



Measurement of Power and Energy Using Arduino

Srividya P., Pusphalatha D.V. and Sharma P.M.

Gokaraju Rangaraju Institute of Engineering and Technology (Autonomous) Hyderabad Andhrapradesh, INDIA

Available online at: www.isca.in

Received 1st October 2013, revised 17th October 2013, accepted 24th October 2013

Abstract

This paper deals with the measurement of power and energy using Arduino. The demand for power has increased exponentially over the last century. One avenue through which today's energy problems can be addressed is through the reduction of energy usage in households. This has increased the emphasis on the need for accurate and economic methods of power measurement. The goal of providing such data is to optimize and reduce their power consumption. This paper explains the process of a condensed design explanation and implementation of a laboratory –scale prototype which includes the energy measurement of the given load and its advantages

Keywords: Power measurement, load, Arduino, energy measurement.

Introduction

As we know that the rate at which electric energy is transferred by an electric circuit is called power. Power is an important electrical quantity and everything in our world today depends on having the power to keep them running. It is mandatory for a power engineer to know how much the amount of power a power plant generates and also the usage by the customer over a period of time¹⁻². It helps in estimation of transmission losses between the generation- distribution and distribution-consumer apparatus³. This estimation helps in power theft detection and in turn reduces the transmission losses. Measurement of electrical power may be done to measure electrical parameters of a system⁴. Depending upon the requirement of accuracy, time and the nature of the circuit there is a choice for method and instrument to be used in any given case of measurement⁵⁻⁶. In the existing power utility set up, consumers are presented with usage information only once a month with their bill⁷⁻⁸. The length of time between updates about power usage is far too long for a consumer to observe a changed behaviour's effect on power usage⁹⁻¹⁰. In addition utility bills can be convoluted in how they present usage information, and a consumer may not be able to decipher changes in their power usage from the last bill. An opportunity to educate customers on power usage is lost because of these realities.

The goal of creating more awareness about energy consumption would be optimization and reduction in energy usage by the user. This would reduce their energy costs, as well as conserve energy. There are various methods for measuring power such as single and two wattmeter methods etc. Power is rate of doing work. For DC circuits and purely resistive AC circuits, power is product of voltage and current. For reactive AC circuits the product of r.m.s values of voltage and current is termed as apparent power (VA)¹¹.

Out of different microcontrollers available in the market, the one, which is single board microcontroller, descendant of the open-source wiring platform designed to make the process of using electronics in multidisciplinary projects was Arduino. It is an open source microcontroller platform of electronics prototyping based on flexible and good interface between hardware cum software. Here in this project we used .Arduino Uno, a microcontroller board based on the ATmega328.

The proposed paper uses the commercial data acquisition board (DAQ) connected to a common personal computer for high accuracy power measurements. The power digitally measured using Arduino is displayed graphically by using Processing and Meguno Link software's.

Power and Power Measurement

Power is rate of expending energy. Watt is the unit for power (joule per second (J/s)). The difference in potentials between two points is equal to the energy per unit charge and this is required to move electric charge between the points, as we know, electric current measures the charge per unit time (in coulombs/second). The electric power p is given by the product of the current I and the voltage V (in joules/second = watts).

$$P = \text{work done per unit time} = qV/t = IV$$

Where: q is electric charge in coulombs, t is time in seconds, I is electric current in amperes, V is electric potential or voltage in volts

Energy: The amount of energy used (or supplied) depends on the power and the time for which it is used. Energy is defined by scientists as the ability to do work. This energy is found in different forms, such as light, heat, sound, and motion. There

are many forms of energy, but they can all be put into two categories: potential and kinetic.

$$E=P*t$$

Where: E= energy in watt hrs, P= power in watts, t= time taken in sec

DC Circuits: DC circuits mainly consists of only of resistive (Ohmic, or linear) loads, Joule's law can be combined with Ohm's law ($V = I \cdot R$) to produce alternative expressions for the dissipated power:

$$P=I^2R=V^2/R$$

where R is the electrical resistance.

AC Circuits: Eenergy storage elements such as inductance and capacitance results in periodic reversals of the direction of energy flow which are alternating in nature.

Active Power: The power consumed by the resistive elements in the circuit or the portion of power flow that, averaged over a complete cycle of the AC wave form, results in net transfer of energy in one direction is known as real power ,also called as Active power. It is the power that is actually being consumed by the load.

Reactive power: Power flow due to storage elements that returns to the source in each cycle is known as reactive power.

