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A Novel approach for Harmonic Analysis using Matlab

Shafqat Mughal[1], Rukhsana Thaker[2]

1Department of Electrical & Renewable Energy Engineering, School of Engineering & Technology, Baba Ghulam Shah Badshah Universit, Rajouri (J&K India).

2Department of Computer Science Engineering, School of Engineering & Technology, Baba Ghulam Shah Badshah University, Rajouri(J&K India).

Abstract— *A harmonic analyzer is used to obtain data in terms of electrical parameters for any point we are interested in for the application of harmonic filters. This device not only shows data on the spot but can also store data digitally which can later be retrieved using computer and a software provided by the harmonic analyzer manufacturer. Here In this paper, an attempt has been made to under the concept of harmonics, their causes and effects. Also various methods adopted for harmonic analysis are described. Finally a Matlab based analysis is derived using various networks to efficiently perform harmonic analysis.*

Keywords— *harmonics, filter, matlab. resistor, switching etc.*

I. INTRODUCTION

Normally, power systems are designed to operate at frequencies of 50 or 60Hz. Although certain types of loads produce current and voltage signal with frequencies that are integer multiples of the 50 or 60 Hz fundamental frequency. These higher frequencies are called electrical pollution that is known as power system harmonics. Harmonics causes obstruction to the normal operation of the equipment or the system. Studying their causes can help to develop protective schemes for harmonic isolation and also clearance of harmonics. Harmonics are caused by various reasons such as saturation, switching and winding connections in transformers, shunt capacitors resonance and nonlinear loads like switching mode power supply, wind and solar power generation. Harmonics analysis involved the calculation of system parameters. The IEEE519-1992 & IEC610003-2 standards address harmonic variations describing distortion limits [1]-[3]. It recognizes that the recommended limits can be exceeded for periods of time without causing harm to equipment. When evaluating compliance with the stated limits, the document recommends that probability plots be developed from the recorded data. The fact that existing steady-state limits cannot be directly applied to time-varying harmonics prompted some utilities [7]-[8] to come up with their own time-dependent limiting curves.

II. CONCEPT OF HARMONICS

The successful operation of any system relates to its approximate lossless and highly efficient operation. Power systems are designed to operate at frequencies of 50 or 60Hz. However, certain types of loads produce currents and voltages with frequencies that are integer multiples of the 50 or 60 Hz fundamental frequency. These higher frequencies are a form of electrical pollution known as power system harmonics.

Power system harmonics are integer multiples of the fundamental power system frequency. Power system harmonics are created by non-linear devices connected to the power system. High levels of power system harmonics can create voltage distortion and power quality problems. Harmonics in power systems result in increased heating in the equipment and conductors. Harmonics are a major cause of power supply pollution lowering the power factor and increasing electrical losses. This results in premature equipment failure and higher rating requirement for equipment. These harmonic-related losses reduce system efficiency, cause apparatus overheating, and increase in overall costs. As the number of harmonics-producing loads has increased over the years, it has become increasingly necessary to address their influence when making any additions or changes to an installation. It is important to consider their impact when planning additions or changes to a system.

While standards to limit the generation of harmonic currents are under consideration, harmonic control today relies primarily on remedial techniques. The harmonics occurring in any electrical system can be analyzed under several approaches and many methods can be implied in their removal, starting from manual calculations to computer-aided simplified techniques with varying degrees of effectiveness and efficiency.

III. CAUSE AND EFFECT OF HARMONICS

A pure sinusoidal voltage is a conceptual quantity produced by an ideal AC generator built with finely distributed stator and field windings that operate in a uniform magnetic field. Since neither the winding distribution nor the magnetic fields are uniform in a working AC machine, voltage waveform distortions are created. The distortion at the point of generation is very small (about 1% to 2%), but nonetheless it exists. Because this is a deviation from a pure sine wave, the deviation is in the form of a periodic function, and by definition, the voltage distortion contains harmonics.

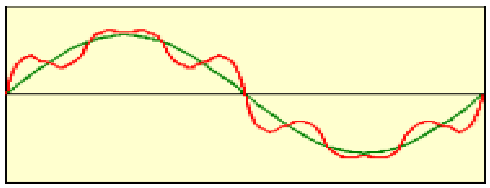

Figure1.

