Visvesvaraya Technological University

Belgaum, Karnataka-590 018

A Project Report on

"RESIDENTIAL ENERGY CONSUMPTION MANAGEMENT USING ATMega2560 MCU"

Project Report submitted in partial fulfillment of the requirement for the award of the degree of

Bachelor of Engineering
In
Electrical & Electronics Engineering

Submitted by

SHASHANK R	**1CR15EE074**	**FAKKEERESH N NAYAK**	**1CR16EE405**
DINESH KUMAR	**1CR15EE062**	**RAHUL PRASAKTHAKUMAR**	**1CR15EE064**

Under the Guidance of
Ms. Nithara P V Asst.Prof

Designation, Department of Electrical & Electronics Engineering
CMR Institute of Technology

CMR Institute of Technology, Bengaluru-560 037

Department of Electrical & Electronics Engineering

2020-2021

CMR INSTITUTE OF TECHNOLOGY

DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

AECS Layout, Bengaluru-560 037

Certificate

Certified that the project work entitled **"Residential Energy Consumption Management Using ATMega2560 MCU"** carried out by Mr.Shashank R(1CR15EE074) Mr.Fakkeeresh N Nayak(1CR16EE405) Mr.Dinesh Kumar(1CR15EE062) Mr.Rahul Prasakthakumar(1CR15EE064) are bonafied students of CMR Institute of Technology, Bengaluru, in partial fulfillment for the award of Bachelor of Engineering in Electrical & Electronics Engineering of the Visvesvaraya Technological University, Belgaum, during the year 2020-2021. It is certified that all corrections/suggestions indicated for Internal Assessment have been incorporated in the Report deposited in the departmental library.

The project report has been approved as it satisfies the academic requirements in respect of Project work prescribed for the said Degree.

Signature of the Guide	*Signature of the HOD*	*Signature of the Principal*
-----------------------------	--------------------------------	-----------------------------
Ms. Nithara p v asst.prof, Designation EEE Department CMRIT, Bengaluru	Dr. K. Chitra Professor & HOD EEE Department CMRIT, Bengaluru	Dr. Sanjay Jain Principal, CMRIT, Bengaluru

External Viva

Name of the Examiners	Signature & Date
1.	
2.	

CMR INSTITUTE OF TECHNOLOY
DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING
AECS Layout, Bengaluru-560 037

DECLARATION

We, [Mr.Shashank R(1CR15EE074) Mr.Fakkeeresh N Nayak(1CR16EE405) Mr.Dinesh Kumar(1CR15EE062) Mr.Rahul Prasakthakumar(1CR15EE064)**],** hereby declare that the report entitled **"Residential Energy Consumption Management Using ATMega2560 MCU"** has been carried out by us under the guidance of Ms. **Nithara P V Asst.Prof** Designation, Department of Electrical & Electronics Engineering, CMR Institute of Technology, Bengaluru, in partial fulfillment of the requirement for the degree of **BACHELOR OF ENGINEERING in ELECTRICAL & ELECTRONICS ENGINEERING**, of Visveswaraya Technological University, Belagaum during the academic year 2020-21. The work done in this report is original and it has not been submitted for any other degree in any university.

Place: Bengaluru

Date:

Shashank R(1CR15EE074)

Fakkeeresh N Nayak(1CR16EE405)

Dinesh Kumar(1CR15EE062)

Rahul Prasakthakumar(1CR15EE064)

ABSTRACT

The major purpose of a smart residence is to ensure proper usage of electricity in an economic and optimized manner. In an effort to make push forward the energy management capability of a smart residence, this paper describes the design, development and implementation of an automatic single phase energy consumption management of a residential management of a residential infrastructure. The following paper deals with the measurement of power and energy using the Arduino. The demand for power has drastically increased over the last decade, thereby giving arise to numerous problems in energy management. One of the many ways of tackling the problems of energy management is by reducing the energy usage with the help of a microcontroller in a residential infrastructures. This provides an ample solution by implementing a condensed design prototype that measures, monitors and manages the residential energy consumption by employing the use of an electronic microcontroller. When properly applied in a residential infrastructure, the system will significantly reduce the total energy consumption in a significant saving in electricity bill.

Acknowledgement

The satisfaction and euphoria that accompany the successful completion of any task would be incomplete without the mention of people, who are responsible for the completion of the project and who made it possible, because success is outcome of hard work and perseverance, but stead fast of all is encouraging guidance. So with gratitude we acknowledge all those whose guidance and encouragement served us to motivate towards the success of the project work.

We take great pleasure in expressing our sincere thanks to ***Dr. Sanjay Jain, Principal, CMR Institute of Technology, Bengaluru*** *for providing an excellent academic environment in the college and for his continuous motivation towards a dynamic career. We would like to profoundly thank* ***Dr. B Narasimha Murthy****, Vice-principal of CMR Institute of Technology and the whole* ***Management*** *for providing such a healthy environment for the successful completion of the project work.*

We would like to convey our sincere gratitude to ***Dr. K Chitra****,* ***Head of Electrical and Electronics Engineering Department, CMR Institute of Technology, Bengaluru*** *for her invaluable guidance and encouragement and for providing good facilities to carry out this project work.*

We would like to express our deep sense of gratitude ***Ms. Nithara P V Assistant Professor, Electrical and Electronics Engineering, CMR Institute of Technology, Bengaluru*** *for his/her exemplary guidance, valuable suggestions, expert advice and encouragement to pursue this project work.*

We are thankful to all the faculties and laboratory staffs of ***Electrical and Electronics Engineering Department, CMR Institute of Technology, Bengaluru*** *for helping us in all possible manners during the entire period.*

Finally, we acknowledge the people who mean a lot to us, our parents, for their inspiration, unconditional love, support, and faith for carrying out this work to the finishing line. We want to give special thanks to all our friends who went through hard times together, cheered us on, helped us a lot, and celebrated each accomplishment.

Lastly, to the ***Almighty****, for showering His Blessings and to many more, whom we didn't mention here.*

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1. General Introduction

Energy is the capacity to do work. It is partially impossible to estimate the actual magnitude of the part that energy has played in developing the present day utilization the availability of large amount of energy in modern time has resulted in lesser use of man power higher agriculture and industrial production and better transportation facilities. As matter of fact, there is closer relationship between the energy used person and his standard of living. However based on the lines above, we can deduce that energy is very important factor for life. To be particular electrical energy is given at most importance. Therefore, it is our duty spend this energy judiciously and prevent the unnecessary and lavish usage to make way for the future generation to generate energy and use it accordingly. Having said that, it is in the very human nature that rate of negligence these obey resulting in uneconomical use of energy.

Energy exists in different forms in nature but the most important form is the electrical energy. The modern society so much dependent upon the use of electrical energy that is has become a part and parcel of our life. Broadly there are four major energy end use sectors

- Commercial.
- Industrial.
- Residential.
- Transportation.

This project deals with the residential end user of electrical energy. We believe, energy can be managing the conserved in many ways. One of such ways is by consumption of electrical energy in a residential infrastructure. Our main focus is to develop a control system which measures, monitors and manage the energy consumption of a residential by effectively managing the loads of the residence. With the help of today's digital technological advancement, we use a microcontroller to manage the loads and monitor them. So that unnecessary use of energy is avoided and a significant savings in the energy is achieved.

The state at which work is done in an electric circuit is called electric power i.e.

$$\text{Electric power} = \frac{\text{Work done in electric circuit}}{\text{Time}}$$

However, $P = \frac{Work}{t} = \frac{V\,I\,t}{t} = V \times I$ = Voltage in volts × current in amps.

Its unit is Joule/second or Watt. The power consumed in circuit is One Watt if a p.d of 1V causes 1A current to flow through the circuit.

The total work done in an electrical circuit is called Electrical energy.

Electrical energy = Electrical power × Time (in seconds).

Joule or Watt –sec is a very small unit of electrical energy, bigger units via,. Watt hour and kilowatt- hour are used.

1 Watt- hour = 1Watt ×1hour.

= 1Watt × 3600 seconds = 3600 Watt-seconds.