When the voltage and current are periodic with the same fundamental frequency, the instantaneous power is also periodic with twice the fundamental frequency.

Power measurement conventional Techniques: Power measurement is done for both AC circuits and DC circuits. Power can be measured by using different methods namely: i. Using various measuring equipments. ii. By interfacing the circuit with any software.

There disadvantage of the above power measurement techniques for example In the first Ammeter measures current which flow into the voltmeter and load. Secondly circuit, Voltmeter is the device which measures voltage drop across the ammeter in addition to that dropping across the load. So the above method is not accurate.

Power measurement can also be done using software like multisim, labview etc. But, the above methods implemented either in software or in hardware. Where as in Arduino Power Measurement project, the load circuit is interfaced with Arduino board, and is then programmed for measuring power for laboratory purpose which is more economical as it is an open source software when compared to other software which are costlier like Labview.

Design

Block diagram: The block diagram of the project Power Measurement using Arduino is as shown. The load circuit consists of resistive loads which are bulbs each of rating 200watts. These loads are energized by single phase 230V AC supply. The current and voltage through the load are stepped down to safer values by using a current transformer and potential transformer respectively. As the AC signals can't be given to Arduino board, these signals are offsetted using voltage and current offset data conditioning cards. These cards are energized using regulated DC supply. The function of offset data conditioning cards is to clamp the AC signal with respect to a preset reference DC voltage. The output waves from the voltage offset card are given as analog input to Arduino board at pins A_0 and ground. Similarly the output from the current offset card is given as analog input to Arduino board at the pins A_2 and ground. Once the analog inputs are given to Arduino and the measurement of power is done by Arduino sketch.

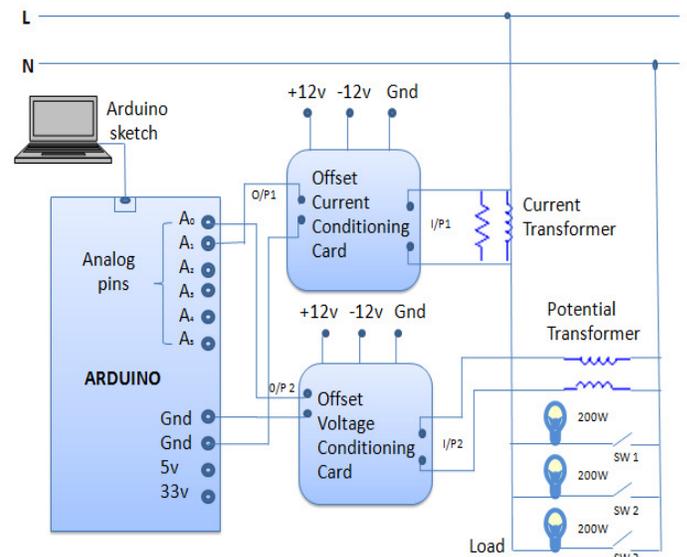


Figure-3(a)
Block diagram for Power Measurement

Offset data conditioning card: The function of offset data conditioning card is to clamp the given AC signal with respect to a reference DC voltage. The reference DC voltage is preset according to the components used in the circuit which intern depends on the maximum load rating. The circuit diagram of the offset data conditioning card is as shown. It consists of two op-amps, UA714CN which are operated in inverting mode. The first op-amp is used as a summing amplifier. It adds up the input signal with the DC reference voltage.

The output of the first op-amp is inverted using the second op-amp which acts as an inverting amplifier. The output of this op-amp is taken out as the output of the offset data conditioning card.

