MSEAUREMENT OF HARMONICS IN POWER SYSTEM USING LabVIEW BASED VIRTUAL INSTRUMENT

A MAJOR PROJECT
Submitted in partial fulfillment of the requirements for
the award of degree of
MASTER OF ENGINEERING
(CONTROL & INSTRUMENTATION)

Submitted By

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Session 2009-11

CERTIFICATE

This is to certify that the thesis entitled "**MEASUREMENT OF HARMONICS IN POWER SYSTEM USING LabVIEW BASED VIRTUAL INSTRUMENT",** by Santosh Kumar, (University Roll No. 9027, College Roll No. 10/C&I/09) in partial fulfillment of the requirements for the award of the degree of Master of Engineering in Control and Instrumentation Engineering, Delhi College of Engineering, Delhi-42, is an authentic. The work is being carried out by him under our guidance and supervision in the academic year 2010-2011. This is to our knowledge has reached requisite standards.

I do hereby state that, I have not submitted the matter embodied in this project for the award of any degree.

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SANTOSH KUMAR

This is to certify that the above statements made by Santosh Kumar are correct to the best of my knowledge.

S.K VALLURU
ASST.PROF. [EED]

ACKNOWLEDGEMENT

It is a matter of great pleasure for me to have opportunity to extent my heartiest gratitude to everybody who helped me throughout this project.

First and foremost, I am profoundly grateful to my project guide S.K VALLURU, Assistant Professor of Electrical Engineering Department and for his expert guidance and continuous encouragement during all stages of this project. I feel lucky to get an opportunity to work with him. I am thankful to the kindness and generosity shown by him towards me, as it helped me morally to complete the project.

I would like to thanks Prof. **NARENDRA KUMAR**, Head, Department of Electrical Engineering, for providing facilities for this project.

I am grateful to my parents and family for their moral support all the time; they have been always around to cheer me up, in the odd times of this work. I am also thankful to my friends and classmates for their unconditional support and motivation during this work.

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ABSTRACT

With the extensive use of non-linear devices in the electric power systems, it has become an important engineering practice to develop a model for harmonic measurement and analysis in order to find the right conditions to design and operate power apparatuses that can reliably operate in harmonics environment..A system can still function satisfactorily in the presence of limited amount of harmonics. However, the increasing use of non-linear loads in industry is keeping harmonic distortion on the rise. The rising harmonic distortion in electric power system can result in communication interference, overheating of power apparatus and the malfunction of solid-state devices.

Harmonic measurements in electric power systems are essential to achieve three objectives. Firstly, for the identification of the sources and characteristics (magnitude, frequency and location) of the harmonics. Secondly, for the design of a filtering system to reduce the harmonic impacts to the electric power system. Thirdly, to ensure that total harmonic distortion after compensation is in compliance with the regulatory requirements such, as IEEE standards.

In the present thesis, graphical programming of LabVIEW software has been utilized to develop a universal virtual harmonic analyzer to detect the harmonic components of a power wave and also to calculate its total harmonic distortion (THD).The power spectrum plots help us to visualize the percent of total power being carried by different harmonic levels. Thus, we can have the picture of the amount of energy being utilized by power waves.

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$$VTHD = \frac{\sqrt{\sum_{h\neq 1} V_h^2}}{V_1} \qquad ..eq\ (4.1)$$

$$ITHD = \frac{\sqrt{\sum_{h\neq 1} I_h^2}}{I_1} \qquad ..eq\ (4.2)$$

$$VTHD_{H-A} = \frac{\sqrt{\sum_{h\neq 1} (C_h V_h)^2}}{V_1} \qquad ...eq\ (4.3)$$

$$ITHD_{H-A} = \frac{\sqrt{\sum_{h\neq 1} (D_h I_h)^2}}{I_1} \qquad ...eq\ (4.4)$$

$$V_{eH}^2 = \sum_{h\neq 1} \frac{V_{ah}^2 + V_{bh}^2 + V_{ch}^2}{3} \qquad ...eq\ (4.5)$$

$$I_{eH}^2 = \sum_{h\neq 1} \frac{I_{ah}^2 + I_{bh}^2 + I_{ch}^2}{3} \qquad ...eq\ (4.6)$$

$$V_{eH-A}^2 = \sum_{h\neq 1} C_h^2 \frac{V_{ah}^2 + V_{bh}^2 + V_{ch}^2}{3} \qquad ...eq\ (4.7)$$

$$I_{eH-A}^2 = \sum_{h\neq 1} D_h^2 \frac{I_{ah}^2 + I_{bh}^2 + I_{ch}^2}{3} \qquad ...eq(4.8)$$

$$QA_1 = VTHD = \frac{V_{e\text{-}HA}}{V_{e\text{-}1}} \quad \text{...eq (4.9)}$$

$$QA_2 = ITHD = \frac{I_{e\text{-}HA}}{I_{e\text{-}1}} \quad \text{...eq (4.10)}$$

$$V_{e\text{-}1}^2 = \sum_{h \neq 1} \frac{V_{a1}^2 + V_{b1}^2 + V_{c1}^2}{3} \quad \text{....eq(4.10)}$$

$$I_{e\text{-}1}^2 = \sum_{h \neq 1} \frac{I_{a1}^2 + I_{b1}^2 + I_{c1}^2}{3} \quad \text{...eq(4.11)}$$

ABBREVIATIONS

THD   TOTAL HARMONIC DISTORTION

ITHD   TOTAL CURRENT HARMONIC DISTORTION

VTHD   TOTAL VOLTAGE HARMONIC DISTORTION

LabVIEW   LABORATORY VIRTUAL INSTRUMENT
               ENGINEERING WORKBENCH

FFT   FAST FOURIER TRANSFORM

SMPS   SWITCHED MODE POWER SUPPLY

QA   QUALITY ASPECTS

VI   VIRTUAL INSTRUMENT

CHAPTER 1

1. INTRODUCTION

1.1 INTRODUCTION

Rapid growth in the industrial and domestic   loads and the usage of various electrical and electronic equipment have been witnessed during the recent past .With the surge of the total number and capacity of the nonlinear components, the electrical harmonic pollution is becoming more and more serious and has been a great threat to the safety of electric power systems and the national economy as a whole.

Treatment of harmonics in power systems is thus a major concern of power system administrators as well as for engineers. In this task, the measurement of harmonics in power networks, as the basic data provider for harmonic analysis and control, is one of the issues of fundamental importance.

At this modern industrial world 90% of the Electrical supply is flown through Power a electronic converter (nonlinear loads) that produces harmonics, which are disturbing the other equipments connected in the same supply. Hence it is necessary to measure the harmonic components to estimate their effect. The separation of various frequency components with respect to the fundamental frequency is carried out to calculate the Total Harmonic Distortion (THD) which is useful to design suitable filters to remove the harmonics in the power signal.

This thesis proposes a novel method to analyze the harmonic contents in a sinusoidal signal. The proposed method is carried out using 'Virtual Instrumentation' concept with the help of Lab VIEW.
.
Traditional methods of measuring power system harmonics employ power harmonic analyzers through Mat lab. However, these methods usually do not have powerful graphical programming capabilities and network functions for remote monitoring and control. **This** thesis presents a novel approach using a virtual instrument (VI) system with data transfer ability to perform power system harmonic measurement based on the interpolating windowed Fast Fourier transform (FFT).. The virtual instrument system is designed and implemented in LabVIEW environment. Harmonic parameters of three-phase voltage and current signals, such as the total harmonic distortion (THD) and the distortions of the 1st to 9th harmonics can be measured and results predicts the accuracy and the performance of the system.

As saving of electrical energy is the main target of industrial consumer and also utility, the use of energy efficient equipment increases rapidly. The modern industrial system utilizes variable speed drives through thyristor converters as the control becomes simple, more efficient   and widely available. However, it gives rise to a varied harmonic spectrum on the ac power systems and pollutes the system. In initial period the converter drives were used sparingly for very specialized applications due to non availability of the higher rated components and higher cost components. However due to modern developments the components are easily available, their reliability has improved and cost becomes manageable. Hence the use of these drives grew

rapidly and the utilization increased. Due to large usage of these equipments, the electrical power slowly and slowly started getting corrupted by introducing harmonics in power systems. Though technocrats are generally aware of the harmful effects of the harmonics, the elimination/reduction of these harmonic currents and distortion due to this remain reflected topic as there is no strict mandatory rule and regulations and the industry does not want an additional cost burden which they feel does not give direct cost benefit.

1.2 METHODOLOGY

This thesis deals with analysis and detection of harmonics generated in the electrical power system with the help of a virtual harmonic analyzer build through LabVIEW software. LabVIEW provide a unique way to analyze any wave with the help of its power package known as "DISTORTION ANALYZER". The virtual harmonic analyzer put together this unique feature of LabVIEW. Also, LabVIEW provides for simulating any sort of wave through its graphical programming technique.

1.3 OBJECTIVE OF THIS DISSERTATION

Objective of this dissertation can be enumerated as follows

1) To analyze and study distortion in a pure sine wave due to various harmonic levels.

2) To analyze and compute total harmonic distortion of a power wave due to presence of harmonics.

3) To compare and analyze the percent of total energy being wasted due to presence of harmonics.

1.4 DISSECTION OF DISSERTATION

The material of this dissertation has been organized in six chapters. The contents of each chapter are briefly outlined as below:

Chapter1-discusses the importance of harmonic analysis and enumerates the objective of this thesis.
Chapter2-discusses on literature review.

Chapter3-discusses the features of LabVIEW.

Chapter4-discussses the THD analyzer build with the help of LabVIEW.

Chapter5-discusses the various waves simulated for THD computation.

Chapter6-discusses the result.

1.5 CONCLUSION

This chapter gives brief introduction about importance of harmonic analysis and THD calculation of a power wave. It also presents the outline of the project design.

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CHAPTER 2

2. LITERATURE REVIEW

2 .1 BACKGROUND OF POWER SYSTEM HARMONICS

In ideal situation, the electric power in a network is supplied at a constant system frequency, known as the fundamental frequency, and at specified voltage magnitudes. In a realistic power system, however, the frequency and voltages are deviated from their designated values. The deviation of a wave form its perfect sinusoid is generally expressed in terms of harmonics. Harmonics in a power system deteriorate the quality of electric energy and can result in

    (1) communication interference

    (2) overheating of power apparatus

    (3) the malfunction of control devices .

There are two general categories of harmonic sources: (a) saturable devices and (b) power electronic devices. Saturable devices produce harmonics due mainly to iron saturation, as is the case for transformers, rotating machines, and fluorescent lightings (with magnetic ballasts). Power electronic loads draw power only during portions of the applied voltage waveform. Thus, the current drawn by the load is no longer sinusoidal and appears chopped or flattened. The non-sinusoidal current can interact with system impedance to give rise to voltage distortion
and, in some cases, resonance. These power electronics loads include switch-mode power supplies, fluorescent lightings (with electronic ballasts), voltage source converters and equipments with non-linear components. Today, harmonics induced by non-linear power electronic loads present inefficient operations of local and global power supply systems. Harmonics have a number of effects on power system components and loads. Power system problems such as communication interference, heating, and solid-state device malfunctions can be the direct result of harmonics. These problems are categorized and listed below.

    a)   communication interference;

    b)   excessive losses and heating in motors, capacitors, and transformers;

    c) degraded meter accuracy;

    d) blown capacitor fuses and failed capacitor;

     e) solid-state device malfunctions

2.2 WHY HARMONIC ANALYSIS

When a voltage and/or current waveform is distorted, it causes abnormal operating conditions in a power system such as-

● Voltage Harmonics with high peak values can weaken insulation in cables, windings, and capacitors.

● Voltage Harmonics can cause malfunction of different electronic components and circuits that utilize the voltage waveform for synchronization or timing.

● Current Harmonics in motor windings can create Electromagnetic Interference (EMI).

● Current Harmonics flowing through cables can cause higher heating over and above the heating that is created from the fundamental component.

● Current Harmonics flowing through a transformer can cause higher heating over and above the heating that is created by the fundamental component.

● Current Harmonics flowing through circuit breakers and switch-gear can increase their heating losses.

● RESONANT CURRENTS which are created by current harmonics and the different filtering topologies of the power system can cause capacitor failures and/or fuse failures in the capacitor or other electrical equipment.

● False tripping of circuit breakers and protective relays.

2.3 LITERATURE SURVEY ON HARMONIC MEASUREMENT BASED ON LabVIEW

L .L .Lai and W . L. Chan [1] designed a new proposal on real-time frequency and harmonic evaluation using Artificial neural networks and the concept of FFT.A neuron model based on FFT technique was developed to evaluate frequency and harmonics.

H.C .Lin [2] proposed an alternative technique to measure line current harmonics with high accuracy, efficiency and simplicity through graphical interface. The successful operation of remote measurement and monitoring for power system harmonics via the internet explorer was also proposed.

Hsiung Cheng Lin [3] proposes an alternative technique to measure line currents using human graphical interface as well as remote harmonic analysis and web viewing. The proposed system was constructed by the microprocessor Intel (8051) and LabVIEW package.

Wang Zhen and Li Yi Hua [4] proposed a new measuring method of harmonics based on wavelet neural network. According to knowledge of wavelet transform and self-learning function of neural network, wavelet neural network is constructed by non-linear sigmoid functions. It has stronger capacity of approximation. The measuring method proposed has been simulated by programs, simulation results were obtained for feasibility and validity.

Robert G. Ellis [5] proposed a technique to analyze harmonics in industrial application based on LabVIEW and graphical programming. The paper also developed a virtual harmonic analyzer using the packages provided in LabVIEW.

IEEE Working Group on POWER System Harmonics [6] develops a new virtual instrument for harmonic measurement and power wave analysis. The virtual instrument is designed with the help of LabVIEW software. Also THD calculator is designed using the concept of block diagram facility given in LabVIEW.

Phang Yoke Yin and M.V . Chilukuri [7] developed a computer based data acquisition system that provides real time monitoring of voltage and current. Any power quality disturbances sustained by the user throughout the monitoring period were detected and recorded on remote PC and was analyzed using LabVIEW programming

2.4CONCLUSION

A brief literature review on harmonic measurement and analysis using LabVIEW has been presented in this chapter with some highlights on importance and need of harmonics measurement and analysis.

