	Main Supply
0-12	0	ON
13-17	14	ON
18-22	24	ON
23-36	0	ON
37-39	24	OFF
39-40	14	ON
40-51	0	ON

The subject UPS was numbered seven and eight which was connected to the R phase coming from a three phase supply. Both the UPS loads supply power to the 24 systems in the programming lab of IT department. Due to the connection of the total loads in the programming lab to R phase, during the working period of lab 3, there were a considerable amount of phase imbalance. During the experiment, other two phases which were connected to server room 1 and project lab were unloaded which develops a phase imbalance. Fig 4.4 indicates that the other two phases remain unloaded by noting the behaviour of the neutral current.

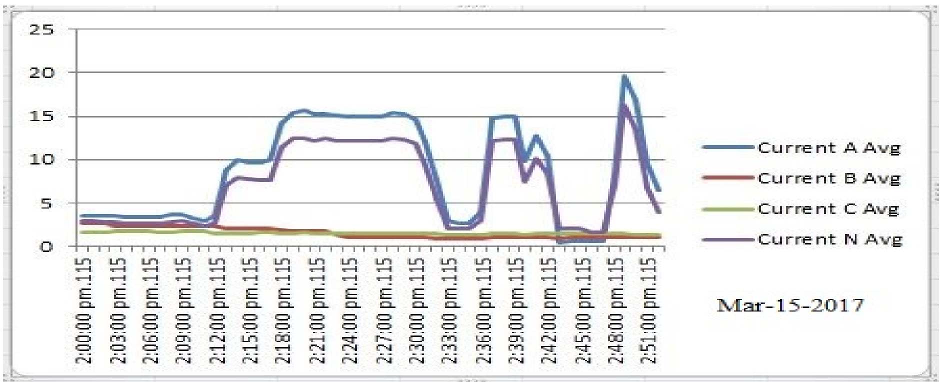

Figure 4.4 Current Vs Time Characteristic

The above graph gives the interpretation that there is a reportedly high amount of current in the neutral conductors due to phase imbalance. This also can be due to the harmonic distortion in the power system. In fig 4.4, the phase current magnitudes are obtained according to the load except for the very high spike at the end of the experiment period i.e. from 2:49:00 PM to 2:51:00 PM. 19.7 A is recorded as the peak current and the maximum current recorded in the whole experiment and it has been obtained at a complete no load condition. This phenomena was due to the main power supply cut and starting of the diesel generator. It caused a rise in phase current and the neutral current rise to a value of 16.2 A.

Effects of harmonics are very important in the study of non linear loads in a power system. Mainly, the effect of 3rd and 5th harmonics are noted in this experiment. The neutral current in the non linear environment has a difference than in linear loads. As shown in fig 4.5, 120V AC non-linear loads like the SMPS used in computers, UPS loads and monitors draw current in two distinct pulses per cycle. Because each pulse is narrow (less than 60 degrees), the currents in the second and third phases are zero when the current pulse is occurring in the first phase. Hence no cancellation can occur in the neutral conductor and each pulse of current on a phase becomes a pulse of current on the neutral. This effect is magnified in a case of any phase imbalance if the other two phases are already unloaded as in this case[4].

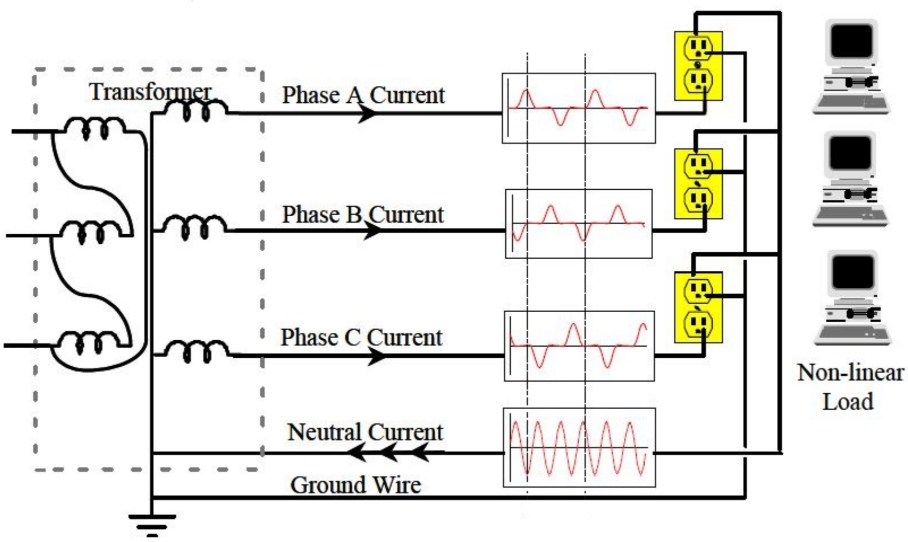

Figure 4.5 Addition of Neutral Current With Non Linear Loads[4]

Table 4.2 gives the average value of voltage and current harmonic amplitude upto the fifth component.

TABLE 4.2 Voltage and Current Harmonics

	PHASE A		PHASE B		PHASE C	
	A harmonics	V harmonics	A harmonics	V harmonics	A harmonics	V harmonics
1	100%	100%	100%	100%	100%	100%
2	0.066%	6.384%	0.064%	19.258%	0.054%	27.729%
3	1.409%	66.063%	0.733%	70.715%	0.833%	56.321%
4	0.023%	3.174%	0.034%	10.478%	0.021%	16.429%
5	0.600%	42.14%	0.054%	3.636%	0.353%	47.019%

From the above listed data, it can be concluded that the third harmonics has the highest amount of distortion in the both current and voltage harmonics for each phase. This can increase the neutral current value. The increased value of the third component should be mitigated. The following figures explain the THD and other parameter levels. As per the IEEE standards, for a power system of AJCE campus, the voltage THD limit is 5% and current THD limit is 20%[6]. Fig 4.6 and Fig 4.7 shows the measured voltage and current THD values. It is evident from those figures that the voltage THD is within the safe limit and the current THD is widely out of the limit. The fig 4.8 shows a relation between the voltage THD and neutral current. It can be seen that each of them have same pattern. This indicates that each parameter is interrelated with each other.