1 kilo-watt hour (kWh) = 1kW × 1Hr = 1000 Watt ×3600 Seconds.

= 36×10^{5} watt-sec.

In this project, an energy consumption management system is presented. The system is capable of measuring the power consumption of the loads, the supply voltage and the total current consumed by the loads. It employs the use of single phase AC voltage sensor module (ZMPT101B) and Allegro AC current sensor module (ACS716) and a Bluetooth module for remote control, that are used to detect the system voltage and current. This voltage and current sensors used in the system are relatively cheap, easy to install in an existing system and reliable. The sensor outputs are processed through Arduino Mega 2560 microcontroller board for the determination of the relevant quantities after which the system will take decision of reducing the total load when the system load exceeded the threshold value. The work generally involved the experimentation and analysis of the sensors to determine their behavior or responses with respect to the input values. The instantaneous calculation method is employed after ascertaining the uniform sensitivity of the sensors. Finally the research leads to the establishment of a standalone system that automatically provides the measurements and control of the house loads consumption with no involvement of the consumer action.

Measuring and monitoring electrical energy consumption of appliances will help in efficient utilization and in estimation of the energy usage. The world is becoming more automated and there is need to have more environmental friendly usage of electrical power in a way to save energy and to cater for global warming and future energy challenges. The development and implementation of smart energy consumption is of much concern among the utility stake holders and even though the technology is very much developed but it is still up coming. The industries have fully upgraded to automated systems whereas the

Residential setting are mostly left behind in terms of automation and efficient usage of the electricity.

In line with the push for green environment and energy efficiency procurement, there is need to have a low cost, robust and simple to use system that can monitor the electricity in a smart residence. This may include the use of mobile communication in the automation system using wireless networks. We may have an instance whereby the occupants of the house may turn on or off appliances like air-conditioner or fan before they arrive using their mobile phone. In actual sense the electricity challenges differ from country to country, with inadequate capacity as the major problems in most developing countries.

However, the efficient and minimized usage of electricity will be most welcomed in any country of the world. The energy consumption awareness is a great facilitator of the energy management, therefore making the energy measurements available to the consumers and even the utility companies will make them take appropriate action towards efficient utilization of the energy. Most of the Arduino researchers limit their works to power measurement and some of the energy management systems required the consumer involvement in order to save energy. A home energy management system that combines measurements and automatic control with appropriate involvement of the consumer is required. A new Home Automation field is emerging with the incorporation of the mobile communications technologies into the automation systems, to control appliances eithervia the existing electrical wiring of the house, or using a wireless network. Indeed, users are using mobile applications on their phones to control their houses from distance. Trivial examples are: turning on the air conditioning system 30 minutes before the resident's arrival, or opening the door lock using a mobile phone. In addition, exploiting such technologies may contribute to a greener planet; and if by a "Smart" Home we mean one that is energy-efficient and that will be able to appropriately manage its energy resources, and then this feature is essential for a safer and healthier future.

CHAPTER 2

LITERATURE SURVEY

When talking about load management, the prerequisite issue is to mention about the measurement or rather monitoring of the energy usage in the system. That is when the energy usage is quantified it becomes viable for the consumers to plan the energy savings. Some researchers have already worked in the area of home energy measurements using microcontrollers. **T. M. Chung** developed a single phase power meter using Arduino microcontroller. The prototype calculates the voltage, current and active power of the load using instantaneous calculation method. The system is 96.54% accurate, though it is limited to measuring active power, voltage and current to a maximum of 13A current.

Similar work has been done by **P. Srividyadevi** in which power and energy of a single phase system is measured using Arduino.

The Power Meter project described by **C. Jao** and **X. Guo** presented another interesting work in power measurement. It is interesting that the opto-isolator IC provides isolation between the main circuit and Arduino. The validation of the project work with a load of 50W using commercial measuring device shows an error of up to 5.13% in current measurement. On the other hand there are researchers that focused on the energy management in their works.

Qinran Hu and **Fanxing Li** presented a hardware design of a smart home energy management system (SHEMS) with communication, sensitivity technology and machine learning algorithm applications. The system is equipped with sensors that detect human activities in the house and intelligently helped the consumers to reduce their total energy consumption automatically. Simulation and testing of the prototype shows that it is capable of reducing the loads during the peak hours by about 10 percent which is significant, though there may be need to extend some of the sensors and load interfaces for increased number of appliances.

Ninad K. developed a non-intrusive load monitoring system utilizing zigbee communication. The system maintains the power consumption below the threshold level by reducing the non-essential loads when it is overloaded.

CHAPTER 3

METHODOLOGY

It is hard to analytically determine the optimal use of power in residence so this proposed system gives the information about power consumption and tool to manage the power consumption. This proposed system gives scope for the design and implementation of an automatic/user controlled single phase energy consumption management of a smart house.

3.1. Block Diagram

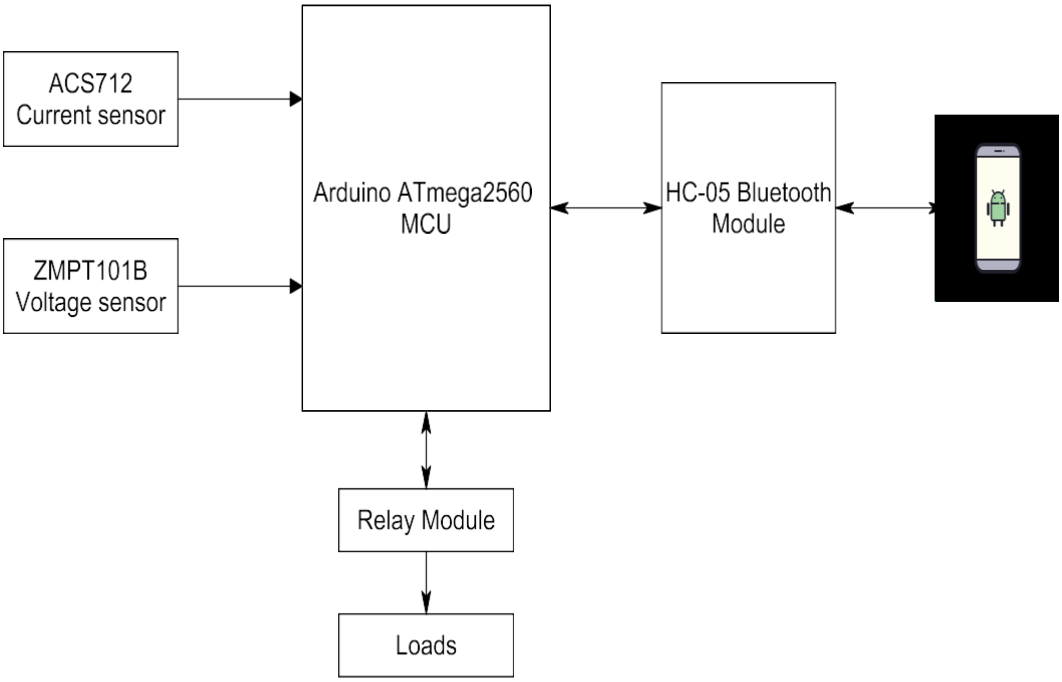

Fig.3.1 *Block Diagram of the module.*

Figure 3.1 shows the block diagram of the module consisting of voltage sensor, current sensor, microcontroller and relays. Its working is explained below:

- Initially, the voltage sensor takes the input from single phase ac supply and sends analogue value to the microcontroller unit.
- The current sensor takes the input from single phase ac supply and sends analogue value to the microcontroller unit.
- The microcontroller unit receives the output from voltage and current sensors. Since the values will be analogue in nature, the built in analogue to digital converter (ADC) converts the analogue value into digital value. Further, the data from the voltage and current sensors are monitored continuously. The microcontroller will wait for the user to switch off any unnecessary load. If not, the microcontroller will perform priority based tripping of relay. The process is real time.

- The Bluetooth module acts as a communication medium between the mobile application and the microcontroller unit. It is two way communication.