CHAPTER 3

3. BRIEF DESCRIPTION OF LabVIEW

3.1 INTRODUCTION

LabVIEW is an integral part of virtual instrumentation as it provides an easy way to use application development environment specifically with the need of engineers and scientists. It is a graphical programming language for developing diverse applications in a multitude of industries. The block diagram provides a unique form of source code to most programming languages.Labview extends this innovation to the user providing tremendous freedom of expression and creativity.

3.2 VIRTUAL INSTRUMENTATION

Virtual instrumentation sets a new standard in measurement by replacing bench top instruments. It uses software like NI LabVIEW and hardware like PCI modules for data acquisition, instrument control and automation. VIs constructed with software are inexpensive, more accurate, maintenance free, can sense different physical quantities offering any range, compared to physical instruments. VIs works fast, handles repetitive tasks, processes data, stores results, generates reports, increases test safety and is controllable by the user. It saves time, money and increases productivity; customizability e.g. same code can be re-used for testing similar instruments. For any lab instead of buying individual instruments, VI can be employed in a computer for all measurements.

Virtual Instruments versus Traditional Instruments

Traditional instruments: Vendor defined, Function-specific; stand-alone with limited connectivity. Hardware is the key, Expensive, Closed, fixed functionality, slow turn on technology (5–10 year life Minimal economics of scale).

Virtual Instruments: User-defined, Application-oriented system with connectivity to networks, peripherals, and applications. Software is the key, low cost, reusable, Open, flexible functionality leveraging off familiar computer technology (Maximum economics of scale). Software minimizes development and maintenance costs.

3.2.1 PROGRAMMING TECHNIQUES

LabVIEW programs are called virtual instruments or VIs, because their appearance and operation imitate physical instruments, such as oscilloscopes and millimeters. LabVIEW VIs contain three components: the front panel window, the block diagram, and the icon/connector pane.

Front panel Window

The Front panel window is the user interface for the VI. Fig.3.2 shows example of a front panel window. We create the front panel window with controls and indicators, which are the interactive input and output terminals of the VI, respectively.
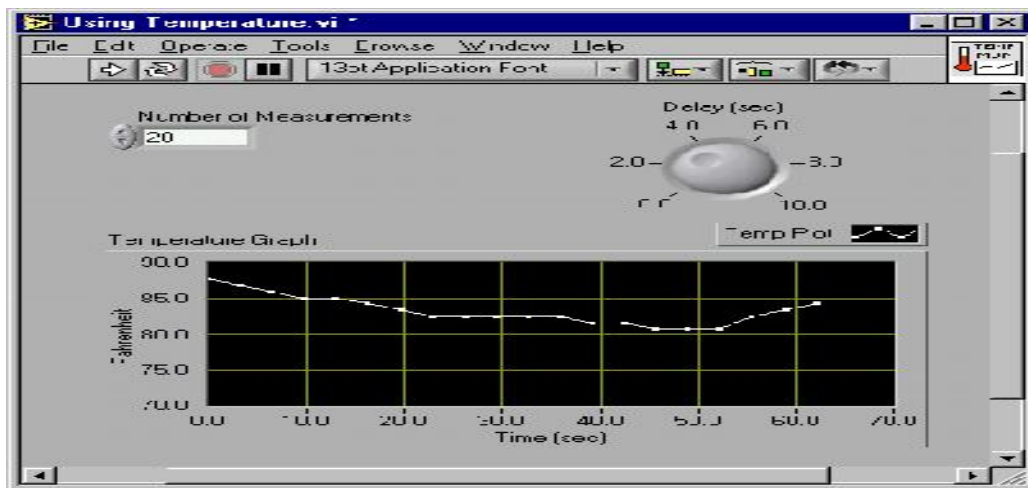
Fig.3.1 VI Front Panel

Block Diagram Window

After creating the Front Panel Window, we add code using graphical representation of functions to control the Front panel objects. Fig.3.3 shows an example of a block diagram window contains this graphical source code. Front panel objects appear as terminals on the block diagram.
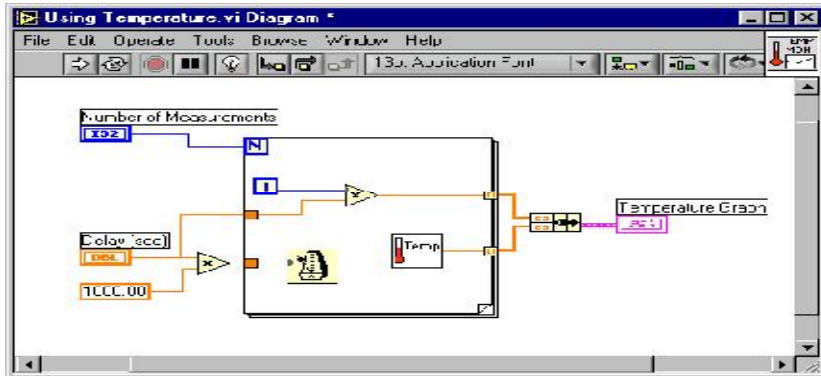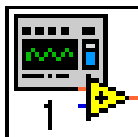
Fig. 3.2 VI Block Diagram

Icon and Connector Pane

A VI can be used as a subVI. A subVI is a VI that is used in another VI, similar to a function in a text based programming language. To use VI as a subVI, it must have an icon and connector Pane.

Every VI displays an icon, shown above, in the upper right corner of the front panel and block diagram windows. An icon is a graphical representation of a VI. It can contain text, images, or a combination of both. If we use a VI as a subVI, the icon identifies the subVI on the block diagram of the VI. The default icon contains a number that indicates how many new VIs we have opened since launching LabVIEW. Create custom icons to replace the default icon by right-clicking the icon in the upper right corner of the front panel or block diagram and selecting Edit Icon from the shortcut menu or by double-clicking the icon in the upper right corner of the front panel. We also can edit icons by selecting File»VI Properties, selecting General from the Category pull-down menu, and clicking the Edit Icon button. Use the tools on the left side of the Icon Editor Dialog box to create the icon design in the editing area. The normal size image of the icon appears in the appropriate box to the right of the editing area, as shown in the following dialog box in Fig.3.3.
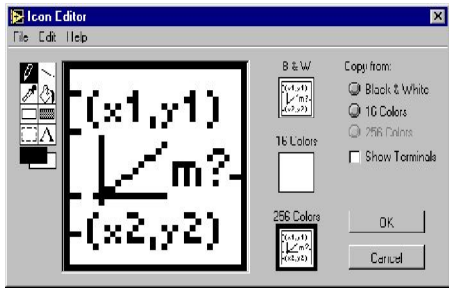
Fig. 3.3 Icon Editor

Use the options on the right side of the editing area to perform the following tasks:

• Show Terminals—Displays the terminal pattern of the connector pane.

• OK—Saves the drawing as the icon and returns to the front panel.

• Cancel—Returns to the front panel without saving any changes.

The menu bar in the Icon Editor dialog box contains more editing options such as Undo, Redo, Cut, Copy, Paste, and Clear.

To use a VI as a subVI, we need to build a connector pane, shown at left. The connector pane is a set of terminals that corresponds to the controls and indicators of that VI, similar to the parameter list of a function call in text-based programming languages. The connector pane defines the inputs and outputs we can wire to the VI so we can use it as a subVI. Define connections by assigning a front panel control or indicator to each of the connector pane terminals. To define a connector pane, right-click the icon in the upper right corner of the front panel window as shown in the Fig. 3.4 and select Connector from the shortcut menu. The connector pane replaces the icon. Each rectangle on the connector pane represents a terminal. Use the rectangles to assign inputs and outputs. The number of terminals LabVIEW displays on the connector pane depends on the number of controls and indicators on the front panel. The following front panel has four controls and one indicator, so LabVIEW displays four input terminals and one output terminal on the connector pane. We cannot access the connector pane from the icon in the block diagram window.
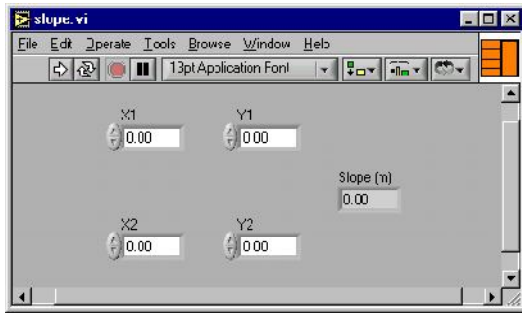
Fig. 3.4 shows icon/connector pane on top right side (orange color box)

Palettes

LabVIEW has graphical, floating palettes to help you create and run VIs. The three palettes include the Tools, Controls, and Functions palettes. We can place these palettes anywhere on the screen.

Tools Palette

We can create, modify, and debug VIs using the tools located on the floating Tools palette. The Tools palette is available on the front panel and the block diagram. A tool is a special operating mode of the mouse cursor. When we select a tool, the cursor icon by itself changes to the tool icon. Use the tools to operate and modify front panel and block diagram objects. Next select Window»Show Tools Palette to display the Tools palette as shown in Fig.3.5. We can place the Tools palette anywhere on the screen. Press the <Shift> key and right-click to display a temporary version of the Tools palette at the location of the cursor.

Fig 3.5 Tools palette

Use the Operating tool to change the values of a control or select the text within a control.

Use the Positioning tool to select, move, or resize objects

Use the Wiring tool to wire objects together on the block diagram.

Control and Function Palettes

The Controls and Functions contain sub-palettes of objects to create a VI. When click on sub-palette icon, the entire palette changes to the selected sub-palette. To use an object on the palettes, click the object and place it on the front panel or block diagram.

Controls Palette

Use the Controls palette to place controls and indicators on the front panel. The Controls palette is available only on the front panel. From there select Window»Show Controls Palette or right-click on the front panel workspace in order to display the Controls palette as shown in Fig.3.6. We also can display the Controls palette by right-clicking an open area on the front panel. Tack down the Controls palette by clicking the pushpin on the top left corner of the palette.

Fig 3.6 Control Palette

Functions Palette

Use the Functions palette to build the block diagram. The Functions palette is available only on the block diagram. Select Window»Show Functions Palette or right-click the block diagram workspace to display the Functions palette as shown in Fig.3.7. You also can display the Functions palette by right-clicking an open area on the block diagram. Tack down the Functions palette by clicking the pushpin on the top left corner of the palette.

Fig 3.7 Function palette

3.2.2 Starting a VI

When we launch LabVIEW, the following dialog box appears as shown in Fig.3.8.
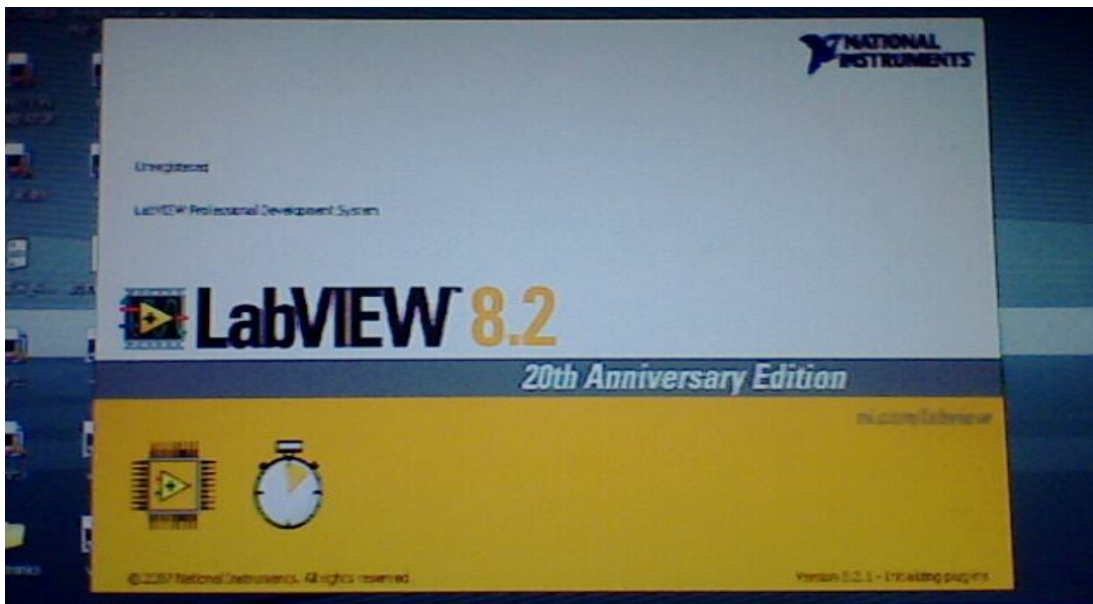

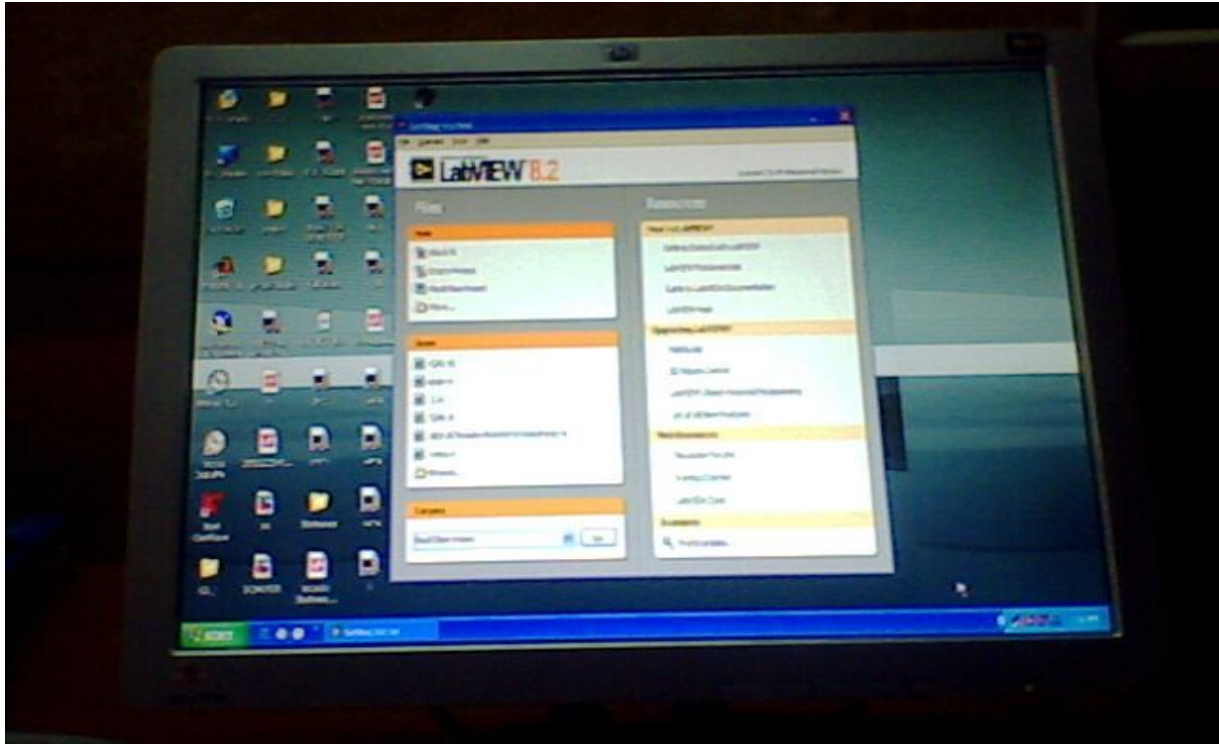Fig 3.8 start window that appears when LabVIEW is launched

Fig 3.9 Dialog box for Getting Started of LabVIEW

The LabVIEW dialog box includes the following components:

• Click the New VI button to create a new VI.