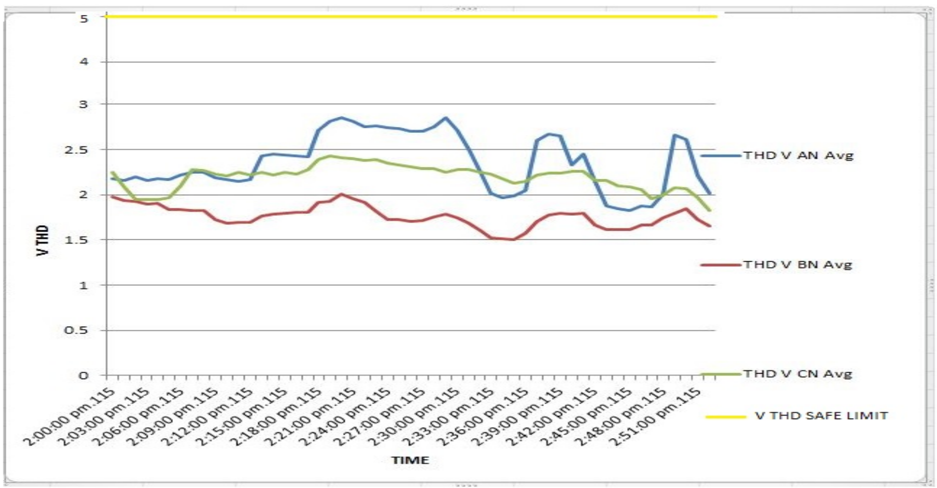

Figure 4.6 Voltage THD Vs Time Characteristic

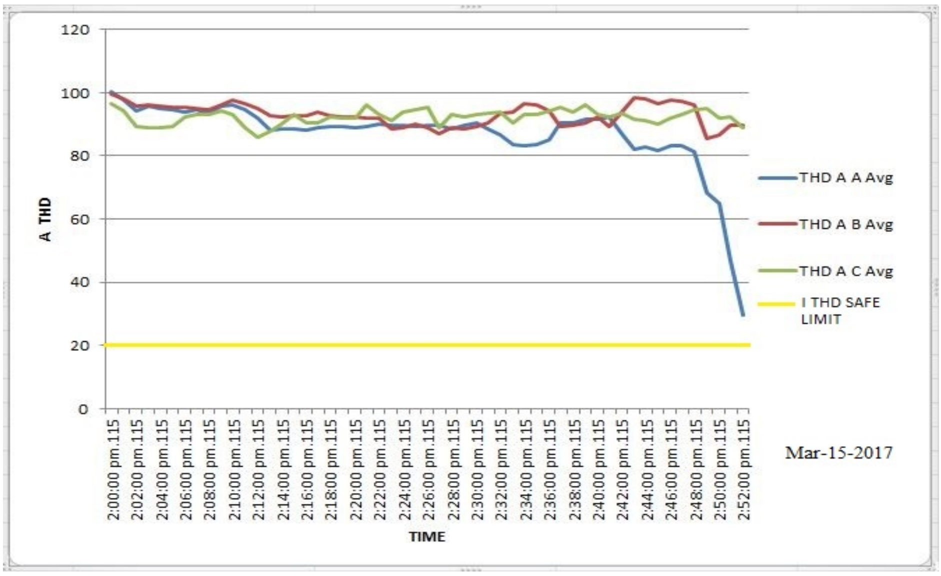

Figure 4.7 Current THD Vs Time Characteristic

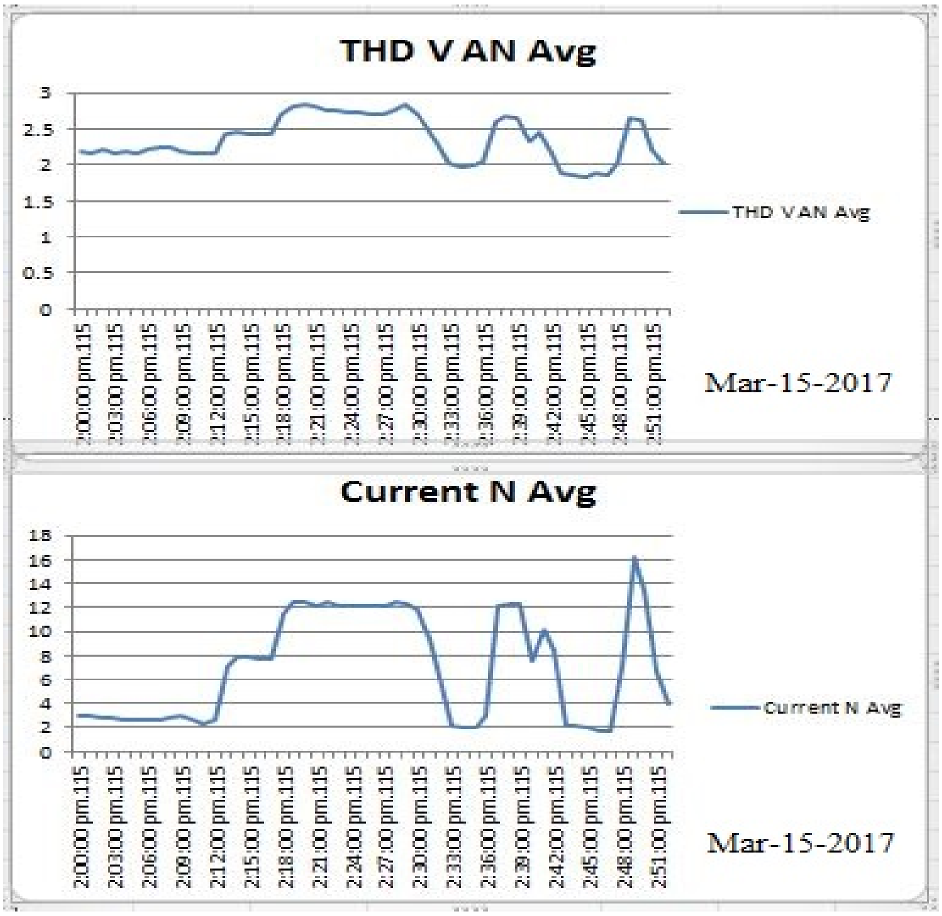

Figure 4.8 Voltage THD And Neutral Current Characteristic

4.4 Power Room

An experiment was conducted in the main power room of the college campus at no load condition where the analyzer was connected at the input feeder and different load patterns were obtained. This was to ensure that the harmonics level at no load condition is within the standard limits[6]. It gives a hint that the high harmonics levels shown in subsection 4.3 was due to the power electronic loads of the divisional block A. Fig 4.9 shows the voltage THD level at partial no load condition and fig 4.10 shows the current THD level at partial no load condition. Only partial no load condition was attained due to the practical effects of attaining total no load condition. The experiment was conducted during the dinner interval. The fig 4.9 and fig 4.10 shows that the both levels are satisfactory. Thus it can be concluded that the UPS loads of divisional blocks entirely produce the high level distortions in the power system.

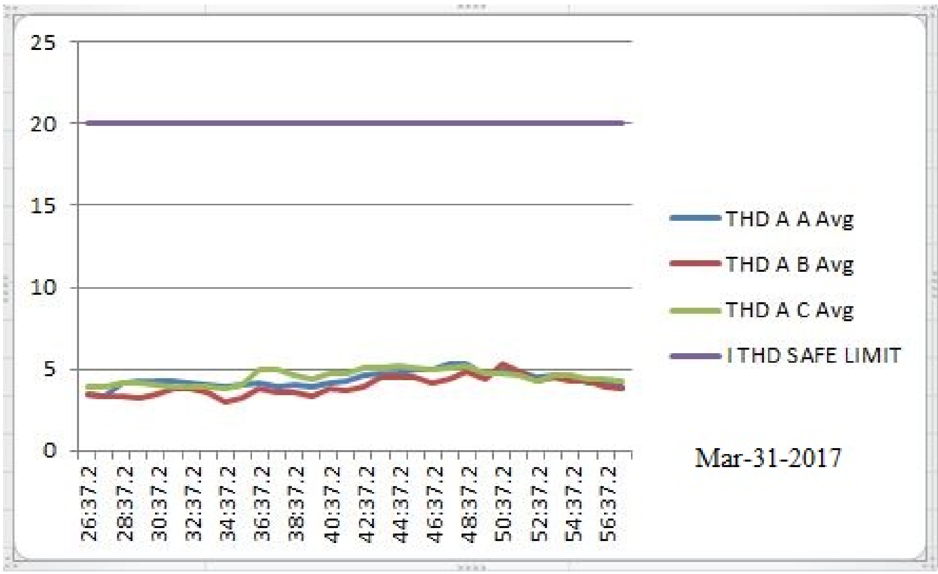

Figure 4.9 Current THD Vs Time Characteristic

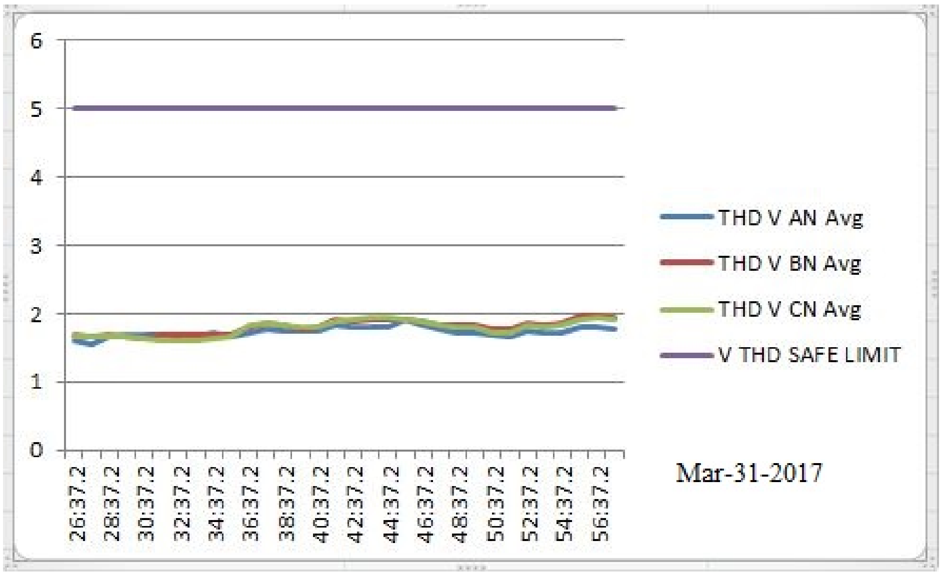

Figure 4.10 Voltage THD Vs Time Characteristic

4.5 Generator Integration

To know precisely about the earlier stated inrush of phase and neutral current in the power system in section 4.2, the KSEB mains was cut off manually and then the generator was started automatically. As shown in the fig 4.11 the systems are turned on from the starting time and it attains a full load at 48:47.3 min. The KSEB main grid was active till 57:47.3 min. After that point, the KSEB grid was cut manually and 59:47.3 min generator started running. And we can see the phase current and the neutral current going to a high value. The peak current is due to the integration of the generator into the power system after the mains was cut. After that instant, it stays at an average of 18 A. These high level of neutral current can cause overloading of the neutral conductor which can cause severe burn outs. It also decreases the durability of the neutral conductor.

Figure 4.11 Current Vs. Time Characteristic

4.6 Inference

In this chapter, the performance of the UPS loads were studied for different load patterns. It was found that there is a considerable amount of increased current harmonics particularly the triplen components in the power system due to the power electronic loads. From measurements taken at the power room, it has been identified that the harmonics level at no load is within the standard limits[6]. During the operation of UPS loads in programming lab, the neutral current level recorded was very high. Neutral current value increases gradually when the generator is integrated into the power system when supply from

KSEB is interrupted. To reduce the effect of high neutral current, full sized neutral wiring and monitoring of the neutral current can be adopted. In order to reduce the high value of current harmonics in the power system, design of an active power filter can be suggested.

4.7 Summary

In this chapter, several measurements were taken in the machines lab, UPS loads and power room. With this information, corrective measures are planned.

Chapter 5

Simulation Work

5.1 Introduction

The power system consists of increased THD of both voltage and current due to incorporation of PE loads. A power system consisting of different PE loads are considered. An active power filter is designed to mitigate the effect of harmonics in the power system[5].

5.2 Power System With PE loads

A power system with a three phase supply with PE loads are shown in fig 5.1. The power system consists of two diode rectifiers phase shifted by 30 degrees represented as load 1 and load 2. Only the delta/delta connected diode rectifier is in-circuit at beginning. The DC current is now set at 2000A. Then it is increased to 3000A at fifth cycle of the current characteristics. The load 2 comes into the circuit when the breaker switch closes at tenth cycle of current characteristics[5].

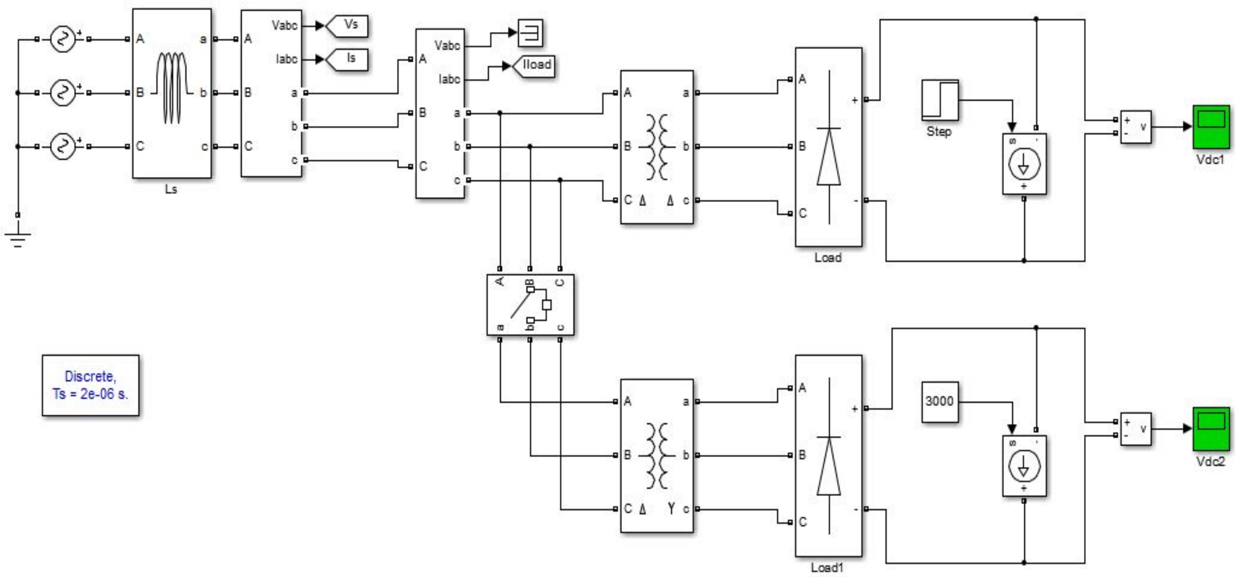

Figure 5.1 Power System With PE Loads[5]

The performance of the source voltage and current and the load voltage and current is shown in fig 5.2. It shows the distortion in the source current due to the PE loads. The THD value of current harmonics are shown in fig 5.3 by which it can be concluded that the current harmonics exceeds the standard limits[6].