3.2. Schematic Diagram

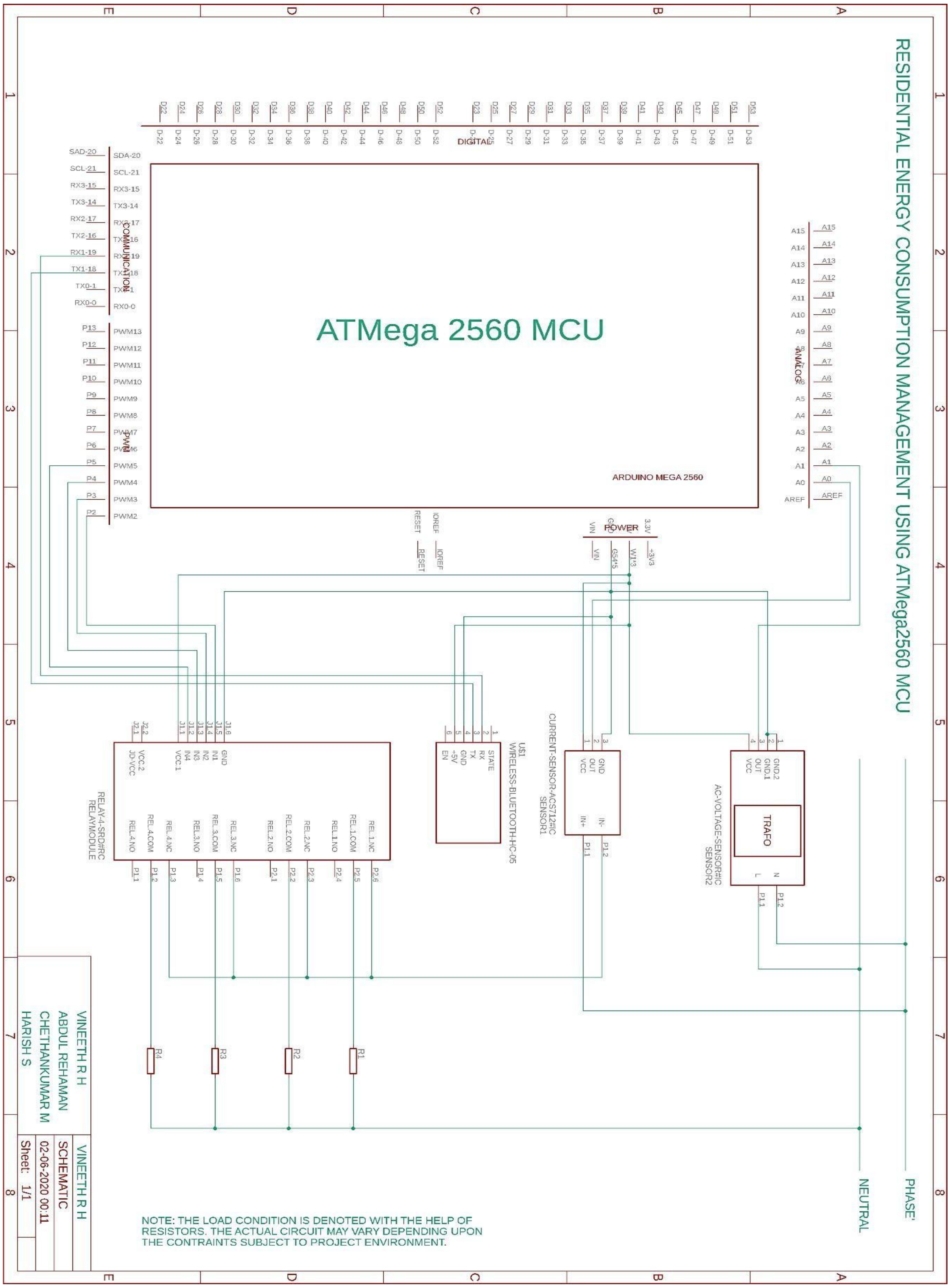

Fig.3.2 *Schematic diagram of the project*

Figure.3.2 shows the schematic diagram of the project. The connection of components is explained below:

- Voltage Sensor: The V_{CC} pin is connected to the 5V pin, the GND pins are shorted and connected to the GND pin, OUT is connected to analogue A_1 of the MCU. It is connected in parallel with the supply.
- Current Sensor: The V_{CC} pin is connected to the 5V pin, the GND pin is connected to the GND pin, OUT is connected to analogue A_0 of the MCU.
- Bluetooth: The 5V pin is connected to the 5V pin, the GND pin is connected to the GND pin, the R_X pin is connected to the T_X pin and the T_X pin is connected to the R_X pin of the MCU.
- Relay Module: The V_{CC1} pin is connected to the 5V pin, the GND pin is connected to the GND pin, IN1 is connected to PWM1, IN2 is connected to PWM2, IN3 is connected to PWM3 and IN4 is connected to PWM4 of the MCU.

3.3 Hardware Components

3.3.1. Arduino ATMega2560 MCU (Arduino Mega)

Arduino board is an open-source microcontroller board which is based on ATMega 2560 microcontroller. The growth environment of this board executes the processing or wiring language. These boards have recharged the automation industry with their simple to utilize platform wherever everybody with small otherwise no technical backdrop can start by discovering some necessary skills to program as well as run the Arduino board. These boards are used to extend separate interactive objects otherwise we can connect to software on your PC like Max MSP, Processing, and Flash.

The microcontroller board like “Arduino Mega” depends on the ATmega2560 microcontroller. It includes digital input/output pins-54, where 16 pins are analogue inputs, 14 are used like PWM outputs hardware serial ports (UARTs) – 4, a crystal oscillator-16 MHz, an ICSP header, a power jack, a USB connection, as well as an RST button. This board mainly includes everything which is essential for supporting the microcontroller. So, the power supply of this board can be done by connecting it to a PC using a USB cable, or battery or an AC-DC adapter. This board can be protected from the unexpected electrical discharge by placing a base plate. The Figure.3.3 shows the Arduino Mega board. The specifications of the board is mentioned in Table 3.1 below.

Fig.3.3 *Arduino Mega Board*

The SCL & SDA pins of Mega 2560 R3 board connects to beside the AREF pin. Additionally, there are two latest pins located near the RST pin. One pin is the IOREFthat permit the shields to adjust the voltage offered from the Arduino board. Another pin is not associated & it is kept for upcoming purposes. These boards work with every existing shield although can adjust to latest shields which utilize these extra pins.

Table.3.1 *Details of ATMega2560.*

Microcontroller	ATmega2560
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	54 (of which 15 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB of which 8 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz
LED_BUILTIN	13
Length	101.52 mm
Width	53.3 mm
Weight	37 g

Pin Configuration

The pin configuration of this Arduino mega 2560 board is shown in Fig 3.4. Every pin of this board comes by a particular function which is allied with it. All analogue pins of this board can be used as digital I/O pins. By using this board, the Arduino megaprojected can be designed. These boards offer flexible work memory space is the more & processing power that permits to work with different types of sensors without delay. When we compare with other types of Arduino boards, these boards are physically superior