• Click the Open VI button to open an existing VI.

• Click the DAQ Solutions button to launch the DAQ Solution Wizard, which helps we find solutions for common DAQ applications.

• Click the Search Examples button to open a help file that lists and links to all available

LabVIEW example VIs

• Click the LabVIEW Tutorial button to open the interactive LabVIEW Tutorial. Use this tutorial to learn basic LabVIEW concepts.

3.2.3 Troubleshooting and Debugging VIs

Use the Context Help window and the LabVIEW Help to help you build and edit VIs.

Context Help Window

To display the Context Help window, select Help » Show Context Help or press the <Ctrl-H>key. When we move the cursor over front panel and block diagram objects, the Context Help window displays the icon for sub VIs, functions, constants, controls and indicators, with wires attached to each terminal. When we move the cursor over dialog box options, the Context Help window displays descriptions of those options. In the window, required connections are bold, recommended connections are plain text, and optional connections are dimmed or do not appear. The following is an example Context Help window as shown in Fig.3.10.
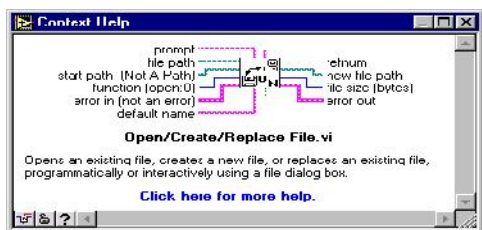

Fig. 3.10 shows Context Help

Click the More Help button to display the corresponding topic in the LabVIEW Help, which describes the object in detail.

3. 3 Advantages of VI:

Long before people used typewriters, which were then replaced by the word processors that offered new levels of productivity and flexibility. Much as the same way, VIs will replace the physical instruments.

The picture on the top is that of a real instrument and the one on the bottom is that of a virtual one. Today's computer's graphic capabilities even make VIs look like real instruments. Virtual instruments are better connected to PC technologies widely used in industries. With VI, users can move applications seamlessly between several bus architectures, such as PC Card, plug-in DA

hardware, and VXI. This portability offers the flexibility to take advantage of improved bus standards as they arise.

Customizability VIs are fully customizable. Range, accuracy, amount of information provided by them can be selected by users. Data can be saved in computer and send it over the internet. They can be made to sense any physical quantity offering any range with the use of corresponding sensors. A VI can be made to control any other instruments including another VI.

Increases productivity VIs are less expensive and maintenance free. They work very fast, handle repetitive tasks, process data, store results and also generate reports. Reuse of code is also possible. Thus the same code can be used for testing similar instruments which saves time and money. Doing things in less time would definitely mean being able to do more. With less time, money and human labour for the same product, the productivity increases rapidly.

Lowers cost for customers Physical instruments are not suited for extreme weathers, but VIs can work in any hazardous environments. When a new product is tested using expensive test equipments, it naturally raises the overhead cost. Employing VI there reduces the testing cost. They also increase the test safety. They do not get damaged and thus no need of replacements. This lessens the price of the final product for customers.

User friendliness The software used for VI is user friendly. In LabVIEW, new users can step through the dialogue boxes and quickly build a fully functioning DA application. LabVIEW will help define signal types, connections, and transducer equations before building the system. Thus, the learning curve is shortened significantly. More experienced developers can use the DAQ Wizards to prototype a system.

Most VI system contains a microprocessor, a data-acquisition unit or system, an I/O port, a display or a way of reporting the results and an analysis engine. Since most of the hardware is the same, only the front-end of the device needs to be changed to suit the equipment's purpose. With a personal computer, software could do the analysis after acquiring the needed data. Thus, the software could be written as such to specifically answer what is called for by the analysis.

The hardware could be changed according to the design of the experiment, whether it will receive data from an apparatus or control it. Instead of using separate hardware front-ends, software could be written for measuring different quantities. Thus with sensors and appropriate software, any physical quantity can be acquired and measured in VI.

Some other applications of VI are data analysis, systems control, process automation, testing and calibration of instruments, telecommunications, semiconductor manufacturing, automotive testing, robotics, automation, embedded systems, etc.

3.4 CONCLUSION

The future of virtual instrumentation is promising. As such companies as Intel and Microsoft continue to usher in new technologies for advanced productivity and connectivity; virtual instrumentation's benefits will increase. Improvements in PC technology and VI hardware and software will make new applications possible. Companies like National Instruments are promoting VI to make it reach everyone. Quite sooner the traditional instrumentation will be completely moved inside the computer.

CHAPTER 4

4.DESIGN OF VIRTUAL HARMONIC ANALYSER

4.1 INTRODUCTION

The ever growing proliferation of power switching devices for source conditioning and motion control in single-phase and three-phase modern industrial applications has increased the eventuality of unbalanced currents, unacceptable harmonic levels, and poor power factor in three-phase distribution systems. The harmful and costly effects of harmonics have been extensively discussed [8] and spurred stringent requirements by international institutions regarding the allowed levels of harmonics at the point of connection to the power supply [9]–[11]. The unbalanced loading of the three-phase supply has no less detrimental effects, such as the underutilization of the power supply equipment and the overloading of neutral conductors with the fundamental frequency in addition to harmonic currents. Finally, as is well known, a phase displacement between the corresponding voltages and currents indicates both a low utilization of the generation and distribution equipment and increased line losses for the same power consumption level.

4.1.1 Total Current and Voltage Harmonic Distortion

Harmonic distortion is the corruption of the fundamental sine wave at frequencies that are multiples of the fundamental. Power signal waveforms are not clean 50 Hz sine waves. In practice the actual waveforms are distorted one due to presence of harmonics. Harmonics occur at an integral multiple of the base frequency. In 3-phase system odd harmonics excluding tripled frequency are prevalent. Hence 5th, 7th, 9th and even higher order harmonics can be found in the supply waveform. Waveform harmonics are usually caused by equipment which draws non-linear currents. Modern electrical equipment such as computerized equipment and telecommunication equipment often use switching power supplies to "step up" or "step down" the voltage. This introduces a non-sinusoidal load which pulls current in short pulses during every cycle. Other non-linear devices such as digital/electronic components and arching devices like fluorescent lamps can cause abnormal waveforms and serious decreases in power quality. Other loads contributing to this problem are variable speed motor drives, lighting ballasts and large legacy UPS systems. Symptoms of harmonic problems include overheated transformers,

neutral conductors, and other electrical distribution equipment, as well as the tripping of circuit breakers and loss of synchronization on timing circuits that are dependent upon a clean sine wave trigger at the zero crossover point. Harmonic distortion has been a significant problem with IT equipment in the past, due to the nature of switch-mode power supplies (SMPS). Methods used to mitigate this problem have included over-sizing the neutral conductors, installing K-rated transformers, and harmonic filters [9, 10].Harmonics work together in distorting the fundamental waveform. Fig.4.1 shows a sinusoidal signal with harmonic content.

Fig. 4.1: Sinusoidal signal with Harmonic content

The representation of the harmonic current with respect to the fundamental waveform is called total harmonic distortion (THD). There is a THD for both voltage and current. The total harmonic distortion of the voltage and current VTHD and ITHD, respectively, for single-phase (or polyphase balanced) networks have been conventionally defined in the literature as where V And I denotes rms values and 1 and h denote the fundamental and the harmonic order, respectively.

$$VTHD = \frac{\sqrt{\sum_{h \neq 1} V_h^2}}{V_1} \quad ..eq\ (4.1)$$

$$ITHD = \frac{\sqrt{\sum_{h \neq 1} I_h^2}}{I_1} \quad ..eq\ (4.2)$$

To account for the fact that higher-order harmonic currents cause greater losses than lower-order harmonics of the same amplitude, harmonic-adjusted total voltage and current harmonic distortions are, respectively defined as:

$$VTHD_{H-A} = \frac{\sqrt{\sum_{h \neq 1} (C_n V_h)^2}}{V_1} \quad ...eq\ (4.3)$$

$$ITHD_{H-A} = \frac{\sqrt{\sum_{h \neq 1} (D_h I_h)^2}}{I_1} \quad ...eq\ (4.4)$$

Where, C_h and D_h are appropriate weighting factors, greater than one, that monotonically increase with the harmonic order h. Various mathematical expressions, by no means exhaustive,

for these weighting factors as a function of the harmonic order h .An extension of the above concepts to unbalanced polyphase networks . To this end a single "equivalent" harmonic rms voltage VeH and harmonic rms current Ieh for the three-phase system a, b, c are defined as:

$$V_{eH}^2 = \sum_{h \neq 1} \frac{V_{ah}^2 + V_{bh}^2 + V_{ch}^2}{3} \quad ...eq(4.5) \qquad I_{eH}^2 = \sum_{h \neq 1} \frac{I_{ah}^2 + I_{bh}^2 + I_{ch}^2}{3} \quad ...eq (4.6)$$

It is proposed to generalize equations (4.5) and (4.6) and separately weigh individual harmonics similar to (4.3) and (4.4), which yield the adjusted harmonic equivalent values

$$V_{eH-A}^2 = \sum_{h \neq 1} C_h^2 \frac{V_{ah}^2 + V_{bh}^2 + V_{ch}^2}{3} \quad ...eq (4.7) \qquad I_{eH-A}^2 = \sum_{h \neq 1} D_h^2 \frac{I_{ah}^2 + I_{bh}^2 + I_{ch}^2}{3} \quad ...eq(4.8)$$

The first introduced quality aspects QA1 and QA2 are identified with the total harmonic distortions VTHD and ITHD for a three-phase unbalanced system and are defined as:

$$QA_1 = VTHD = \frac{V_{e-HA}}{V_{e-1}} \quad ...eq (4.9) \qquad QA_2 = ITHD = \frac{I_{e-HA}}{I_{e-1}} \quad ...eq (4.10)$$

Where Ve1 and Ie1 denote the fundamental equivalent phase voltage and current defined, similarly to Equation (4.5) & (4.6), from the fundamental components of the generally unbalanced three-phase voltages and currents as:

$$V_{e-1}^2 = \sum_{h \neq 1} \frac{V_{a1}^2 + V_{b1}^2 + V_{c1}^2}{3} \quad ....eq(4.10) \qquad I_{e-1}^2 = \sum_{h \neq 1} \frac{I_{a1}^2 + I_{b1}^2 + I_{c1}^2}{3} \quad ...eq(4.11)$$

Definition of Equations 4.(5-8),4.11 and 4.12 satisfy the particular requirement that the total losses in the equivalent balanced three-phase system be equal to those in the actual system considered. The underlying assumptions are that a) the line and equipment losses for a certain frequency are proportional to either the square of the voltage or the square of the current and b) the line and equipment parameters are symmetrical.

Linear loads have very low values of THD because they have little or no harmonic current. Non-linear loads have large values of THD, and cause considerable distortion to the normal sine wave. Within the IEEE [9], the standard established limits on harmonic currents and voltages at the point of common coupling (PCC) or at the point of metering are 5% THD at the distribution system voltage level. As far as the historical development of the compatibility levels within the IEC [10] standards framework is concerned, the newly published standard allows THD of the voltage to be 11 % for a short period of time, and sets the long-term limit to 8 %. This development shows that the trend is to allow for more distortion in the distribution networks in the future.

4.1.2 Implementation of QA1 and QA2 in LabVIEW:

To implement the above quality aspects i.e. QA1 (VTHD) and QA2 (ITHD) using LabVIEW first we need to simulate voltage and current waveforms hence voltage and current waveforms are simulated keeping in mind the actual distorted waveform due to presence of harmonics which occur at integral multiple of the base frequency. In this project distorted waveform has been simulated by superimposing 5th harmonic on fundamental frequency waveform.

To simulate a signal in LabVIEW, first we need to create new VI (File >> New VI) and then it will show Front Panel from where we should go to block diagram by pressing <ctr-E> or from toolbar (windows>>show Block diagram) from where we should right click anywhere on the block diagram then it will show functions palette i.e. (functions>>Express>>Input>>Simulate Signal) then you will get simulate signal Express VI which is shown below from where we need to configure signal according to our requirement.