When a sinusoidal voltage is applied to a certain type of load, the current drawn by the load is determined by the voltage and impedance. These loads are referred to as linear loads; examples of linear loads are resistive heaters, incandescent lamps, and constant speed induction and synchronous motors. In contrast, some loads cause the current to vary disproportionately with the voltage during each cyclic period. These are classified as nonlinear loads, and the current taken by them has a non sinusoidal waveform. Waveform distortion can be mathematically analysed to show that it is equivalent to superimposing additional frequency components onto a pure sine wave. These frequencies are harmonics (integer multiples) of the fundamental frequency, and can sometimes propagate outwards from nonlinear loads, causing problems elsewhere on the power system.

The classic example of a non-linear load is a rectifier with a capacitor input filter, where the rectifier diode only allows current to pass to the load during the time that the applied voltage exceeds the voltage stored in the capacitor, which might be a relatively small portion of the incoming voltage cycle. Harmonic disturbances are generally caused by equipment with nonlinear voltages-current characteristics. Following are the major effect created by the presence of harmonics.

- Distortion of main supply voltage, unwanted currents flowing in the supply network generate additional energy losses.
- Defective operation of regulating devices, disturbed operation of florescent lamps, television receivers or other equipment.
- Malfunction of ripple control and other mains signalling systems, protective relays and, possibly, other of control systems.
- Additional losses in capacitors and rotating machines.
- Additional acoustic noise from motors and other apparatus, reducing the efficiency of motors.
- Telephone interference in case of harmonics in case of communication systems. High harmonic amplitudes may not only cause malfunctions, additional losses and overheating, but also overload the power distribution network and overheat the neutral conductor and cause it to burn out.
- Malfunction of sensitive equipments.
- Random tripping of circuit breakers.
- Overheated phase conductors, panels and transformers.
- Premature failure of transformers and uninterrupted power supplies.
- Reduced power factor
- Reduced system capacity (because harmonic create additional heat, transformers and distribution equipments cannot carry full rated load).

IV. METHODS OF HARMONIC ANALYSIS

Harmonic analysis is a branch of mathematics concerned with the representation of functions or signals as the superposition of basic waves, and the study of and generalization of the notions of Fourier series and Fourier analysis. In the past two centuries, it has become a vast subject with applications in areas as diverse as signal processing, quantum mechanics etc. It is used to obtain data in terms of electrical parameters for any point we are interested in for the application of harmonic filters. This device not only shows data on the spot but can also store data digitally which can later be retrieved using computer and a software provided by the harmonic analyzer manufacturer. Harmonics reduction can be done either by structural modifications in the drive system or by using external filtering. The structural modifications can be to strengthen the supply, to use 12 or more pulse drive, to use a controlled rectifier or to improve the internal filtering in the drive. Following are the different methods for Harmonic Analysis.

1. NUMERICAL CALCULATION METHOD:
   This method is a crude representation of harmonic series corresponding to a particular fundamental frequency.It involves

- Determining fundamental frequency.
- Multiply this frequency by integer multiples, starting from 2 to 15 (say), and record each value.
- The 1st harmonic is your fundamental frequency, f. The second harmonic is 2f, the third harmonic is 3f, and so on. Harmonics are measured in Herts.

2. HARMONICS CALCULATOR:

This calculator requires the use of JAVASCRIPT enabled and capable browsers. This calculator can be used to determine the 1st through 15th harmonic of any fundamental frequency. The frequency range can be in any hertz range (cycles) to gigahertz. The default primary frequency is that of alternating current (50 Hz). Connect the system, enter the frequency, then click on CALCULATE to see the harmonics. Click CLEAR to start again. To eliminate the harmonics, line filters or filters of desired frequency or capacitors acting as filters can help

3. FOURIER BASED METHODS

In energy metering or power quality monitoring systems, when the harmonic analysis is performed, phase currents and voltages are simultaneously sampled and then processed to compute the following power quality measurements on the fundamental and harmonic components: active, reactive and apparent powers, rms values, power factors and harmonic distortions. Fast Fourier Transform (FFT) analysis comes immediately to mind as per manual calculations are concerned.

