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Harmonics Detection and Measurement in Power System

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Abstract: In present scenario use of power electronic systems and time-variant nonlinear loads in industry has been increased and hence the harmonics gets resulted in power-line pollution. Thus, it can be said that harmonic voltage and currents in an electric power system appear because of non-linear electric loads. Power supply quality is therefore gets reduced. Harmonics are found to have venomous effects on power system equipments including transformers, capacitor banks, rotating machines, switchgears and protective relays. As the number of harmonics-producing loads has increased over the years, it has become increasingly necessary to detect them when making any changes or additions to a system installation. Hence, reduction of harmonics is considered desirable for analyzing power supply quality. One of the widely used computation algorithm for harmonic analysis is Fast Fourier Transform (FFT). In this paper, the fundamental frequency of 50 Hz is generated using ARM7 and for study purpose, here harmonics are generated by adding various frequencies. This distorted signal is being analyzed using FFT algorithm. The amplitude of harmonics and THD which are computed using the controller is displayed on a graphic LCD. This harmonic detector is tested on various instruments like rotors, power convertors, SMPS. The results from designed system are much agreeing with ideal harmonics analyzing system.

Keywords—Nonlinear loads, harmonics, power supply quality, harmonic analysis, THD, FFT

I. INTRODUCTION

As technology tends to improve, the wide use of the power electronics equipments in power system occurs, and then the harmonics comes in picture to cause negative impacts on power system and disturbs it's working.

Definition of power quality is a set of electrical boundaries allowing an equipment to function in its intended manner with no significant loss of performance or life expectancy. Various methodologies and techniques were proposed to improve the power quality. Any deviation from the perfect sinusoidal waveform is nothing but distortion and hence harmonic distortion. Harmonics are voltages or currents with frequencies which are integer multiples of the fundamental power frequency. Harmonics current is one of the parameters which affect the quality of power and they are supplied by the non-linear equipment, which disrupts the desired linear system. Common risks of harmonics include potential fire hazard, excessive heat, false tripping of branch circuit breakers and consequently increases maintenance cost [2], [3], [17].

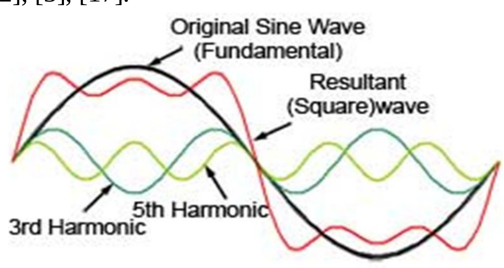

Fig 1: Waveform Distortion

The figure 1 shows the distorted waveform, its fundamental frequency and its 3^{rd} and 5^{th} order harmonic frequency.

The harmonic component in an AC power system is nothing but the sinusoidal component of a periodic waveform that has a frequency of an integer multiple of the fundamental frequency of the system. It can be given as:

$$fh = n * \text{fundamental frequency}$$

Where, fh= harmonic order, n= integer, and the fundamental frequency is either 50Hz or 60Hz.

For example, if a system has the fundamental frequency as 60Hz then its 2nd and 3rd harmonic would have frequencies of 120Hz and 180Hz respectively [1], [2], [17].

Until now discussion has been carried out regarding harmonics, their orders and causes. Harmonics analysis is the issue of great importance for maintaining good quality of power system. Quite a lot of algorithms have been proposed on harmonic analysis. Among them Fast Fourier transform (FFT) is the most widely used computation algorithm. FFT is a competent algorithm used to figure out Discrete Fourier transform (DFT). For analysis of these harmonics which are relatively stationary compared to other power quality disturbances, the signals should be from the time domain to the frequency domain. This is done by means of the discrete Fourier transform (DFT), which can be implemented well by the fast Fourier transform (FFT). DFT uses a finite set of discrete-time sample of an analogue signal and produces a finite set of magnitudes of frequency amplitudes in the required spectrum. This paper focuses on implementation of 230V, 50Hz power supply harmonic analysis on using FFT algorithm.

II. RELATED WORK

It is quite obvious that any power system contains harmonics and many techniques have been implemented to measure them so far. Following are some methodologies that have been use for harmonics measurement.

For the consistent and proficient working of any system a properly designed electrical system is necessary. And the system should be harmonic free. For this purpose, capacitors in harmonic environment are applied. They are beneficial because they result in minimized THD, improved power factor and elimination of power factor penalties [3]. Authors in this paper have discussed two harmonic detection methods. The methods are selective harmonic compensation and overall harmonic compensation [4].