Here in this case a balanced three phase non-sinusoidal voltage source was implemented defined by Vphase=220V (rms) and by adding a fifth-order harmonic having an amplitude of 5 % of the fundamental which is as shown below block diagram.
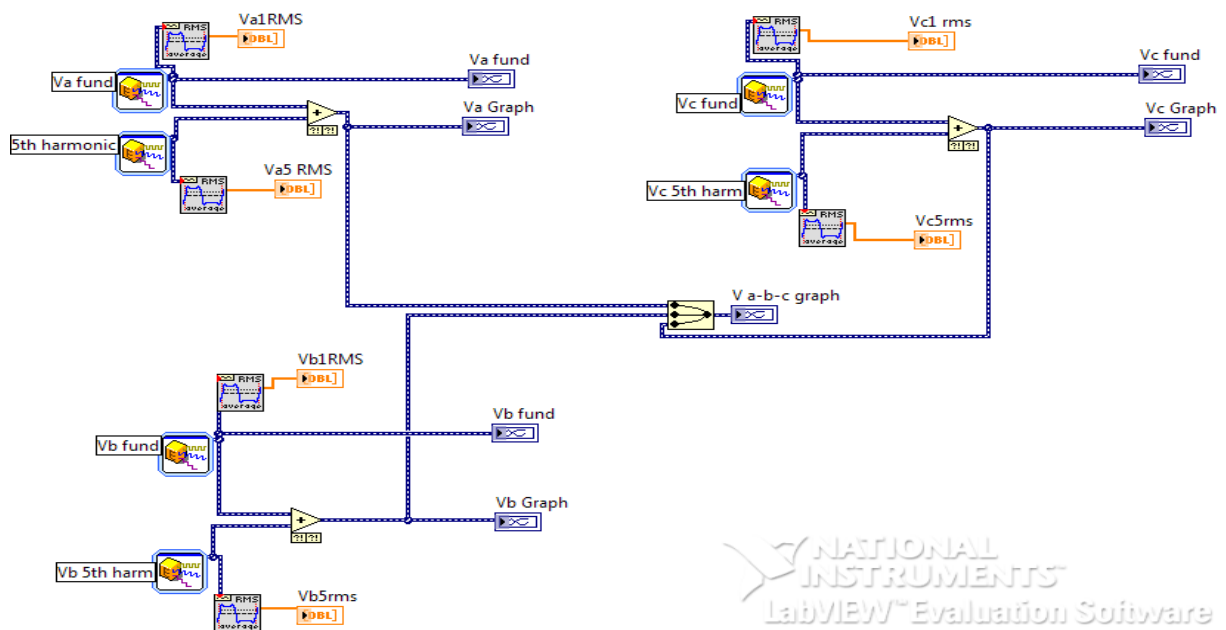
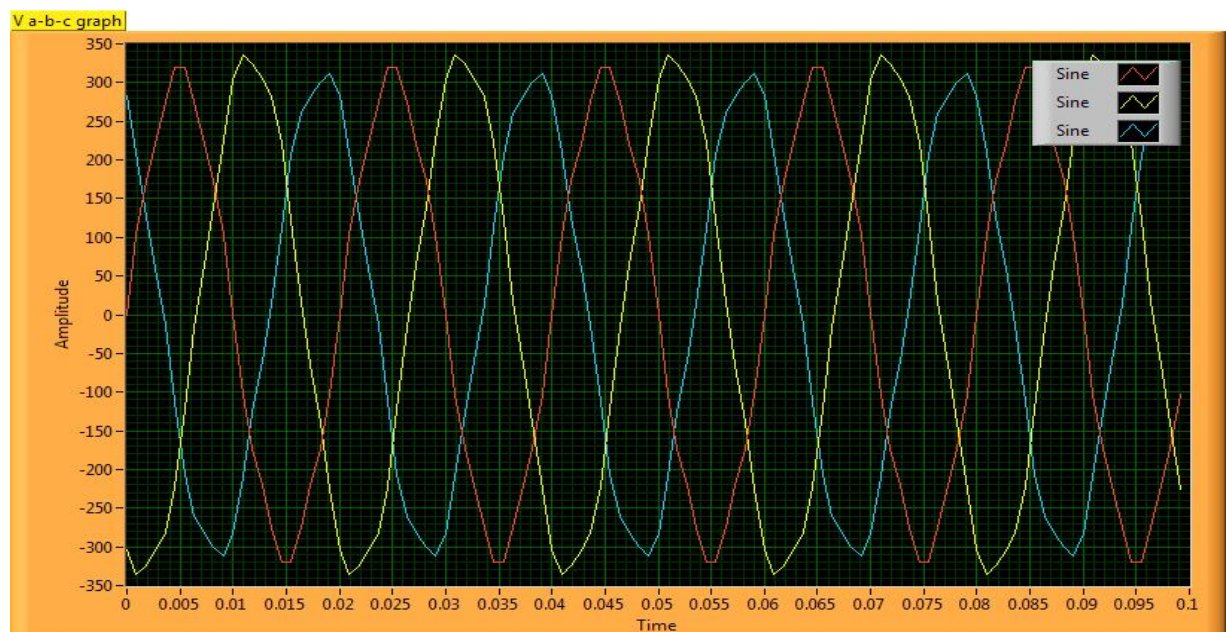Fig 4.2 Block Diagram /G programming of distorted voltage wave form

Fig 4.3 Front Panel Presenting Distorted voltage waveform

Here in the Front Panel signal we can see simulation of three phase voltage forms. In the same manner distorted current wave form is simulated by assuming a balanced resistive load defined by Ra=Rb=Rc =10Ω is connected to above source.
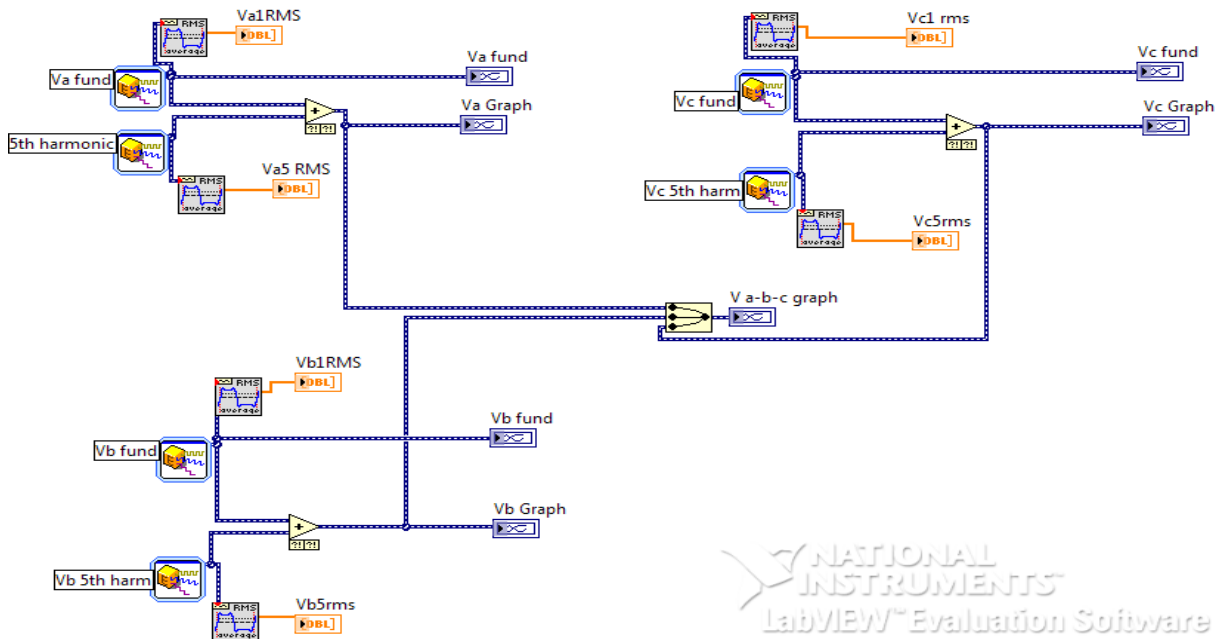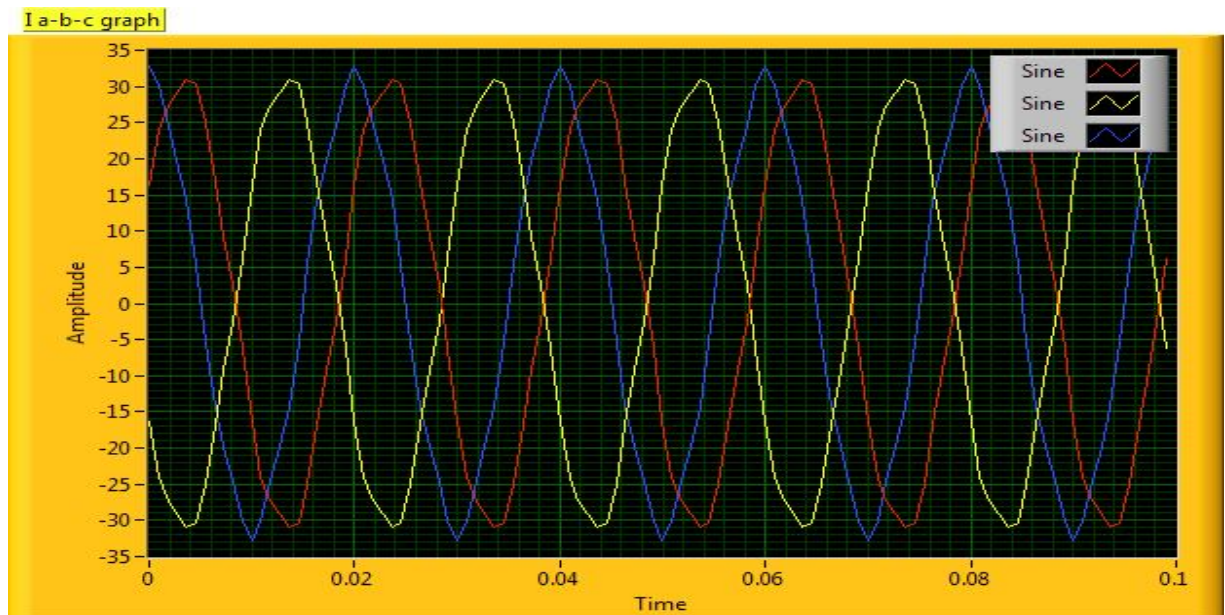
Fig 4.4 Block diagram of current wave form

Fig 4.5 Front Panel presenting current waveform

The above VIs are used as subVI as shown below for calculating QA1 and QA2. A subVI is a VI that is used in another VI similar to a function in text programming language . Advantage of

using a VI as subVI is to simplify the programming complexity. The programmer can easily manage and test these subtasks to reduce dependencies tha might cause unexpected behaviour this shows the importance of modularity property in LabVIEW.

QA1 and QA2 are calculated by programming the above discussed formulas in block diagram which is as shown below.
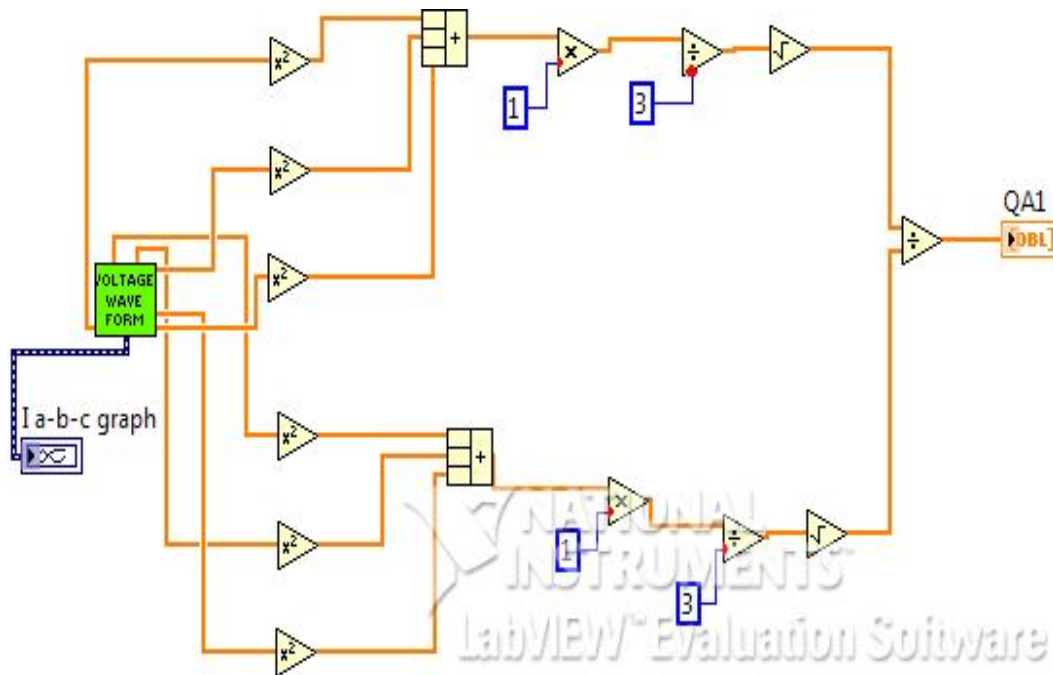
Fig 4.6 Block diagram of voltage total harmonic distortion analyzer
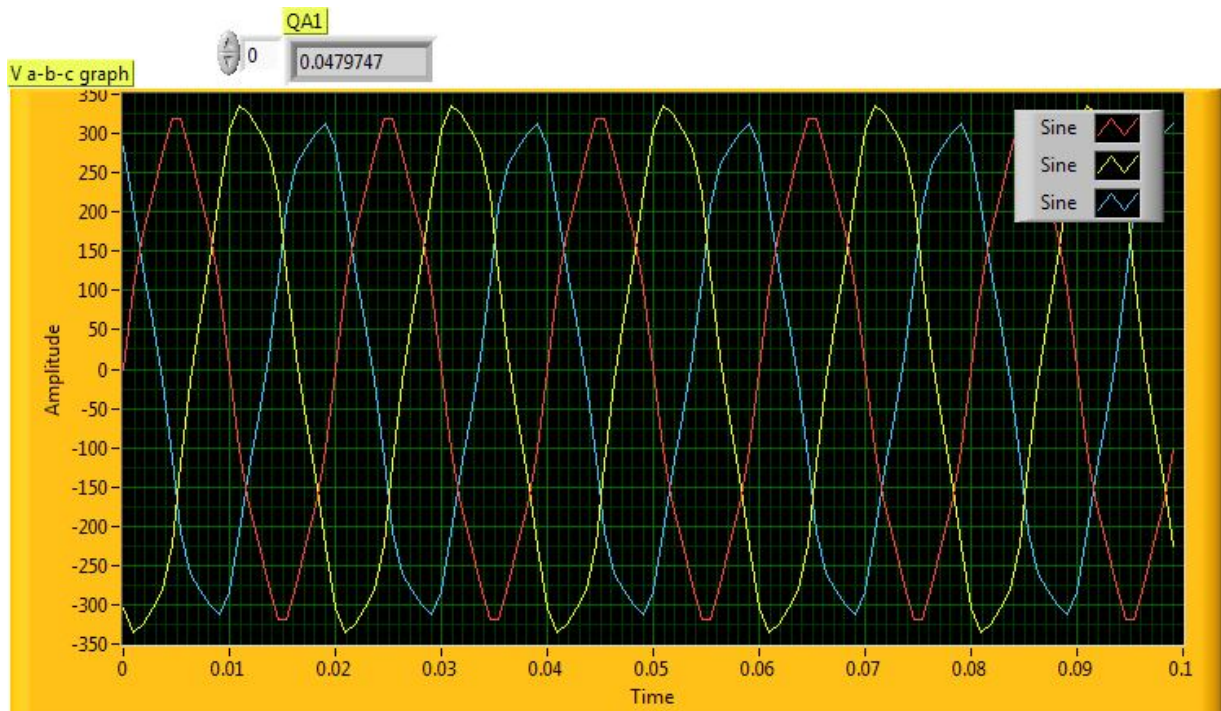
Fig 4.7 Front Panel Presenting Voltage Total Harmonic Distortion Analyzer

