

# Harmonics Sensing Smart Meter Using Arduino

S.Thirunavukkarasu

*Associate Professor, Department of Electrical and Electronics Engineering  
Paavai Engineering College, Namakkal, Tamil Nadu, India*

A.Sanjeet, S.Santhosh, N.Sriram, S.Sridhar

*UG Students, Department of Electrical and Electronics Engineering  
Paavai Engineering College, Namakkal, Tamil Nadu, India*

**Abstract-** In this article, the value of THD is found using the FFT method. Due to increase in usage of electrical appliance, it may consume more power. It may also produce harmonics in power signal and variation in the power factor. Some of harmonics in the power signal are harmful to sensitive equipment and also cause power loss. It is essential to analyze the power signal and find the value of THD (Total Harmonic Distortion) using the Fast Fourier Transform method. It is therefore important to find such harmonics and use different harmonic mitigation techniques to get the pure signal for safe operation of the connected equipment and minimize the power loss. Here we also calculate the value of power factor to avoid damage to the machines in the generating stations. The power factor value is also determined to balance the inductive and capacitive load. The THD value and the power factor value are calculated for both single phase and three phase circuits.

**Keywords –** Analysis of harmonics, Potential transformer, Arduino, Power factor, Induction Motor.

## I. INTRODUCTION

In the modern world we are under necessity to use the electrical equipment in our day to day life and it becomes one of our essential requirements. The usage of power electronic has drastically increased in commercial, domestic and industrial equipment. There are many advantages of power converters such as high power density, small losses and low weight. Harmonics are voltages or current with frequency that are integral multiple of fundamental power frequency being 50 or 60 Hz. In [1] it details the design and implementation of harmonic analyzer for analyzing the harmonic content in the power signal. The analyzing of power signal is carried out by DSP based instrument that make use of signal processing techniques. The module of analog to digital converter is one of the key interfaces to the real world. The TMS320F2812 has an integrated 12-bit ADC. In [2] it deals with the single phase as well as three phase power factor correction, reactive power and THD compensation using Arduino UNO micro controlling chip. This detects the power factor lead/lag and improves the power factor automatically. In [3] the article details about the fault diagnosis in the CHB multilevel inverter. The fault is caused due to interactions of switches in the multilevel inverter. The possible switch fault location is determined by the normalization factor (NF) of the output current and THD value. The fault signal is identified according to the threshold level. In [4] high burden is created on the feedback current correction loop due to harmonic distortion induced by current transconductance amplifier and it may compromise the measurement accuracy. By recording THD level in the load current periodically, we can test the stability of this method. In [5] the THD value is measured using low pass filter and a grid monitoring system which provides fundamental and harmonic components of the grid voltage. This method is developed by using SOGI error signal notch filter transfer function. It can be easily implemented into the digital signal processing (DSP) as it has small computational burden. The behavior of the method in front of grid perturbations, such as frequency steps and voltage sag perturbations was also analyzed.