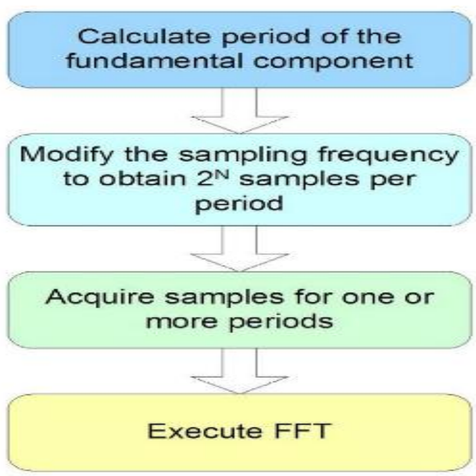

Figure 2. Steps required in implementing FFT algorithm.

One must determine the period of the fundamental component. The sampling frequency must be modified to obtain 2N samples per period. This implies using analog to digital converters that allow variable sampling frequencies. Then one must acquire 2N samples corresponding to one or more periods. The last step is to execute the FFT algorithm.

4. GOERTZEL ALGORITHM

The Goertzel algorithm is a digital signal processing (DSP) technique that provides a means for efficient evaluation of individual terms of the Discrete Fourier Transform (DFT). The algorithm was first described by Gerald Goertzel in 1958.
Like the DFT, the Goertzel Algorithm analyses one selectable frequency component from a Discrete signal. Implementing an entire program with dynamic adjustment of such coefficients may be avoided if the Goertzel algorithm is adopted. This approach computes the DFT using a number of samples per period different than 2N, allowing for a constant sampling frequency independent of the fundamental period.

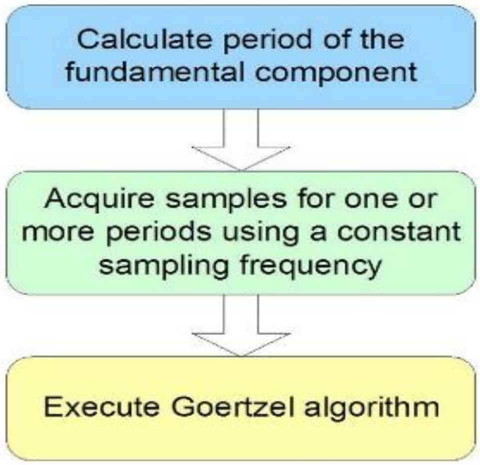

Figure 3. Steps to implement the Goertzel algorithm.

The period of the fundamental component still needs to be determined as already presented for the FFT implementation. The coefficients used in the Goertzel algorithm are computed based on the number of samples per period. The Fourier transform is then executed.

5. BAND PASS FILTER BASED METHOD

Perhaps the simplest approach to harmonic analysis is to use bandpass filtering. It basically takes the phase currents and voltages and applies a narrow band filter around one harmonic. One can analyze multiple harmonics simultaneously if multiple filters are implemented in parallel.

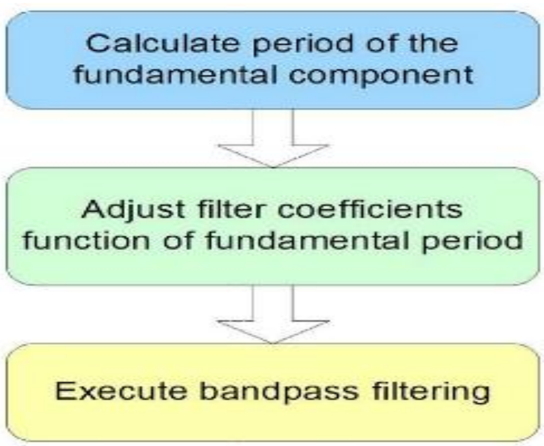

Figure 4. Steps to implement a bandpass filter.

In this approach, the period of the fundamental harmonic still needs to be determined. The accuracy of this measurement needs to be substantially increased because at higher harmonics, there is the risk of missing the harmonic frequency of interest. This practically means longer time reserved to filtering the time period between consecutive zero crossings. The filter coefficients are computed based on the fundamental period. One drawback of this method is that only the amplitude of the harmonic is preserved and any phase information is lost. Hence, the harmonic powers, the power factors and harmonic distortions cannot be computed.