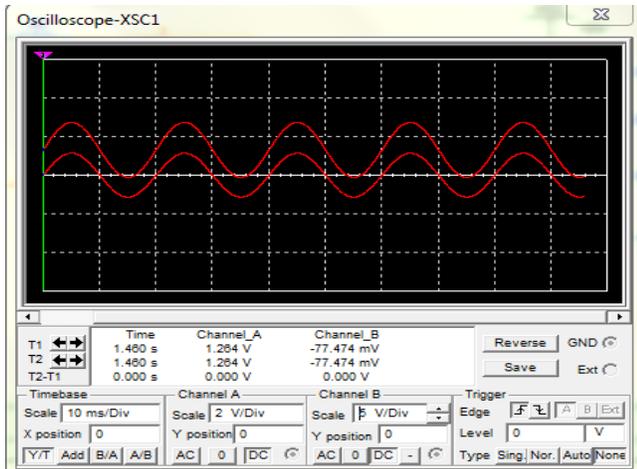


Figure-3(b)
 Simulation results of offset card in multisim

```

powermeasure | Arduino 1.0.1
File Edit Sketch Tools Help
powermeasure
}
void loop()
{
  float realPower = 0;
  for(int i=0;i<400;i++)
  {
    float P = 0;
    V= ((analogRead(Voltage)-(2.3*204.6))/204.6)*(66.474*1.414);
    I= ((analogRead(Current)-(2.22*204.6))/(204.6*20))*(76.667*1.414);
    P=V*I;
    realPower=realPower+abs(P);
    delay(0.05);
  }
  P1=realPower/400.0;
  time=millis();
  E=(P1*time*0.001)/(3600);
  delay(1);
  Serial.println(E);
  g_aGraphs[0].SendData(E);
}
    
```

Figure-3(c)
 Arduino programming sketch for power and energy measurement

Software: Arduino is a small microcontroller board with a USB plug to connect to the computer and a number of connection sockets that can be wired up to external electronics, such as motors, relays, light sensors, laser diodes, loudspeakers, microphones, etc. They can either be powered through the USB connection from the computer or from a 9V battery. They can be controlled from the computer or programmed by the computer and then disconnected and allowed to work independently. Arduino Uno, a microcontroller board based on the ATmega328 is used in this project. The hardware consists of a simple open hardware design for the Arduino board with an on-board input/output support. The software consists of a standard programming language compiler and the boot loader that runs on the arduino board. Arduino hardware is programmed using a Wiring-based language (syntax and libraries), similar to C++ with some slight simplifications and modifications, and a processing-based Integrated Development Environment (IDE).

The Arduino board is where the code is written and executed. Arduino senses the environment by receiving input from a variety of sensors and can affect its surroundings by controlling lights, motors and other actuators. The microcontroller on the board is programmed using the Arduino programming language and the Arduino development environment (based on Processing). Arduino projects can be stand-alone or can communicate with software running on a computer (e.g. Flash, Processing, MaxMSP and Megunolink). The hardware reference designs (CAD files) are available under an open-source license which is free to adapt to our needs. The open-source Arduino environment makes it easy to write the code and upload it to the I/O board. It runs on Windows, Mac OS X, and Linux. In addition to all the features of the previous board, the Uno now uses an ATmega8U2 instead of the FTDI chip. This allows for faster transfer rates and no drivers are needed for Linux or Mac (in file for Windows is needed), and the ability to have the Uno show up as a keyboard, mouse, joystick, etc.

Simulation Results

Our load circuit comprises of Resistive, Inductive, Capacitive loads. In this project we have used only Resistive loads of bulbs of each 200watts. We used potential transformer and current transformers, are stepdown to 3V. Arduino can accept up to 5 volts only. We calibrated each and measurement of power by the rating of bulb. Thus, an interface with hardware and software is made easier with arduino sketch for power and energy measurement.

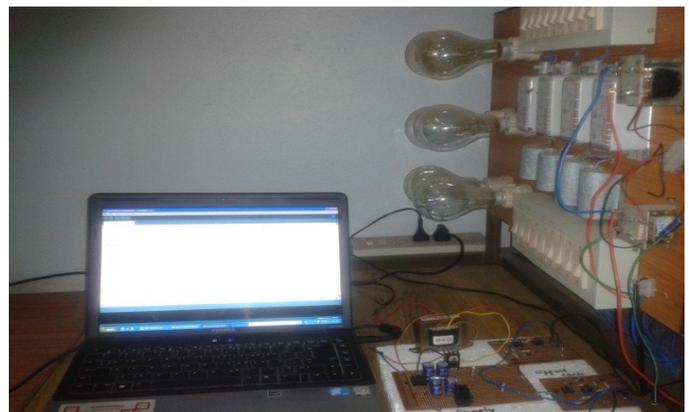


Figure-4(a)
 Hardware setup for power measurement

Single Load: When the first load having a rating of 200watts is switched on, the Arduino Serial monitor displays the average power consumed as 170watts in its COM window as shown in figure 4(b). Graphically it can be obtained using Megunolink software and processing software. The figure 4.1(b) represents a graph between average power in watts and time in seconds using Megunolink software. Figure 4.2(b) represents the graph which is displayed using Processing software.