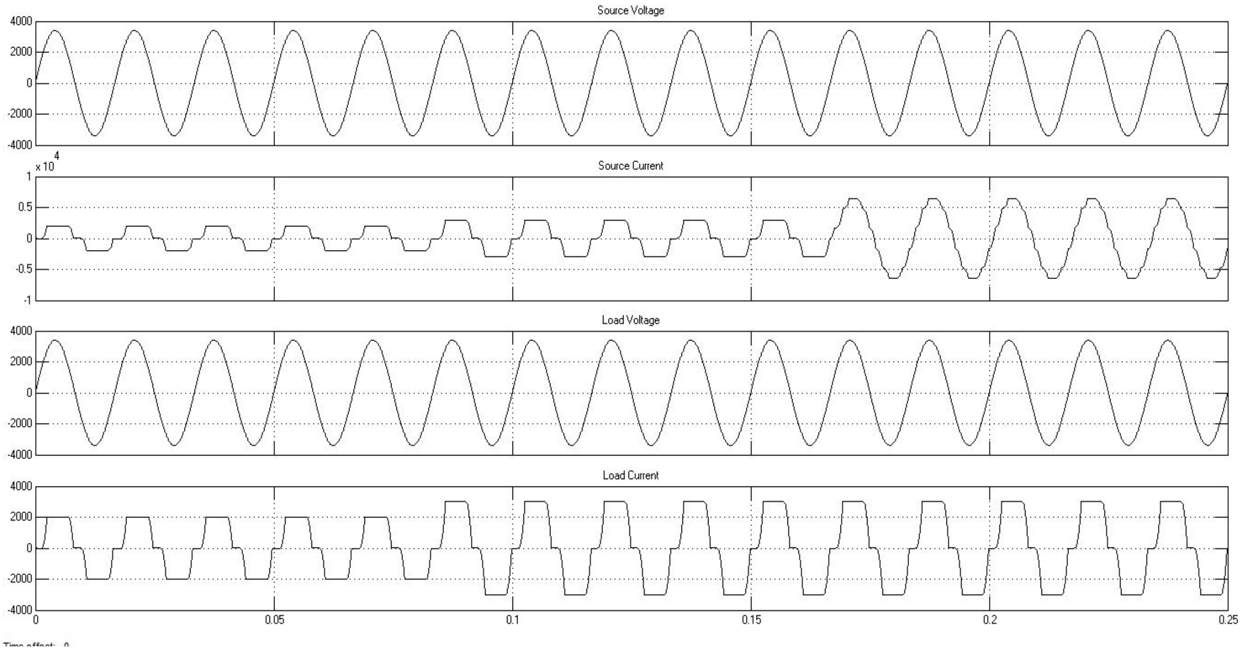

Figure 5.2 Current and Voltage Plot

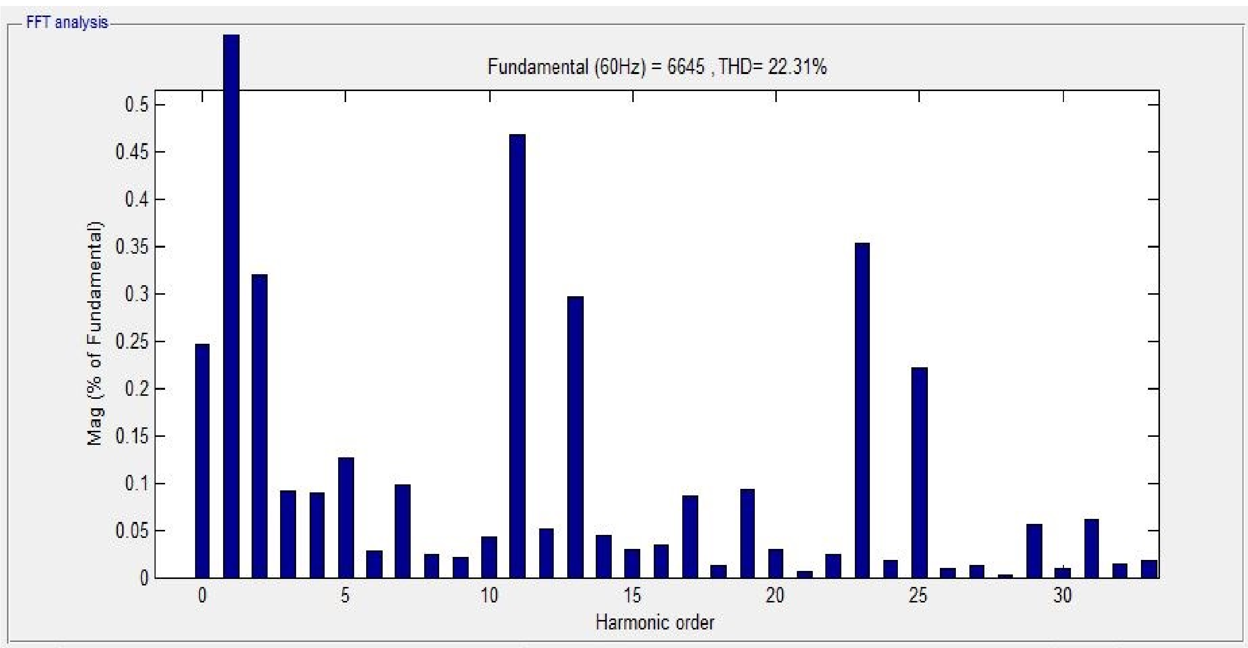

Figure 5.3 THD Values

The table 5.1 gives the specifications of the power system with PE loads.

TABLE 5.1 System Specifications

Parameters	Specification
Phase Voltage (RMS)	4 KV
Frequency	60 Hz
Delta - Delta Transformer	4KV/4KV
Delta - Star Transformer	4KV/4KV
Diode rectifier (load1)	0.001 ohms
Diode rectifier (load2)	0.001 ohms

5.3 Active Power Filter

Due to the high amount of voltage and current distortion, a simple active power filter is designed with the help of MATLAB software. The shunt active power filter used here obeys the principle of obtaining the error value of source with respect to a reference value. An active power filter eliminates voltage and current harmonics irrespective of the harmonics frequency, it regulates source voltage and compensates voltage flickering. The given filter is a voltage sourced active filter which creates AC voltage at its output terminal. A shunt active power filter is shown in fig 5.4.

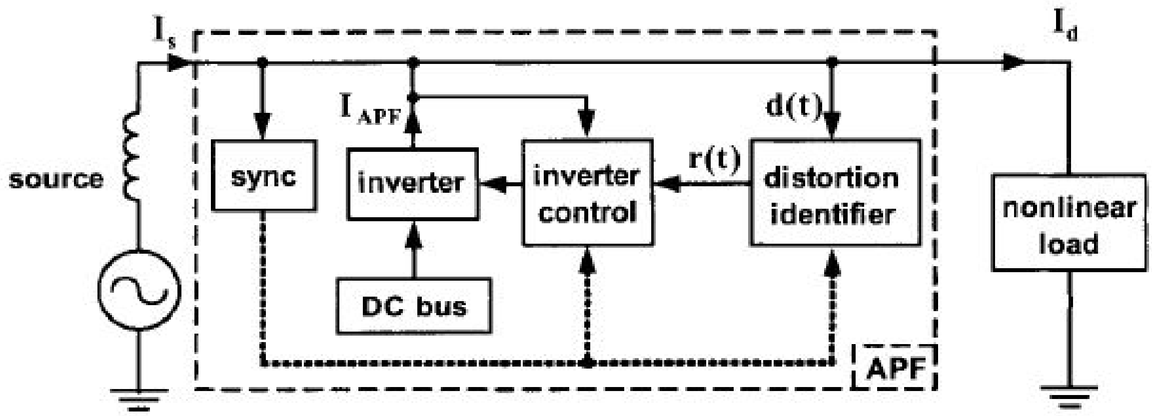

Figure 5.4 Shunt Active Power Filter[7]

Distortion identifier is a signal-processing function that takes the measured distorted waveform to reduce the distortion. Inverter is a power converter that reproduces the reference waveform with appropriate amplitude for shunt active filtering. Inverter controller is usually a pulse-width modulator with local current control loop. Synchronizer is a signal-processing block to ensure compensation waveforms are correctly synchronized with the power system voltage. DC bus is an energy storage device that supplies the fluctuating instantaneous power demand of the inverter[7].

5.4 Compensated Power System

In subsection 5.3, it is seen that there is distortion in source current and the current THD is above the standard limits[6]. This phenomena can be reduced by using a shunt active power filter in the circuit. As shown in fig 5.5, the circuit model is a standard shunt AHF with IGBT inverter and series inductor on the AC side and DC capacitor energization. The Delta-Y connected rectifier is connected after 10 cycles to change the load by a circuit breaker[5].

The AHF uses a PLL controller 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.

In fig 5.6, it is seen that when the simulation is started only the delta/delta connected diode rectifier is in circuit. The DC current is set at 2000A. At t=5/60s, the DC current is increased from 2000A to 3000A. Observe that the AHF effectively responds to this change in load and captures the new reference current within one cycle[5]. At t=10/60s, the delta/wye diode rectifier is connected, thus producing more load. Observe that the AHF again captures the new reference current within one cycle. The circuit has been discretized with a 2us time step. The Fig 5.6 gives the performance of the circuit with filter. It can be observed that the distortion in source current in circuit with SAPF is reduced and the normal value is captured with the first cycle which is represented by arrows in fig 5.6. It is seen that the AHF has effectively reduced the THD from 22.41 to 0.69% in fig 5.7[5].