6. PASHA (POWER APPARATUS & SYSTEM HOMOLOGICAL ANALYSIS)

Power Apparatus & System Homological Analysis (PASHA) is a highly interactive, very powerful software product designed to improve the analysis of planning & operation of electric utility & industrial systems. It contains some very advanced, coordinated algorithms for load flow, fault level, relay coordination, harmonic analysis, reliability evaluation & transient analysis & makes extensive use of computer graphics to provide a flexible, highly interactive & user friendly procedure for system input, results output and program control functions.

Power system analysis involves some very complex analytical and numerical processes. Usually, the input of system data, the manipulation of programs and the extraction of the essential results frequently involve a fairly intimate knowledge of the analytical aspects, as well as computer operating system procedure and commands. To overcome this overhead, the algorithms and the interactive procedure used in PASHA effectively remove all organizational aspects from the foreground and allow the user to concentrate on his primary objective. This is achieved by the 'user-friendly' interface PASHA provides between the algorithms and the user.Harmonic Analysis using PASHA

- Harmonic penetration calculation.
- Plotting frequency spectrum in network.
- Filter design for harmonic elimination.

7. CYMHARMO - Harmonic Analysis

CYMHARMO is the Harmonic Analysis Module of the CYME power engineering software. It features various analyses, including frequency scan, voltage distortion and current distortion calculations on balanced and unbalanced systems and covers both single phase and full three-phase modeling capabilities.The CYMHARMO software includes a number of analyses, including frequency scan, voltage distortion and current distortion calculations on balanced and unbalanced systems. The module allows the user to easily detect resonant frequencies due to capacitor banks, and to model non-linear loads and other sources of harmonic currents.

V. HARMONIC ANALYSIS USING MATLAB

A harmonic analyzer is used to obtain data in terms of electrical parameters for any point we are interested in for the application of harmonic filters. This device not only shows data on the spot but can also store data digitally which can later be retrieved using computer and a software provided by the harmonic analyzer manufacturer. MATLAB has a high level language compiler very close to natural writing techniques. It has a vast collection of well designed functions and tools to aid in all kinds of applications. It supports Object Oriented Programming (OOP) thus same functions can be used again and again. It has support for drawing all kinds of 2-dimentional and 3-dimentional graphs as well as charts and function mapping techniques.

It has a Graphical User Interface Development Environment (GUIDE) which can be used to make input of data and output of results easier to understand and comprehend for a novice user. GUI is a way to interact with user by virtue of friendly graphical instructions or decisions which are easy to understand and follow. Any programmer can use its flexibility and strength to add various options as well as user decision levels as required.

It can be used for extensive graphical and technical facilities and functions available for all kinds of computation and calculations involving simple everyday procedures to complex higher order mathematical applications.

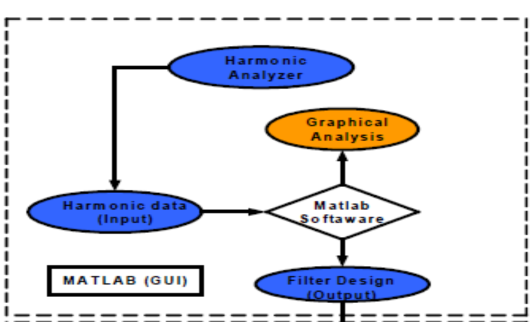

Figure 5. harmonic analysis using MATLAB

Using a Harmonic Analyzer circuit harmonic analysis is done and data is fed to MATLAB program. MATLAB provides user friendly approach and can be used for any input data again and again.

VI. RESULT AND DISCUSSION

A number of different circuits were considered for analyzing the effectiveness of the methodology. In this work we have done harmonic analysis on the hardware the picture of which is shown in fig. 6.

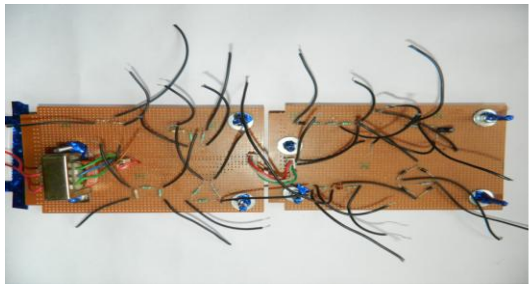

Figure 6.