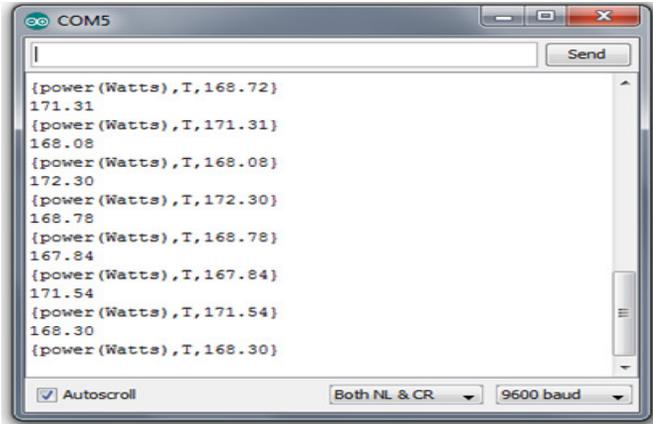


Figure-4(b)
 Serial monitor values for single load in Arduino

see spikes at the starting when the load is switched on. From this graph we can observe the change in average power consumed when the second load is switched on.

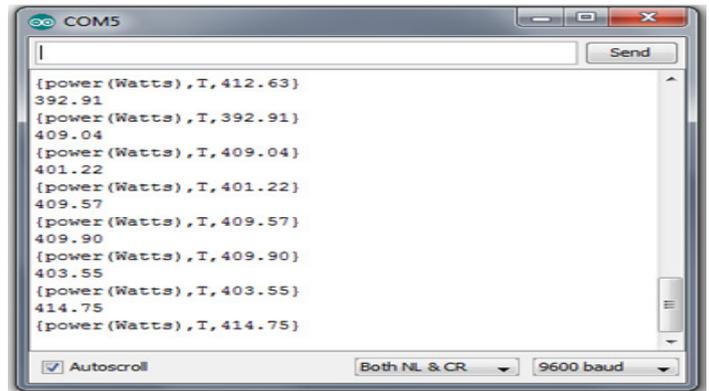


Figure-4(c)
 Serial monitor values for two loads in Arduino

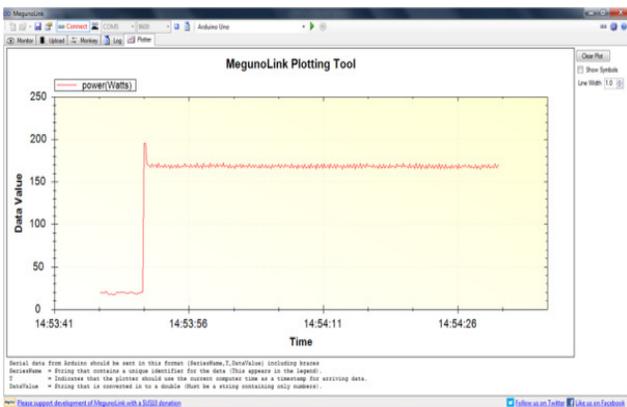


Figure-4.1(b)
 Megunolink plotting for single load

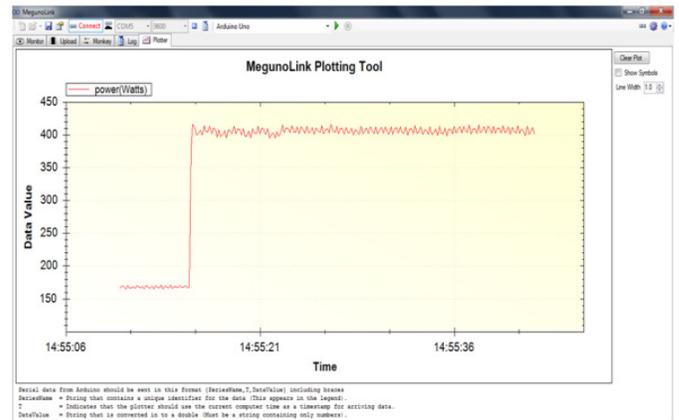


Figure 4.1(c):Megunolink plotting for two loads

Three Loads: When three loads are switched on (having a total rating of 600 watts, the average power values in the serial monitor shows nearly 615 watts as shown in the figure 4(d).