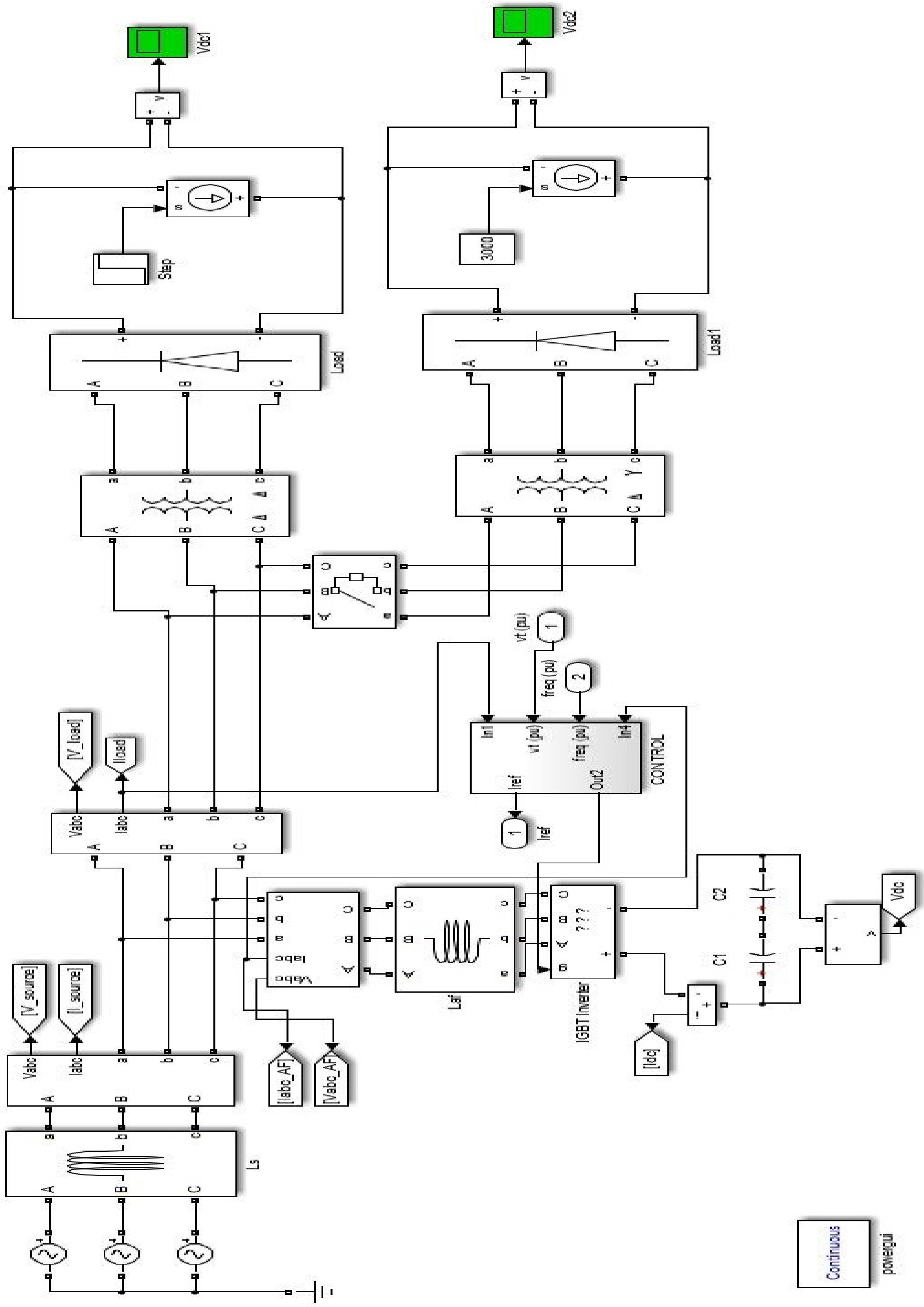

Figure 5.5 Compensated Power System With SAPF[5]

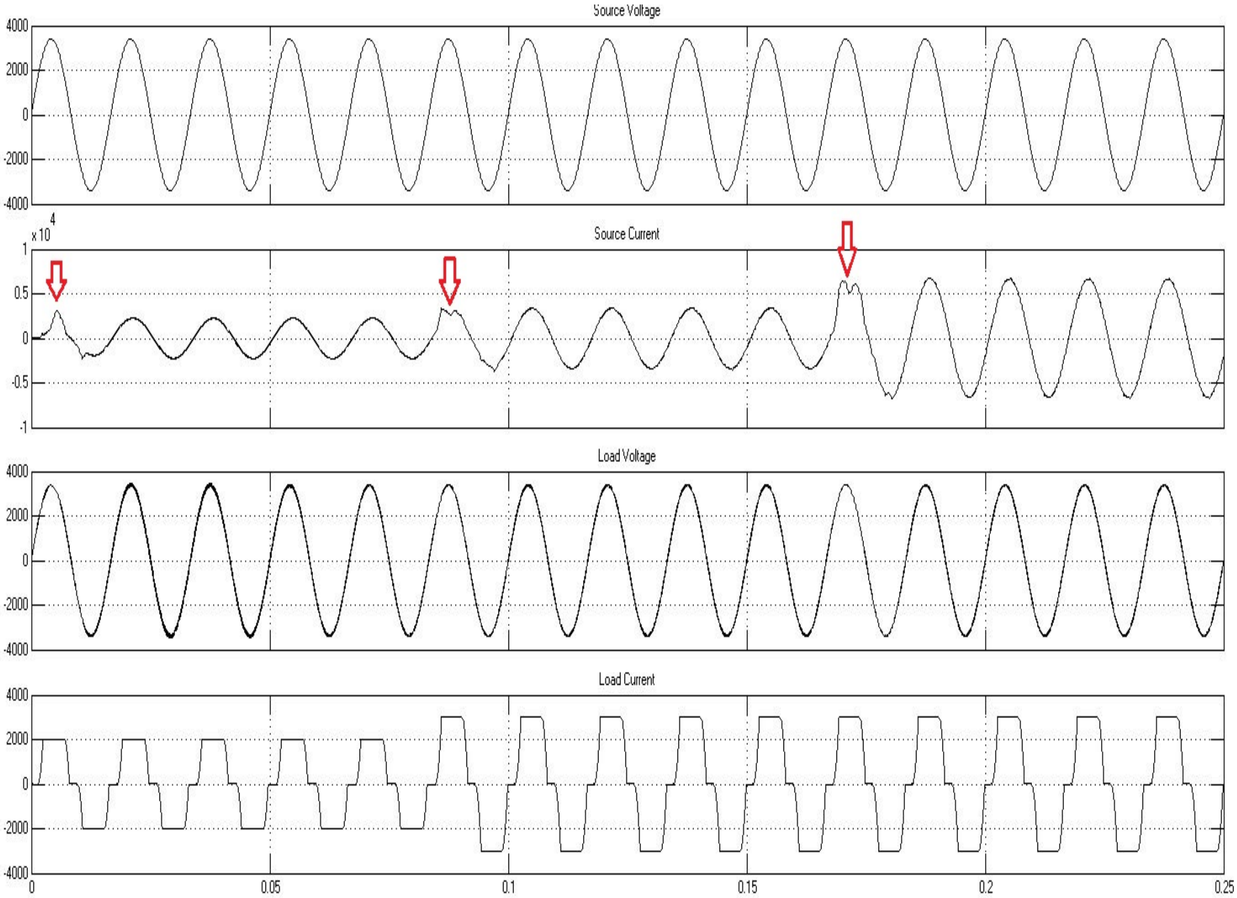

Figure 5.6 Voltage and Current With SAPF

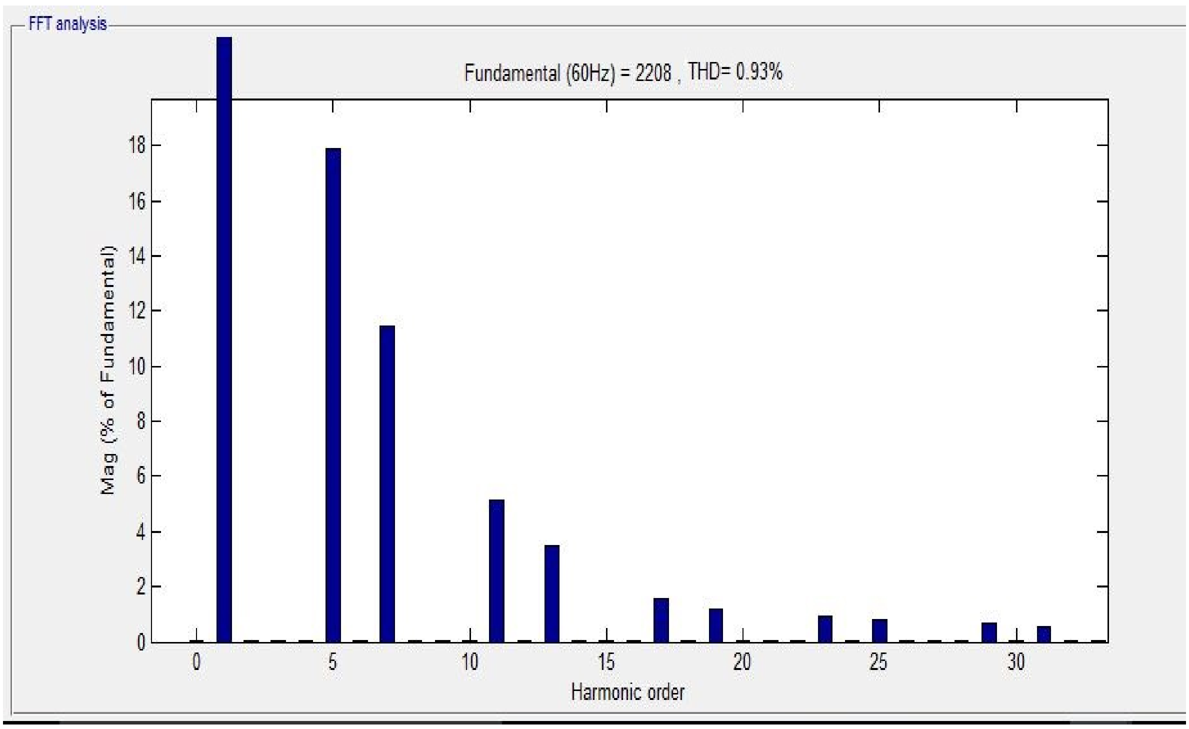

Figure 5.7 THD of Circuit With SAPF

5.5 Summary

In this chapter, conditions of a power system with and without PE loads have been studied. The various voltage and current behaviour have been studied. It is noted that the incorporation of the SAPF have reduced the current THD from 22.31% to 0.93% and the distortion in the source current is mitigated. And the working of the power system circuit has also been studied in this chapter.