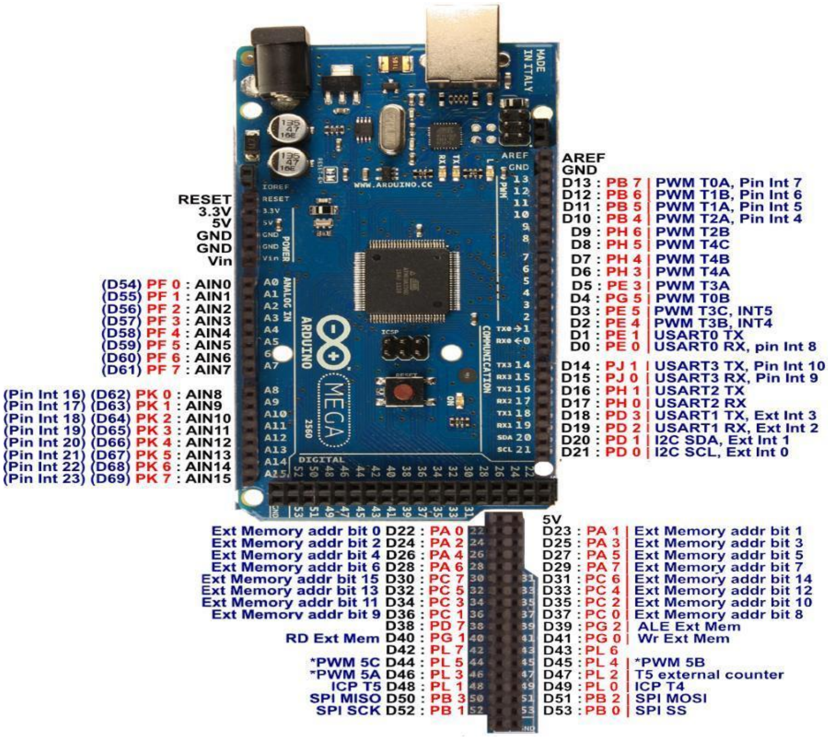

Fig.3.4 *Arduino pin configuration*

As shown in Figure.3.4. The pin description is given below:

- **Pin 3.3V & 5V**

These pins are used for providing o/p regulated voltage approximately 5V. This RPS (regulated power supply) provides the power to the microcontroller as well as other components which are used over the Arduino mega board. It can be attained from Vin-pin of the board or one more regulated voltage supply-5V otherwise USB cable, whereas another voltage regulation can be offered by 3.3V0-pin. The max power can be drawn by this is 50mA.

- **Reset (RST) Pin**

The RST pin of this board can be used for rearranging the board. The board can be rearranged by setting this pin to low.

- **V_{in} Pin**

The range of supplied input voltage to the board ranges from 7volts to 20volts. The voltage provided by the power jack can be accessed through this pin. However, the output voltage through this pin to the board will be automatically set up to 5V.

- **Serial Communication**

The serial pins of this board like TXD and RXD are used to transmit & receive the serial data. Tx indicates the transmission of information whereas the RX indicates receive data. The serial pins of this board have four combinations. For serial 0, it includes Tx(1) and Rx (0), for serial 1, it includes Tx (18) & Rx (19), for serial 2 it includes Tx (16) & Rx (17), and finally for serial 3, it includes Tx (14) & Rx (15).

- **External Interrupts**

The external interrupts can be formed by using 6-pins like interrupt 0(0), interrupt 1(3), interrupt 2(21), interrupt 3(20), interrupt 4(19), interrupt 5(18). These pins produce interrupts by a number of ways i.e. providing LOW value, rising or falling edge or changing the value to the interrupt pins.

- **LED**

This Arduino board includes a LED and that is allied to pin-13 which is named as digital pin 13. This LED can be operated based on the high and low values of the pin. This will give you to modify the programming skills in real time.

- **AREF**

The term AREF stands for Analogue Reference Voltage which is a reference voltage for analogue inputs.

- **Analogue Pins**

There are 16-analog pins included on the board which is marked as A0-A15. It is very important to know that all the analogue pins on this board can be utilized like digital I/O pins. Every analogue pin is accessible with the 10-bit resolution which can gauge from GND to 5 volts. But, the higher value can be altered using AREF pin as well as the function of analogue Reference ().

- **I2C**

The I2C communication can be supported by two pins namely 20 & 21 where 20-pin signifies Serial Data Line (SDA) which is used for holding the data & 21-pin signifies Serial Clock Line (SCL) mostly utilized for offering data synchronization among the devices.

- **SPI Communication**

The term SPI is a serial peripheral interface which is used to transmit the data among the controller & other components. Four pins like MISO (50), MOSI (51), SCK (52), and SS (53) are utilized for the communication of SPI.

- **Dimensions**

The dimension of Arduino Mega 2560 board mainly includes the length as well as widths like 101.6mm or 4 inch X 53.34 mm or 2.1 inches. It is comparatively superior to other types of boards which are accessible in the marketplace. But, the power jack and USB port are somewhat expanded from the specified measurements.

- **Programming**

The programming of an Arduino Mega 2560 can be done with the help of an IDE (Arduino Software), and it supports C-programming language. Here the sketch is the code in the software which is burned within the software and then moved to the Arduino board using a USB cable. An Arduino mega board includes a boot loader which eliminates an external burner utilization to burn the program code into the Arduino board. Here, the communication of the boot loader can be done using an STK500 protocol.

When we compile as well as burn the Arduino program, then we can detach the USB cable to remove the power supply from the Arduino board. Whenever you propose to use the Arduino board for your project, the power supply can be provided by a power jack otherwise V_{in} pin of the board.

Another feature of this is multitasking wherever Arduino mega board comes handy. But, Arduino IDE Software doesn't support multi-tasking however one can utilize additional operating systems namely RTX & Free RTOS to write C-program for this reason. This is flexible to use in your personal custom build program with the help of an ISP connector.

3.3.2. Allegro Microsystems ACS712 Current Sensor

Hall Effect Sensors are transducer type components that can convert magnetic information into electrical signals for subsequent electronic circuit processing. Generally, current sensors use the Hall Effect to convert current inputs into voltage outputs. In the Hall Effect, electrons from an electric current flow through a magnetic field plate. The field then causes the electrons to "push" to one side of the plate and produce a voltage difference between the two sides. The difference in voltage from the side of the plate is the output of the sensor.

ACS712 is a current sensor that can operate on both AC and DC. This sensor operates at 5V and produces an analogue voltage output proportional to the measured current. This tool consists of a series of precision Hall sensors with copper lines. The figure 3.5 shows the Pin IC of ACS712 current sensor.

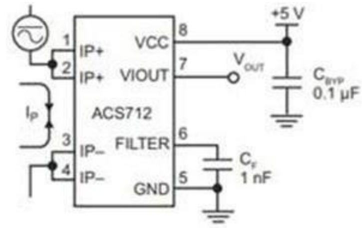

Fig.3.5 *PIN* IC *of* ACS712

The output of this instrument has a positive slope when the current increases through the copper primary conduction path (from pins 1 and 2 to pins 3 and 4). The internal resistance of the conduction path is 1.2 mΩ.

This sensor has an output voltage of VCC x 0.5 = 2.5 at the input current 0A and a 5V VCC power supply. There are three types based on the readable current range, ± 5A, ± 20A, and ± 30A with output sensitivity of each type of 185mV / A, 100mV / A, and 66mV a respectively. Its working principle is shown in Figure 3.6.

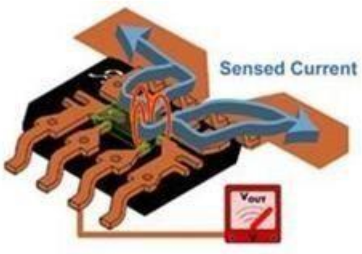

Fig.3.6 *Working principle of Hall Effect on ACS712*

3.3.3. ZMPT101B Micro-Transformer based Voltage Sensor

The ZMPT101B voltage sensor module is a voltage sensor made from the ZMPT101B voltage transformer. It has high accuracy, good consistency for voltage and power measurement and it can measure up to 250V AC. It is simple to use and comes with a multi turn trim potentiometer for adjusting the ADC output. The analysis in this paper tends to find more accurate relationship between the input voltage and the ADC output by regression analysis. The ADC output is adjusted using the trim pot to an appropriate value against a reference input. Below is the ZMPT101B voltage sensor module. The Figure.3.7 shows the ZMPT101B micro-transformer based voltage sensor.