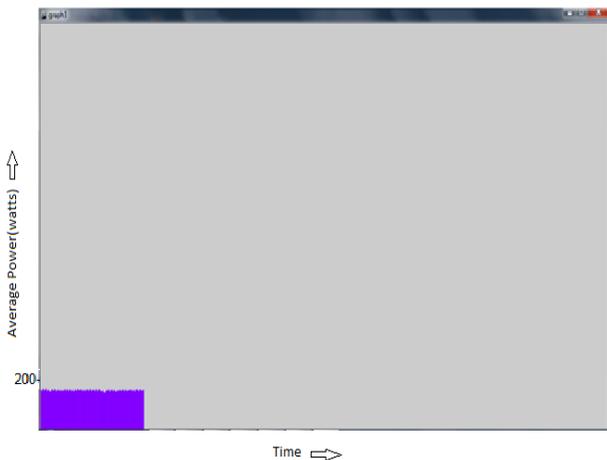


Figure-4.2(b)
 Graph for single load in processing sketch

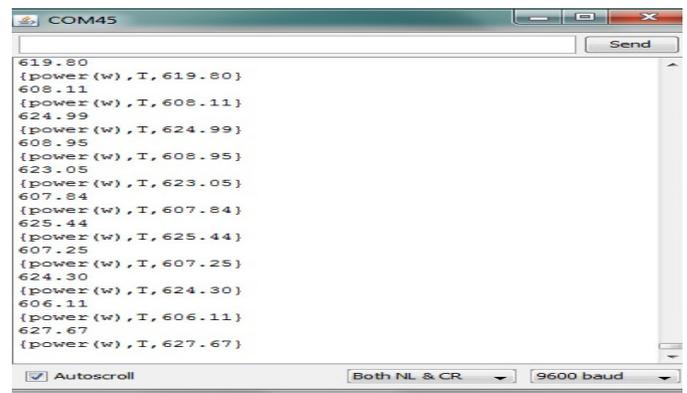


Figure4(d)
 Serial monitor values for three loads in Arduino

Two Loads: When two bulbs each of rating 200 watts is switched on, the average power values in the serial monitor shows nearly 410watts as shown in the figure 4.(b). At the initial stage usually load draws some high current due to which we can

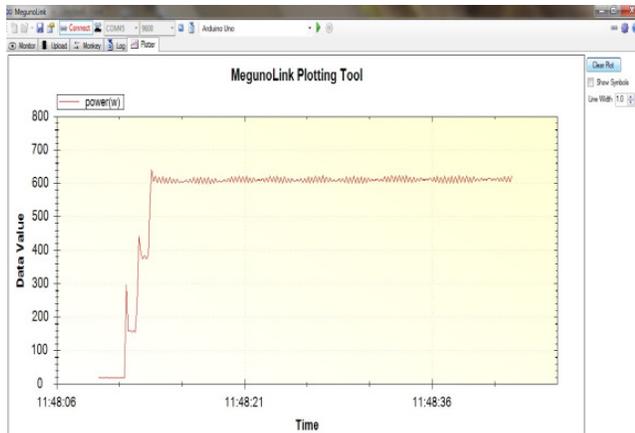


Figure-4.1(d)
 Megunolink plotting for three loads

Varying Loads: If the loads are increased and decreased in a step wise manner below are the graphs which are obtained in Megunolink and Processing software

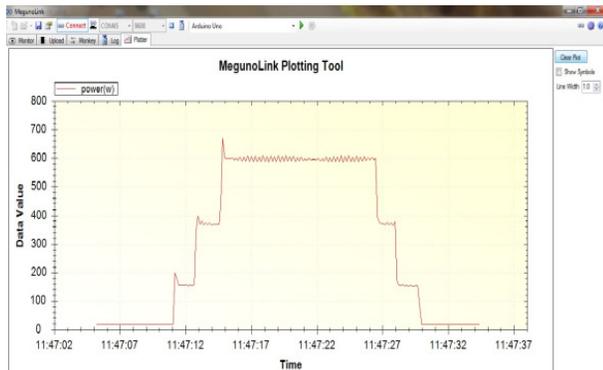


Figure-4(e)
 Megunolink Plotting for varying loads

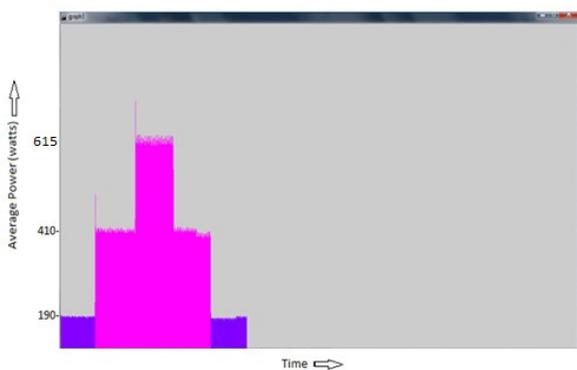


Figure-4(f)
 Graph for varying loads in processing sketch

Figure 4(g) shows how the energy is varying for various types of loads in megunolink. A linear curve which increases for each load with respect to the time.