## II. PROPOSED ALGORITHM

### 2.1 The proposed Harmonics sensing smart-

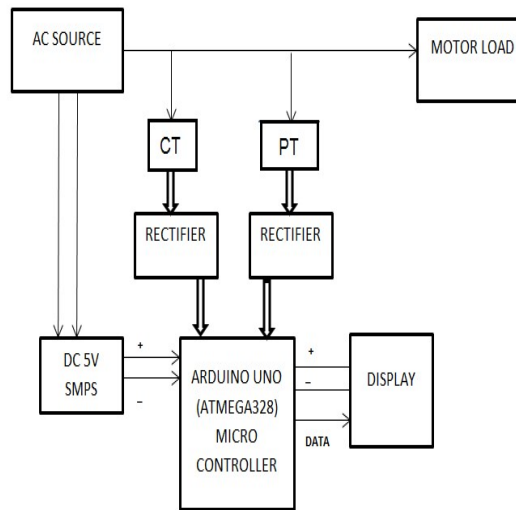


Figure 1. Block Diagram of the proposed system

## 2.2 Demonstration-

The alternating current (AC) is the power supply given to the electrical equipment through switched mode power supply (SMPS). The switched mode power supply (SMPS) converts AC source into DC source and it also step downs voltage to 5V which gives constant supply to arduino. The current transformer and potential transformer is used to measure the waveform and compare it with reference waveforms which is previously fetched in arduino. In the arduino embedded c program is fetched to detect the value of power factor and harmonics using Fast Fourier Transformer (FFT). Here we using arduino UNO which is a microcontroller board based on the ATmega328 (Data sheet). The secondary winding of current transformer (CT) will supply an output current of 5amps when the primary winding current is 4000 amps. The secondary winding can be single or multi-ratio, with five taps being common for multi-ratio CTs. Current harmonic measurements are measured by proteus software; harmonic meter is simulated using arduino micro controller. The arduino micro controller is programmed to display order of the harmonics and it also mentions the danger harmonic were supplied in the power line were displayed in the LCD. The THD value, voltage value and power factor value is displayed in the LCD display

## 2.3 Harmonic Analysis

Harmonic analysis is a technique used to determine the steady state response of a linear structure to loads that vary simultaneously with respect to time. The transient which occur at the initial condition of excitation is not accounted in harmonic response analysis.

The harmonic analysis is carried out by using the Arduino Uno where the code is fetched to it. The coding consists of FFT method which helps in separating the odd/even/inter harmonics. The voltage wave is compared with the current wave so that the harmonics in the power signal is determined by using the FFT method in the coding Fourier series

The trigonometric series for the periodic function can be mathematically expressed by

$$F(t) = \sum_{N=1}^{\infty} (a_n \cos(2\pi nt/T) + b_n \sin(2\pi nt/T) + a_0) \quad (1)$$

The THD value is identified by using the method of Fast Fourier transform. This Fourier transform helps us to separate odd/even and inter harmonics etc. STFT can be used for fundamental component as well as harmonic component. In electrical system, to view the harmonic distortion in its fundamental frequency is defined as Total Harmonic Distortion (THD).

$$THD = \sqrt{\frac{\sum_{n=2}^{\infty} V_n^2}{V_1^2}} * 100\% \quad (2)$$

$$C_n = \sqrt{p_n^2 + q_n^2} \quad (3)$$

and to find phase angle can be used,

$$\phi_n = \tan^{-1}(q_n/p_n) \quad (4)$$

With the coefficients  $a_0, c_n$ , and  $d_n$  are respectively

$$a_0 = \frac{1}{T} \int_0^T f(t) dt \quad (5)$$

The fundamental  $f$  value for a period is from 0 to  $T$

$$c_n = \frac{2}{T} \int_0^T f(t) \cos n\omega t dt \quad (6)$$

$$d_n = \frac{2}{T} \int_0^T f(t) \sin n\omega t dt \quad (7)$$

Where  $n$  is the harmonic order. Based on the Fourier series above we get the odd harmonic frequency waveform forming a multiple of fundamental frequencies like the third, fifth, seventh, and so on. In a network of alternating current systems  $a_0$  will not appear, and if the waveform is perfect or sinusoidal then the existing order is 1st order, ordinary harmonic amplitudes are expressed by:

$$C_n = \sqrt{c_n^2 + d_n^2} \quad (8)$$

Where  $n \geq 1$  for the value of  $C$  as a function  $n$  is often described in a bar chart and is known as the "Harmonic Spectrum". The Harmonic spectrum is the distribution of all the amplitudes of the harmonic component as its harmonic order function and is illustrated using a histogram. Fig 1 below shows an example of a harmonic spectrum. It can be said that the spectrum is the ratio of current and harmonic frequency voltage to the current and the basic frequency voltage.