CIRCUIT-1

220 volts AC input is given to the circuit, which contains resistors as shown in below circuit diagram:

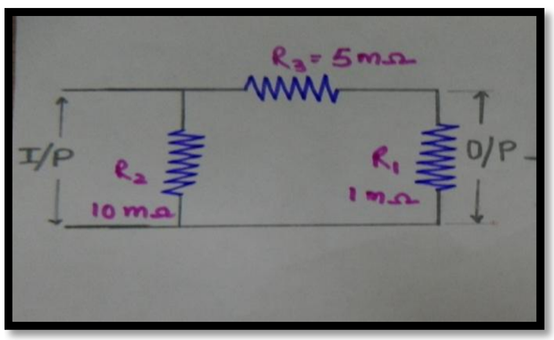

Figure 7.

Here the output is taken across 1mΩ resistor and harmonic analysis is obtained. Fig. 8 shows the waveforms obtained.

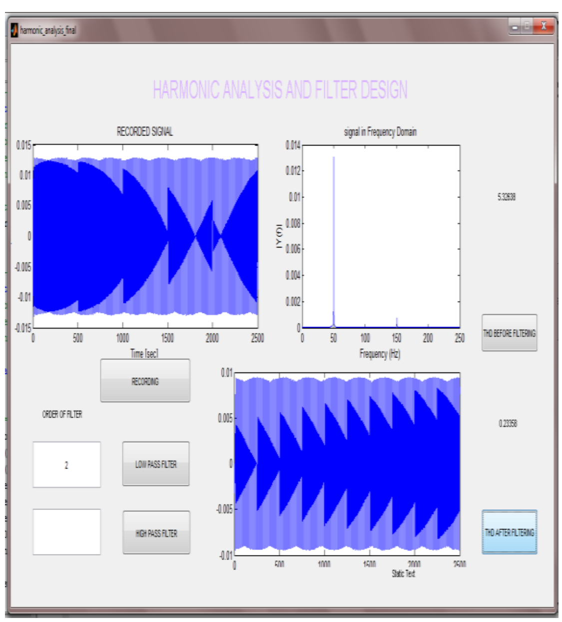

Figure 8.

CIRCUIT-2

220 volts AC input is given to the circuit, which contains resistors as shown in below circuit diagram:

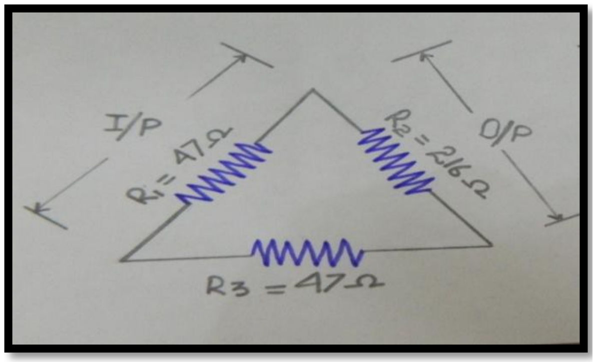

Figure 9.

Here the output is taken across 1mΩ resistor and harmonic analysis is obtained. Fig. 10 shows the waveforms obtained.

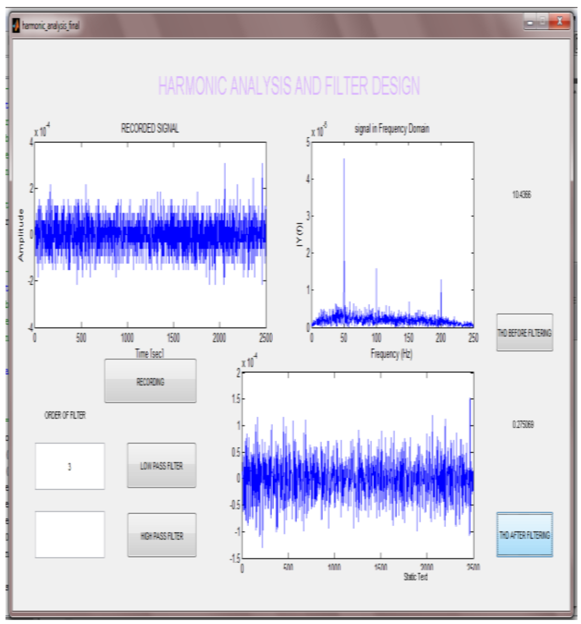

Figure 10.

