

# Energy Conservation By Wireless Energy Monitoring System With Data Logging and Control Using Concept Of Internet Of Things

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**Abstract-** Increasing cost and demand of energy has led many organizations to find smart ways for monitoring, controlling and saving energy. A smart Energy Management System (EMS) can contribute towards cutting the costs while still meeting energy demand. The emerging technologies of Internet of Things (IOT) and Big Data can be utilized to better manage energy consumption in residential, commercial, and industrial sectors. The main aim of this project is to make wireless energy monitoring system with data logging and control using the concept of Internet of Things. This system has measuring circuit to measure voltage and current and calculates power and this data will be transmitted over wireless technology which is Wireless fidelity. Now a days, there is smart technology available to monitor as well as control the energy usage in industrial area and house hold system. User not only monitor the power as well as some control portion is also available to retain low power usage by means of controlling devices. User can ON/OFF devices at desire by using wireless controlling system.

Thus energy monitoring device integrating with the concept of internet of things allow their measured data to be monitored and retrieved at any location where internet is available. This will result in qualitatively different life style from today by using energy conservation method in smart way. We also get brief knowledge about IOT. It's architecture, applications, functional view and future challenges for IOT.

**Index Terms**— LM2576 Voltage Regulator, AVR microcontroller, ESP8266 Wireless Fidelity Module, Internet of Things (IOT), UDP application, Proteus Software, Processing Software.

## I. INTRODUCTION

In this project, two analog inputs of the microcontroller are used for measuring the input voltage and current. By sampling method implemented in the microcontroller, Analog-To-Digital conversions take place and every sample is stored in the memory in particular time interval. Sampled values are compared and calibrated with the help of input biasing circuitry which gives scaled values for the AC input and a current flowing through the device. Arduino has a library readily available to use for this calculation named Emon (Energy Monitor). This library has many functions readily available for calculating input voltages and current. Energy monitoring is one of the important applications arising from research in Internet of Things (IOT). Smart meters allow us to obtain periodic updates of energy consumption data that can be analyzed to provide important insights into energy usage. Wi-Fi is selected for serial communicating due to high availability in homes.

## VI CIRCUIT:

In this, two analog inputs of the microcontroller is used for measuring the input voltage and current. By sampling method implemented in the microcontroller, Analog-To-Digital conversion taken place and every sample is stored in the memory in particular time interval. Sampled values are compared and calibrated with the help of input biasing circuitry which gives scaled values for the AC input and a current flowing through the device. Arduino has a library readily available to use for this calculation named Emon (Energy Monitor). This library has many function readily available for calculating input voltages and current. This library helps to keep monitor the following quantities, Input Voltage AC ( $V_{rms}$ ) and Current Flowing through device ( $I_{rms}$ ).

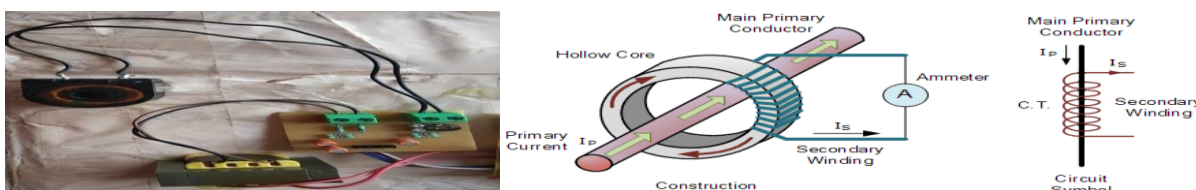


Fig.1. (a) VI circuit (b) Current Transformer

## Voltage Measurement

The main objective for the signal conditioning electronics detailed below, is to condition the output of the Step Down transformer so it meets the requirements of the Arduino analog inputs: a **positive voltage between 0V and the ADC reference voltage** (Usually 5V). Step Down transformer is available in many voltage ratings. The first thing important to know is the voltage rating of your Step Down transformer. (We have 12V RMS Step Down transformer). The output signal from the Step Down transformer is a near-sinusoidal waveform. If you have a 12V (RMS) Step Down transformer the positive voltage peak be 16.9V, the negative peak -16.9V. The voltage output of the transformer is proportional to the AC input voltage. The signal conditioning electronics needs to convert the output of the transformer to a waveform that has a positive peak that's less than 5V (3.3V for the emonTx) and a negative peak that is more than 0V. So we need to: **scale down the waveform and add an offset** so there is no negative component. The waveform can be scaled down using a voltage divider connected across the transformer terminals, and the offset (bias) can be added using a voltage source created by another voltage divider connected across the Arduino power supply (in the same way we added a bias for the current sensing circuit). **Scale Down Process** : Resistors **R1** and **R2** form a voltage divider that scales down the Step Down transformer AC voltage. R1 and R2 need to be chosen to give a peak-voltage-output of ~1V. For Step Down transformer with 12V RMS output, a resistor combination of 10k for R1 and 100k for R2 would be suitable.

$$\begin{aligned}\text{Peak voltage output} &= R1 / (R1 + R2) \times \text{peak voltage input} \\ &= 10k / (10k + 100k) \times 16.9V = 1.54V\end{aligned}$$

**Voltage Bias:** Resistors **R3** and **R4** provide the voltage bias. The voltage bias provided by R3 and R4 should be half of the Arduino supply voltage. As such, R3 and R4 need to be of equal resistance. Higher resistance lowers energy consumption. We use 470k resistors for R3 and R4. If the Arduino is running at 5V the resultant waveform has following result which is satisfying the Arduino analog input voltage requirements.