Chapter 6

Conclusion and Future Work

From the past studies done in this field it has been came to the knowledge that the UPS loads have been showing the harmonic problems and phase imbalances in the power system. The project investigates the impact of power electronic loads, mainly UPS loads which are used to supply power for the computer system loads of divisional block A at Amaljyothi College of Engineering, Kanjirapally. It studies the major impacts of UPS loads in a hybrid power system of an educational institution and discusses the various phase imbalance due to excessive neutral current and presence of excessive harmonics.

It has been found that the current THD levels deviate from the specified values. Triplen harmonics are found to be more prevailing than others. A solution has been put forward for mitigating these harmonics effects i.e. to design an active power filter for the compensation of harmonics, especially triplen components.

From the analysis of neutral current, there has been a phase imbalance in the system on to which the UPS loads are connected. From the plots, it is evident that the magnitude of the neutral current coincides almost with the phase current in the graphs. Therefore the high current flow in the neutral conductors may reduce its life. Increased rate of ageing of conductors will put on the risk of burn outs. As the neutral current is meant to be small in a three phase system, the neutral conductors are usually of small size due to economic reasons which will increase the risks of burn outs. A remedy for reducing the neutral current is to check for adequate size of neutral conductors. To reduce the effect of phase imbalance, the UPS must be connected across the three phases in manner to reduce the neutral current.

References

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[3] Omer GUL,Mehmet BAYRAK,“Power quality and neutral current problems from unbalanced loads and non-linear loads in three-phase power systems”, International conference on electricity distribution, 1999, CIRED, Istanbul, Turkey, Page no 2-3.

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[6]

[7] Ewald F Fuchs, Mohammad A S Masoum,“*Power quality in Power systems and Electrical Machines*”, Chapter 9, March 2008, Page no. 382-383.

Appendices

Date: 01-03-2017

Appendix - 1

1.MACHINES LAB MEASUREMENTS

Time	Vrms ph-n AN Avg	Vrms ph-n BN Avg	Vrms ph-n CN Avg
2:00:00 pm.115	231.44	231.78	231.4
2:01:00 pm.115	230.54	231.04	231.36
2:02:00 pm.115	232.24	232.2	232.3
2:03:00 pm.115	231.52	232.4	232.02
2:04:00 pm.115	229.96	230.94	230.78
2:05:00 pm.115	230.74	231.28	230.88
2:06:00 pm.115	230.78	231.48	230.88
2:07:00 pm.115	230.26	231.58	230.56
2:08:00 pm.115	230.16	231.42	230.02
2:09:00 pm.115	231.2	232.32	230.8
2:10:00 pm.115	231.52	232.3	231.18
2:11:00 pm.115	230.94	231.6	230.08
2:12:00 pm.115	230.56	231.22	230.64
2:13:00 pm.115	229.1	231.42	230.76
2:14:00 pm.115	228.42	231.34	230.5
2:15:00 pm.115	228.56	231.64	230.96
2:16:00 pm.115	229.06	232.5	231.28
2:17:00 pm.115	228.6	232.9	231.14
2:18:00 pm.115	227.92	233.1	230.78
2:19:00 pm.115	227.14	232.8	230.18
2:20:00 pm.115	227.08	233.02	229.96
2:21:00 pm.115	227.44	233.22	230.36
2:22:00 pm.115	227.12	232.74	230.56
2:23:00 pm.115	228.14	233.7	231.88
2:24:00 pm.115	228.4	233.9	231.94
2:25:00 pm.115	227.5	232.88	231.2
2:26:00 pm.115	226.86	232.22	230.54
2:27:00 pm.115	227.6	232.88	231.26
2:28:00 pm.115	227.02	232.96	230.26
2:29:00 pm.115	226.2	232.86	230.2
2:30:00 pm.115	226.2	233.46	230.84
2:31:00 pm.115	226.72	233.46	230.76
2:32:00 pm.115	227.3	232.74	230.82
2:33:00 pm.115	227.52	231.46	230.56
2:34:00 pm.115	228.9	232.48	231.5
2:35:00 pm.115	228.58	232.3	231.26
2:36:00 pm.115	230.14	233.28	231.48
2:37:00 pm.115	228.56	234.46	232.24
2:38:00 pm.115	229.72	235.32	232.7
2:39:00 pm.115	229.58	235.56	233.08
2:40:00 pm.115	229.24	235.24	233.12
2:41:00 pm.115	229.52	235.58	233.9
2:42:00 pm.115	231	235.24	234.38
2:43:00 pm.115	231.72	234.42	234.54
2:44:00 pm.115	232.42	235.58	234.8
2:45:00 pm.115	232.7	235.64	234.46
2:46:00 pm.115	233.22	235.18	234.14
2:47:00 pm.115	233.56	235.42	234.52
2:48:00 pm.115	233.42	236.34	234.42

APPENDIX - 1 Contd.

1. MACHINES LAB MEASUREMENTS

Vrms ph-ph AB Avg	Vrms ph-ph BC Avg	Vrms ph-ph CA Avg	Current A Avg
401.72	402.44	398.86	3.6
400.1	401.9	398.12	3.6
403.02	403.36	400.32	3.5
402.6	403.18	399.52	3.5
399.88	400.94	397.16	3.4
401.08	401.18	397.8	3.4
401.06	401.62	397.78	3.4
400.14	401.84	397.2	3.4
400.02	401.06	396.72	3.7
401.8	402.42	398.28	3.7
401.86	402.72	399.1	3.3
400.84	400.92	397.78	3
400.42	400.92	397.86	3.5
399.52	400.72	397	8.8
398.8	400.28	396.36	9.9
399.08	401	396.96	9.7
400.26	401.92	397.74	9.7
400.08	401.96	397.56	10
399.48	401.92	396.68	14.2
398.36	401.22	395.62	15.4
398.46	401.14	395.46	15.7
398.86	401.7	396.22	15.3
398.4	401.38	395.96	15.3
400.16	403.26	398.02	15.1
400.6	403.52	398.24	14.9
398.9	402.04	396.8	14.9
397.8	400.92	395.6	14.9
399.08	402.08	396.86	14.9
398.18	401.62	395.6	15.4
396.88	401.74	395.1	15.2
397.46	402.74	395.64	14.7
397.9	402.74	396.02	12
398.28	401.86	396.38	7.6
397.6	400.64	396.02	2.9
399.98	402.12	397.96	2.6
399.32	401.96	397.48	2.6
401.36	403.26	398.92	3.9
401.34	404.18	398.62	14.8
402.76	405.42	400.24	15
402.56	406.1	400.58	15
401.78	406.26	400.18	9.8
402.5	406.66	401.44	12.8
404.1	406.68	402.66	10.4
403.9	406.58	403.08	0.5
405.46	407.92	403.84	0.6
405.72	407.9	403.58	0.6
405.6	407.62	403.54	0.6
406.26	408.02	404.2	0.6
406.72	408.68	404.2	8.4

1. MACHINES LAB MEASUREMENTS

Current B Avg	Current C Avg	Current N Avg	THD V AN Avg
2.7	1.7	2.9	2.18
2.7	1.7	2.9	2.16
2.6	1.7	2.8	2.2
2.4	1.8	2.8	2.16
2.3	1.8	2.7	2.18
2.3	1.8	2.7	2.17
2.3	1.8	2.6	2.22
2.3	1.7	2.6	2.25
2.3	1.7	2.8	2.25
2.3	1.8	2.9	2.19
2.3	1.8	2.6	2.17
2.3	1.8	2.4	2.15
2.3	1.5	2.7	2.17
2.1	1.5	7	2.43
2.1	1.5	7.9	2.45
2.1	1.5	7.8	2.44
2.1	1.6	7.7	2.43
2.1	1.6	7.7	2.42
1.9	1.5	11.4	2.71
1.8	1.5	12.4	2.81
1.8	1.6	12.5	2.85
1.8	1.5	12.2	2.81
1.8	1.5	12.4	2.75
1.4	1.5	12.2	2.76
1	1.5	12.1	2.74
1	1.5	12.1	2.73
1	1.5	12.2	2.7
1	1.5	12.1	2.7
1	1.5	12.5	2.75
1	1.5	12.3	2.85
1	1.5	11.8	2.71
1	1.5	9.4	2.5
0.9	1.5	5.5	2.25
0.9	1.4	2.1	2.02
0.9	1.4	2	1.97
0.9	1.4	2	1.99
0.9	1.4	2.9	2.05
1	1.5	12.1	2.6
1	1.5	12.3	2.67
1	1.5	12.3	2.65
1	1.4	7.5	2.33
1	1.5	10.1	2.45
1	1.5	8.4	2.15
0.9	1.5	2.1	1.88
1	1.5	2.1	1.85
1	1.5	2	1.83
1	1.5	1.6	1.88
1	1.5	1.6	1.87
1	1.5	7	2.01

APPENDIX - 1 Contd.

1. MACHINES LAB MEASUREMENTS

THD V BN Avg	THD V CN Avg	THD V NG Avg	/olts Harmonics3 AN Av
1.98	2.25	207.62	1.1
1.94	2.09	184.63	1.07
1.93	1.95	162.39	1.07
1.9	1.95	171.86	1.07
1.91	1.95	164.2	1.03
1.84	1.97	162.46	1.09
1.84	2.1	208.72	1.16
1.83	2.28	272.63	1.17
1.83	2.27	305.73	1.14
1.72	2.23	297.84	1.18
1.68	2.21	259.61	1.19
1.69	2.25	235.3	1.17
1.69	2.22	327.67	1.17
1.76	2.25	327.67	1.58
1.78	2.22	183.85	1.59
1.8	2.25	181.13	1.55
1.81	2.23	165.46	1.55
1.81	2.28	120.71	1.6
1.92	2.39	126.57	1.86
1.93	2.43	121.68	1.94
2.01	2.41	118.53	1.96
1.96	2.4	118.01	1.92
1.92	2.38	113.13	1.9
1.82	2.39	110.71	1.92
1.72	2.35	108.22	1.9
1.72	2.33	110.16	1.87
1.7	2.31	109.32	1.86
1.71	2.29	110.53	1.85
1.75	2.29	113.99	1.89
1.78	2.25	109.08	2.11
1.74	2.28	93.02	1.95
1.68	2.28	90.53	1.76
1.6	2.25	81.95	1.49
1.52	2.23	82.9	1.15
1.51	2.18	81.27	1.01
1.5	2.13	100.53	1.11
1.57	2.15	179.85	1.15
1.7	2.22	103.54	1.8
1.77	2.24	113.09	1.83
1.79	2.24	106.88	1.81
1.78	2.26	84.91	1.38
1.8	2.26	84.81	1.52
1.66	2.16	80.19	1.26
1.61	2.16	73.76	0.75
1.61	2.1	72.48	0.78
1.61	2.09	327.67	0.78
1.66	2.06	327.67	0.76
1.66	1.96	327.67	0.76
1.74	2	327.67	0.93

APPENDIX - 1 Contd.