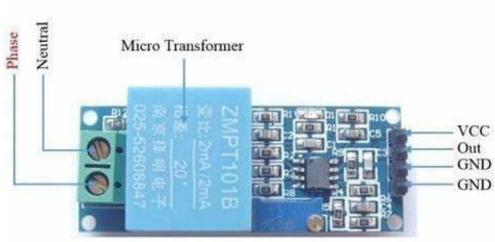

Fig.3.7 *ZMPT101B Micro-Transformer based voltage sensor.*

3.3.4. HC-05 BLUETOOTH MODULE

Bluetooth is a wireless LAN technology designed to connect devices of different functions such as telephones, notebooks, computers (desktop and laptop), Cameras, printers, and even coffee makers when they are at a short distance from each other. A Bluetooth LAN is an ad hoc network, which means that the network is formed spontaneously; the devices, sometimes called gadgets, find each other and make a network called a piconet. A Bluetooth LAN, by nature, cannot be large. If there are many gadgets that try to connect, there is chaos. Today, Bluetooth technology is the implementation of a protocol defined by the IEEE 802.15 standard. The standard defines a wireless personal-area network (PAN) operable in an area the size of a room or a hall. The Figure 3.8 shows the HC-05 bluetooth module.

Fig.3.8*\ HC-05 Bluetooth Module*

A Bluetooth device has a built-in short range radio transmitters. The current data rate is 1Mbps with a 2.4 GHz bandwidth. This means that there is a possibility of interference between the IEEE 802.11b wireless LANs and Bluetooth LANs. The Figure 3.9 shows pin out diagram of HC-05 bluetooth module

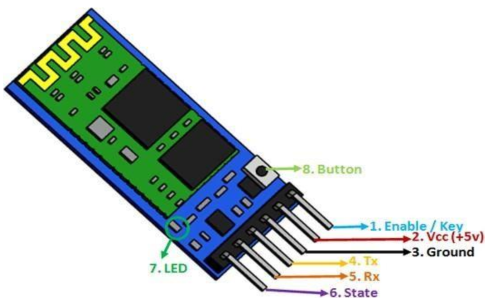

Fig.3.9 *Pin-out of HC-05 Bluetooth Module.*

During power up the key pin can be grounded to enter into Command mode, if left free it will by default enter into the data mode. As soon as the module is powered we should be able to discover the Bluetooth device as "HC-05" then connect with it using the default password 1234 and start communicating with it.

3.3.5. Relay Module

Fig.3.10 *4 Channel relay module.*

It is 4 Channel Isolated 5V 10A Relay Module, A wide range of microcontrollers such as Arduino, AVR, PIC; ARM and so on can control it. It is also able to control various appliances and other types of equipment with large current. Relay output maximum contact is AC250V 10A and DC5V 10A. One can connect a microcontroller with standard interface directly to it. Red working status indicator lights are conducive to the safe use. It has a wide range of applications such as all MCU control, industrial sector, PLC control, smart home control. This neat relay module features 4 x 5V relays rated at 10A/250V each. It is designed to switch up to 4 high current (10A) or high voltage (250V) loads with the help of microcontroller. Each relay can individually switch on/off by an opto-isolated digital input, which that can connect directly to a microcontroller output pin. It only requires a voltage of approximately 1.0V to switch the inputs on but can handle input voltages up to 5V. This makes it ideal for 1.0V to 5V devices. Figure.3.10 shows the relay module.

When the signal port is at low level, the signal light will light up and the optocoupler 817c (it transforms electrical signals by light and can isolate input and output electrical signals) will conduct, and then the transistor will conduct, the relay coil will be electrified, and the normally open contact of the relay will be closed. When the signal port is at high level, the normally closed contact of the relay will be closed. So we can connect and disconnect the load by controlling the level of the control signal port. Figure.3.11 shows the typical wiring diagram of relay.

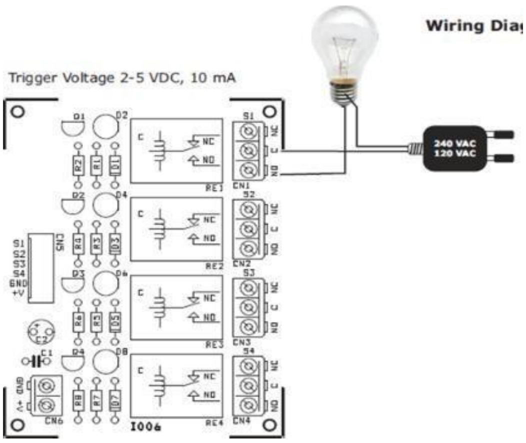

Fig.3.11 *Typical wiring diagram of Relay*

3.3.6. Liquid Crystal Display

A LCD is a Liquid Crystal Display which shows electronic visual display. Among various types of LCD's 2×16 LCD module is an extremely basic kind of LCD module that is utilized as a part of embedded projects. A 2×16 LCD implies it can show 16 characters for every line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. It is accessible in a 16 pin bundle with backdrop illumination, differentiate adjustment function and each dot matrix has 5×8 dot declaration. 2×16 LCD has two registers, in particular, Command and Data. The command register stores the command instructions given to the LCD. A command is a guideline given to LCD to complete a predefined undertaking like initializing it, clearing its screen, setting the cursor position, controlling display and so forth. The information is the ASCII estimation of the character to be shown on the LCD. The Figure.3.12 shows the 2 × 16 LCD and the pin description is shown by Figure.3.13.

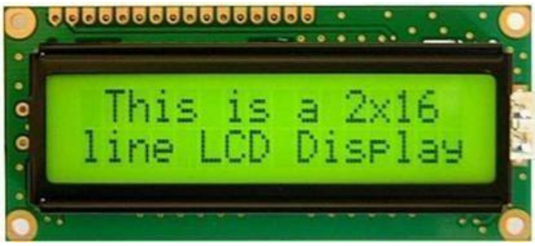

Fig.3.12 *A 2×16 LCD*

PIN DESCRIPTION

- **RS-Register Select**

As said above there are 2 very important registers in LCD; the Command Code register and the Data Register.

If RS=0, the Code register is selected, allowing user to send command. If RS=1, the Data register is selected allowing to send data that has to be displayed.

- **R\W-Read\Write**

R\W input allows the user to write information to LCD or read information from it. The data that is being currently displayed will be stored in a buffer memory DDRAM. This data could be read if necessary.

If R\W=1, then set for reading. R\W=0, then set for Writing

- **E-Enable**

The enable Pin is used by the LCD to latch information at its data pins. When data is supplied to data pins, a high to low pulse must be applied to this pin in order for the LCD to latch the data present in the data pins. This pulse must be minimum of 450ns wide. E=1 then 0, set the LCD a Toggle.

- **VEE**

VEE pin is meant for adjusting the contrast of the LCD display and the contrast can be adjusted by varying the voltage at this pin. This is done by connecting one end of a POT to the VCC (5V), other end to the Ground and connecting the centre terminal (wiper) of the POT to the VEE pin.

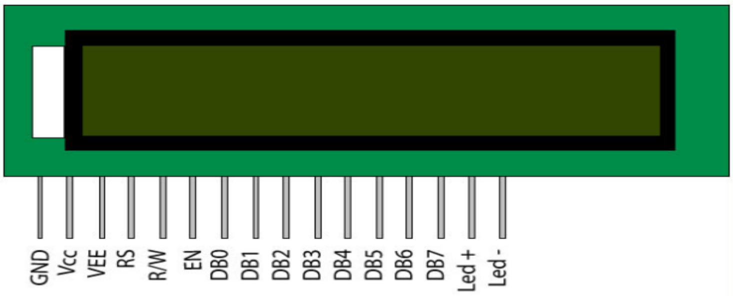

Fig.3.13 *LCD Pin description.*

- **Data pins**

DB0 to DB7 are the data pins. The data to be displayed and the command instructions are placed on these pins.

- **LED+ and LED-**

LED+ is the anode of the back light LED and this pin must be connected to VCC through a suitable series current limiting resistor. LED- is the cathode of the back light LED and this pin must be connected to ground.

- **Sending Data to the LCD**

The steps for sending data to the LCD module are given below. It is the logic state of these pins that make the module to determine whether a given data input is a command or data to be displayed.

- Make R/W low.
- Make RS=0 if data byte is a command and make RS=1 if the data byte is a data to be displayed.
- Place data byte on the data register.
- Pulse E from high to low.
- Repeat above steps for sending another data.