Positive peak of  $2.5V + 1.54V = 4V$

Negative peak of  $2.5 - 1.54 = 0.96V$

**Capacitor C1:** It provides a low impedance path to ground for the AC signal. The value is not critical, between 1  $\mu$ F and 10  $\mu$ F will be satisfactory. We are measuring the mains voltage. In order to do that, it is first transformed down to a safe voltage, and then divided further before being applied to one of the analog inputs of the microcontroller.

### **AC Voltage input:**

- (1) Give AC Input calibration value,  
Supply Voltage =  $247V * 1.414 = 350V$   
(Exact Measured by Multimeter)  
Noted Voltage =  $230V * 1.414$   
= 325V
- (2) Now, the calibration value is calculated by this formula,  
Calibration = Total Supply Vrms – Total Noted Voltage Vrms  
=  $350V - 325V$   
= 25V Approx.
- (3) So, now input voltage calibration is  $230V - 25V = 205V$  Approx. but in the case of resistance tolerances 10% then to ensure this value we need to apply this by approx. value of 200V in the calibration.

### **Voltage Calculation Function**

#### **Emon1.voltage (Analog PIN, Calibration, Phase Shift);**

Where,

Analog PIN = Analog input pin of Arduino board.

Calibration = calibrated value for ADC;

Phase Shift = Optional (by default 0);

## Current Measurement

The **Current Transformer** (C.T.), is a type of “instrument transformer” that is designed to produce an alternating current in its secondary winding which is proportional to the current being measured in its primary. *Current transformers* reduce high voltage currents to a much lower value and provide a convenient way of safely monitoring the actual electrical current flowing in an AC transmission line using a standard ammeter. The principal of operation of a basic current transformer is slightly different from that of an ordinary voltage transformer. CT in the picture above can be clipped onto either the live or neutral wire coming Current transformers (CTs) are sensors that measure alternating current (AC). They are particularly useful for measuring whole building electricity consumption or generation, without the need to do any high voltage electrical work. Like any other transformer, a current transformer has a primary winding, a magnetic core, and a secondary winding. In the case of whole building monitoring, the primary winding is the live or neutral wire (NOT both!) coming into the building, that is passed through the opening in the CT. The secondary winding is made of many turns of fine wire housed within the transformer case. The alternating

current flowing in the primary produces a magnetic field in the core, which induces a current in the secondary winding circuit. The current in the secondary winding is proportional to the current flowing in the primary winding:

$$I_{\text{secondary}} = CT_{\text{turnsRatio}} \times I_{\text{primary}}$$

$$CT_{\text{turnsRatio}} = \text{Turns}_{\text{primary}} / \text{Turns}_{\text{secondary}}$$

The number of secondary turns in the CT pictured above is 1000, so the current in the secondary is one 1000th of the current in the primary. **Burden Resistor:** A "current output" CT needs to be used with a burden resistor. The burden resistor completes or closes the CT secondary circuit. The burden value is chosen to provide a voltage proportional to the secondary current. The burden value needs to be low enough to prevent CT core saturation. **Isolation:** The secondary circuit is galvanically isolated from the primary circuit. (I.e. it has no metallic contact). **Safety:** In general, a CT must **never** be open-circuited once it's attached to a current-carrying conductor. A CT is potentially dangerous if open-circuited. If open-circuited with current flowing in the primary, the transformer secondary will attempt to continue driving current into what is effectively infinite impedance. This will produce a high and potentially dangerous voltage across the secondary. To connect a CT sensor to an Arduino, the output signal from the CT sensor needs to be conditioned so it meets the input requirements of the Arduino analog inputs, i.e. a **positive voltage between 0V and the ADC reference voltage**. This can be achieved with the following circuit which consists of two main parts:

- (1) The CT sensor and burden resistor
- (2) The biasing voltage divider ( $R1$  &  $R2$ )

If the CT sensor is a "current output" type such as the YHDC SCT-013-000, the current signal needs to be converted to a voltage signal with a burden resistor. If it is a voltage output CT you can skip this step and leave out the burden resistor, as the burden resistor is built into the CT.

#### a) Choose the current range you want to measure

The YHDC SCT-013-000 CT has a current range of 0 to 100 A. For this example, let's choose 100 A as our maximum current.

#### b) Convert maximum RMS current to peak-current

$$\begin{aligned} \text{Primary peak-current} &= \text{RMS current} \times \sqrt{2} \\ &= 100 \text{ A} \times 1.414 \\ &= 141.4 \text{ A} \end{aligned}$$

#### c) Divide the peak-current by the number of turns in the CT to give the peak-current in the secondary coil.

The YHDC SCT-013-000 CT has 2000 turns, so the secondary peak current will be:

$$\begin{aligned} \text{Secondary peak-current} &= \text{Primary peak-current} / \text{no. of turns} \\ &= 141.4 \text{ A} / 2000 \\ &= 0.0707 \text{ A} \end{aligned}$$