A inventive system is presented and which is made from a combination of the ARM9 chip and virtual instrument methodology. It is designed for measurement of real-time harmonics [7]. Frequency is a significant factor for harmonics measurement. The paper contains a review of several commonly used methods for power system harmonics measurement. And those methods are compared according to the feature of frequency recognition [8]. This paper gives a new idea for harmonic detection adopting the algorithm with combination of FFT with and wavelet transform for obtaining parameters of harmonic [9]. Harmonic components and harmonic distortion can be calculated using distortion meter. This paper presents the harmonic distortion meter based on microcontroller and its software part carries out calculations using DFT. DFT is used to find amplitude in order to measure THD in power system [10]. In this review paper an author has discussed harmonic detection methods in frequency domain as well as in time domain [11].

Usage of non-linear loads in power system is leading sources of harmonics; and this has become much serious problem. One of the widely used algorithms for harmonic analysis is Fast Fourier Transform (FFT). In this project, a harmonic analyzer is implemented using FFT on ARM7 core processor (LPC2138). This system has the advantage of being available in at low cost [14]. It is very well known that harmonics is a very basic property of power quality. So it has become necessary a thing to measure these harmonics. Instead of using traditional measurement device a new method to detect and measure harmonics is presented. This device consists of the analog to digital converter, FFT unit, LCD display unit, and network communication unit. This methodology adopts FPGA and DSP processor. [16].

III. METHODOLOGY

In this work significant modifications in the existing systems have been proposed in performing better and more accurate analysis of harmonics in power system. Existing harmonics detection and measurement techniques has been studied together for designing a new efficient method for harmonics analysis which will meet expectations of high efficiency, good performance and eliminating limitations of existing techniques up to great extent.

The proposed methodology for harmonics detection and measurement is:

A. Generation of a 50Hz pure sinusoidal waveform using ARM7 using either PWM technique or using DAC technique
B. Design of variable oscillator which will produce signals of different frequencies and of different amplitudes.
C. Design of analog mixer for addition of two or more signals of different frequencies, different shapes and different amplitudes.
D. Combine the 50 Hz signal with oscillator output using mixer. And obtain the distorted waveform of different shape at mixer output. These are nothing but harmonics added in the system.
E. After addition of signals, the mixer output is observed on spectrum analyzer. The distorted waveform is given to controller input to measure its parameters. The FFT algorithm is used for harmonic analysis.
This method is using FFT algorithm because it is efficient and effective than other advanced methods. Still it has some difficulty in analyzing non-Fourier based and disturbing signals. FFT is suitable for steady and stationary harmonics only. But it gives faster results with minimum number of performing operations.

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IV. PROPOSED SYSTEM DESIGN

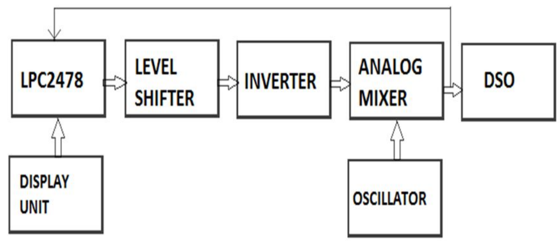

Fig 2: Block Diagram of proposed System

Figure 1 shows the block diagram of proposed system. From which idea behind working of the system is gets cleared. Let's have a brief view on each block and its function.

The block diagram of system contains sine wave generator (using PWM techniques), mixer, and local oscillator.

Here, Arm7 (LPC 2478) is used as the microcontroller. The whole section can be divided into three main sections, pure sinusoidal wave generation using DAC on ARM 7 platform, designing of variable oscillator and frequency adder (mixer) and harmonics analysis using FFT algorithm. If the harmonics signal is detecting, then it will be showed on graphical LCD. It shows the percentage of total harmonic distortion (THD) or it can be seen on spectrum analyzer.

A. Sinusoidal Waveform Generation

The basic idea here is to generate or synthesize a sine wave by passing a digitally generated PWM through a filter. This technique can be also used to generate other different shaped waveforms like sawtooth, square, etc. Generally, lookup tables are used to make it easier and faster. Also by changing the lookup table, changes apparently occur in the wave form.

B. Oscillator Circuit

The Wien bridge oscillator is used to generate variable frequencies. These frequencies will get added with the fundamental frequency by using mixer circuit.