Some of the commands for LCD is given in Table.3.2.

LCD Commands

Table.3.2 *LCD Commands*

Code(Hex)	Command to LCD Instruction Register
1	Clear Display screen
2	Return home
4	Decrement cursor(Shift cursor to left)
5	Increment cursor(Shift cursor to right)
6	Shift display right
7	Shift display left
8	Display off, cursor off
A	Display on, cursor off
C	Display on, cursor off
E	Display on, cursor blinking
F	Display on, cursor blinking
10	Shift cursor position to left
14	Shift cursor position to right
18	Shift the entire display to the left
1C	Shift the entire display to the right
80	Force cursor to beginning of the 1st line
0C0	Force cursor to beginning of the 2nd line
38	2 lines and 5 X 7 matrix

3.4. Flowchart

The flowchart of the source code is given in Figure.3.14. When the code is initialized, the microcontroller starts reading the analogue values from the voltage and current sensors. Further it calculates power and if the power is exceeding the set limit, it will start the tripping of relays until the power is below the limit of consumption.

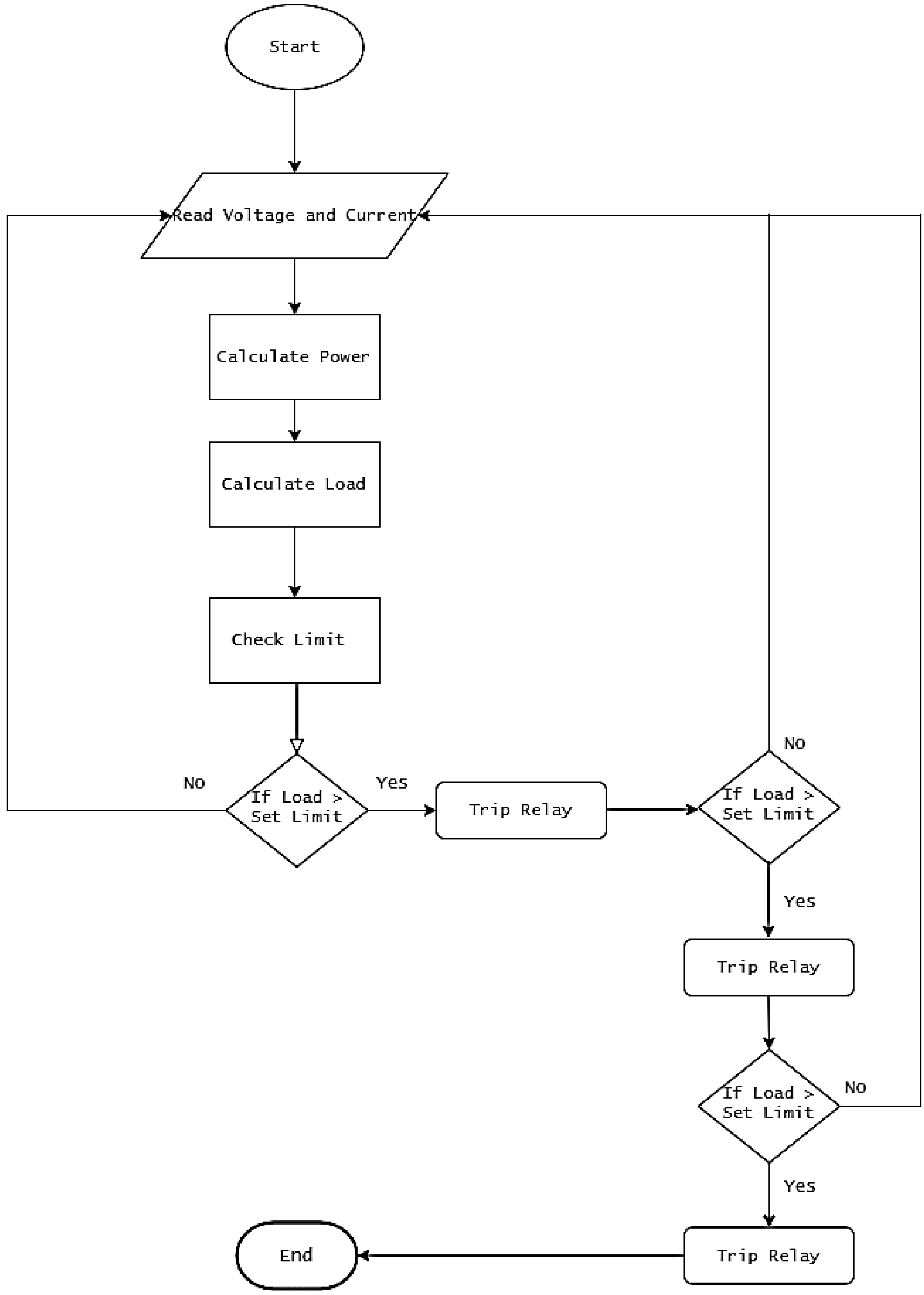

Fig.3.14 *Flowchart of energy management*

CHAPTER 4

RESULTS AND DISCUSSION

4.1. Current Sensor Analysis

The output of this current sensor is analogue, so to read it, we can directly measure the output voltage using voltmeter or measure it by using a microcontroller like Arduino. An experiment was conducted to study the characteristics of current sensor and the circuit connections were made as shown in Figure.4.1 and Table 4.1 shows the values of current sensor obtained post experiment and Figure.4.2 shows the experiment in progress and Figure.4.3 shows its characteristics.

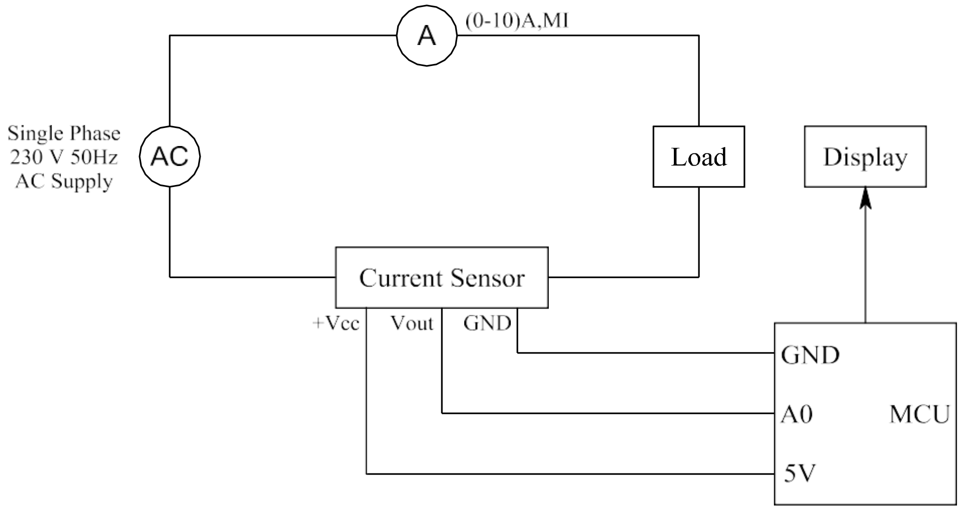

Fig.4.1 *Current Sensor circuit connection for experimental analysis*

Table.4.1 *Current Sensor reading tabulation.*

Load in Watt	Applied Value of Current in Amps	Sensed Value of Current in Amps	Percentage Error
200	0.86	0.95	10.46
400	1.72	1.72	0
600	2.58	2.55	-1.16
800	3.44	3.42	-0.58
1000	4.30	4.22	-1.86
1200	5.16	4.98	-3.48

$$\text{Percentage error} = \frac{\text{Measured current - Sensed current}}{\text{Measured current}}$$