**d) To maximize measurement resolution, the voltage across the burden resistor at peak-current should be equal to one-half of the Arduino analog reference voltage. ( $AREF / 2$ )** If you're using an Arduino running at 5V:  $AREF / 2$  will be 2.5 Volts. So the ideal burden resistance will be:

$$\begin{aligned} \text{Ideal burden resistance} &= (AREF/2) / \text{Secondary peak-current} \\ &= 2.5 \text{ V} / 0.0707 \text{ A} \\ &= 35.4 \Omega \end{aligned}$$

35  $\Omega$  is not a common resistor value. The nearest values either side of 35  $\Omega$  are 39 and 33  $\Omega$ . Always choose the smaller value, or the maximum load current will create a voltage higher than  $AREF$ . We recommend a 33  $\Omega \pm 1\%$  burden. In some cases, using 2 resistors in series will be closer to the ideal burden value. The further from ideal the value is, the lower the accuracy will be. Here are the same calculations as above in a more compact form: [Burden Resistor =  $(AREF * CT \text{ TURNS}) / (2\sqrt{2} * \text{max primary current})$ ]

$$\begin{aligned} \text{Ideal burden resistance} &= (AREF/2) / \text{Secondary peak-current} \\ &= 1.35 \text{ V} / 0.0707 \text{ A} \\ &= 19.1 \Omega \end{aligned}$$

19  $\Omega$  is not a common value. We have a choice of 18 or 22  $\Omega$ . We recommend using an 18  $\Omega \pm 1\%$  burden.

**Choosing a suitable value for resistors  $R1$  &  $R2$ :** Higher resistance lowers quiescent energy consumption. We use 10 k $\Omega$  resistors for mains powered monitors. The emonTx uses 470 k $\Omega$  resistors to keep the power consumption to a minimum, as it is intended to run on batteries for several months.

#### Current Calculation

To measure the exact current flowing through the device, user must calculate the current transformer ratings by its turns ratio, burden resistor and ADC scale value.

#### Current Input Function:

#### Emon1.current (Arduino PIN, Calibration);

Where,

Arduino PIN= Current input pin to Arduino Analog input pin;

Calibration = Total MAX current supported by Current Transformer;

## Implementation

In this, two analog inputs of the microcontroller is used for measuring the input voltage and current. By sampling method implemented in the microcontroller, Analog-To-Digital conversion taken place and every sample is stored in the memory in particular time interval. Sampled values are compared and calibrated with the help of input biasing circuitry which gives scaled values for the AC input and a current flowing through the device. Arduino has a library readily available to use for this calculation named **Emon (Energy Monitor)**. This library has many functions readily available for calculating input voltages and current. This library helps to keep monitor the following quantities,

1. **Input Voltage AC (Vrms)**
2. **Current Flowing through device (Irms)**
3. **Real Power**

User must use this library in the Arduino sketch software to implementing the calculation regarding the input voltages and current in RMS values. To implement this calculation first use this library header file `#include <EmonLib.h>`. Then after user must declare the variable for the library.

**Microcontroller** : A micro-controller can be comparable to a little stand alone computer; it is an extremely powerful device, which is able of executing a series of pre-programmed tasks and interacting with extra hardware devices. Being packed in a tiny integrated circuit (IC) whose size and weight is regularly negligible, it is becoming the perfect controller for as robots or any machines required some type of intelligent automation. A single microcontroller can be enough to manage a small mobile robot, an automatic washer machine or a security system. Several microcontrollers contains a memory to store the program to be executed, and a lot of input/output lines that can be a used to act jointly with other devices, like reading the state of a sensor or controlling a motor. A microcontroller is a complete computer system, including a CPU, memory, a clock oscillator, and I/O on a single integrated circuit chip. The ATmega328 is a single-chip microcontroller created by Atmel in the megaAVR family (later Microchip Technology acquired Atmel in 2016). It has a modified Harvard architecture 8-bit RISC processor core.

**ATmega328** is an eight (8) bit Microcontroller. It can handle the data sized of up to eight (8) bits. It is an AVR based micro-controller. Its builtin internal memory is around 32KB. It operates ranging from 3.3V to 5V. It has an ability to store the data even when the electrical supply is removed from its biasing terminals. Its excellent features include the cost efficiency, low power dissipation, programming lock for security purposes, real timer counter with separate oscillator. It's normally used in Embedded Systems applications. Atmega328 has 28 pins in total. It has 3 Ports in total which are named as Port B, Port C and Port D. Port C is an analogue Port and it has six pins in total. So, in simple words, ATmega328 has 6 analogue pins. Port B and Port D are digital ports and have 7 pins each. So, in total ATmega328 has 14 digital pins. It also supports Serial Communications, we can perform serial communication via Pin # 2 (RX) and Pin # 3 (TX). It also supports SPI Protocol. It needs a crystal oscillator for generating the frequency. You can use crystal oscillator ranging from 4MHz to 40 MHz. Arduino UNO board uses 16MHz crystal oscillator.

**LM2576 Voltage Regulator:** The **LM2576** is a **voltage Regulator IC**, it uses the Buck-converter topology to step-down and regulate higher level voltage values to lower level. It is of non-sync type and can take in an input voltage 40V maximum and source an output current of 3A maximum with a peak efficiency of 90%. LM2576 Regulator features and specifications: Switch mode step down voltage regulator. Output Voltage for fixed voltage regulator: 3.3V, 5V, 12V or 15. Output Voltage for Variable type regulator: 1.23V to 37V, Output Current: Upto 3A, Maximum Input Voltage: 40V, In-built Thermal Shutdown and Current Limit Protection, Internal Oscillator: 52-kHz (Fixed Frequency), Available in TO-220 and TO-263 packages .