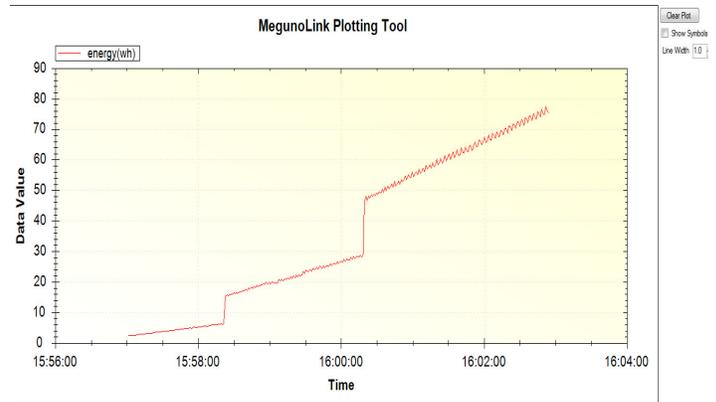


Figure-4(g)
 Graph showing the energy measurement

Conclusion

Power measurement is done for resistive loads up to a maximum load of 600 watts using Arduino environment. Results for three loads are shown in simulation. Arduino Power Measurement is an advanced method of determining power which uses a microcontroller and this method is more advantageous because the programming part is easier than C language. The advantages of Arduino over other software's are it simplifies the amount of hardware and software development needed in order to get a system running. It is open source software and can be extended by experienced programmers. Arduino has simple and clear programming environment and also has a quicker writing code. From the above discussion Arduino Power Measurement is an advanced method of measuring power and can also observe it graphically can be implemented for laboratory scale.

Apart from this Arduino based wireless power meter' can also be implemented. The Arduino based wireless power meter is a non-invasive current meter for household power with an Arduino interface. Current through the load is measured using split core current transformers. This data is then transmitted through the home's wireless router and back to the base station and is represented visually to the user. This method provides the domestic power consumption accurately, safely, and with a relatively fast update rate, thus helping the user optimize and reduce their power usage.

References

1. Cataliotti A. and Cosentino V., *A PC-based wattmeter for high accuracy power measurements*, Instrumentation and Measurement Technology Conference (I2MTC), IEEE 1453–1458 (2010)
2. Misakian, *Measurement of electrical parameters near AC and DC power lines* Instrumentation and Measurement

- Technology Conference, IMTC-88 Conference Record, 5th IEEE (1988)
3. Kuznetsov V., Kuznetsov A., *Measurement of power quality factors in electrical networks*, Precision Electromagnetic Measurements Digest, Conference (1996)
 4. IEEE Master Test Guide for Electrical Measurements in Power Circuits, *IEEE Power and Energy Society* (1989)
 5. Driesen J., Deconinck, *Development of a measurement system for power quantities in electrical energy distribution systems*, Instrumentation and Measurement Technology Conference. IMTC/2002, Proceedings of the 19th IEEE Page(s), 2, 1625-1630 (2002)
 6. Influence of Instrument Transformers on Quality of Electrical Power and Energy, Measurement Industrial Electronics, ISIE IEEE International symposium (2007)
 7. IEEE Master Test Code for Electrical Measurements in Power Circuits Power Engineering Society, IEEE Std 120-1955; ASME PTC 19.6-1955 (1955)
 8. A.K. Sawhney, A Course In Electrical And Electronic Measurements And Instrumentation, Publisher, Dhanpat Rai and Co., (2005)
 9. T.E.D. Liacco *Real-Time Computer control of Power Systems*, *Proceedings of the IEEE*, 62(7), 884 -891 (1975)
 10. D. Al. Katsaprakakis, D.G. Christakis, A. Zervos and S. Voutsinas, A Power Quality Measure, *IEEE Transactions on Power Delivery*, 23(2), (2008)
 11. Sandesh J., Singh T.S. and Phulambrikar S.P., improve power factor and reduce the harmonic distortion of the system, *Research Journal of Engineering Sciences*, (5), 31-36 (2012)