Similarly,
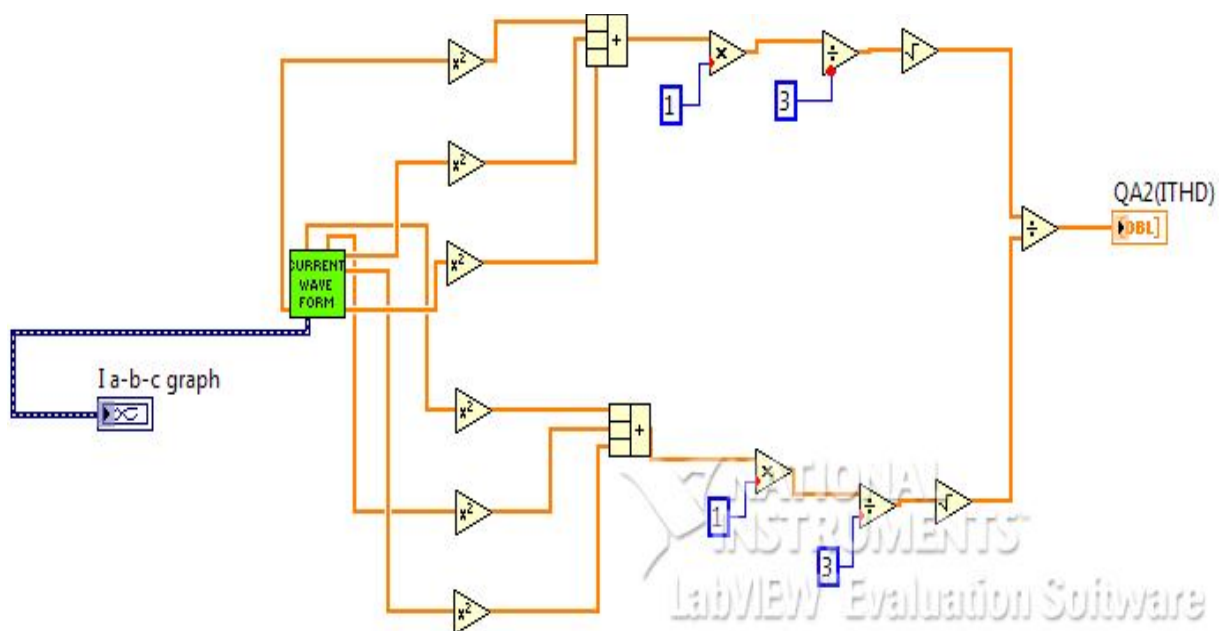
Fig 4.8 Block diagram of current total harmonic distortion analyzer
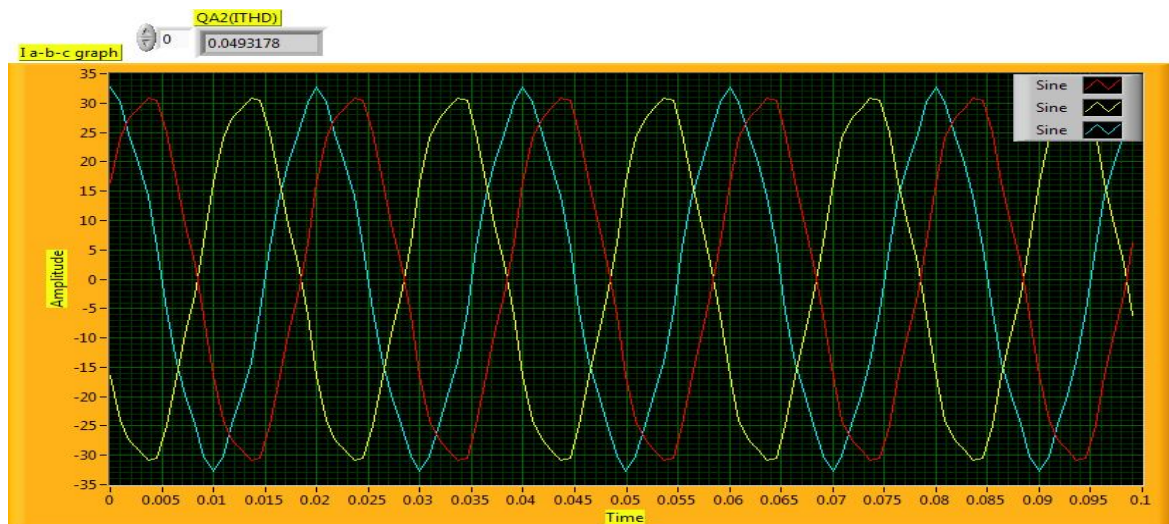
Fig 4.9 Front Panel Presenting Current Total Harmonic Distortion Analyzer

4..2 The THD Analyzer

The key programming package includes "Harmonic Distortion Analyzer" that takes a signal in and performs a full harmonic analysis, containing measuring the fundamental frequency tone and harmonics and returning the fundamental frequency , all harmonic levels, and the total harmonic distortion(THD).
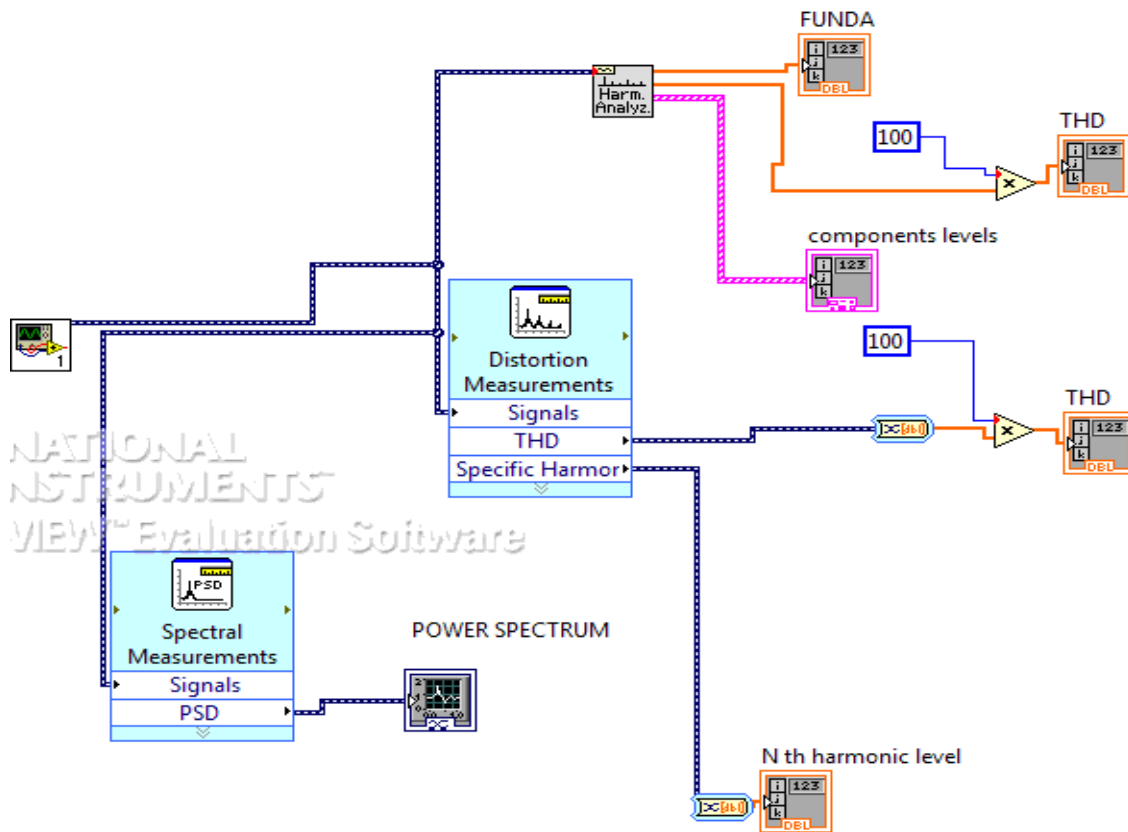
Fig 4.10 Block Diagram of THD Analyzer.

CHAPTER 5

5.SIMULATION OF SEVERAL TEST WAVEFORMS

5.1 Sine wave with 3rd harmonic

This wave signal is simulated with the help of LabVIEW taking fundamental component of amplitude 350 volt and frequency 50hz. It has been superimposed with its 3rd harmonic with amplitude 5% of the fundamental.
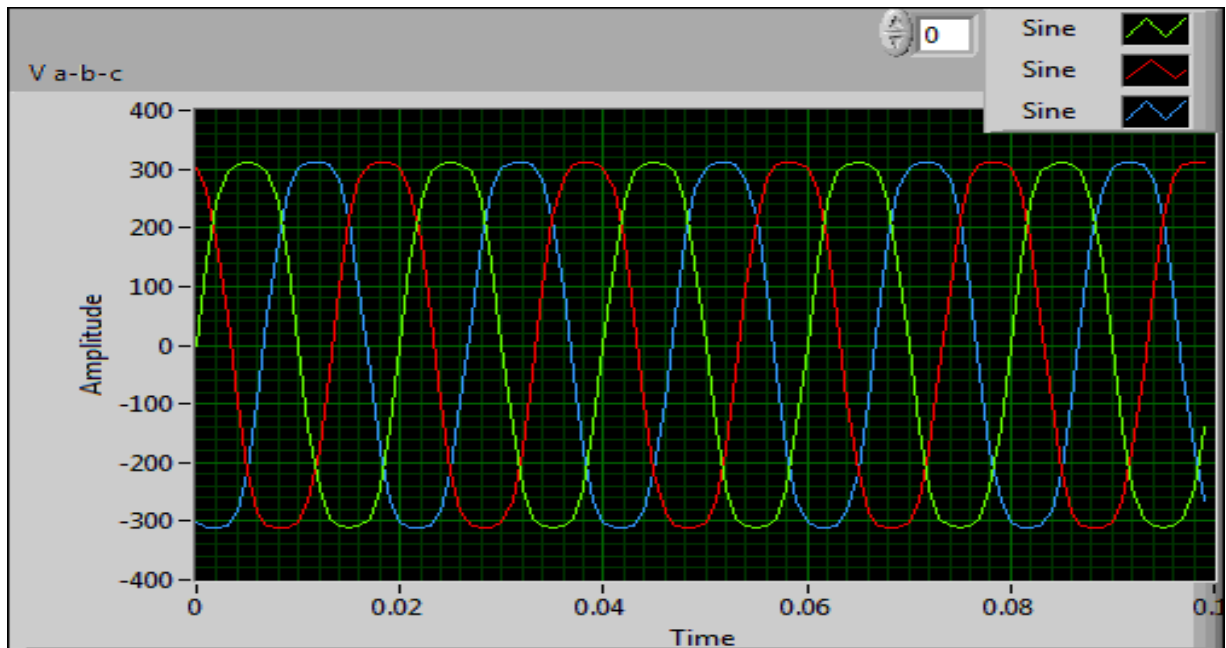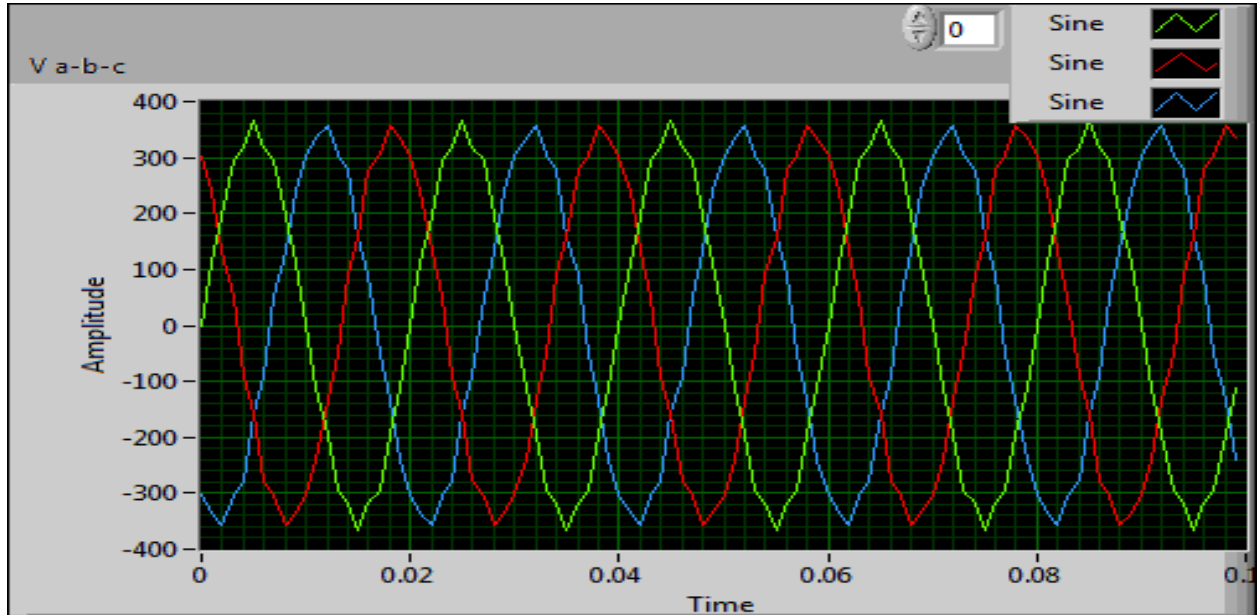