## Working Process

In this project, two analog inputs of the microcontroller is used for measuring the input voltage and current. By sampling method implemented in the microcontroller, Analog-To-Digital conversion taken place and every sample is stored in the memory in particular time interval. Sampled values are compared and calibrated with the help of input biasing circuitry which gives scaled values for the AC input and a current flowing through the device. Arduino has a library readily available to use for this calculation named Emon(Energy Monitor). This library has many function readily available for calculating input voltages and current. This library helps to keep monitor the quantities as we discuss above.

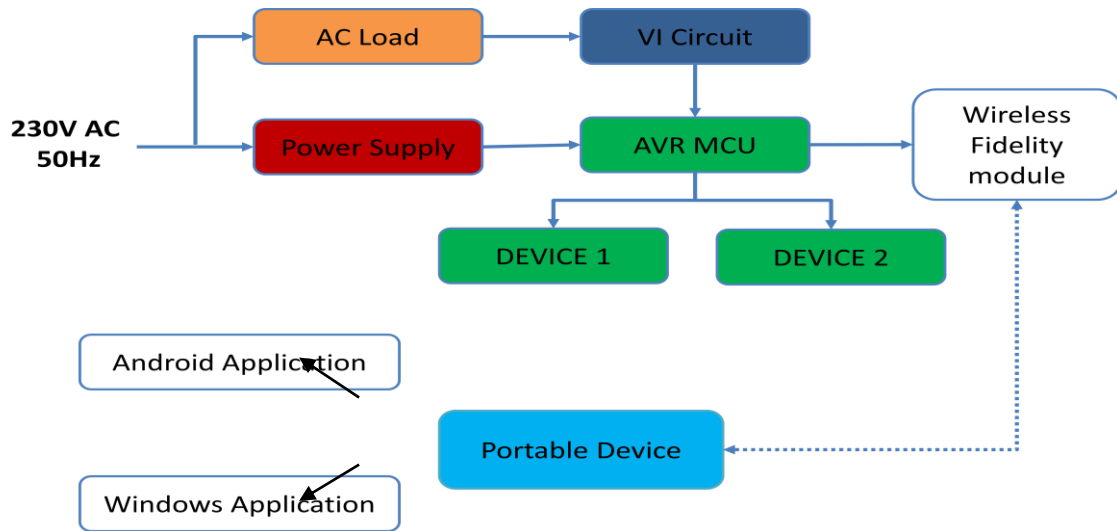
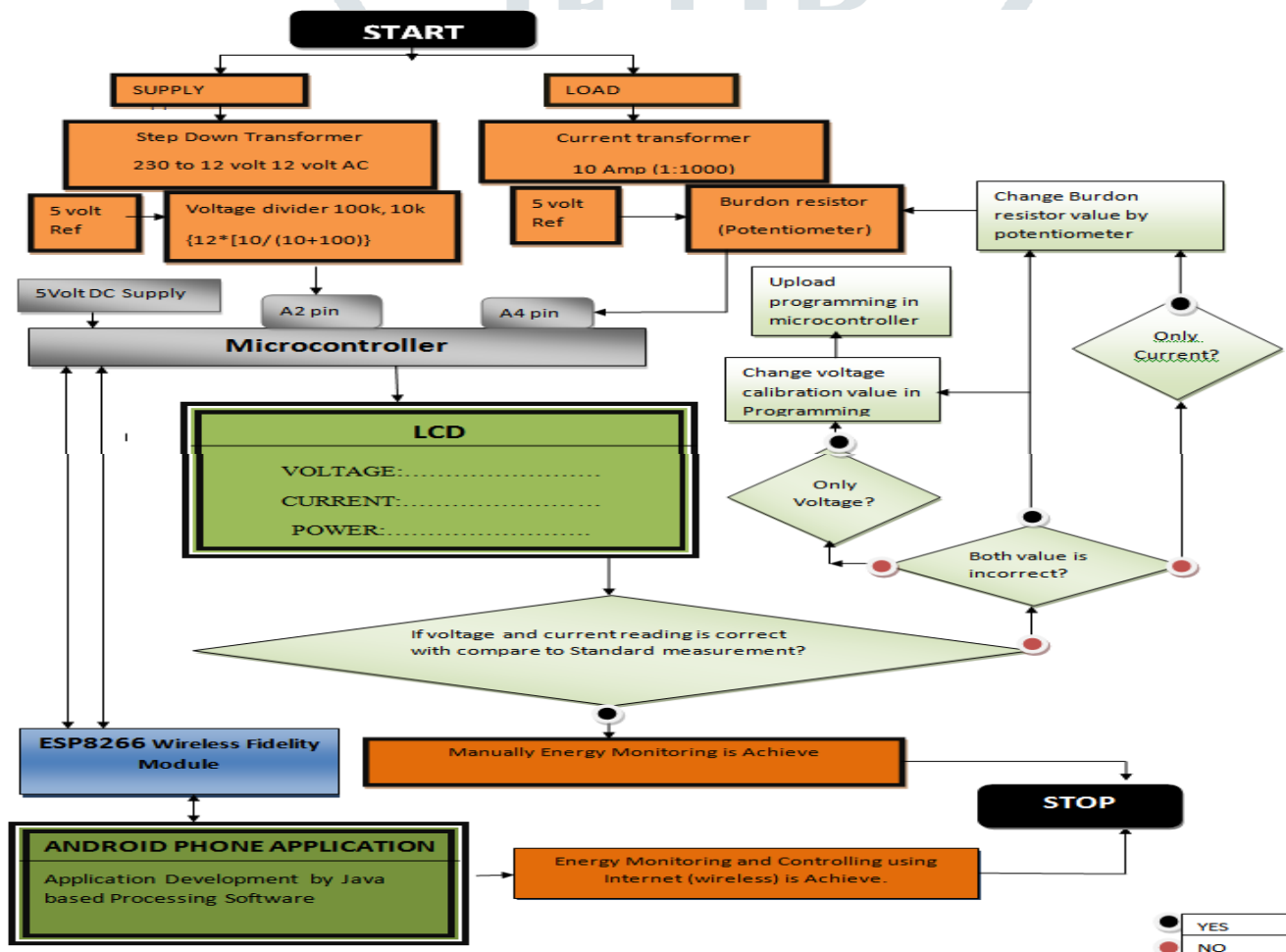