## 2.4 Arduino Uno-

The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter. "Uno" means one in Italian and is named to mark the upcoming release of Arduino 1.0. The Uno and version 1.0 will be the reference versions of Arduino, moving forward. The Uno is the latest in a series of USB Arduino boards, and the reference model for the Arduino platform; for a comparison with previous versions, The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter. "Uno" means one in Italian and is named to mark the upcoming release of Arduino 1.0. The Uno and version 1.0 will be the reference versions of Arduino, moving forward. The Uno is the latest in a series of USB Arduino boards, and the reference model for the Arduino platform; for a comparison with previous versions,

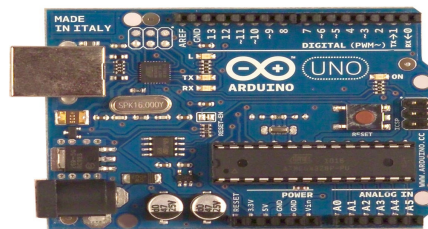


Figure 2. Arduino Uno

## III. EXPERIMENT AND RESULT

### 3.1 THD Analysis-

The circuit which is practically done is simulated using the circuit drawn below. This gets the value from the CT and PT circuits and it compares the value with the reference value. So that the THD value can be identified while performing simulation using this circuit.

The simulation result is attached below so that we can be able to view the harmonics in a form of waveform or in the numerical values. The current waveform is taken from the given supply and it compares with the reference waveform so that we can view the harmonics in the waveform for the first 15 or 30 cycles. The voltage also compares the waveform in the same manner. With this we can find THD (Total Harmonic Distortion) value in both the forms (numerical and in waveform). The power factor value is also identified to avoid penalty. The penalty is given only to the big industries as they create huge impact on the equipment used in generating stations. Here we can simulate the circuit using the MATLAB software. This shows the THD value in the numerical form or in the waveform. If this value exceeds the preset value then it may cause damage to the equipments connected across the line. The entire circuit is simulated using the components present in the simulation software (MATLAB). This displays the order of harmonics, power factor value and the THD value in the percentage.