1. MACHINES LAB MEASUREMENTS

THD A A Avg	THD A B Avg	THD A C Avg	THD A N Avg
100.27	99.53	96.52	233.57
97.8	97.92	94.27	218.51
94.37	95.73	89.41	204.87
95.7	96.08	88.92	201.88
95.2	95.94	89.06	196.76
94.48	95.41	89.49	189.95
93.86	95.58	92.37	181.73
94.73	95.05	93.3	171.32
93.46	94.5	93.06	162.61
95.66	96.13	94.22	167.41
96.09	97.86	93.16	187.29
94.61	96.58	89.04	187.93
91.84	94.92	85.95	182.48
88.36	92.7	87.62	115.13
88.7	92.19	90.14	113.48
88.67	92.68	93.2	114.33
88.17	92.85	90.53	119.36
89.11	93.93	90.35	130.01
89.34	92.67	92.37	109.05
89.48	92.21	92.11	106.06
89.04	92.4	92.12	105.92
89.44	92.15	96.2	106.58
90.15	92.05	93.07	108.94
89.72	88.69	91.06	105.96
89.68	88.84	93.7	103.24
89.5	89.92	94.79	103.05
89.59	88.81	95.58	103.19
89.8	87.14	88.77	103.61
88.58	88.9	93.28	100.93
89.88	88.65	92.36	103.07
90.51	89.28	93.22	108.58
88.5	90.45	93.5	111.89
86.48	93.34	93.73	137.1
83.49	93.78	90.57	187.2
83.04	96.45	93.13	188.13
83.75	96.29	93.14	188.21
85.19	94.23	94.18	200.66
90.27	89.38	95.38	105.79
90.48	89.84	94.06	104.38
91.44	90.63	96.31	107.12
91.62	92.52	93.2	137.24
92.29	89.16	92.32	121.39
87.08	93.74	93.51	89.05
81.92	98.47	91.69	60.73
82.93	98.19	91.34	60.43
81.85	96.39	90.23	69.37
83.06	97.53	91.9	95.98
83.09	97.33	93.06	99.24
81.14	96.13	94.68	102.22

Date: 15-03-2017

Appendix - 2

2. PROGRAMMING LAB MEASUREMENTS

Time	Vrms ph-n AN Avg	Vrms ph-n BN Avg	Vrms ph-n CN Avg	Vrms ph-n NG Avg
2:16:53 pm.269	240.78	242.06	240.88	0.22
2:17:53 pm.269	240.8	242.34	240.72	0.24
2:18:53 pm.269	214.3	215.92	215.52	0.36
2:19:53 pm.269	228.3	230.24	231.12	0.3
2:20:53 pm.269	229.78	231.32	232.34	0.28
2:21:53 pm.269	228.82	230.02	231.16	0.22
2:22:53 pm.269	230.12	230.94	231.92	0.22
2:23:53 pm.269	230.16	230.94	231.42	0.18
2:24:53 pm.269	229.78	230.5	231.02	0.2
2:25:53 pm.269	230.42	230.92	231.68	0.2
2:26:53 pm.269	231.2	231.7	232.58	0.2
2:27:53 pm.269	233.24	233.76	234.74	0.18
2:28:53 pm.269	234.42	234.92	235.68	0.2
2:29:53 pm.269	233.96	234.28	235.04	0.2
2:30:53 pm.269	234.16	234.28	235.1	0.2
2:31:53 pm.269	233.42	233.18	234.3	0.2
2:32:53 pm.269	232.88	232.78	233.98	0.2
2:33:53 pm.269	232.32	232.12	233.42	0.2
2:34:53 pm.269	232.2	231.96	233.18	0.18
2:35:53 pm.269	233.44	232.98	234.42	0.18
2:36:53 pm.269	232.98	232.94	234.1	0.18
2:37:53 pm.269	232.48	232.96	233.72	0.18
2:38:53 pm.269	232.78	233.24	234.1	0.18
2:39:53 pm.269	232.58	232.54	233.54	0.18
2:40:53 pm.269	233.12	232.94	234.08	0.18
2:41:53 pm.269	233.06	233.32	234.12	0.2
2:42:53 pm.269	233.96	234.32	235.34	0.2
2:43:53 pm.269	233.92	234.66	235.56	0.2
2:44:53 pm.269	233.92	234.56	235.58	0.18
2:45:53 pm.269	234.86	235.22	236.16	0.2
2:46:53 pm.269	233.64	233.88	234.8	0.2
2:47:53 pm.269	231.66	231.62	233	0.2
2:48:53 pm.269	232.24	232.4	233.82	0.2
2:49:53 pm.269	235.68	235.52	236.86	0.2
2:50:53 pm.269	236.18	236.34	237.62	0.2
2:51:53 pm.269	236.24	236.18	237.9	0.2
2:52:53 pm.269	235.8	235.76	237.84	0.2
2:53:53 pm.269	231.92	231.84	233.98	0.2
2:54:53 pm.269	232.86	233.12	234.58	0.2
2:55:53 pm.269	234.6	234.74	236.32	0.2
2:56:53 pm.269	236.5	236.62	237.42	0.2
2:57:53 pm.269	236.78	236.98	237.6	0.2
2:58:53 pm.269	236.22	236.7	237.24	0.2
2:59:53 pm.269	236.56	236.96	237.52	0.2
3:00:53 pm.269	235.74	236.1	236.64	0.2
3:01:53 pm.269	232.38	232.98	233.16	0.2
3:02:53 pm.269	230.48	231.08	231.84	0.2
3:03:53 pm.269	232.4	233.18	234.1	0.2
3:04:53 pm.269	232.7	233.08	234.12	0.2

2. PROGRAMMING LAB MEASUREMENTS

3:05:53 pm.269	230.98	230.84	232.58	0.2
3:06:53 pm.269	231.46	231.46	233.42	0.2
3:07:53 pm.269	232.58	232.38	234.5	0.22
3:08:53 pm.269	231.56	231.6	233.1	0.22
3:09:53 pm.269	231.92	232.14	233.44	0.22
3:10:53 pm.269	233.98	234	235.46	0.22
3:11:53 pm.269	235.04	234.9	236.42	0.2
3:12:53 pm.269	230.52	231.26	232.46	0.2
3:13:53 pm.269	228.64	229.6	230.6	0.2
3:14:53 pm.269	229.78	230.78	231.52	0.2
3:15:53 pm.269	230.48	231.04	231.9	0.2
3:16:53 pm.269	231.12	232.52	233.4	0.2
3:17:53 pm.269	231.32	232.66	233.48	0.2
3:18:53 pm.269	231.74	233.1	233.78	0.2

Appendix - 2 Contd.

2. PROGRAMMING LAB MEASUREMENTS

Vrms ph-ph AB Avg	Vrms ph-ph BC Avg	Vrms ph-ph CA Avg	Current A Avg	Current B Avg
418.6	418.58	416.34	6.7	2.1
419.18	418.48	416.06	9.8	2.1
372.62	374.24	371.58	7.1	2.2
396.64	400.38	397.48	9.7	2.1
398.74	402.36	399.92	7	2.1
396.72	400.38	398	0.9	2.5
398.82	401.74	399.72	3.4	4.6
399.04	401.28	399.18	7.7	9.7
398.14	400.72	398.48	9.9	12.2
399.08	401.54	399.72	4.7	5.9
400.24	403.1	401.26	2.4	3.3
403.86	406.68	404.9	2.4	3.3
405.92	408.52	406.68	2.5	3.3
405	407.4	405.68	2.5	3.3
405.32	407.36	405.9	2.5	3.3
403.74	405.54	404.68	2.4	3.2
402.76	405.02	404.02	5.2	6.2
401.48	404.12	403.14	10.7	12.6
401.24	403.72	402.88	10.7	12.3
403.1	405.58	405.22	11.4	12.2
402.72	405.38	404.36	12	12.1
402.5	405.18	403.3	7.9	8
402.96	405.72	403.96	3.4	4.9
402.34	404.34	403.38	3.5	4.5
403.36	404.96	404.36	5	5.2
403.52	405.74	404.02	5.2	5.2
404.88	407.9	405.88	4	4.6
405.02	408.52	406.02	4.3	4.8
404.8	408.34	406.32	7.7	8.2
406.34	409.32	407.54	4.8	6.1
404.1	406.94	405.4	4.7	5.8
400.42	403.24	402.32	4.4	5.7
401.54	404.78	403.42	4.8	6.1
407.3	410.08	408.98	5.5	6.7
408.42	411.58	410	5.9	7.1
408.24	411.64	410.38	7.2	8.4
407.28	411.3	410.14	9	10.6
400.6	404.5	403.42	10.1	11.8
402.7	406.06	404.64	4.6	5.9
405.68	408.88	407.68	5.2	6.4
409.26	411.22	410.22	2.7	3.4
409.96	411.56	410.58	2.7	3.4
409.18	411.14	409.68	2.7	3.5
409.82	411.58	410.14	2.7	3.4
408.36	410.08	408.68	2.9	3.4
402.84	404.38	402.62	7.6	4.8
399.26	401.8	399.92	7	7.7
402.54	405.82	403.5	7.2	8
402.86	405.56	403.82	7.7	8.5

Appendix - 2 Contd.