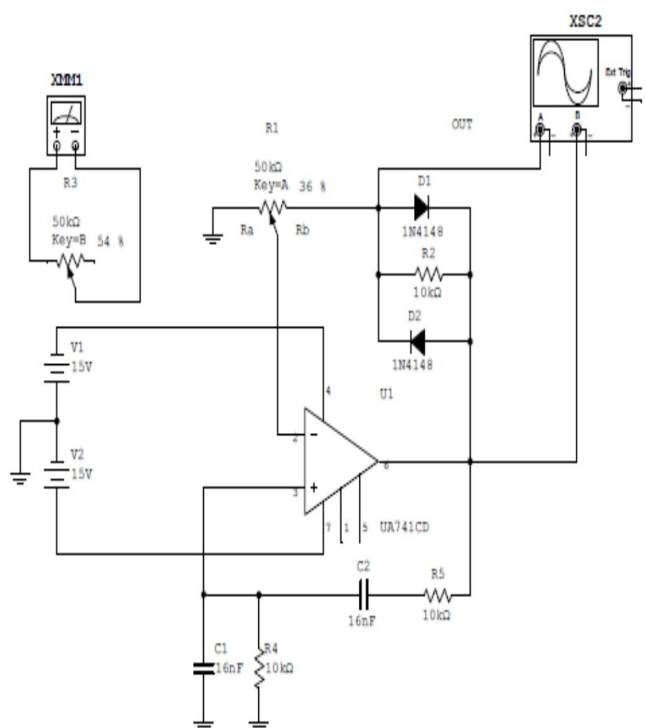

Fig 3: Block diagram of Wien bridge oscillator circuit

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C. Mixer Circuit

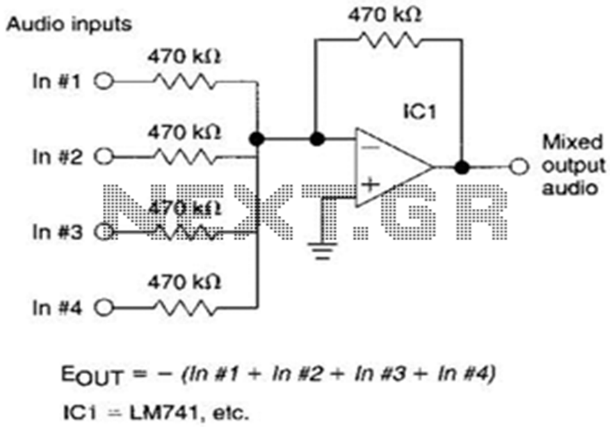

Fig 4: Circuit Diagram of Analog Mixer

In order to generate distorted signal i.e. harmonics signal simple adder or mixer circuit is required. This mixer will add the fundamental frequency (50Hz) and other frequencies signal generated by Wien bridge oscillator. The output of mixer circuit is distorted signal and called as harmonics.

D. Harmonics Analysis using FFT Algorithm

For maintenance system power quality harmonic detection is of necessity for this purpose FFT is widely used. Many instruments used for harmonic detection adopt FFT algorithm. FFT algorithm is quite mature method, it obtains parameters of stable harmonics precisely and it gives its results in less number of computational steps.

The most well known method for frequency detection techniques are discrete Fourier transform (DFT) and fast Fourier transforms (FFT). DFT transforms the discrete time domain signal into the frequency domain, and determines the magnitude and the phase angle of all harmonic components. FFT improves DFT by significantly reducing the number of computational steps.

To analyze the distorted waveform obtained, the quantity of the Total Harmonic Distortion, THD is used. THD is the ratio of the sum of amplitudes of harmonic components to the amplitude of fundamental frequency. It is necessary to find is the voltage distortion and this can be done by finding the sum of the RMS of the harmonic components.

$$THD = \frac{\sum Vn^2}{V1^2} * 100$$

Where, Vn and the RMS of(the fundamental frequency, V1.

Generally, representation of harmonic components is given with equation:

$$fh = \frac{fn}{f1} * 100$$

Where fn= current amplitude of nth order harmonic, $f1$=fundamental current amplitude.

3rd harmonic components are leading cause of the problems in power systems. Since the 3rd harmonic is the 2nd highest energy from the fundamental component. So, in finding only the 3rd harmonic distortion using this equation

$$HD = \frac{V3}{V1} * 100.$$

1) *Discrete Fourier Transform (DFT):* Using the Discrete Fourier Transform, deterioration of the periodic waveform can be done. f(t) gets divided into the addition of a number of sinusoids waveforms different frequencies. A0 is the amplitude of DC components. For AC voltage waveform, A0 is zero.

$$f(t) = A0 + \sum (Bv \sin Vwt) + (Cv \cos Vwt)$$

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The amplitude for each harmonic can be computed from given equation.

$$Av = \sqrt{Bv^2 + Cv^2}$$

The coefficients of harmonic components are Bv and Cv. They can be calculated by multiplying the equivalent sine wave and cosine wave to the input signal respectively.