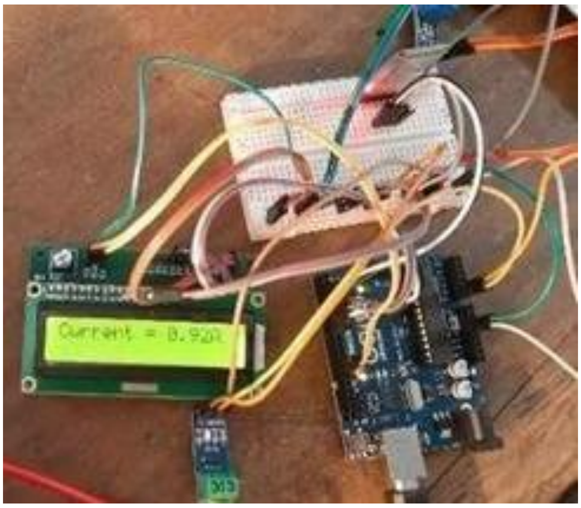

Fig.4.2 *Experiment on ACS712 Hall Effect Based current sensor*

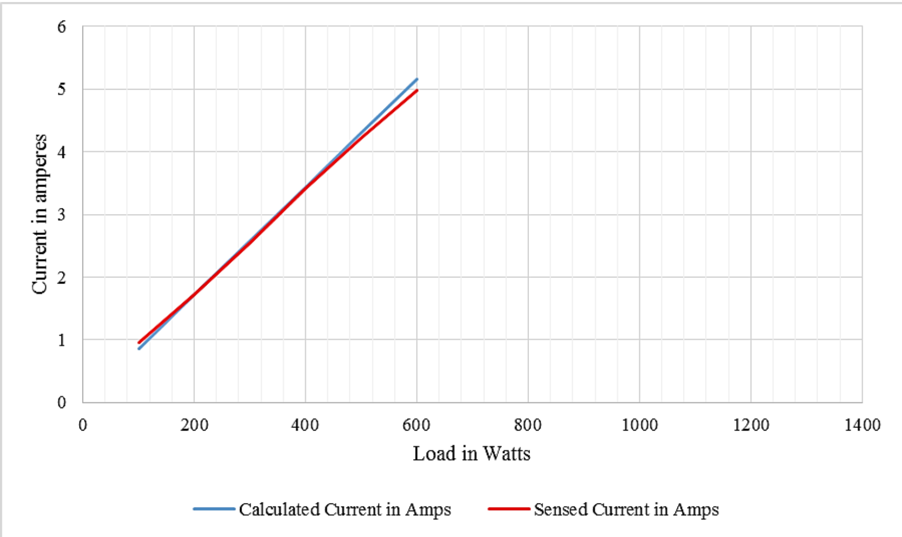

Fig.4.3 *Plot of Calculated current and Sensed Current.*

4.2. Voltage Sensor Analysis

In order to determine the accuracy and calibration of the equipment, we carried out an experiment by making the circuit connection as shown in Figure.4.4 and thus obtained the following results. The results are as shown in Table.4.2 and its characteristics isshown in Figure 4.5 below.

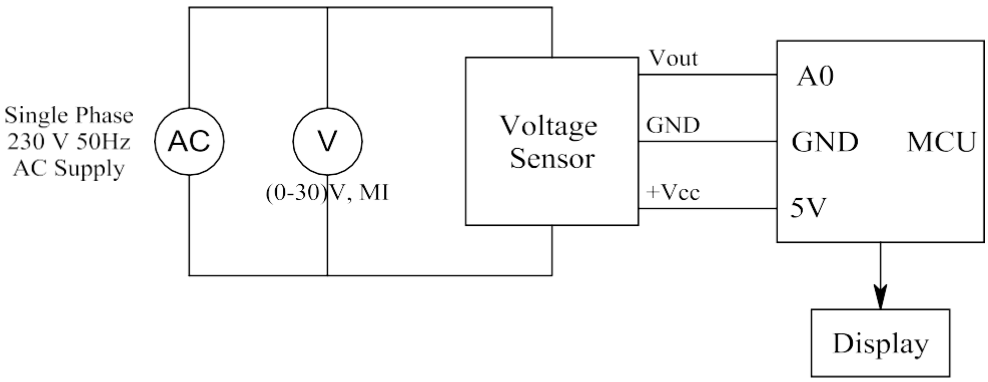

Fig.4.4 *Voltage Sensor circuit connection*

Table.4.2 *Voltage Sensor reading tabulation.*

Voltage Measured using Voltmeter	Voltage Measured using Sensor	Percentage Error
230	230.97	-0.42
232	231.56	0.19
234	235.26	-0.54
236	236.80	-0.34
238	237.38	0.26
240	240.53	-0.22
242	241.76	0.10
244	244.33	-0.14
246	244.92	0.44
248	246.48	0.33
250	247.17	1.41

$$\text{Percentage error} = \frac{\text{Measured voltage - Sensed voltage}}{\text{Measured voltage}}$$

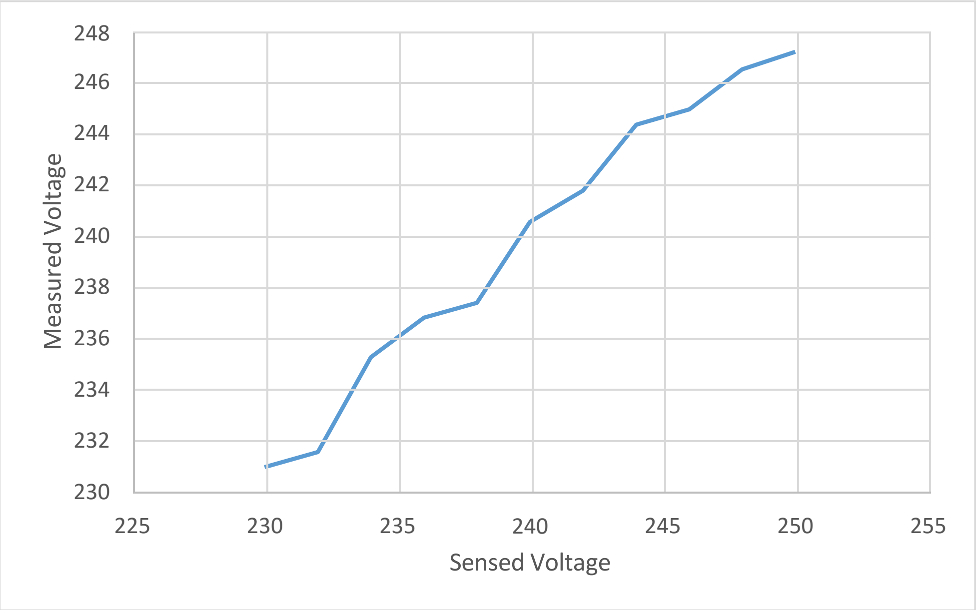

Fig.4.5 *Plot of Measured Voltage and Sensed Voltage*

4.3. LCD and Mobile Application output

- **Results in LCD**

Fig.4.6 *Output results shown in LCD*

- **Results in Mobile Application**

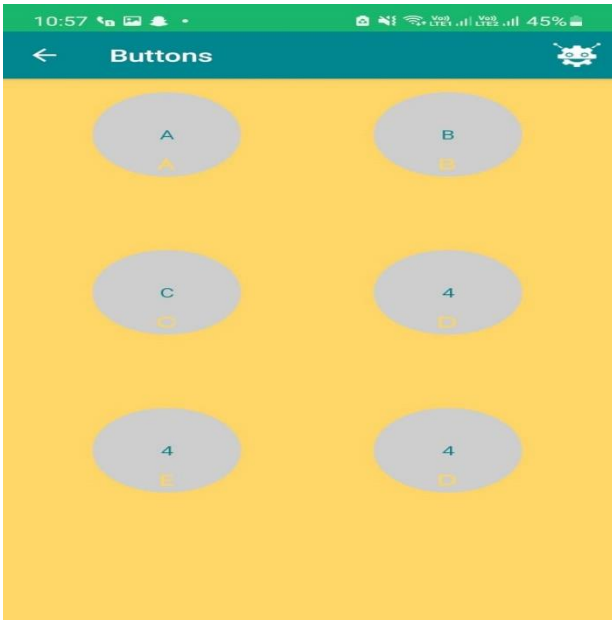

Fig.4.7 *Output Results in mobile application via Bluetooth*

Figure.4.6 shows output in the module's LCD and Figure.4.7 shows the output in the mobile application.