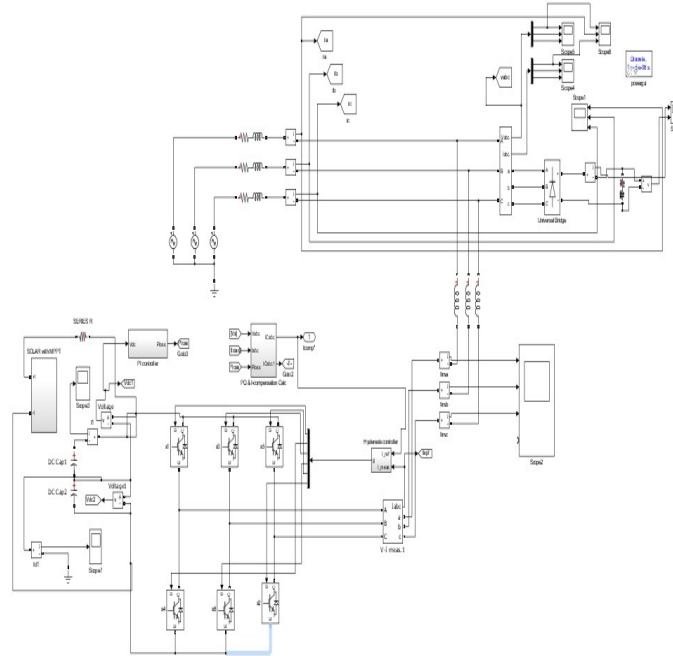


Figure 3. Simulink Model of the proposed system

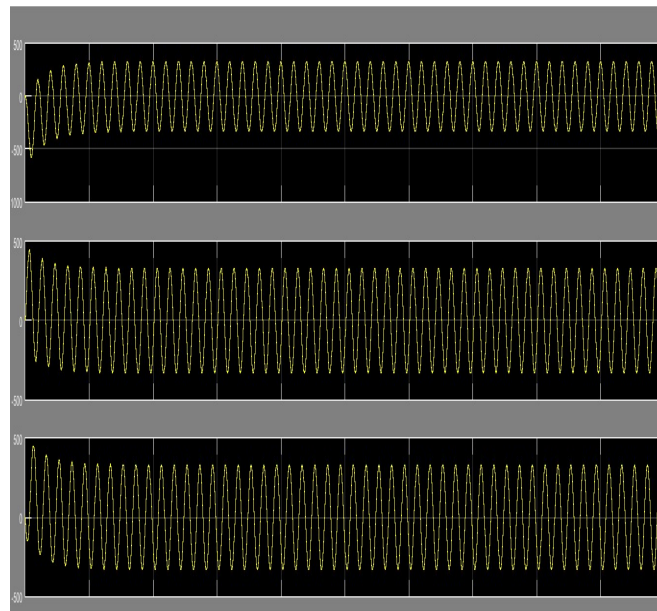


Figure 4. Three phase current value

This is the current waveform which is obtained from the power signal. This current waveform is compared with a reference value to check whether it has any frequency changes in the power signal. If there is any presence of frequency change then it may cause harmonic distortion in the power signal which will affect the life span of the equipment. Here we have taken three phase so it shows the current value of three phase. The current is required to compare it with the voltage waveform and it gives us the THD value in an approximate manner. The program is already fetched to the arduino where it compares the voltage value with the current waveform. This process is done to show the frequency change by comparing the current and voltage waveform with the fundamental frequency.

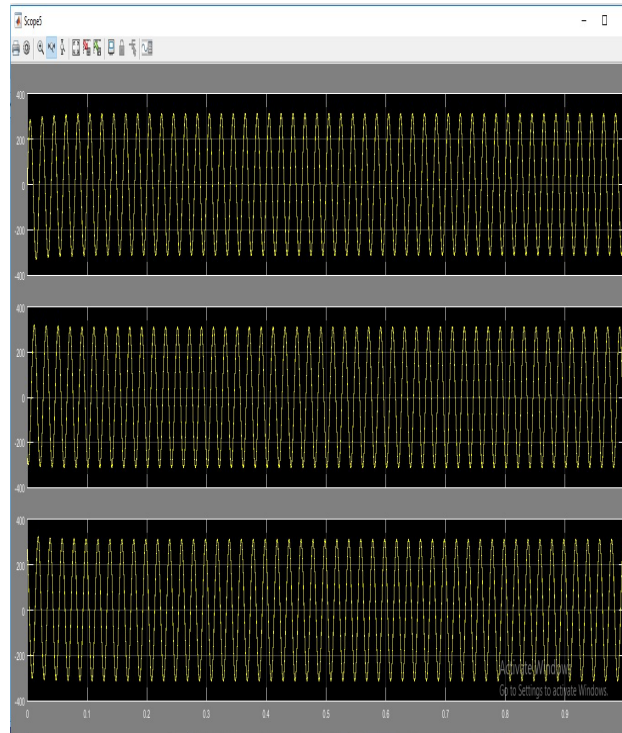


Figure 5. Output Voltage

The voltage waveform is obtained as per the connections made in the circuit. The program which is fed in the arduino helps us to compare the current and voltage waveform and shows us the frequency change in the form of THD value and also in the form of wave form. Here the voltage waveform and current wave form is compared and gives us the frequency change in the form of THD value. By using the simulation we can find the danger harmonic which cause damage to the equipment in both the industrial and commercial purpose.

In the FFT window, we select some of the cycles and check whether there is any vary in frequency and magnitude and the order of the harmonic in the form of bar chart or in the numerical form. The 3<sup>rd</sup> order, 5<sup>th</sup> order and 7<sup>th</sup> order can be identified and we can specify which harmonic cause damage to the equipment and we can also find which order of harmonic exceeds the value. The load connected across the circuit shows the THD value and the order of the harmonic in the bar chart. By identifying the order of the harmonic we can provide the filter circuit according to it. So that we can eliminate the danger harmonics in a easier mannner.

In this chart we select particular frequency cycles as we can view it clearly and can identify the order of the harmonics. With the knowledge of order of harmonic we can provide the filter circuit according to it. By knowing the specific harmonic which causes the danger harmonic we can use the filter circuit accordingly.