Fig 2 .Block Diagram of Energy Monitoring System

**Flow chart of Working for Energy monitoring and controlling System**



In this section we divide work in many sections such that we can focus in every section one by one. We start with designing the circuit in proteus software then after get simulation result. After that portion we focus on preparing Hardware using many components such as microcontroller, wifi module, ac voltage control component, liquid crystal display and many other components. First of all I tried to make voltage and current measurement circuit which used to get voltage and current reading on display. Then after this circuit send the data to microcontroller analog pins. Now after getting analog input Microcontroller comes in work. It provide analog to Digital data to LCD by using Wireless fidelity system. The data of voltage, current and Power can also shown on Android Application by serial communication using ESP8266 Wireless Fidelity module. Here Android application is develop using Processing Software. It provide platform for IOT application. So as per above we tried to make hardware of Wireless energy monitoring system with data logging and control using Concept of IOT. For further analysis we take three cases to get result of above working procedure.

In first case, we check result of voltage and current reading which shown in LCD. Then after this data is communicate with UDP Android Application. UDP application is available in Play store which can easily download and interface with microcontroller to get Data. In this section control portion is not available.

In second case, I develop my own android application using Processing Software. So control portion is available. Here I take five different loads for analysis and get result as per shown in table of second case result.

In third case, I change the Loads and can get monitor the data and also provide control again by using Android application for Analysis. So we can implement our objective by taking three different cases.

here start the working Procedure. Here work divided in many steps as below...

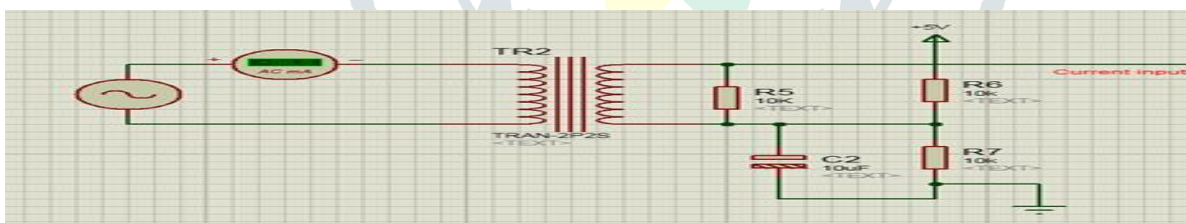
- Design of Voltage circuit in Proteus
- Design of Current Circuit in Proteus
- Upload Programming in Microcontroller
- Check Simulation in Proteus
- Correct the Calibration Value in Program
- Hardware prepare using Simulation result
- Check Result
- Decide Calibration value in Voltage Measurement circuit
- Adjust Potentiometer according to Current measurement
- To get Real Time monitoring Connect LCD to get Voltage, Current and Power Ratings.
- To Provide Control, Connect ESP8266 Wireless Fidelity Module as Communication Part between Micro controller and Android Application
- Prepare own Android Application to Get Real time Data and also to provide Control using this Application. Processing Software is used to develop Application. By using that we can monitor as well as control the five load any time and get data related to Power Consumption.

**Design of Voltage circuit in Proteus**



Fig.3 Voltage measurement Circuit

**Design of Current Circuit in Proteus**



measurement Circuit

Fig. 4 Current

**Check Simulation and Set Calibration Value**

Circuit Specification

Supply Voltage Amplitude: 325

RMS voltage =  $325/1.414 = 230$

Calibration Value = 198

No.	Calibration value	Resultant value
1	180	210
2	182	212
3	185	215
4	190	221
5	196	228
6	197	230