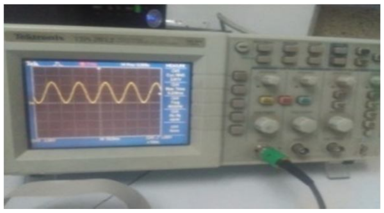
$$Bv \sim \frac{2 \vartriangle t}{T} \sum_{r=1}^{n} VrsinVwtr$$

$$Cv \sim \frac{2 \vartriangle t}{T} \sum_{r=1}^{n} VrcosVwtr$$

V. EXPERIMENTAL RESULTS

Proposed system starts with generating a pure sinusoidal waveform of 50Hz using ARM7 microcontroller (LPC2478). Then comes designing of variable frequency oscillator and analog mixer. The main function of mixer is addition of 50 Hz sinusoidal signal and oscillator output with different frequencies. Thus, at the mixer output, distorted waveform is observed. This distorted waveform is analyzed using FFT algorithm and output can be seen on spectrum analyzer. Following images are taken during experiments which give clear idea of working of proposed system.

(a)



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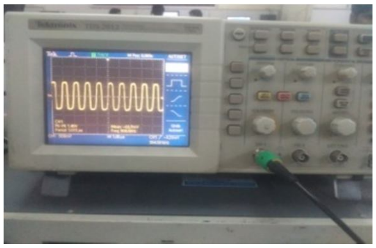

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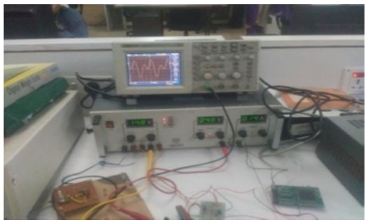

(d)

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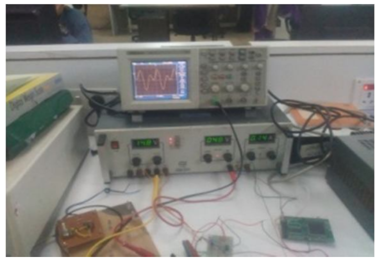

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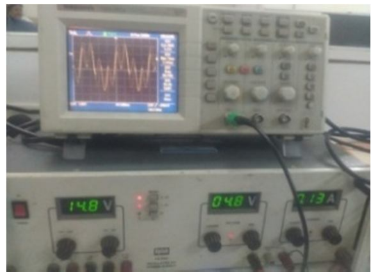

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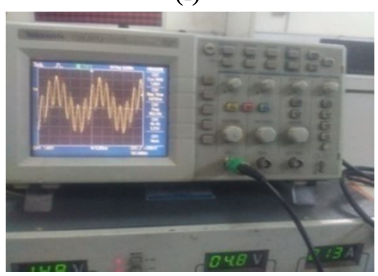

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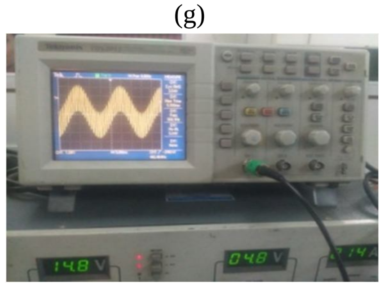

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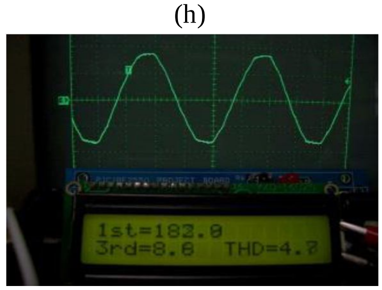

(i)

(a) Experimental set up for getting sinusoidal wave (b) Pure sinusoidal wave form of 50 Hz (c) Oscillator variable output (d) Experimental set up to get distorted waveform output at mixer end obtained by getting different frequencies (e) Distorted mixer output with order N=2 (50Hz+100Hz) (f) Distorted mixer output with order N=3 (50Hz+150Hz) (g) Distorted mixer output with order N=4 (50Hz+200Hz) (h) Distorted mixer output with higher order frequencies (50Hz+1KHz) (i) Detected and measured 3rd harmonics

VI. EXPERIMENTAL RESULTS IN TABULAR FORMS

Table below shows results obtained from different readings. It includes fundamental frequency, THD with ideal and practical values for different readings.