CIRCUIT-3

220 volts AC input is given to the circuit, which contains two resistors and one inductor as shown in below circuit diagram:

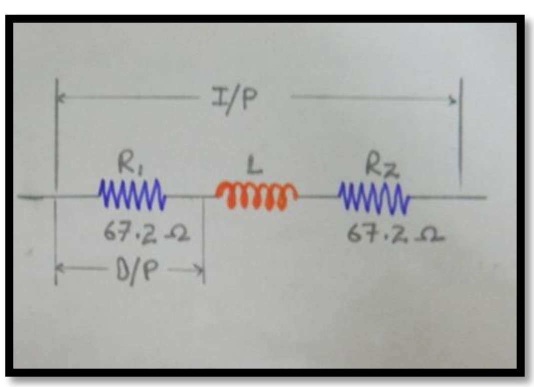

Figure 11.

Here the output is taken across 67.2 Ω resistor and harmonic analysis is obtained. Fig. 12 shows the waveforms obtained.

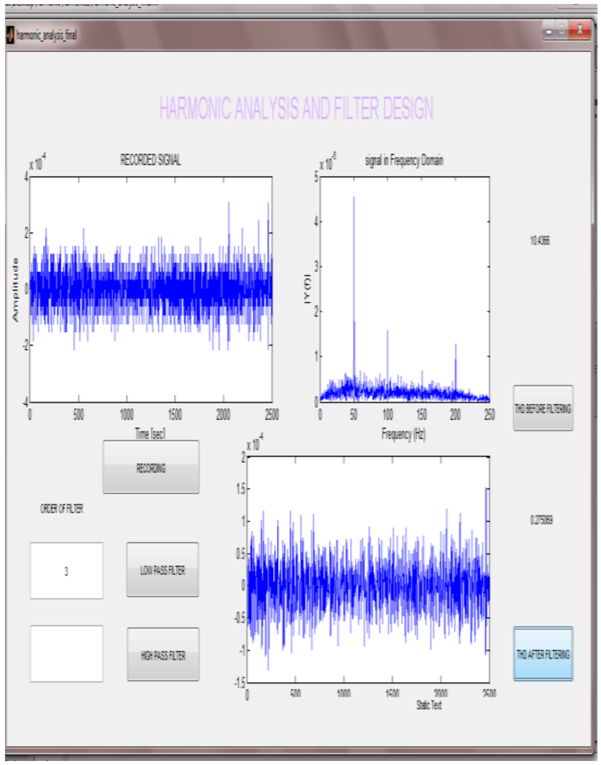

Figure 12.

CIRCUIT-4

220 volts AC input is given to the circuit, which contains two resistors and one capacitor as shown in below circuit diagram:

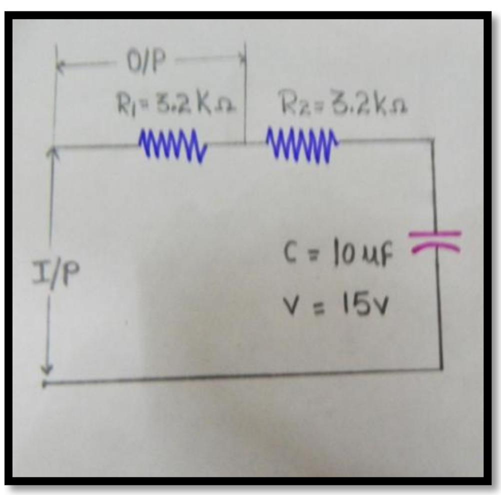

Figure 13.

Here the output is taken across 3.2 kΩ resistor and harmonic analysis is obtained. Fig. 14 shows the waveforms obtained.