Calibration Value measurement

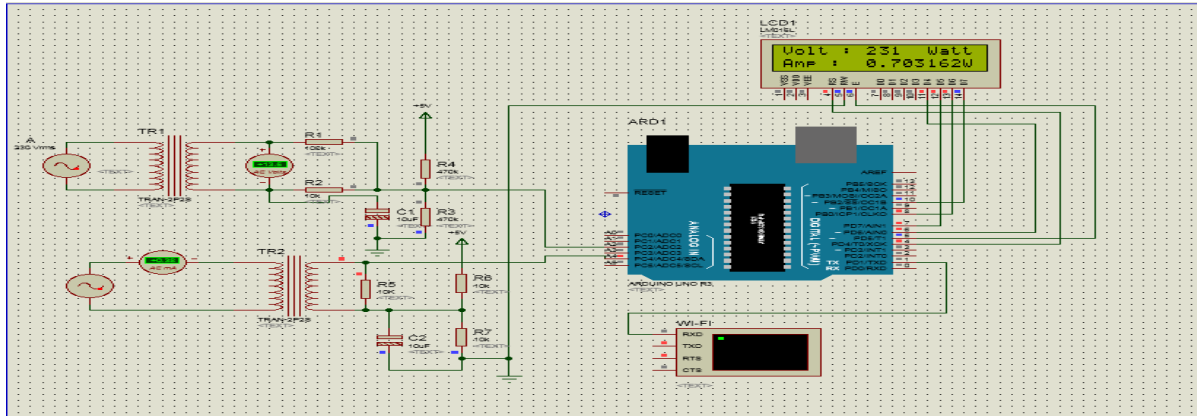


Fig. 5.Simulation for calibration process

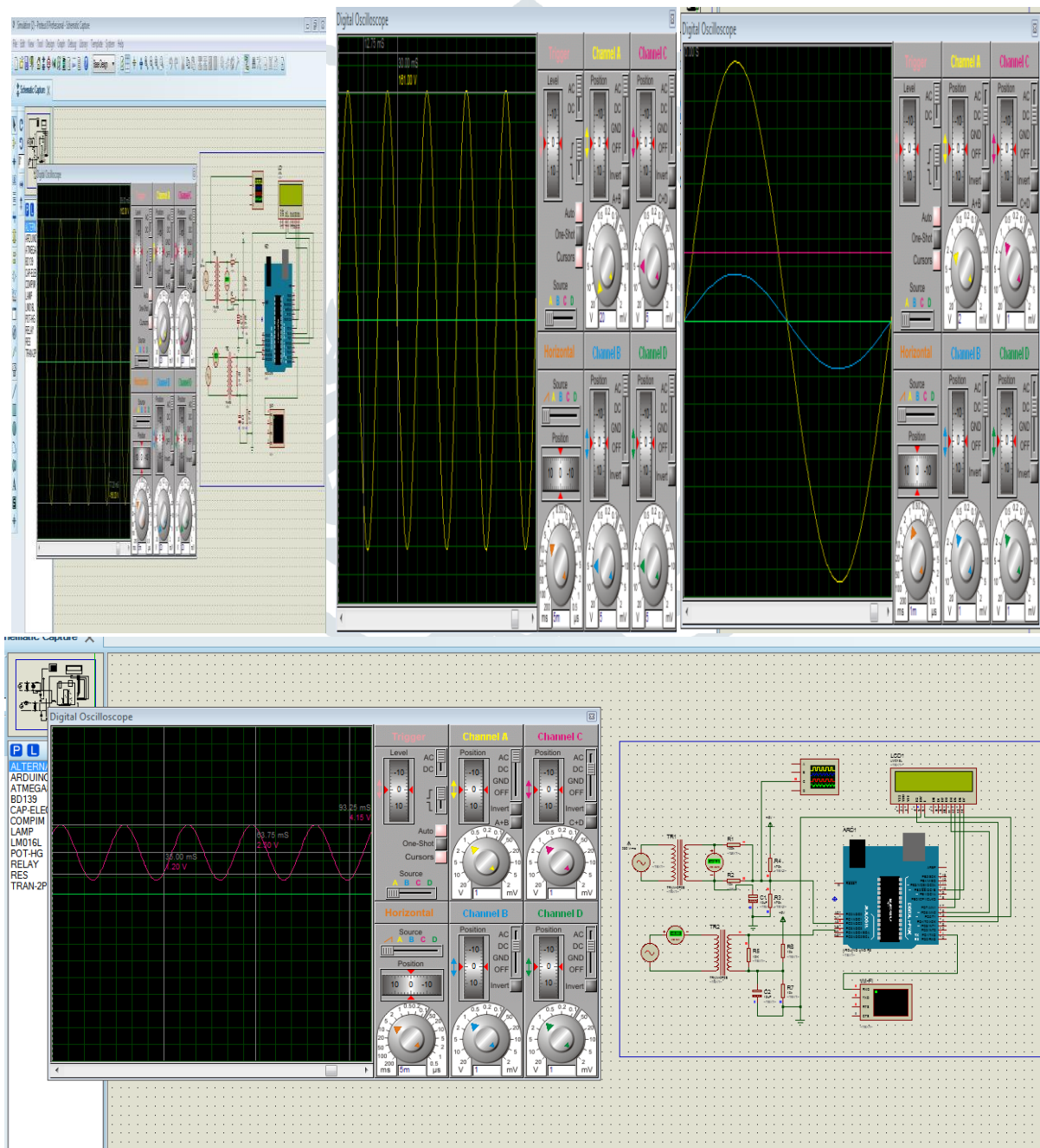


Fig 6.Simulation Result after Calibration Process

**Hardware Setup with result**

**Case 1:**

**Energy Monitoring System with one Load**

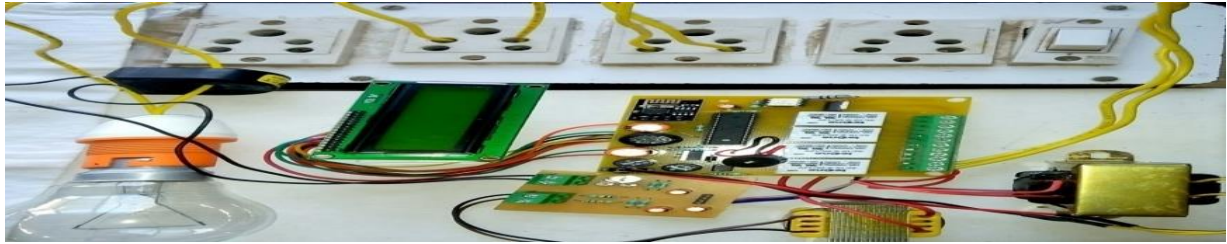


Fig.7 Hardware Setup

**Energy Data logging display**



Fig.8. Energy Data logging display

**RESULT:**

**Result display on LCD as well as UDP application**



Fig 9. Real time Data monitoring



**Case 2:**

**Energy Monitoring System with Five different Loads**

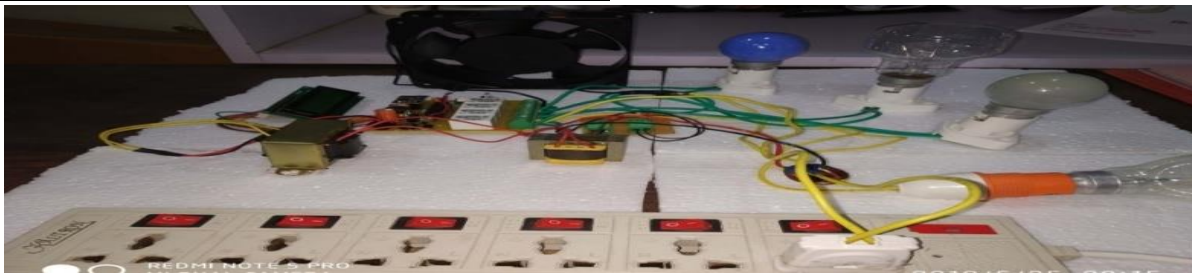