After entering the fundamental frequency and the maximum frequency in the pop up menu then click ok. This shows the frequency variation in the current waveform by comparing it with the fundamental frequency and displays the THD value in percentage. It also shows the order of harmonic and the power factor value.

We can't check the entire power signal so the first 5 to 8 cycles were taken as sample and we find the frequency change for these cycles. Then we multiply with the proportional value so that the entire power signal is verified. After setting the start point and the end point we can able to see the THD value in the display.

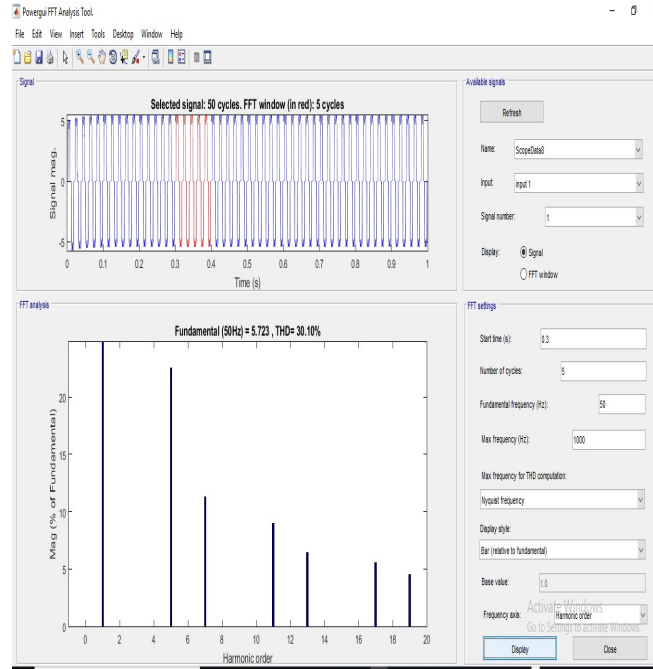


Figure 6. THD analysis for current

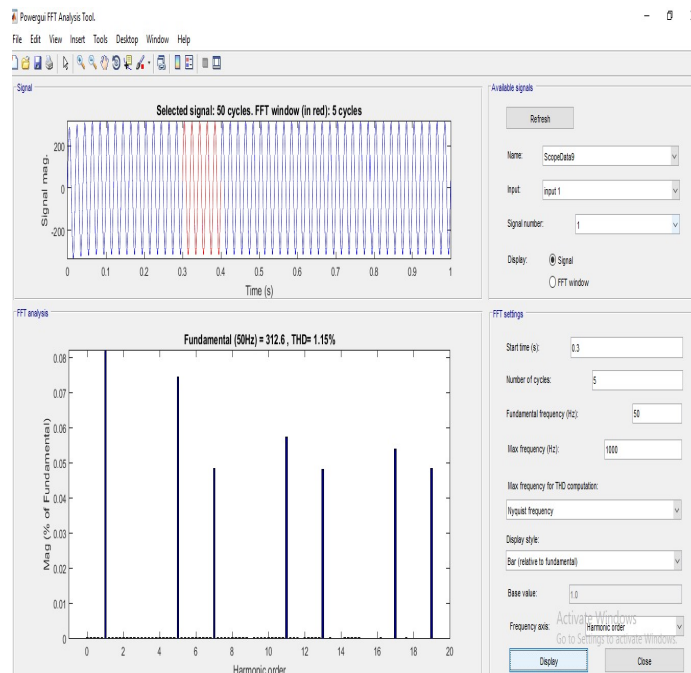


Figure 7. THD analysis for voltage

Here we check the order of the harmonic with the voltage value and compare it with the fundamental frequency. We can't check the entire power signal so we take the initial 5 to 8 cycle and check the frequency variation. In the FFT window, we select some of the cycles and check whether there is any vary in frequency and magnitude and the order of the harmonic in the form of bar chart or in the numerical form. The 3<sup>rd</sup> order, 5<sup>th</sup> order and 7<sup>th</sup> order can be identified and we can specify which harmonic cause damage to the equipment and we can also find which order of harmonic exceeds the value. This can be done using the MATLAB software and the result can be viewed by clicking the scope. The load connected across the circuit shows the THD value and the order of the



harmonic in the bar chart. By identifying the order of the harmonic we can provide the filter circuit according to it. So that we can eliminate the danger harmonics in a easier mannner.

