A minor project report on

INNOVATIVE SMART ENERGY METERING OPTION

submitted in fulfillment of the requirements for the degree of

B. Tech

In

Electronics and Electrical Engineering

By

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BHUBANESWAR

CERTIFICATE

This is to certify that the project report entitled **"INNOVATIVE SMART ENERGY METERING OPTION "** submitted by

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in fulfilment of the requirements for the award of the **Degree of Bachelor of Technology** in **Electronics and Electrical Engineering** is a bonafide record of the work carried out under my(our) guidance and supervision at School of Electronics Engineering, KIIT University.

Signature of Supervisor 1
Prof. H.S. Rauth
School of Electrical Engineering
KIIT University

The Project was evaluated by us on _____________

EXAMINER 1 EXAMINER 2
EXAMINER 3 EXAMINER 4

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ABSTRACT:

A smart meter is a device which keeps a track of the consumption of electrical energy at given intervals of time (typically an hour or less) and communicates that information back to the utility for billing and monitoring purposes. The Smart meters are enabled with two-way communication between the meter and the central system of the utility company. Unlike conventional energy meters, smart meters are capable of remote data recording. Such an Advanced Metering Infrastructure (AMI) differs from traditional Automatic Meter Reading (AMR) as two-way communication isn't enabled in traditional meters and hence it requires manual recording of data at the consumer premise itself. Communications from the meter to the network can be done using two options; one is through wired connection (such as power line carrier communications) or using wireless mode. Wireless systems include cellular communications which is quite expensive, Wi-Fi which is readily available, wireless ad hoc networks over Wi-Fi, wireless mesh networks, Low Power Long Range wireless abbreviated as LORA, ZigBee which is a low power low data rate wireless, Wi-SUN (Smart Utility Networks),etc.

The term Smart Meter is commonly referred to an energy meter, but it broadly refers to any electronic device that is used for measurement of different physical quantities like gas, water etc. and are enabled with two way communication for near real time monitoring of data. Here we will restrict to the former only. Smart Meters usually involve real-time or near real-time sensor and power quality monitoring. These additional features are more than AMR. They are similar in many AMI meters. Meters with predefined intervals and time of use have been installed for measuring consumption of commercial and industrial customers, but may not be equipped with automatic reading. Advanced Metering Infrastructure (AMI) are the systems that asses, gather, accumulate and analyse energy usage, and communicate the same with different types of metering devices they are connected with such as electricity meters, gas meters, heat meters, and water meters. These type of systems are inclusive of hardware, software, communication systems, displays for energy consumption and controllers, meter data management software, and supplier business systems. Government agencies and utilities are investing into AMI systems for developing smart grid infrastructures. AMI supplements AMR technology by providing two way meter communications, allowing commands to be sent toward the home for different purposes, which include time based cost estimation information, demand response actions, or disconnecting through remote service whenever the

consumer fails to pay the bill. Wireless technology is an essential element of the neighbourhood network which may aggregate a mesh configuration of up to thousands of meters for backhauling to the utility company's server. The network between the sensing devices and business systems permits collection and distribution of information to customers, suppliers, utility companies, and service providers. This allows these businesses to take part in demand response services. Consumers can use information provided by the system to lower their normal consumption rates to take advantage of lower prices. Pricing if done properly can be of great significance in reducing growth of peak demand consumption. AMI differs from traditional AMR as it enables two way communications between the meter and utility company server of which the AMR systems aren't capable of. Systems which are only capable of displaying meter reading does not qualify as AMI systems. Smart meters are a part of a smart grid infrastructure, but alone they do not constitute a smart grid infrastructure.

Many confuse smart meters with energy meters, also known as in-home display meters. The main role of smart meters is to save energy and eliminating any possibilities of theft of power. While energy suppliers could save a lot of money every year by installing them, consumer benefits will depend on people actively changing their energy usage. For example, time of use tariffs offering lower energy price rates at off-peak times, and selling electricity back to the grid with net metering will also benefit consumers.

In this subject study we are trying to focus on smart metering technique which can be activated based on IOT applications to control, supervise and monitor the entire activity for a purposeful activity.