Fig.10. Hardware setup with five different load

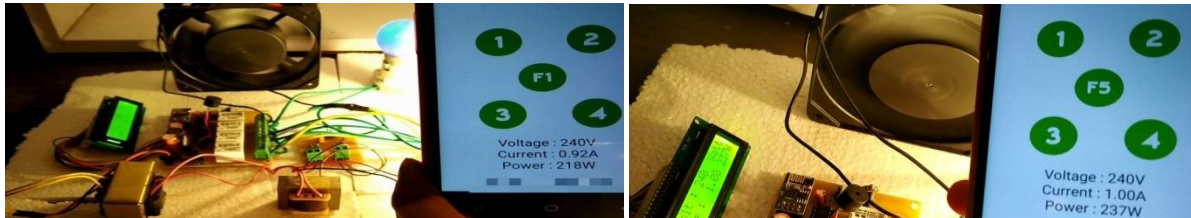


Fig.11. Real time data monitoring and control using android application with result shown in application

**Result:**

No.	Load	Voltage (volts)	Current (ampere)	Power Ratings	Display in Application
0	No Load	240	0.16		004
1	lamp L1	240	0.45		104
2	lamp L2	240	0.52		120
3	lamp L3	241	0.85		200
4	lamp L4	240	0.90		212
5	Fan F1	240	0.92		218
6	Fan F2	240	0.95		223
7	Fan F3	241	0.96		227
8	Fan F4	240	0.99		233
9	Fan F5	240	1.00		237

**Case 3:**

**Energy monitoring system with five different load**

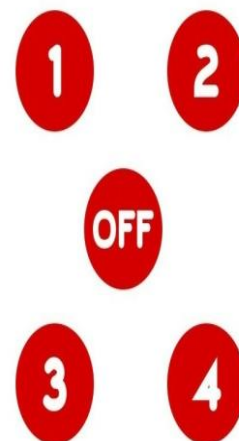
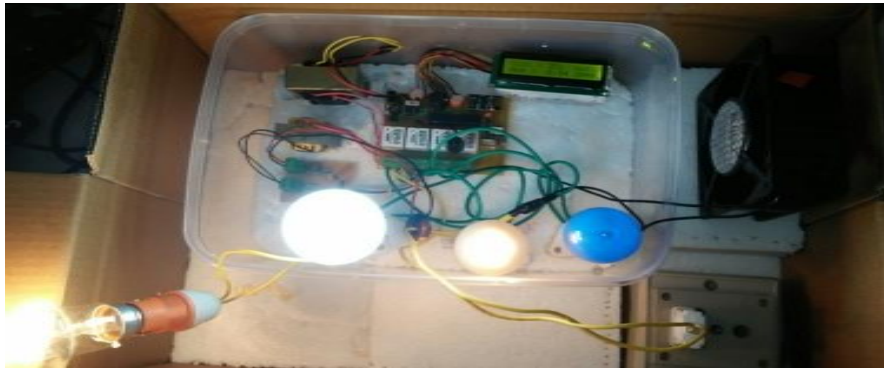