5.2 Sine wave with 5th harmonic

This wave signal is simulated with the help of LabVIEW taking fundamental component of amplitude 350 volt and frequency 50hz. It has been superimposed with its 5th harmonic with amplitude 5% of the fundamental.
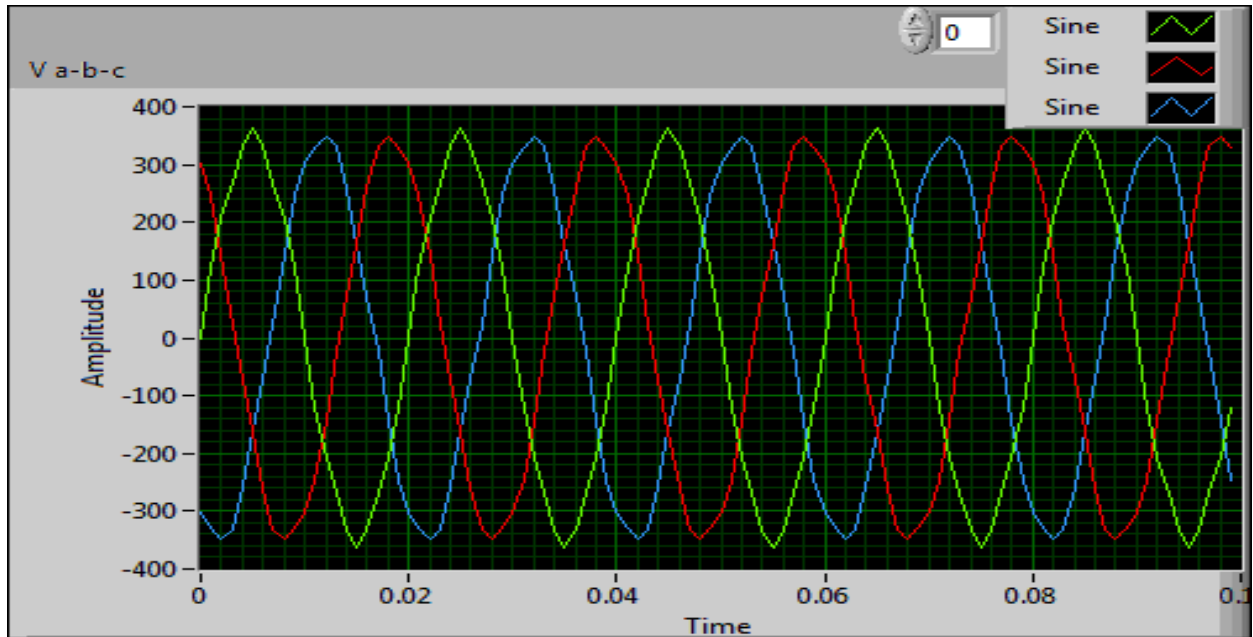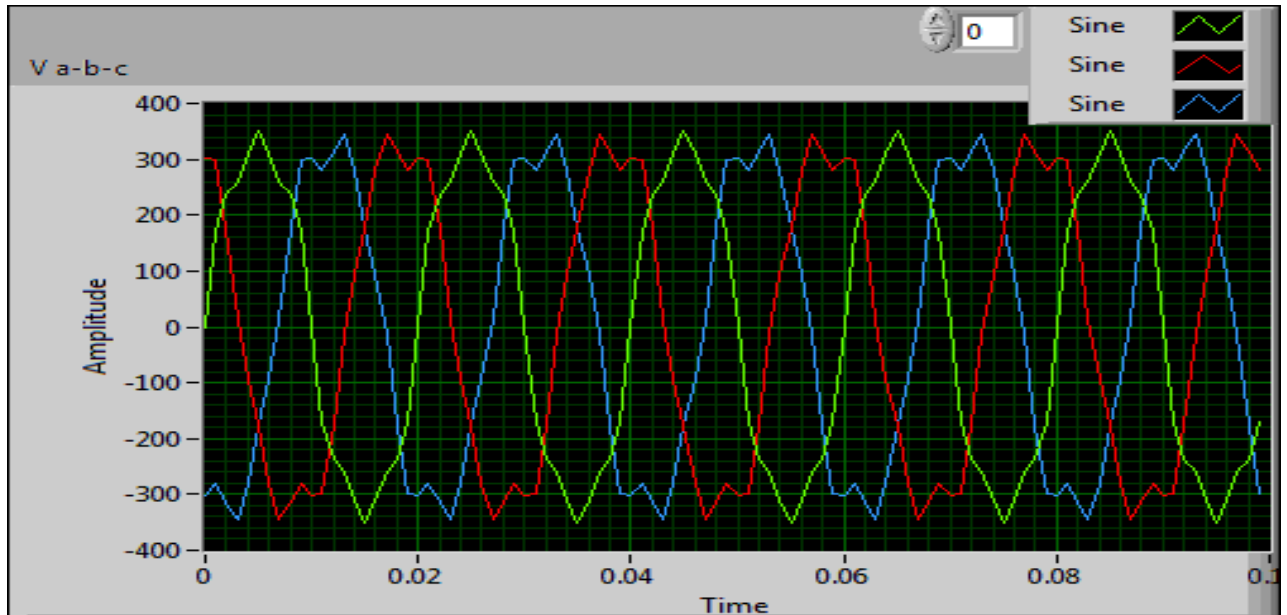
5.3 Sine wave with 7th harmonic

This wave signal is simulated with the help of LabVIEW taking fundamental component of amplitude 350 volt and frequency 50hz. It has been superimposed with its 7th harmonic with amplitude 5% of the fundamental.
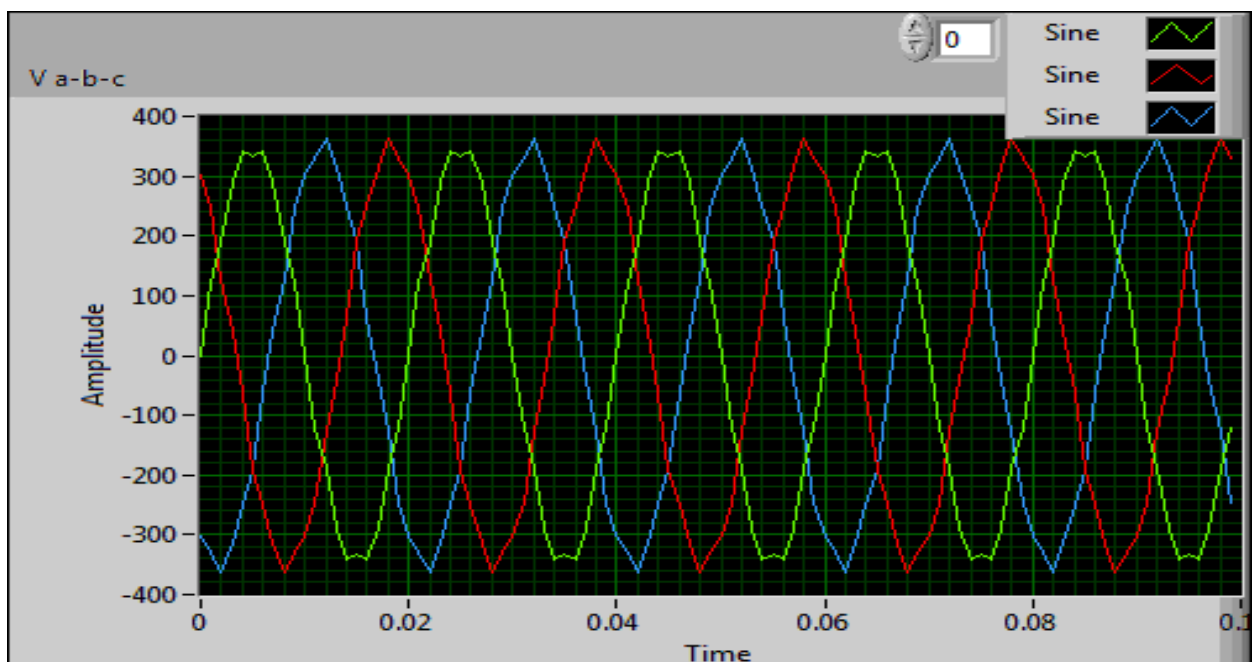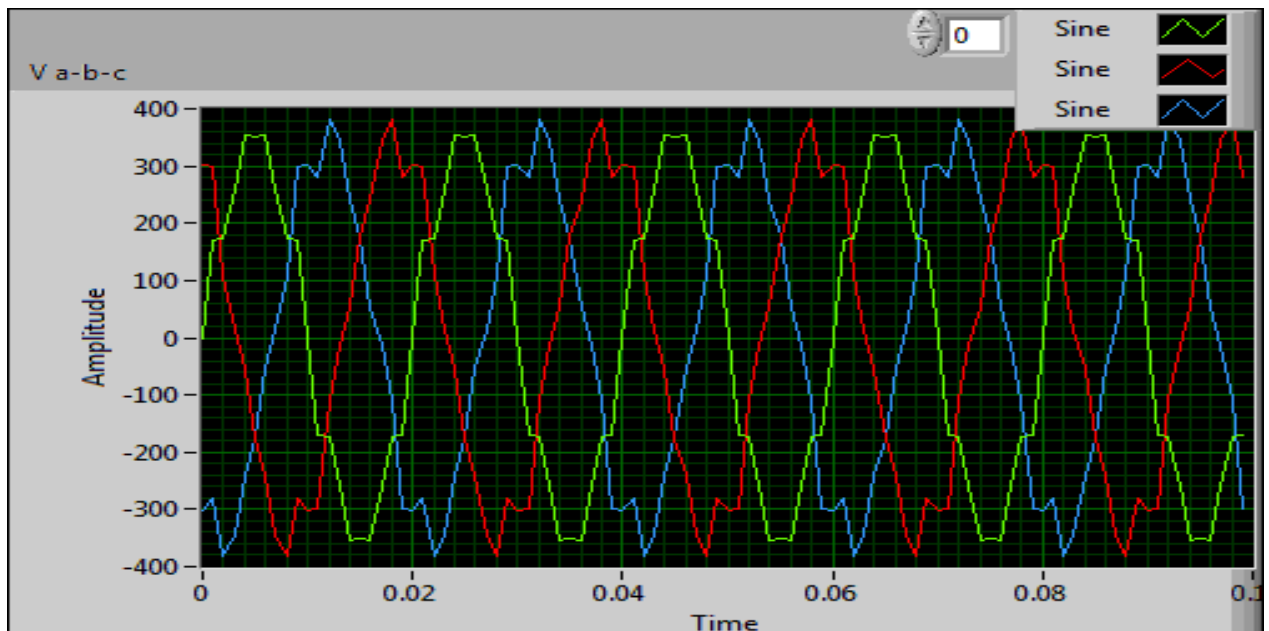
5.4 Sine wave with 9th harmonic

This wave signal is simulated with the help of LabVIEW taking fundamental component of amplitude 350 volt and frequency 50hz. It has been superimposed with its 9th harmonic with amplitude 5% of the fundamental.

5.5 Sine wave with 3rd and 5th harmonic

This wave signal is simulated with the help of LabVIEW taking fundamental component of amplitude 350 volt and frequency 50hz. It has been superimposed with its 3rd and 5th harmonic with amplitude 10% of the fundamental.
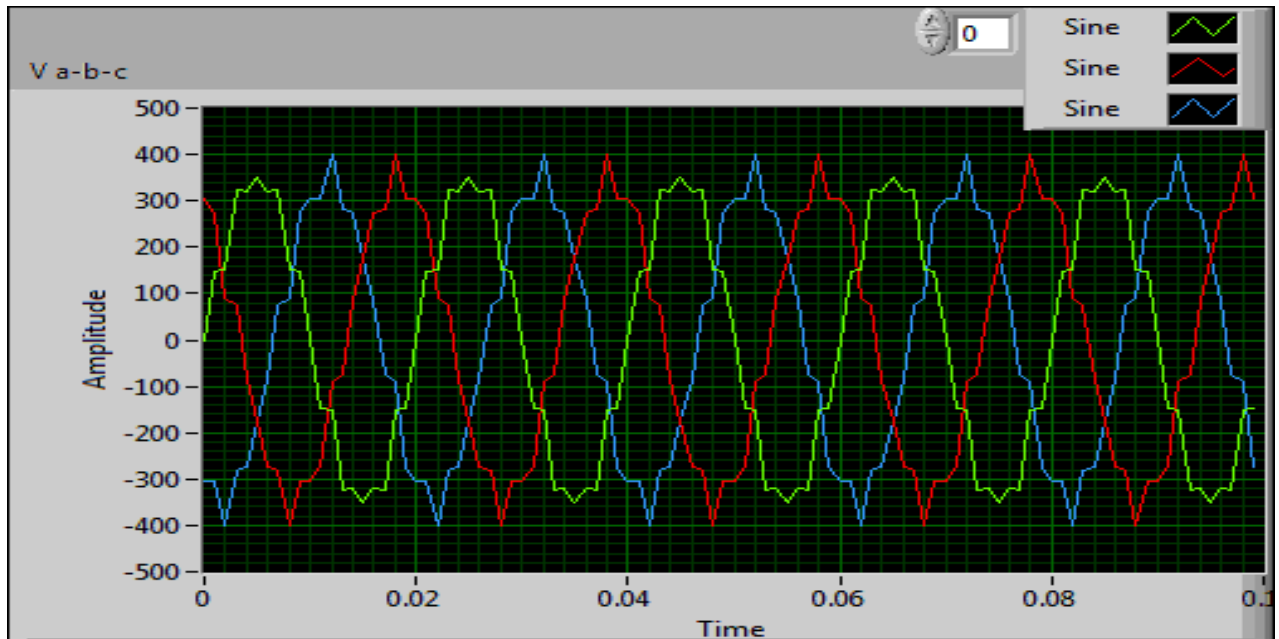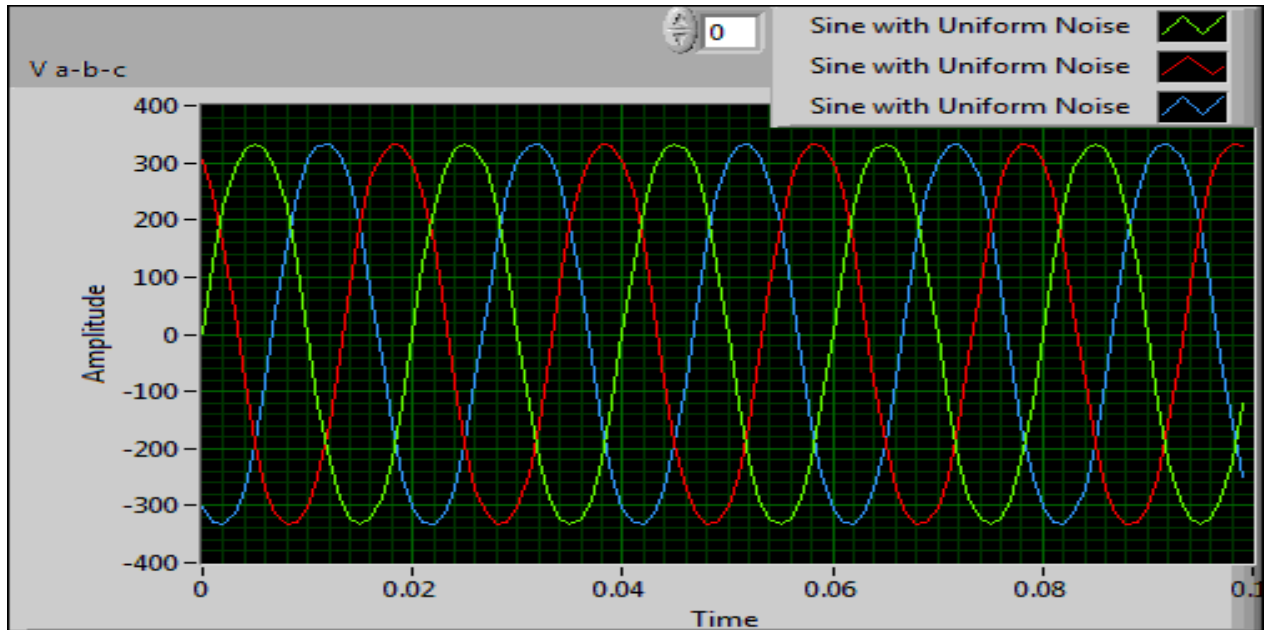
5.6 Sine wave with 5th and 7th harmonic

This wave signal is simulated with the help of LabVIEW taking fundamental component of amplitude 350 volt and frequency 50hz. It has been superimposed with its 5th and 7th harmonic with amplitude 10% of the fundamental.

