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ENERGY MEASUREMENT, MONITORING AND CONTROL OF ELECTRICAL DEVICES USING ARDUINO

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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: Energy Management, Home Energy Monitoring, Arduino, Embedded System

I.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 behavior'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).

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 is digitally measured using Arduino.

II. 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=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. Thereare 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·R) to produce alternative expressions for the dissipated power:

P=I2R=V2/R

Where R is the electrical resistance.

AC Circuits: Energy 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.

III. MATERIALS AND METHOD

Block diagram: The block diagram of the project Power Measurement using Arduino is as shown in Fig.1 . 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 A0 and ground. Similarly the output from the current offset card is given as analog input to Arduino board at the pins A2 and ground. Once the analog inputs are given to Arduino and the measurement of power is done by Arduino sketch.

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 opamps, 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 opamp which acts as an inverting amplifier. The output of this opamp is taken out as the output of the offset data conditioning card.

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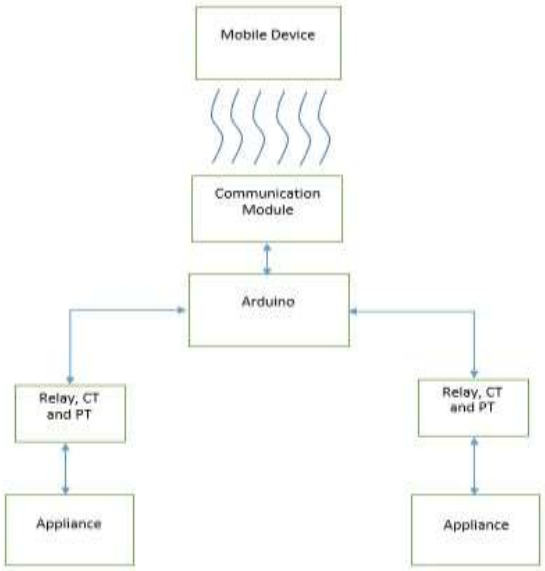

Fig.1

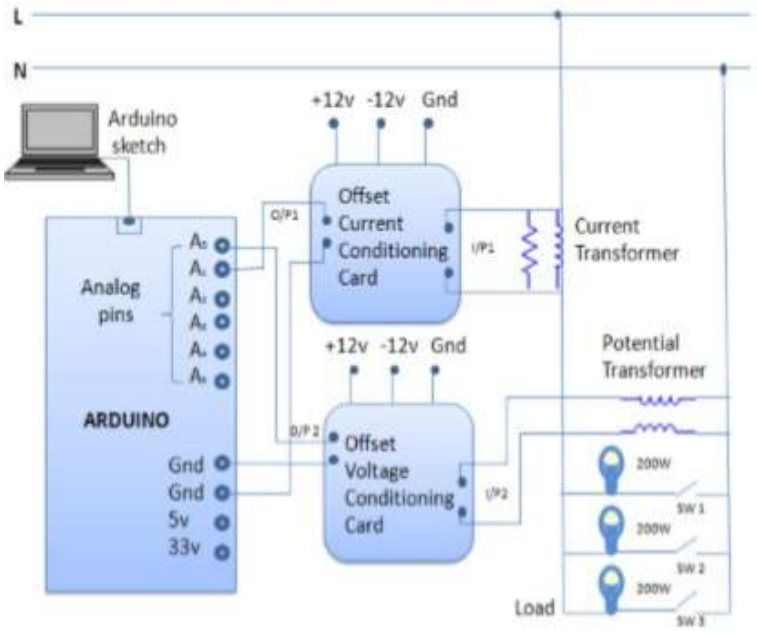

Fig.2

Arduino UNO: In the design of prototypes we use Arduino UNO. Arduino UNO is one of popular Arduino that uses ATmega328. Arduino UNO has 14 input / output digital pins (6 of which can be used as PWM outputs), 6 analog inputs, an oscillator crystal 16 MHz, a USB connection, a power jack, an ICSP header, and a reset button. It can be seen in Fig.3. The characteristics of the ArduinoUNO can be seen in Table I.

Mikrokontroler	ATMega328
Operation Voltage	5 V
Input Voltage	7 – 12 V (recommended)
Input Voltage	6 – 20 (limit)
I/O	14 pin digital input / output (6 pin for PWM) dan 6 pin only for analog input
Current	50 mA
Flash Memory	32 KB
EEPROM	1 KB
Speed	16 Hz

Table I

Fig.3

RM54OC Relay Module:Relay Module is a module that is very practical for use as a main switch relay for 4 channels project with microcontroller based electronic circuits. This module turns on / off other electronic devices that are powered by 240 VAC electrical AC or DC high-voltage devices (up to 28 VDC), such as High Power DC motors. It has a maximum current of 7 Ampere for each channel . The figure of RM54OC Relay Module can be seen in Fig.4 .

Fig.4

IV. RESULTS AND DISCUSSION

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 step down 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.

Fig.5

Fig.6

The results of the qualitative and quantitative analysis of the data were through testing of the system and interviews. During the testing of the energy monitoring system it was successful in getting data and passing data through Bluetooth Module to the mobile web application. The system was tested only on small scale household appliances such as lamp shades. Data gathered from the energy monitoring system is around 94 percent accurate from the exact energy during tests for 10 minutes and data was passed every 30 seconds.

V. 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.

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