If the power exceeds more than threshold value the relay will trip. For example,

- If the power exceeds more than 220W the relay will trip according to priority given to relay, In our case the microcontroller unit waits for 5 seconds for the user to switch of any load(s) otherwise the Relay 3 will trip
- Suppose if the power is still more than the 220W the next relay say relay 2 will trip after the 5 second of wait.

The detailed output of the module is given in the Table.4.3.

Table.4.3 *Output readings from the model.*

Sl.No.	Power limit in Watt	Voltage in Volts	Current in Amps	Power in Watt	Energy in KWH	Relay Status
1	0 W	0.0	0.0	0.0	0.0	ON
2	Case 1 (0 – 180W)	244.0	0.24	60	0.06	ON
3		244.5	0.47	115	0.12	ON
4		240.0	0.75	181	0.181	Relay 3 OFF
5	Case 2 (0 W– 220W)	241.0	0.76	185	0.120	ON
6		249.2	0.72	215	0.180	ON
7		252.0	0.86	221	0.221	Relay 3 OFF
8	Case 3 (0 W– 240W)	255.3	0.86	220	0.180	ON
9		257.0	0.93	241	0.241	Relay 3 OFF
10		243.5	0.98	241	0.241	Relay 2 OFF

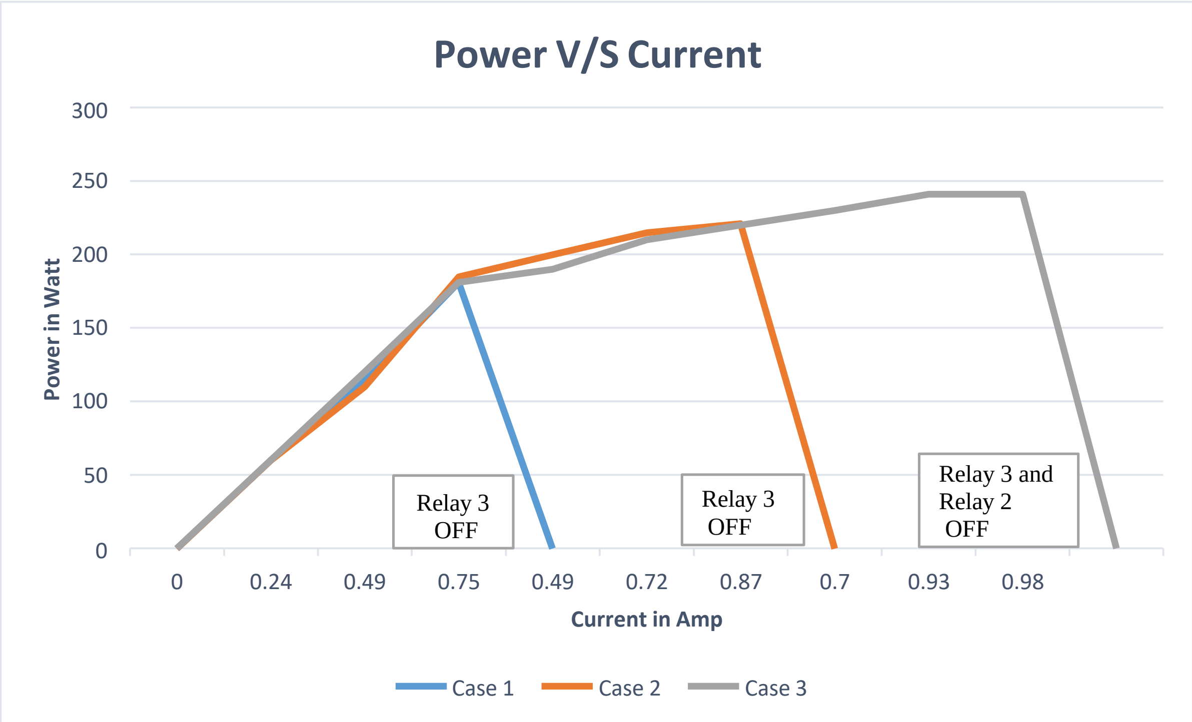

Fig.4.8 *Plot of Power (load) and current.*

4.4. Advantages

- It is compact in size and user friendly.
- It can be tailored as per the user's need.
- It can be operated remotely via Bluetooth.
- Energy saving can be achieved over a period of time thereby resulting in a significant saving in electricity bill.
- It is affordable.

4.5. Disadvantages

- The sensors have to be calibrated very accurately or else leads to high error in measurement and as a chain reaction unnecessary tripping of relays takes place.
- Proper protection has to be provided to the module. High currents may lead to damage of the equipment

CONCLUSION

- The smart module has been developed for measuring, monitoring and control of load is done reliably.
- The Bluetooth module acts as a communication medium between the micro controller and mobile application, which ensures remote control of load by the user.
- The prototype built is capable of managing the system loads effectively by not allowing more than the threshold value of the power to operate in the system and it is equipped with automatic reconnection capability.

FUTURE SCOPE

- The project will become more effective when IoT is introduced in it.
- The user interface in the mobile application can be improved in the future.
- More number of loads can be connected using an edge-triggered flip-flop and multiplexer circuits.
- Cost can be reduced when manufactured in bulk quantities.
- In the emerging trend of Artificial Intelligence and Machine Learning, a fully automated module can be developed using the base design and can be designed to operate without human intervention being fully automated.
- Using Machine Learning, the module can be designed to learn usage pattern and adapt accordingly

BIBLIOGRAPHY

REFERENCES

[1] Abubakar, I & Khalid, S. & Mustafa, Mohd & Mustapha, Mamunu & Shareef, Hussain. (2018). *Residential Energy Consumption Management Using Arduino Microcontroller. Advanced Science Letters*. 24. 3887-3893. 10.1166/asl.2018.11505. pp-2

[2] K. Baraka, M. Ghobril, S. Malek, R. Kanj and A. Kayssi, "*Low Cost Arduino/Android-Based Energy-Efficient Home Automation System with Smart Task Scheduling*," 2013 *Fifth International Conference on Computational Intelligence, Communication Systems and Networks, Madrid*, 2013, pp. 296-301, doi: 10.1109/CICSYN.2013.47.

[3] Tiong, Meng Chung and Daniyal Hamdan. "*Arduino Based Power Meter Using Instantaneous Power Calculation Method." (2015). VOL. 10, NO. 21*, NOVEMBER 2015, ISSN 1819-6608

[4] Jao, C.; Guo, X. (2008, May). *PowerBox: The Safe AC Power Meter. Retrieved from Cornell ECE476 course site: http://instruct1.cit.cornell.edu/courses/ee476/FinalProjects/s2008/cj72_xg37/cj72_xg37/index.html*

[5] Srividyadevi P, Pusphalatha DV, Sharma PM. *Measurement of Power and Energy Using Arduino. Research Journal of Engineering Sciences* 2013.

[6] Hu, Qinran and Fangxing Li. "*Hardware Design of Smart Home Energy Management System with Dynamic Price Response." IEEE Transactions on Smart Grid 4 (2013):* 1878-1887.

[7] Ninad Khandekar, Kalpak Thube, Nilesh Patil, Dr P. B. Mane, 2014, *Non-Intrusive Appliance Load Monitoring System Using Zigbee Protocol, INTERNATIONAL JOURNAL OF ENGINEERING RESEARCH & TECHNOLOGY (IJERT) Volume 03, Issue 04* (April 2014).

[8] V.K.Mehta, Rohit Mehta; *Principles of Power Systems, 4th Edition*, S.Chand, 2016.

[9] B.H.Khan., *Non-Conventional Energy Resources, 3rd Edition*, McGrawHill, 2018.

[10] V.K.Mehta, Rohit Mehta; *Principles of Electrical Engineering and Electronics, 4th Edition*, S.Chand, 2018.

[11] Behrouz A.Ferouzan, *Data Communication and Networking, 5th Edition,*

♦ ♦ ♦ ♦ ♦ ♦