5.7 Sine wave with 7th and 9th harmonic

This wave signal is simulated with the help of LabVIEW taking fundamental component of amplitude 350 volt and frequency 50hz. It has been superimposed with its 7th and 9th harmonic with amplitude 10% of the fundamental.


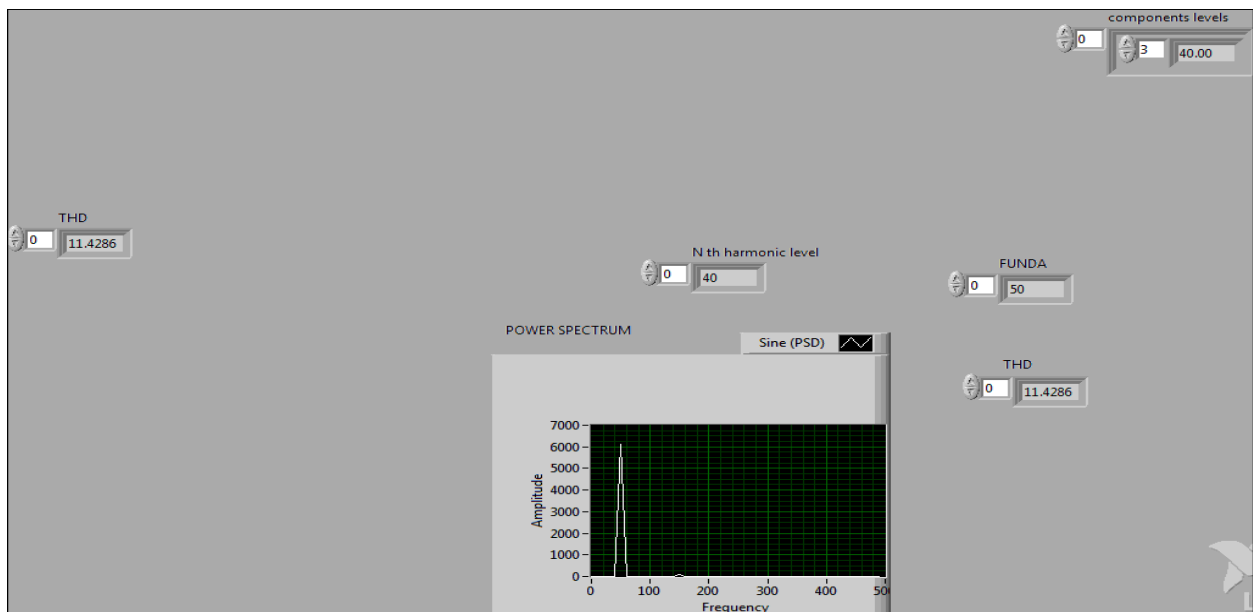## 5.8 Sine wave with 3rd harmonic and uniform noise

This wave signal is simulated with the help of LabVIEW taking fundamental component of amplitude 350 volt and frequency 50hz. It has been superimposed with its 3rd harmonic with amplitude 5% of the fundamental and uniform noise is added to it.

5.9 Sine wave with 3rd and 5th harmonic and uniform noise

This wave signal is simulated with the help of LabVIEW taking fundamental component of amplitude 350 volt and frequency 50hz. It has been superimposed with its 3rd and 5th harmonic with amplitude 10% of the fundamental and uniform noise is added to it.
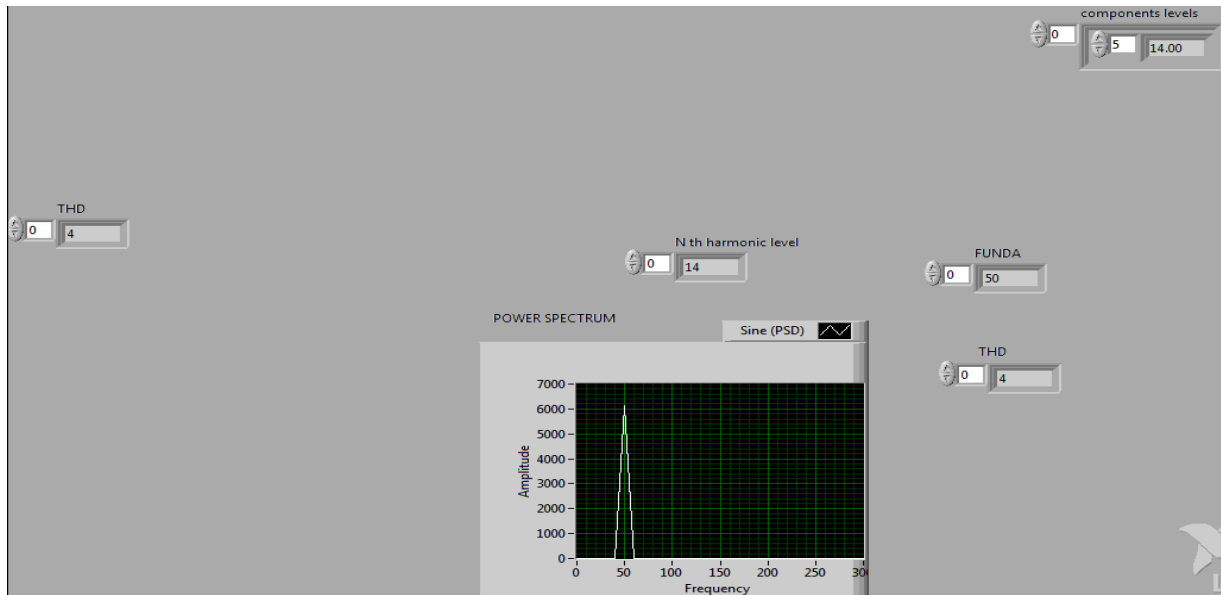

\
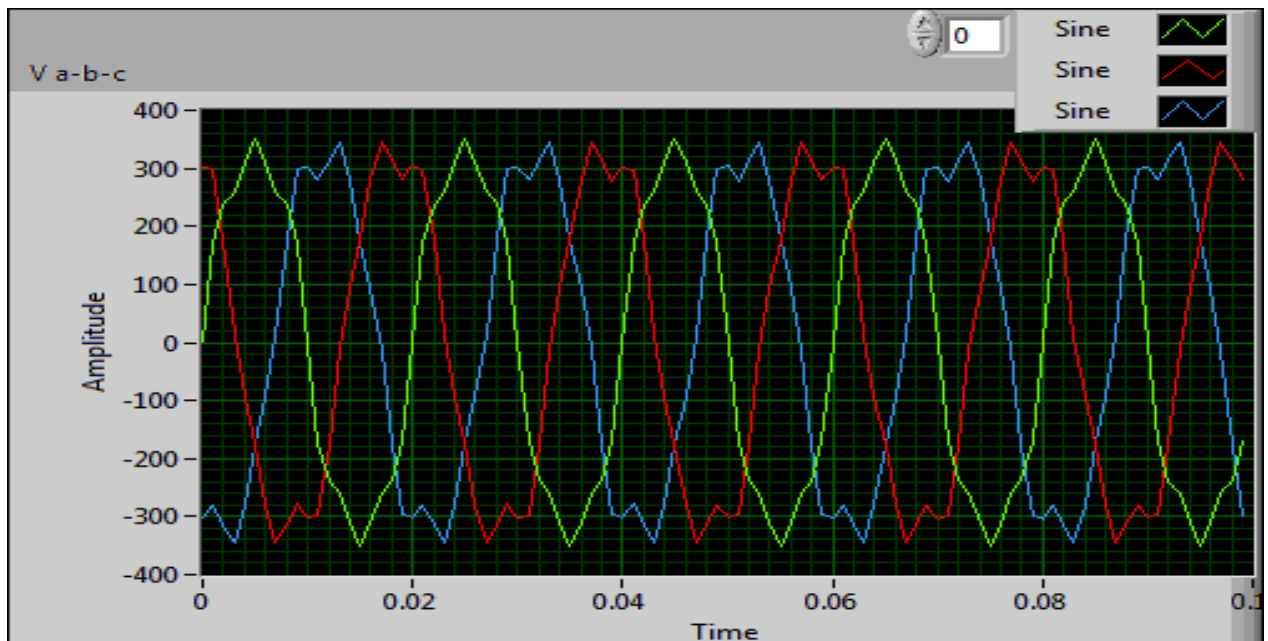
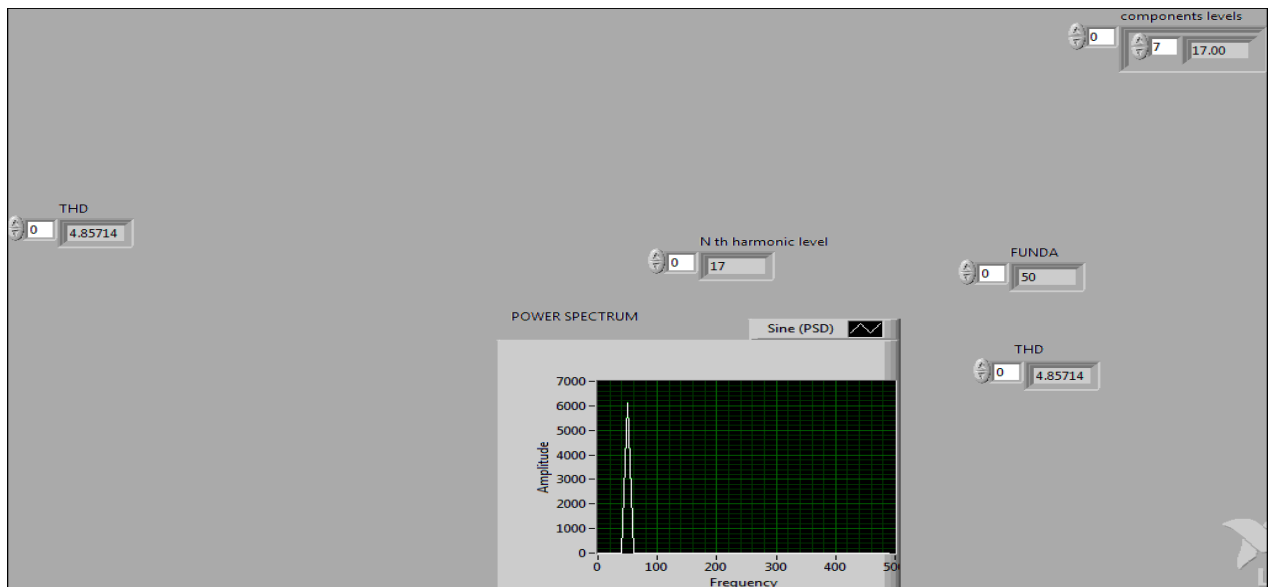# CHAPTER 6