2. PROGRAMMING LAB MEASUREMENTS

399.36	402.04	401.32	8	8.9
400.1	403.36	402.64	8.4	9.4
401.72	405.08	404.68	8.9	9.7
400.42	403.2	402.3	7.8	8.6
401.18	403.96	402.94	2.6	3.4
404.54	407.34	406.54	4.5	5
406.24	408.84	408.32	6.6	7
399.22	402.48	400.74	3.3	4.2
396.24	399.44	397.42	2.4	3.4
398.48	401.22	399	2.5	3.4
399.36	401.5	400.16	2.4	3.4
400.86	404.58	401.84	2.4	3.5
401.22	404.7	402.1	2.9	4
402.04	405.32	402.68	2.4	3.5

2. PROGRAMMING LAB MEASUREMENTS

Current C Avg	Current N Avg	THD V AN Avg	THD V BN Avg	THD V CN Avg
2.2	5.3	3.58	3.42	3.21
2.2	7.3	3.45	3.18	3.12
2	5.5	3.24	3.03	3
2.1	7.6	2.13	2.18	1.99
2.1	5.7	1.98	2.04	1.92
2.4	2.1	1.92	1.86	1.79
4.4	2.5	1.98	2.02	2.02
9.2	3.5	1.82	1.93	1.88
11.4	2.9	1.77	1.87	1.79
5.9	2.8	1.77	1.86	1.76
3.8	2.7	1.67	1.72	1.62
3.9	2.9	1.69	1.69	1.62
3.9	2.8	1.75	1.73	1.67
3.9	2.8	1.59	1.61	1.53
3.9	2.8	1.74	1.76	1.74
3.9	2.9	1.67	1.71	1.68
6.5	2.8	1.67	1.73	1.67
12.1	2.6	1.65	1.71	1.64
12.1	3.2	1.76	1.7	1.62
12.5	3.2	1.81	1.72	1.69
13	2.8	1.82	1.73	1.72
9.3	3.4	1.8	1.75	1.71
5	3.4	1.85	1.82	1.81
4.9	3.1	1.87	1.8	1.79
6	3.9	1.8	1.73	1.73
6.8	2.8	1.76	1.77	1.69
5.4	2.7	1.74	1.75	1.63
5.7	2.6	1.73	1.75	1.66
9.2	2.6	1.72	1.77	1.71
6.9	2.6	1.77	1.77	1.71
6.7	2.5	1.76	1.77	1.69
6.6	2.7	1.74	1.72	1.63
6.8	2.8	1.56	1.58	1.47
7.5	2.8	1.48	1.5	1.39
7.9	2.6	1.56	1.59	1.49
9.5	2.6	1.53	1.58	1.45
11.6	2.5	1.54	1.6	1.44
12.6	2.7	1.54	1.59	1.46
6.8	2.7	1.56	1.56	1.43
7.2	3.2	1.61	1.57	1.49
4	2.8	1.65	1.62	1.53
4	3	1.65	1.67	1.61
4	2.9	1.62	1.61	1.56
4	3	1.66	1.63	1.54
4	3.2	1.74	1.71	1.62
5.1	2.9	1.84	1.84	1.72
8	2.9	1.81	1.83	1.74
8.4	3.1	1.75	1.8	1.75
9.3	3.3	1.83	1.86	1.76

Appendix - 2 Contd.

2. PROGRAMMING LAB MEASUREMENTS

9.9	3.7	1.87	1.83	1.85
10.2	3.5	1.81	1.77	1.81
10.7	3.5	1.75	1.71	1.72
9.5	3.4	2.02	1.75	1.98
4.2	3.5	1.76	1.71	1.72
5.8	3.3	1.75	1.69	1.67
7.6	3.3	1.73	1.69	1.65
4.8	3.4	1.78	1.75	1.73
4.1	3.5	1.79	1.77	1.76
4.2	3.6	1.8	1.8	1.81
4.2	3.8	1.7	1.86	1.85
4.3	3.9	1.76	1.77	1.79
5	4.1	1.83	1.82	1.83
4.4	3.9	1.81	1.82	1.81

Appendix - 2 Contd.

2. PROGRAMMING LAB MEASUREMENTS

THD A A Avg	THD A B Avg	THD A C Avg	THD V AN Avg
16.27	8.58	13.8	1.48
4.51	8.64	13.6	1.53
14.42	11.85	16.36	1.54
5.82	7.18	13.34	1.54
10.02	7.04	12.24	1.56
16.57	8.08	12.29	1.56
12.09	8.52	8.16	1.56
21.14	16.99	14	1.59
13.48	10.08	8.8	1.61
33.29	29.56	20.67	1.62
37.05	35.08	23.39	1.65
37.73	34.18	23.53	1.65
36.31	34.69	23.41	1.65
36.9	35.66	23.78	1.66
37.19	34.9	23.2	1.67
38.25	35.53	23.13	1.67
25.82	24.81	18.18	1.67
12.12	9.68	8.59	1.69
13.57	11.44	9.22	1.7
13.18	12.64	8.99	1.72
10.92	13.73	8.29	1.73
21.74	25.28	13.68	1.73
46.62	35.01	26.67	1.74
40.15	34.18	25.71	1.74
30.56	34.03	24.61	1.74
25.38	31.29	15.94	1.74
25.14	25.7	17.72	1.75
25.16	26.02	18.59	1.75
15.2	16.96	12.44	1.75
26.74	24.26	17.23	1.75
27.38	25.5	17.91	1.76
29.85	26.26	18.89	1.76
29.55	26.35	19.23	1.76
28.16	24.31	19.57	1.76
26.38	23.43	18.61	1.76
21.26	19.5	15.34	1.77
16.89	15.24	12.39	1.77
15.63	14.17	11.72	1.77
29.7	25.41	18.82	1.78
27.87	25.51	18.49	1.79
33.65	34.91	24.16	1.8
33.83	34.89	23.54	1.8
34.78	33.89	24.26	1.8
35.8	34.09	24.7	1.81
37.52	36.82	25.5	1.81
27.58	29.75	21.66	1.81
13.81	15.21	12.07	1.81
14.44	15.4	12.27	1.82
13.53	14.56	9.44	1.82

Appendix - 2 Contd.

2. PROGRAMMING LAB MEASUREMENTS

13.88	14.53	9.62	1.83
12.44	12.95	8.67	1.83
12.23	13.29	8.47	1.84
15.77	15.52	10.17	1.85
43.95	39.87	21.57	1.87
30.12	29.71	16.77	1.87
16.14	17.51	11.27	1.92
38.08	33.25	18.85	1.98
46.58	38.13	21.2	1.98
47.38	38.63	21.32	2.02
47.9	38.37	21.83	2.13
47.08	38.15	20.58	3.24
44.87	37.11	20.89	3.45
46.81	38.35	20.12	3.58

Appendix - 3 Contd.

POWER ROOM MEASUREMENTS

Time	Vrms ph-n AN Avg	Vrms ph-n BN Avg	Vrms ph-n CN Avg
26:37.2	229.82	232.82	229.94
27:37.2	229.04	232.3	229.54
28:37.2	228.04	231.8	229.64
29:37.2	229.1	232.12	229.52
30:37.2	229.32	232	229.04
31:37.2	229.5	232.34	229.2
32:37.2	228.72	232.18	229.1
33:37.2	228.2	232.1	228.94
34:37.2	227.88	231.74	228.7
35:37.2	228.88	232.5	229.02
36:37.2	228.86	232.38	229.36
37:37.2	228.82	232.4	229.34
38:37.2	228.76	232.32	228.98
39:37.2	228.56	231.78	228.92
40:37.2	228.38	231.72	228.78
41:37.2	228.06	231.7	228.82
42:37.2	228.44	231.9	228.86
43:37.2	228.48	231.88	229.28
44:37.2	228.74	232.2	229.3
45:37.2	228.92	232.28	229.2
46:37.2	229.2	232.74	228.94
47:37.2	229.52	233.1	230.18
48:37.2	230.3	233.98	230.56
49:37.2	229.3	233.14	229.44
50:37.2	229.9	234.1	230.62
51:37.2	230.64	234.66	230.86
52:37.2	228.7	232.34	229.02
53:37.2	229.3	232.92	229.8
54:37.2	229.7	233.42	229.92
55:37.2	228.86	232.8	229
56:37.2	228.3	232.14	229.18
57:37.2	228.32	232.4	228.82

Appendix - 3 Contd.

POWER ROOM MEASUREMENTS

Vrms ph-n NG Avg	Vrms ph-ph AB Avg	Vrms ph-ph BC Avg	Vrms ph-ph CA Avg
0.14	401.44	401.76	396.38
0.14	400.18	401.14	395.32
0.14	398.32	401.26	394.62
0.14	400.04	400.9	395.46
0.14	400.36	400.1	395.28
0.14	400.76	400.66	395.48
0.14	399.74	400.76	394.6
0.14	399.18	400.68	393.9
0.14	398.62	400.22	393.36
0.14	400.36	401	394.48
0.14	400.04	401.22	394.92
0.16	400.14	401.12	394.8
0.16	400.22	400.7	394.3
0.16	399.42	400.12	394.26
0.16	399.16	400	394
0.16	398.74	400.24	393.68
0.16	399.36	400.32	394.02
0.16	399.04	400.84	394.62
0.16	399.7	401.1	394.72
0.14	400.12	401.04	394.64
0.16	401.18	401.08	394.34
0.16	401.3	402.7	395.96
0.14	402.88	403.74	396.88
0.16	401.4	402.06	394.94
0.14	402.48	404.18	396.44
0.14	403.94	404.66	397.16
0.16	400.04	401.04	394.1
0.16	400.92	402.12	395.56
0.16	401.88	402.6	395.92
0.16	400.6	401.44	394.2
0.16	399.18	401.14	394.14
0.16	399.68	400.98	393.64

Appendix - 3 Contd.

POWER ROOM MEASUREMENTS

Current A Avg	Current B Avg	Current C Avg	Current N Avg
287.6	292.2	294.9	24.5
292.2	298.5	298.6	24.2
290.8	297.7	297	27.2
285.7	296.8	291.4	24.7
292	296.5	295.5	27.7
288	286.6	295.7	32.2
288.8	281.5	295.1	32
304	295.5	299.7	31.2
317.2	318.8	321	28.3
307.6	301.4	312.4	31.9
303.3	295.7	310.5	31.3
314.6	316.4	317.2	28.5
319.6	320.5	322.3	28.6
323.9	330.3	327.5	28.1
338	334.6	339.9	32.9
336.6	333.5	339	32.6
338.9	336.4	343.7	38
336.1	324.9	344.2	41.8
327.9	319.3	340	41.4
322.7	321.6	343.5	43.7
327.8	333	344.5	41.3
288.2	291.4	303.1	38.5
271.1	259.4	278.8	36.9
321.7	308.4	328.7	39
256	237.1	265.5	36.8
259.4	249.1	267.7	34.4
346.6	337.9	357.3	41.8
317.7	299.7	318	37
316.9	295.4	315.1	37.9
369.1	342.9	372.8	46.4
373.9	356.6	378	42.1
391.6	370.6	390.9	43.5

Appendix - 3 Contd.