Fig.12 Hardware setup with five different load



IOT Based Power Monitoring



Voltage : 251V  
Current : 0.83A  
Power : 204W

Designed By Drashti Balai

Fig.13 Real time data monitoring and control using android application with result shown in application

**Results:**

No.	Load	Voltage (volts)	Current (ampere)	Power Ratings Display in Application
0	No Load	250	0.18	004
1	lamp L1	250	0.45	111
2	lamp L2	251	0.48	121
3	lamp L3	250	0.58	145
4	lamp L4	251	0.67	168
5	Fan F1	250	0.70	175
6	Fan F2	249	0.74	186
7	Fan F3	251	0.76	191
8	Fan F4	250	0.78	196
9	Fan F5	251	0.83	204

**IOT Implementation by ESP8266 Wireless Fidelity Module**

AT command is used to define four types of a command, for details of which please refer to the following table.

1	AT+RST- Restart the module = ok
2	AT+UART_DEF—Default UART Configuration; Saved in the Flash AT+UART_DEF= <baudrate>,<databits>,<stopbits>,<parity>,<flow control>
	<ul style="list-style-type: none"> <li>• &lt;baudrate&gt;: UART baud rate Range = 110- 115200*40</li> <li>• &lt;databits&gt;: data bits                             <ul style="list-style-type: none"> <li>▸ 5: 5-bit data</li> <li>▸ 6: 6-bit data</li> <li>▸ 7: 7-bit data</li> <li>▸ 8: 8-bit data</li> </ul> </li> <li>• &lt;stopbits&gt;: stop bits                             <ul style="list-style-type: none"> <li>▸ 1: 1-bit stop bit</li> <li>▸ 2: 1.5-bit stop bit</li> <li>▸ 3: 2-bit stop bit</li> </ul> </li> <li>• &lt;parity&gt;: parity bit                             <ul style="list-style-type: none"> <li>▸ 0: None</li> <li>▸ 1: Odd</li> <li>▸ 2: Even</li> </ul> </li> <li>• &lt;flow control&gt;: flow control                             <ul style="list-style-type: none"> <li>▸ 0: flow control is not enabled</li> <li>▸ 1: enable RTS</li> <li>▸ 2: enable CTS</li> <li>▸ 3: enable both RTS and CTS</li> </ul> </li> </ul>
	Command= AT+UART_DEF=9600,8,1,0,0

3	AT+CWMODE_DEF—Sets the Default Wi-Fi mode; Configuration Saved in the Flash
	Set Command: AT+CWMODE_DEF=<mode> Function: to set the current Wi-Fi mode of ESP8266.
	<ul style="list-style-type: none"> <li>• &lt;mode&gt;: †1: Station mode</li> <li>‡2: SoftAP mode</li> <li>‡3: SoftAP+Station mode</li> </ul>
	Command= AT+CWMODE_DEF= 2

4	AT+CWJAP_DEF—Connects to an AP; Configuration Saved in the Flash
	Set Command: AT+CWJAP_DEF=<ssid>,<pwd>,[<bssid>][,<pci_en>] Function: to set the AP to which the ESP8266 Station needs to be connected.
	<ssid>: a string parameter showing the SSID of the target AP.
	AT+CWJAP_DEF="abc","1234567890" (Port Address 5000)

5	AT+CWLAP—Lists Available APs.
	Function: to list all available APs.

6	AT+SAVETRANSLINK—Saves the Transparent Transmission Link in Flash
	Command : AT+SAVETRANSLINK=1,192.168.9.255,5000,UDP,5555

## II. CONCLUSION

Here I use this concept for energy conservation that can be use for multiple appliances or we can say that for whole world by using IOT to save energy usage. Thus energy monitoring device integrating with the concept of internet of things allow their measured data to be monitored and retrieved at any location where internet is available. This will result in qualitatively different life style from today by using energy conservation method in smart way.

In this section I compare three case in which conclude that by using play store UDP application ,we can only monitor the data but control can not be provided. But after developing Android application with the help of processing software as shown in case 2 and 3, monitoring and controlling both portion is available.

This can help to reduce energy usage and make comfort life for future generation by providing control to system and make life style easy. In future I will focus to get more accurate results and also implement this feature with many different load and make analysis report of energy saving and also trying to add some new idea for Energy Saving.

## III. ACKNOWLEDGMENT

The satisfaction that comes with successful completion of a task would be but incomplete without the mention of the people who made it possible it gives us immense pleasure to acknowledge all those who have extended their valuable guidance and magnanimous help. The success of any work depends upon the dedication, Sincerity and hard work. It also requires some ingredients such as motivation, guidance, encouragement and time.

I wish to express my deepest gratitude to my project guide **Prof. (Dr.) C. K.Vibhakar** and CO–guide **Prof. Kishan Bhayani** Department of ElectricalEngineering, V.V.P. Engineering College, Rajkot for his constant guidance, encouragement, and support. I warmly acknowledge and express my special thanks for his inspiring discussion and infallible suggestion.

Finally, I would like to thank my friends & all the staff members of V.V.P Engineering College, Rajkot who are always beside me.

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