### 3.2 Experimental Setup-

The supply is given parallel to the kit and the load used across the kit. The SMPS (Switched Mode Power Supply) is used to give constant supply to the circuit and it also converts AC supply into DC supply. The potential transformer is used to reduce the rating of the voltage as we have only small measuring instrument. This reduces the rating so that we can able to perform the mathematical operation in an easier way. The current transformer is also used to reduce the rating and gives the ratio in 4000:5 A. Mostly we use 5A in the secondary coil of the current transformer. Here we were connected the CT and PT to the arduino and SMPS is also connected to the arduino which provides a constant supply to the micro controller. The FFT algorithm is used in the C program so that it separates the even/odd/inter harmonics. The program fetched in the arduino compares the waveform with the reference waveform to give the frequency changes in the THD value. The THD value is displayed in the LCD display which is connected next to the arduino board. We can find the THD value for both the single phase and three phase machines or equipment. Here we also find the power factor value. The power factor value is need to be measured as it may cause damage to the equipment connected across it. In some cases, the government will put a penalty to industries who violates the pre-determined value. So this circuit determine the value and this value is also displayed in the LCD display.

The experimental setup is done as per the diagram shown below. The load can be used according to the user convenience. This may help the user to increase the life span of the equipment which they use. This makes the equipment to perform in an optimal way so that the life span can be increased in easier way

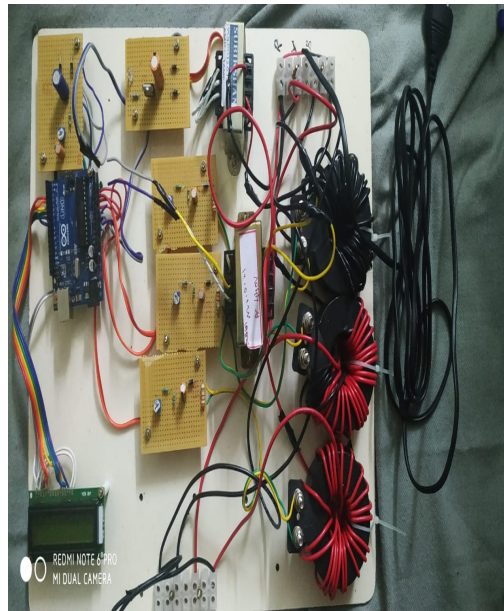


Figure 8. Hardware Impelementation

Table -1 Experiment Result

Types of Load	Voltage value	THD value	Power factor value
Lamp	227 V	4%	0.98
Quarter HP induction motor	228V	6%	0.94
Induction fan	229V	9%	0.96
3 phase motor	439V	7%	0.91

## IV.CONCLUSION

The THD value and the power factor value is measured or calculated in a mathematical operation carried out by the program which is fetched to the arduino UNO micro controller. The THD value and power factor value is identified for both single phase and three phase equipment which is used in the industries and also in the houses. From the research that has been done then arduino managed to show the measurement of harmonic content of 3rd order current, voltage, current and power factor displayed by LCD. The programming language used is C language, this programming language tends to be widely used by programmers because of its more practical use. For the next research it is advisable to design a series of harmonic meters using wireless.

In the future the study will be based on power factor so that we can do power factor correction in the circuit. In this circuit we have calculated the THD value and also the power factor value for both the single phase and three phase machines. The power factor plays a major role in the industry as they may cause damage to the machines in the generating station and due to this the government sector may put a penalty to the industry. So we are going to do a study in doing power factor correction and it may be implemented with the circuit.