POWER ROOM MEASUREMENTS

THD V AN Avg	THD V BN Avg	THD V CN Avg	THD V NG Avg
1.6	1.69	1.66	173.34
1.55	1.66	1.65	159.94
1.67	1.7	1.66	157.46
1.69	1.65	1.66	150.91
1.68	1.64	1.63	170.35
1.68	1.68	1.61	237.83
1.67	1.7	1.6	224.92
1.67	1.7	1.61	159.53
1.71	1.7	1.63	129.04
1.67	1.7	1.66	159.2
1.72	1.81	1.83	161.46
1.76	1.85	1.86	125.23
1.74	1.84	1.83	134.06
1.74	1.77	1.81	130.02
1.75	1.8	1.8	126.2
1.83	1.9	1.89	119.26
1.8	1.89	1.91	135.32
1.79	1.92	1.94	167.58
1.81	1.9	1.93	171.01
1.9	1.91	1.92	201.4
1.82	1.88	1.88	161.6
1.78	1.82	1.82	160.34
1.73	1.84	1.81	208.54
1.72	1.84	1.81	181.09
1.7	1.78	1.73	327.67
1.66	1.77	1.72	229.87
1.75	1.87	1.84	187.83
1.72	1.83	1.8	159.63
1.72	1.87	1.84	151.23
1.79	1.98	1.92	199.34
1.81	1.97	1.95	158.53
1.76	1.94	1.91	141.41

Appendix - 3 Contd.
POWER ROOM MEASUREMENTS

THD A A Avg	THD A B Avg	THD A C Avg	THD A N Avg
3.48	3.45	3.94	327.67
3.33	3.29	3.91	327.67
4.1	3.34	4.14	327.67
4.25	3.21	4.14	327.67
4.2	3.41	4	208.45
4.29	3.76	3.89	131.1
4.15	3.75	3.92	131.63
4	3.5	3.87	150.54
3.91	3.02	3.83	327.67
4.03	3.23	4	136.62
4.11	3.78	4.95	327.67
3.96	3.52	4.9	327.67
4.03	3.57	4.63	327.67
3.9	3.28	4.36	327.67
4.13	3.74	4.66	327.67
4.2	3.7	4.75	327.67
4.63	3.91	5.07	327.67
4.73	4.45	5.1	191.98
4.71	4.53	5.2	183.57
4.91	4.49	5.05	155.27
4.96	4.17	5	188.63
5.25	4.38	5.1	175.65
5.25	4.81	5.14	167.74
4.64	4.42	4.69	172.47
4.96	5.27	4.75	140.55
4.87	4.84	4.55	151.16
4.47	4.3	4.27	141.48
4.63	4.43	4.62	327.67
4.59	4.31	4.63	327.67
4.15	4.3	4.37	122.36
4.09	3.9	4.34	162.43
3.89	3.81	4.22	158.35

Appendix - 4

GENERATOR MEASUREMENTS

Time	Vrms ph-n AN Avg	Vrms ph-n BN Avg	Vrms ph-n CN Avg
26:37.2	229.82	232.82	229.94
27:37.2	229.04	232.3	229.54
28:37.2	228.04	231.8	229.64
29:37.2	229.1	232.12	229.52
30:37.2	229.32	232	229.04
31:37.2	229.5	232.34	229.2
32:37.2	228.72	232.18	229.1
33:37.2	228.2	232.1	228.94
34:37.2	227.88	231.74	228.7
35:37.2	228.88	232.5	229.02
36:37.2	228.86	232.38	229.36
37:37.2	228.82	232.4	229.34
38:37.2	228.76	232.32	228.98
39:37.2	228.56	231.78	228.92
40:37.2	228.38	231.72	228.78
41:37.2	228.06	231.7	228.82
42:37.2	228.44	231.9	228.86
43:37.2	228.48	231.88	229.28
44:37.2	228.74	232.2	229.3
45:37.2	228.92	232.28	229.2
46:37.2	229.2	232.74	228.94
47:37.2	229.52	233.1	230.18
48:37.2	230.3	233.98	230.56
49:37.2	229.3	233.14	229.44
50:37.2	229.9	234.1	230.62
51:37.2	230.64	234.66	230.86
52:37.2	228.7	232.34	229.02
53:37.2	229.3	232.92	229.8
54:37.2	229.7	233.42	229.92
55:37.2	228.86	232.8	229
56:37.2	228.3	232.14	229.18
57:37.2	228.32	232.4	228.82

Appendix - 4 Contd.

GENERATOR MEASUREMENTS

Vrms ph-n NG Avg	Vrms ph-ph AB Avg	Vrms ph-ph BC Avg	Vrms ph-ph CA Avg
0.14	401.44	401.76	396.38
0.14	400.18	401.14	395.32
0.14	398.32	401.26	394.62
0.14	400.04	400.9	395.46
0.14	400.36	400.1	395.28
0.14	400.76	400.66	395.48
0.14	399.74	400.76	394.6
0.14	399.18	400.68	393.9
0.14	398.62	400.22	393.36
0.14	400.36	401	394.48
0.14	400.04	401.22	394.92
0.16	400.14	401.12	394.8
0.16	400.22	400.7	394.3
0.16	399.42	400.12	394.26
0.16	399.16	400	394
0.16	398.74	400.24	393.68
0.16	399.36	400.32	394.02
0.16	399.04	400.84	394.62
0.16	399.7	401.1	394.72
0.14	400.12	401.04	394.64
0.16	401.18	401.08	394.34
0.16	401.3	402.7	395.96
0.14	402.88	403.74	396.88
0.16	401.4	402.06	394.94
0.14	402.48	404.18	396.44
0.14	403.94	404.66	397.16
0.16	400.04	401.04	394.1
0.16	400.92	402.12	395.56
0.16	401.88	402.6	395.92
0.16	400.6	401.44	394.2
0.16	399.18	401.14	394.14
0.16	399.68	400.98	393.64

Appendix - 4 Contd.

GENERATOR MEASUREMENTS

Current A Avg	Current B Avg	Current C Avg	Current N Avg
287.6	292.2	294.9	24.5
292.2	298.5	298.6	24.2
290.8	297.7	297	27.2
285.7	296.8	291.4	24.7
292	296.5	295.5	27.7
288	286.6	295.7	32.2
288.8	281.5	295.1	32
304	295.5	299.7	31.2
317.2	318.8	321	28.3
307.6	301.4	312.4	31.9
303.3	295.7	310.5	31.3
314.6	316.4	317.2	28.5
319.6	320.5	322.3	28.6
323.9	330.3	327.5	28.1
338	334.6	339.9	32.9
336.6	333.5	339	32.6
338.9	336.4	343.7	38
336.1	324.9	344.2	41.8
327.9	319.3	340	41.4
322.7	321.6	343.5	43.7
327.8	333	344.5	41.3
288.2	291.4	303.1	38.5
271.1	259.4	278.8	36.9
321.7	308.4	328.7	39
256	237.1	265.5	36.8
259.4	249.1	267.7	34.4
346.6	337.9	357.3	41.8
317.7	299.7	318	37
316.9	295.4	315.1	37.9
369.1	342.9	372.8	46.4
373.9	356.6	378	42.1
391.6	370.6	390.9	43.5

Appendix - 4 Contd.

GENERATOR MEASUREMENTS

THD V AN Avg	THD V BN Avg	THD V CN Avg	THD V NG Avg
1.6	1.69	1.66	173.34
1.55	1.66	1.65	159.94
1.67	1.7	1.66	157.46
1.69	1.65	1.66	150.91
1.68	1.64	1.63	170.35
1.68	1.68	1.61	237.83
1.67	1.7	1.6	224.92
1.67	1.7	1.61	159.53
1.71	1.7	1.63	129.04
1.67	1.7	1.66	159.2
1.72	1.81	1.83	161.46
1.76	1.85	1.86	125.23
1.74	1.84	1.83	134.06
1.74	1.77	1.81	130.02
1.75	1.8	1.8	126.2
1.83	1.9	1.89	119.26
1.8	1.89	1.91	135.32
1.79	1.92	1.94	167.58
1.81	1.9	1.93	171.01
1.9	1.91	1.92	201.4
1.82	1.88	1.88	161.6
1.78	1.82	1.82	160.34
1.73	1.84	1.81	208.54
1.72	1.84	1.81	181.09
1.7	1.78	1.73	327.67
1.66	1.77	1.72	229.87
1.75	1.87	1.84	187.83
1.72	1.83	1.8	159.63
1.72	1.87	1.84	151.23
1.79	1.98	1.92	199.34
1.81	1.97	1.95	158.53
1.76	1.94	1.91	141.41

Appendix - 4 Contd.

GENERATOR MEASUREMENTS

THD A A Avg	THD A B Avg	THD A C Avg	THD A N Avg
3.48	3.45	3.94	327.67
3.33	3.29	3.91	327.67
4.1	3.34	4.14	327.67
4.25	3.21	4.14	327.67
4.2	3.41	4	208.45
4.29	3.76	3.89	131.1
4.15	3.75	3.92	131.63
4	3.5	3.87	150.54
3.91	3.02	3.83	327.67
4.03	3.23	4	136.62
4.11	3.78	4.95	327.67
3.96	3.52	4.9	327.67
4.03	3.57	4.63	327.67
3.9	3.28	4.36	327.67
4.13	3.74	4.66	327.67
4.2	3.7	4.75	327.67
4.63	3.91	5.07	327.67
4.73	4.45	5.1	191.98
4.71	4.53	5.2	183.57
4.91	4.49	5.05	155.27
4.96	4.17	5	188.63
5.25	4.38	5.1	175.65
5.25	4.81	5.14	167.74
4.64	4.42	4.69	172.47
4.96	5.27	4.75	140.55
4.87	4.84	4.55	151.16
4.47	4.3	4.27	141.48
4.63	4.43	4.62	327.67
4.59	4.31	4.63	327.67
4.15	4.3	4.37	122.36
4.09	3.9	4.34	162.43
3.89	3.81	4.22	158.35