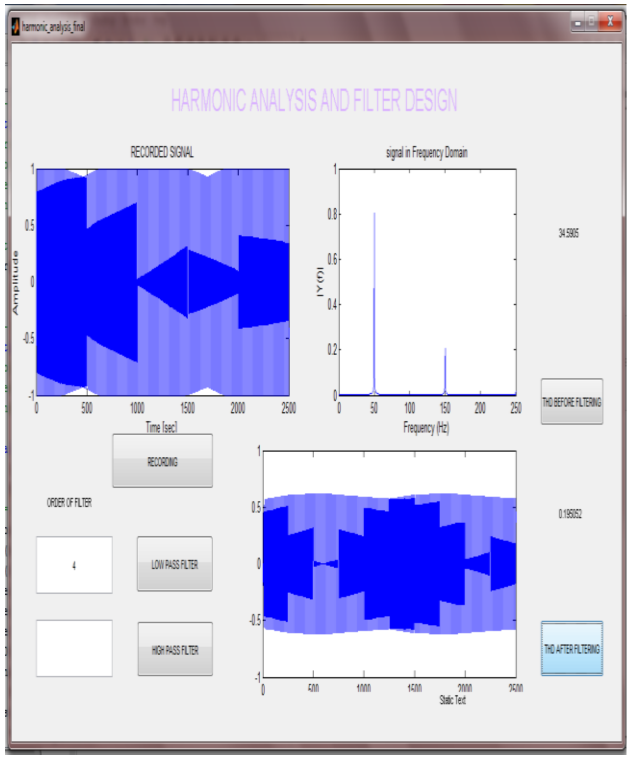

Figure 14.

In all the above circuits output across one of the resistor is taken by connecting its output terminals through line in wire/male connector. This male connecter is then connected to MIC female connecter of the laptop and then program in MATLAB is executed, then waveform which contains harmonic is seen on graph. This can also be visualized into frequency domain, and finally the low pass filters and high pass filters are employed to analyze the best filtering circuit. Fig shows the waveform before and after filtering, giving us the choice of best filter and its number.

VII. CONCLUSION

Recent advancement in the field of electronic computing has shown its effects in every aspect of life. Use of computers for Design and Analysis has reduced the time, energy and resources required to be spent using conventional methods involving manual calculations. Computer aided design and analysis has another edge over orthodox means; we can only verify the design to catch any errors in the design process. Thus, powerful computer software like MATLAB can greatly reduce the time and effort spent on the calculation required for the design process.

REFERENCES

[1] Ward Jewell, Daniel J Ward, "Single Phase Harmonic Limits", PSREC EMI, Power Quality, and Safety Workshop, April 18-19, 2002.

[2] Arindam Maitra, Christopher A Litton, "Application of Harmonic Limits at Wholesale Points of Delivery", IEEE Transaction on Power Delivery, Vol. 22, No. 1, January 2007.

[3] W. Xu, Y. Mansour, C. Siggers, M. B. Hughes, " Developing Utility Harmonic Regulations Based on IEEE STD 519 - B.C. Hydro's Approach," IEEE Trans. on Power Delivery, Vol. 10, No. 3, 1995, pp. 137-143.

[4] Shafqat Mughal, Neeten Sharma, Pankhuri Kishore "An Analysis of Power Quality Problems and Its Mitigation" Published in the proceedings of National Conference on Emerging Technologies in Renewable energy & Electrical Engineering-2012 (ETREEE-2012) held on 25-26,Feb,2012 at Sangam University Rajasthan.

[5] M Izhar, C M Hadzer, Syafrudin, M S Tiab and S Idris, " Performance for passive and Active Power Filter in Reducing Harmonics in the Distribution System", Proceedings of National Power and Energy Conference, Kuala Lumpur, Malasia, pp. 104-108, 2004.

[6] B. Palethorpe, M. Sumner, and D.W.P. Thomas, "Power system impedance measurement using a power electronic converter", Proceedings of IEEE International Conference on Harmonics and Quality of Power (ICHQP00), Orlando, FL, Vol. 2, pp. 280-293, October, 2000.

[7] David M McNamara, Alireza K Ziarani, Thomas H Ortmeyar, " A new Techniques of Measurement of Non stationary Harmonics," IEEE Trans. on Power Delivery, Vol. 22, No. 1, 2007, pp. 387-395.

[8] Julio Barros, Ramon I Diegos, "Analysis of Harmonics in Power systems Using the Wavelet Packet Transform," IEEE Trans. on Inst. & Measurement, Vol. 57, No.1, 2008, pp. 63-69.

[9] B. Palethorpe, M. Sumner, and D.W.P. Thomas, "Power system impedance measurement using a power electronic converter", Proceedings of IEEE International Conference on Harmonics and Quality of Power (ICHQP00), Orlando, FL, Vol. 2, pp. 280-293, October, 2000.

[10] Y. Baghzouz, "An overview on probabilistic aspects of harmonics in power systems", Proceedings of IEEE Power Engineering Society General Meeting(PES05), San Francisco, CA, pp. 2813 - 2815, June, 2005.