## REFERENCES

- [1] Prasheel V. Suryawanshi, Ganesh Bhujbal and S.L.Patel "A FFT BASED HARMONIC ANALYZER ON TMS320F2812 DIGITAL SIGNAL CONTROLLER" International J.of Multi.displ.Research & Advcs in Engg.(IJMRAE), ISSN 0975-7074, Vol.1, No. I, November 2009, pp 71-86.
- [2] Saurabh B. Jarad1. Vishal D. Lohar2. Shubham P. Choukate3. Mr. Shrikant D. Mangate4. 123Students, 4Asst.Prof. At SVPM's COE, Malegaon (BK) Department of Electrical Engineering, Savitribai Phule Pune University. "Automatic optimization and control of power factor, reactive power and reduction of THD for linear and nonlinear load by using arduino uno." Proceedings of the 2nd International Conference on Inventive Communication and Computational Technologies (ICICCT 2018) IEEE Xplore Compliant - Part Number: CFP18BAC-ART; ISBN:978-1-5386-1974-2.in 2018.
- [3] Pavan Mehta, Mayank Kumar, Subhanarayan Sahoo "Fault Diagnosis in Five-level CHB Inverter using Normalization Factor and THD Analysis" IEE JOURNAL in 2018
- [4] Amr Said, Eddy So, and Dave Angelo National Research Council Canada, Ottawa, Ontario, K1A-0R6, Canada (amr.said@nrc-cnrc.gc.ca) "Harmonic Mitigation of an Improved High Voltage Current Source for On-site System Calibration of High Voltage Transformer Loss Measurement Systems" IN 2018
- [5] J. Matas\*, H. Martin\*, J. de la Hoz\*, A. Abusorrah†, Senior Member, IEEE, Y.A. Al-Turki†, Senior Member, IEEE, H. Alshaeikh "A New THD Measurement Method with Small Computational Burden using a SOGI-FLL Grid Monitoring System" in 2019.
- [6] P. D. V. and S. P. M. Srividya Devi P., "Measurement of Power and Energy Using Arduino," Res. J. Eng. Sci., vol. 2, no. 10, pp. 10–15, 2013.
- [7] U. P. Yagnik and M. D. Solanki, "Comparison of L, LC LCL filter for grid connected converter," in 2017 International Conference on Trends in Electronics and Informatics (ICEI), 2017, pp. 455–458.
- [8] E. Özer, "A Real-Time Harmonic Detection Method for SinglePhase Active Power Filters," Int. J. Appl. Math. Electron. Comput., vol. 4, p. 87, 2016.
- [9] J. Driesen et al., "Development of a measurement system for power quantities in electrical energy distribution systems," in IMTC/2002. Proceedings of the 19th IEEE Instrumentation and Measurement Technology Conference (IEEE Cat. No.00CH37276), 2002, vol. 2, pp. 1625–1630 vol.2.
- [10] E. So and E. Hanique, "In-situ calibration of high-voltage three-phase transformer loss measuring systems", IEEE Trans. Instrum. Meas., vol. 50, no. 2, pp. 422–425, April 2001.
- [11] A. Cataliotti, V. Cosentino, D. Di Cara, A. Lipari, S. Nuccio, and C. Spataro, "A PC-based wattmeter for high accuracy power measurements," in 2010 IEEE Instrumentation Measurement Technology Conference Proceedings, 2010, pp. 1453–1458.
- [12] Lukas Muller, Masihuddin Mohammed, Jonathan W. Kimball, "Using the Arduino Uno to Teach Digital Control of Power Electronics", Institute of Electrical and Electronics Engineers (IEEE), 2015.
- [13] Murad Ali, "Design and Implementation of Microcontroller-Based Controlling of Power Factor Using Capacitor Banks with Load Monitoring" Global Journal of Researches in Engineering Electrical and Electronics Engineering Type: Double Blind Peer Reviewed International Research Journal Online ISSN: 2249-4596 & Print ISSN: 0975-5861 Volume 13 Issue 2 Version 1.0 Year 2013.
- [14] T. S. Rathnayake, K. T. Rukshan, R.A.T J .K.Rupasinghe, R.M.Ruwanthika, "Design and Simulation of Single Phase Active Current Harmonic Filter", International Conference on Circuit, Power and Computing Technologies [ICCPCT] 2014.