LIST OF FIGURES:

LIST OF ABBREVIATIONS:

AC	Alternating Current
ADC	Analog to Digital Converter
AMI	Advanced Metering Infrastructure
AMR	Automatic Meter Reading
ASIC	Application Specified Integrated Circuit
COM	Common
DC	Direct Current
DMA	Direct Memory Access
DMT	Digital Micro Technology
DPDT	Double Pole Double Throw
DPST	Double Pole Single Throw
EEM	Electronic Energy Meter
GND	Ground
GPIO	General Purpose Input Output
IC	Integrated Circuit
ICSP	In Circuit Serial Programming
IOT	Internet of Things
IP	Internet Protocol
KB	Kilo Byte
KW	Kilowatt
KWH	Kilowatt Hour
LCD	Liquid Crystal Display
MB	Mega Byte
NO	Normally Open
NC	Normally Closed
PCB	Printed Circuit Board

PWM	Pulse Width Modulation
RAM	Random Access Memory
SPST	Single Pole Single Throw
SPDT	Single Pole Double Throw
TTL	Transistor Transistor Logic
TCP	Transmission Control Protocol
UART	Universal Asynchronous Receiver Transmitter

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OVERVIEW

The current metering system uses either an electronic energy meter or an electro-mechanical meter that is set up at the consumer's end for measuring the energy usage. A typical single phase Electromechanical Energy Meter works on the basic principle of electromagnetic induction and there is a non-magnetic but electrically conductive metal disc that rotates due to induction and keeps a count of number of rotations and the speed of rotation is proportional to the power passing through the meter. Hence the number of revolutions of the disc is directly proportional to the energy consumption. Electronic Energy Meter which are based on DMT that have no movable parts in it which is why they are also known as "Static Energy Meter". It consists of a specially designed IC known as ASIC which is responsible for controlling the accurate functioning of EEM. Construction of ASIC is done only for limited applications using Embedded System Technology.

The main drawback of these meters is that these meters are only capable of recording kWh consumption by the consumer. This data recorded by the meter is then reported by an employee of the meter reading company who visits the consumer premises and records it. The recorded data is then processed by the meter reading company. For processing the meter reading data, the company needs to link each recorded piece of information about power usage to an account holder and then calculate the bill according to the tariff plan in use. This involves a lot of manual data handling and thus gives rise to complexities during data processing and increases the chance of error in processing.

The governments of different states have started to replace the conventional electromechanical energy meters with electronic energy meters when the world is embracing the smart energy metering technology with such great pace. Smart energy meters eliminate any chances of human error that may arise in the conventional metering systems and also eliminate the need of any manual data handling as they are enabled with two way communication system that stores and communicates the data recorded by it with the utility center. This accounts for assurance on both sides the consumer as well as the service provider. Smart meters are more reliable, tamper proof, energy efficient and provide near about real time values.

PROS & CONS:

Advantages for Electric Companies:

- It eliminates manual monthly or quarterly meter readings.
- It monitors the electric system more quickly.
- It makes it possible to use electrical power resources more efficiently
- It provides real-time data which is useful for balancing electric loads while reducing power outages i.e., blackouts and load shedding.
- It enables dynamic pricing which raises or lowers the cost of electricity based on demand
- It avoids the capital expense of building new power plants
- It helps in optimizing income with existing resources

Advantages for Users of Electricity:

After the electric company has fully installed its advanced metering infrastructure (AMI), smart meters will offer the following benefits to electricity customers:

- It will provide much better feedback regarding energy use
- It will compel consumers to refrain from wastage of electricity.
- It reduces the number of load shedding and electricity failures

Advantages for the Environment:

- It will prevent the need for new power plants that produce greenhouse gases like CO, SO2, etc. that substantially creates pollution which increases health risks
- It will help to reduce existing greenhouse gas emissions from existing power plants

Disadvantages of Smart Meters are Short Term

Every technology has its own benefits and drawbacks. While smart meters accomplish a lot, they also present challenges to electrical utilities as well as consumers. While the majority of these disadvantages are not having any prolonged effects, and currently there are no environmental hazards involved.

Disadvantages for the Electric Companies:

Smart meters present the following challenges to electrical utilities:

- The cost in terms of training of personnel and equipment development and production to transition to a new technology and new set of processes
- Managing negative public reaction and acquiring customer acceptance of the new metering technology.
- Making a long-term financial investment to the new metering technology and also to the related software involved
- Managing and storing enormous quantities of the metering data collected by their servers.
- Ensuring the data security.

Disadvantages of Smart Meters for Consumers:

- It is hard to verify the accuracy of the new meter.
- There is no way to protect the privacy of the personal data collected by smart meters.
- There is an additional fee for the installation of the new smart meters.

Other disadvantages include the reality that smart meters put meter mans out of work, which hurts the economy and increase employability. To date, hundreds of individuals have lost their jobs due to automation and most would not find new ones based on their esoteric skill-set. In addition, while it was anticipated that smart meters would save customers money, customers rarely check their meters because the system is so complex. As a result, customers are unable to make energy consumption changes.

ARCHITECTURE:

Smart meters are built according to the AMI (Automatic Metering Infrastructure) which require two way meter communications, allowing data to be sent toward the utility server for multiple purposes, including time-based pricing information, demand-response actions, or disconnecting through remote service. When developing such a smart meter we should keep in mind the following points:

- Meter should be built with future aspirations in-built, i.e. there should be provision for future up gradation with the future development of metering infrastructure.
- Interoperability between systems should be ensured for such smart meters.
- It should be easy to build but it should also have state of the art security so that electricity theft by meter tampering can be detected easily.
- It should follow standard protocol. In India, IS16444 and IS15959 are defined for smart metering.