Table 1: 3rd Harmonic Distortion Readings (THDs)

Fundamental Frequency (Hz)	50	50	50	50
Total Harmonic Distortion	3.2	4.7	6.3	0.8
Ideal Distortion Meter	3.7	4.8	5	1.2

Table 2: Measured Amplitudes of Different Harmonics

Fundamental Frequency(Hz)	A0	A1	A2	A3	A4
50	2.5	0.208	0.553	o.419	0.294
50	1.75	0.145	0.388	0.297	0.201

VII. CONCLUSION

A new technique of harmonic detection which adopts the FFT algorithm is implemented. This instrument not only obtains the parameters of each harmonic but also responds to sudden changes. This is of great significance. The proposed system becomes more effective and efficient compared to other advanced methods because of its ability of performing faster calculations with less no of calculations and correct interpretation of transformed parameters. From Table 1, it shows that the designed system is much agreeing with ideal harmonics analyzing system. The results are used further to determine power quality of an instrument. Thus, our proposed system can be used as the "Power Quality Analyzer".

While going through repeating experimental results, it can be obvious that in Table 2 3rd harmonic amplitude is the second highest amplitude. They are highest second energy of fundamental component and they contribute more in harmonic distortion. Hence, focus on 3rd harmonic distortion than giving much attention to the other higher order harmonics is much beneficial.

In the actual power system, some of signals do have the nonlinearity, random nature and non-placidity. In such situations, proposed system faces difficulty to measure harmonic parameters of these disturbing waveforms. FFT algorithm suits to steady harmonics only. This problem would lead to inaccuracies due to the leakage effect when directly applying FFT for the spectral analysis

REFERENCES

[1] Harmonics Detection and Filtering, Low Voltage Expert Guides by Schneider Electric.

[2] Harmonics in Your Electric System, A White Paper of Eaton Corporation.

[3] Douglas Andrews, Martin T. Bishop, John F. Witte. May-June 1996. Harmonic Measurements, Analysis and Power Factor Correction in a Modern Steel Manufacturing Facility. IEEE Transactions on Industry Applications, Vol. 32, No. 3.

[4] Lucian As iminoae, Sergej Kalaschnikow and Steffan Hansen. Two harmonic Detection Methods used in Industrial Shunt Active Filters,

[5] Masoud Karimi-Ghartemani, and M. Reza Iravani. January 2005. Measurement of Harmonics/Inter-harmonics of Time-Varying Frequencies. IEEE Transactions On Power Delivery, Vol. 20, No.3.

[6] David M. McNamara, Alireza K. Ziarani, Thomas H. Ortmeye. January 2007. A New Technique of Measurement of Nonstationary Harmonics. IEEE Transactions on Power Delivery, Vol. 22, No.1

[7] Weicheng XIE, Xia YANG. 2010. A Power Harmonic Measurement System Based on Wavelet Packet Transform and ARM9. IEEE.

[8] Gary W. Chang, Senior Member, IEEE and Cheng-I Chen. 2010. Measurement Techniques for Stationary and Time-Varying Harmonics. IEEE

[9] Shouxi Zhu, Wenlai Ma. 2012. Design of Power Harmonic Detection Instrument Based on DSP and ARM. CISME Vol.2 No.2

[10] Jaipreet Kaur Bhatti, Deepak Asati. June 2012. Harmonic Detection using Microcontroller. International Journal of Computer Technology and Electronics Engineering (IJCTEE) Volume 2, Issue 3.

[11] Yi Fei Wang,Yun Wei Li.2013. An Overview of Grid Fundamental and Harmonic Components Detection Techniques. IEEE

[12] Zhaobi CHU, Ming DING, Shaowu DU, Xueping DONG. 2013. Normalized estimation of fundamental frequency And measurement of harmonics/interharmonics.

Volume 4 Issue X, October 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

[13] Alexander Kamenka. 2014. Six Tough Topics about Harmonics Distortion and Power Quality Indices in Electric Power System. A White Paper of Schaffner Group.
[14] Jeena Joy, Amalraj P.M, Aswin Raghunath, Nidheesh M.N Vinu Joseph. August 2014. Harmonic Analysis of 230 V AC Power Supply Using LPC2138 Microcontroller. Transactions on Engineering and Sciences, Vol.2, Issue 8.
[15] Manish Kumar Soni, Nisheet Soni. February 2014. Review of Causes and Effect of Harmonics on Power System. International Journal of Science, Engineering and Technology Research (IJSETR), Volume 3, Issue 2.
[16] Feng Guihong, Zhang Jing, Zhao Yisong, Ying Yong, Zhang Bingyil. Harmonic Power Detection and Measurement Device Based on Harmonic Power Flow Analysis.
[17] Snehal R. Durdhavale, Dnyaneshwar D. Ahire. . June 2016. A Review of Harmonics Detection and Measurement in Power System. International Journal of Computer Applications, Volume 143 – No.10.