6. THD CALCULATIONS AND SIMULATED RESULTS
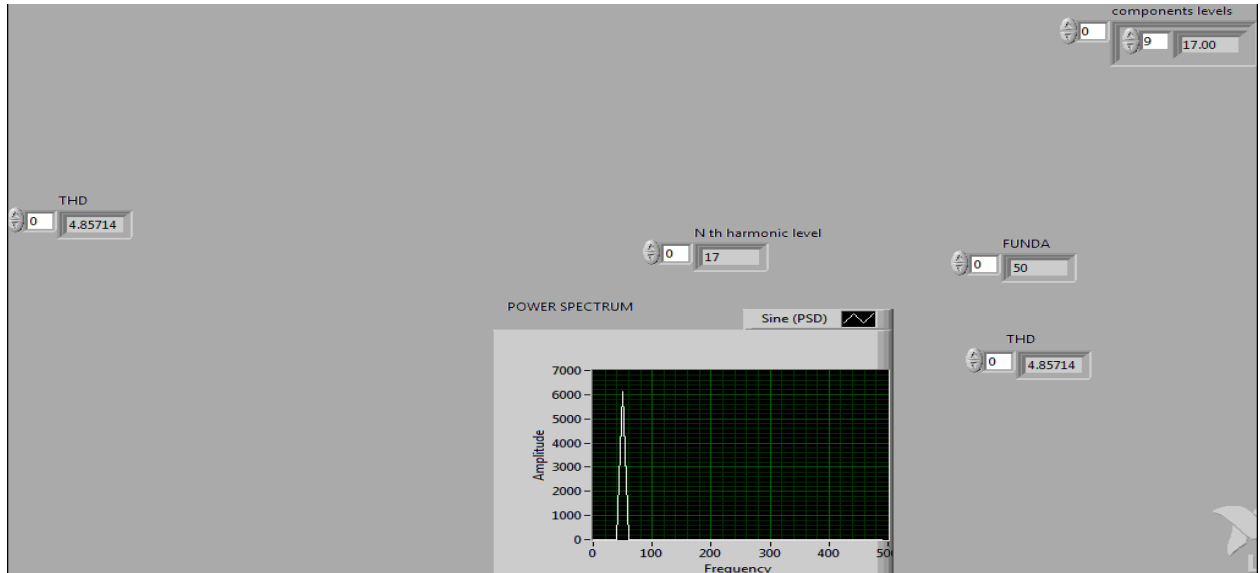
6.1 Sine wave with 3rd harmonic

6.2 Sine wave with 5th harmonic

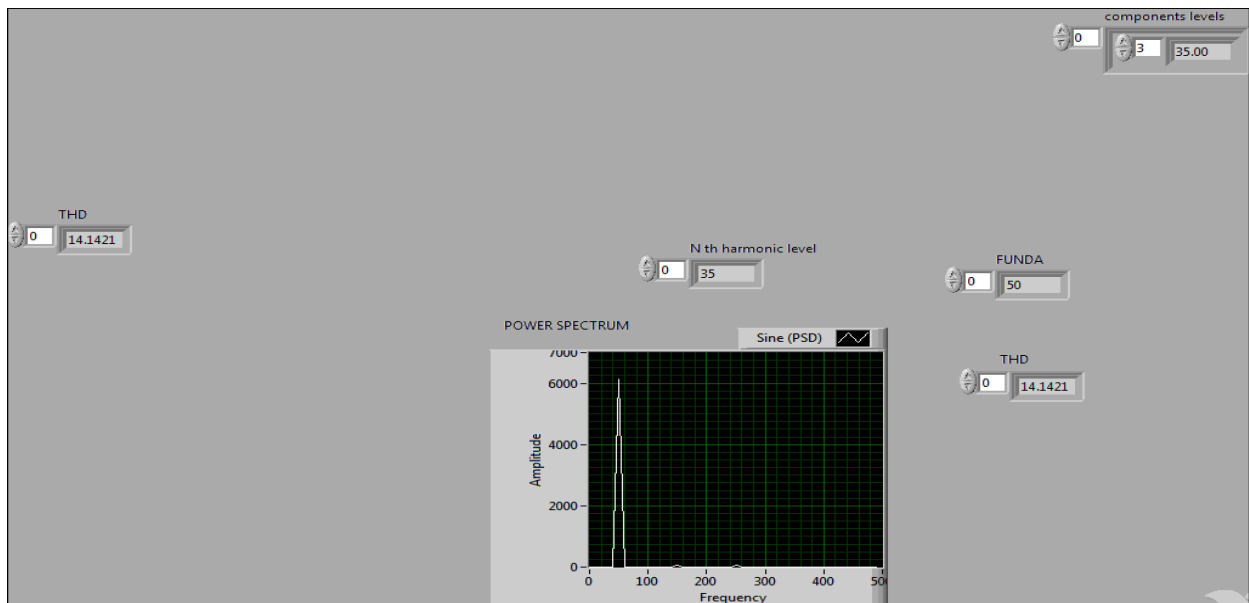## 6.3 Sine wave with 7th harmonic

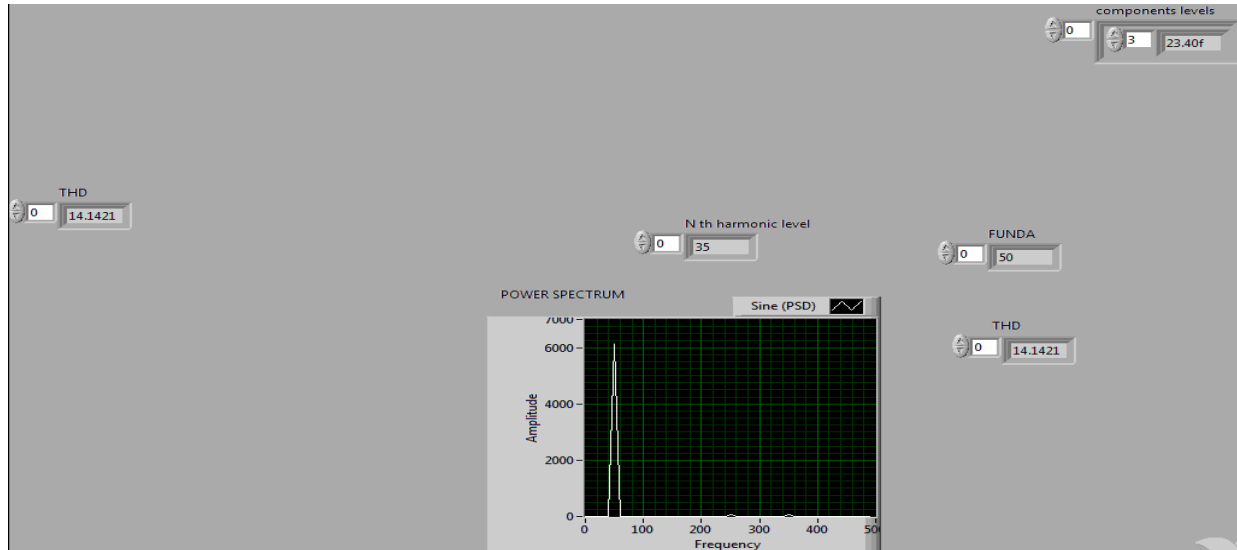## 6.4 Sine wave with 9th harmonic

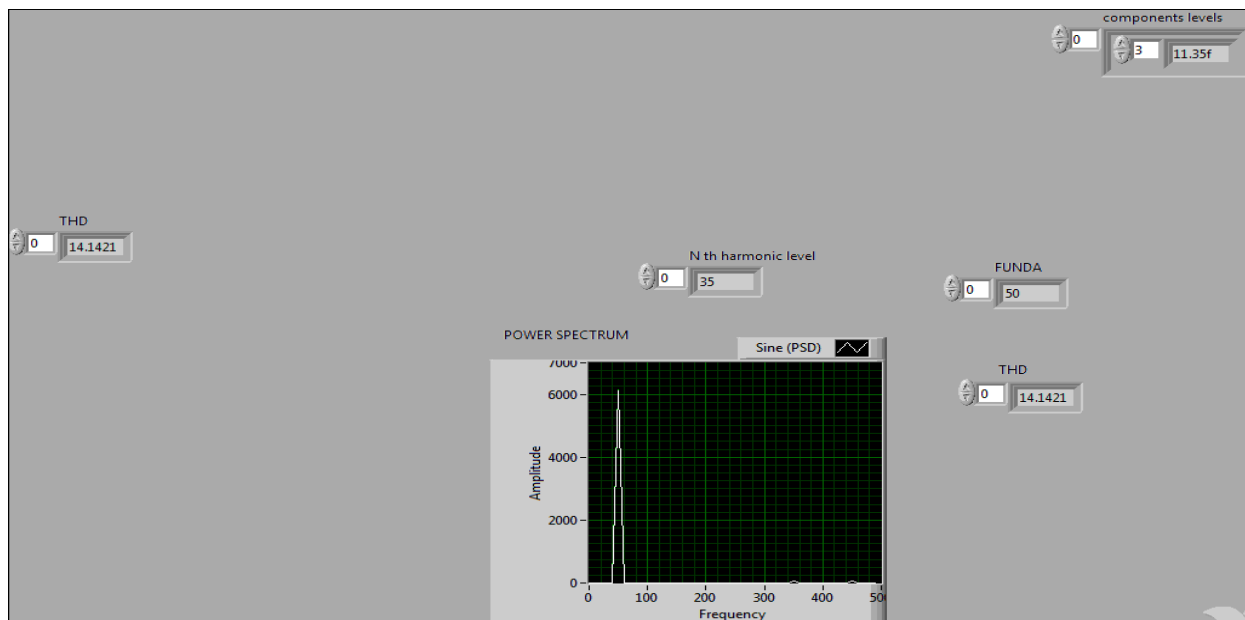## 6.5 Sine wave with 3rd and 5th harmonic

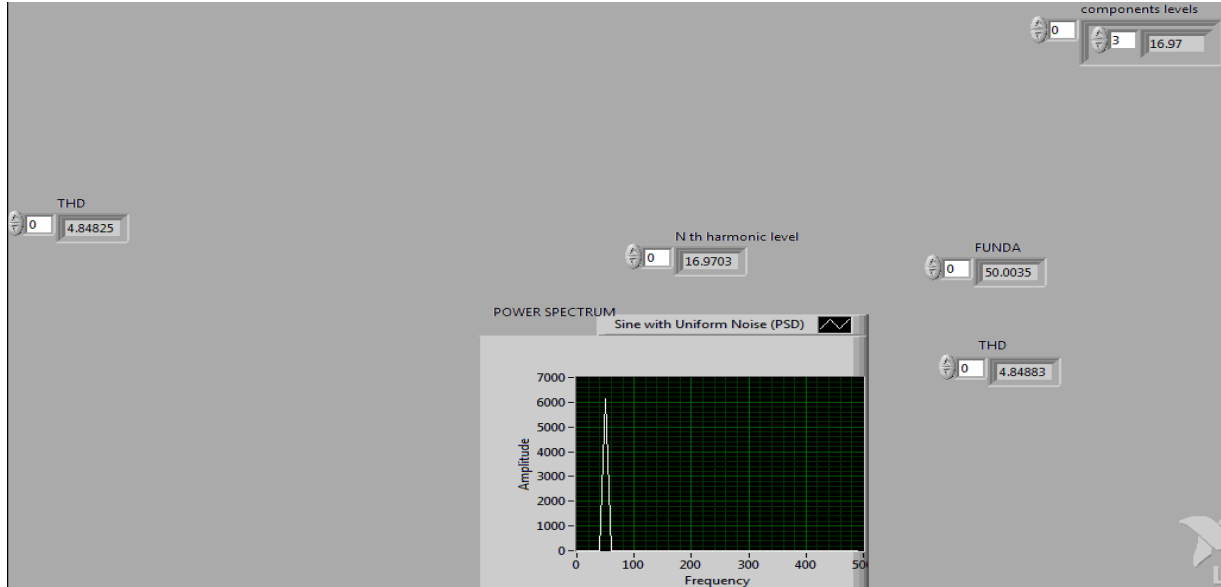## 6.6 Sine wave with 5th and 7th harmonic

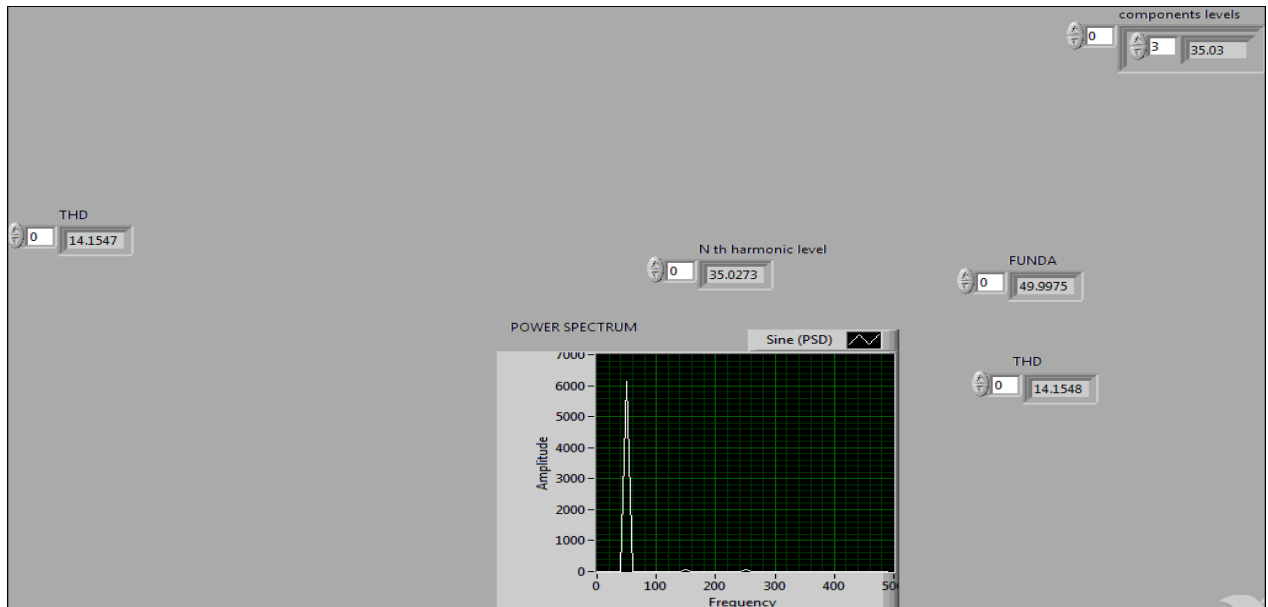

6.7 Sine wave with 7th and 9th harmonic

6.8 Sine wave with 3rd harmonic and uniform noise

6.9 Sine wave with 3rd and 5th harmonic and uniform noise

CHAPTER 7

7. CONCLUSION AND FUTURE SCOPE OF THE WORK

The project describes the utility of virtual instrumentation to offer a cost effective and at the same time producing an accurate and speedy analysis report on the signal harmonics.

The objective of this thesis was to introduce the background needed for electrical engineer students in understanding of power system harmonics using graphical programming tool. In brief, harmonics are energy levels existing at multiples of the fundamental wave's frequency. Harmonics produce undesirable effects in the generator, but motors also suffer from excessive harmonics. The remainder of this discussion will be limited to harmonics of lower orders, those with significant magnitudes, are the 3rd, 5th, and 7th. Thus, we see that higher the order of harmonics, higher is the quantity of energy possessed by it. The same is also depicted in the plots of power spectrum in the chapter 6 of this thesis .thus, in the order severity , we can say that a waveform containing 7th harmonic is more severe than a waveform containing 3rd harmonic , as more quantity of useful energy is wasted. The power spectrum is a powerful analogy tool to show and compare the amount of useful energy being wasted due to the presence of harmonics in the signal waveform. The observation made so far is, that with the increase in number or order of harmonics in a single voltage or current waveform, the amount of useful energy being wasted also increases. Thus, harmonics need to be reduced and the voltage or current waveform in a power system needs to be as sinusoidal as possible.

The THD Analyzer is a interpolated windowed Fast Fourier Transform (FFT) technique that analyses any waveform by giving the harmonic components, THD value and its power spectrum. Sine waves with different harmonics components are, first, simulated through a block diagram designed with the help of LabVIEW as shown in chapter5. Then these simulated waveforms were run through the THD analyzer to obtain the THD value of the various waveforms..These results are shown in chapter 6.

This thesis also preserves and presents much wider scope of research and analogy in future times by exploring a new potential way of simulating different sort of waveforms with the help of LabVIEW(virtual instrumentation) and analyzing the effects of harmonic levels using power spectrum plots.

CHAPTER 8

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