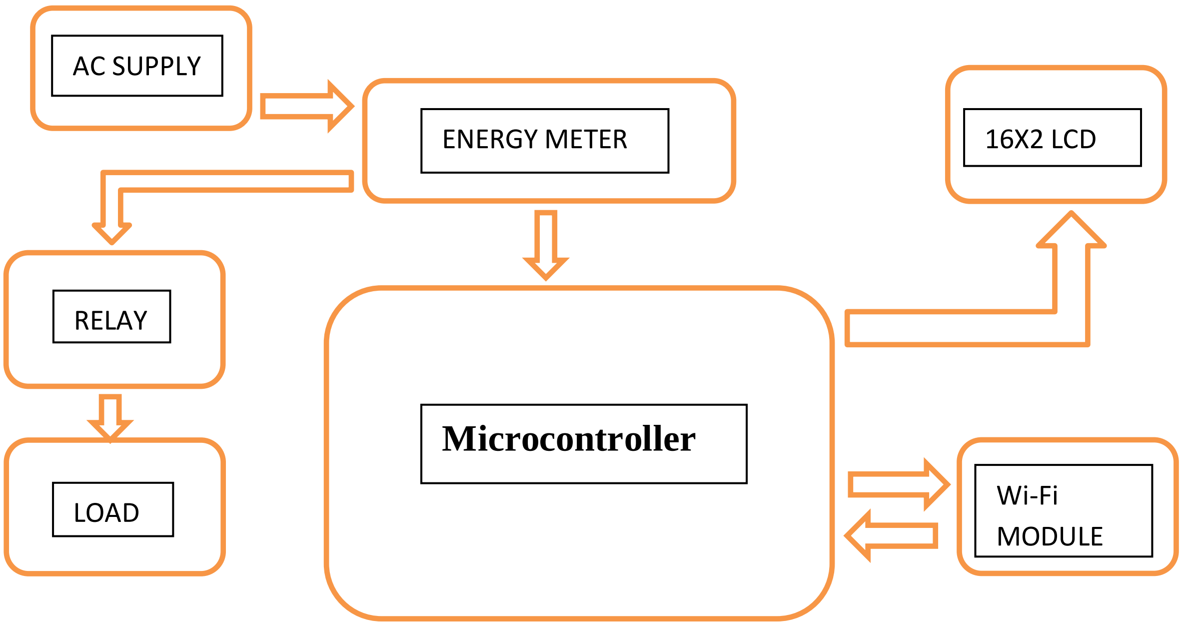

Figure 1

- AC SUPPLY: The AC supply main is the source of the electrical energy. It is the form of electrical power that is delivered to homes. The two principal properties of the electric power supply, voltage and frequency. Here, 1-phase AC supply of 230 V and 50 Hz is used.

- ENERGY METER: The energy meter is connected to the ac supply mains for the recording the voltage and current and it provides that data to the microcontroller for calculation of electric power, energy and other electrical quantities measured.

- MICROCONTROLLER: The microcontroller is the brain of the smart meter. It takes input from the energy meter in form of current and voltage, then computes the electrical power and electrical energy and displays the information to the output device and also exports it to the utility organisation with the help of transmission device.

- RELAY: Relay is a protection device which is used to trip the total power supply in case of any anomalous condition like flowing of overvoltage, overcurrent, undercurrent, etc. through the circuit. It is controlled by the microcontroller which on detection of fault trips the circuit.

- LOAD: The load constitutes of the appliances connected to the supply which consumes electrical power. Load affects the performance of circuits with respect to output voltages or currents, such as in sensors, voltage sources, and amplifiers. Mains power outlets provide an easy example: they supply power at constant voltage, with electrical appliances connected to the power circuit collectively making up the load. When a high-power appliance is switched on, it accounts for a drastic reduction in load impedance.

- 16X2 LCD DISPLAY: The LCD display displays the various electrical quantities consumed such as voltage, current, power and energy.

- Wi-Fi MODULE: The Wi-Fi module collects the data from the microcontroller and sends the data to the electrical utility company once a day or so about the electricity consumption of the consumer over wireless channels.

WORKING PRINCIPLE AND CIRCUIT DIAGRAM:

The basic circuit of a smart meter comprises of:

- Arduino microcontroller
- Current measurement circuit
- Voltage measurement circuit
- Display circuit
- Control circuit
- ESP8266

The current measurement circuit and the voltage measurement circuit measure the current consumed by and voltage across the load and send the data to the Arduino microcontroller. The Arduino calculates the electrical power consumed and electrical energy and displays the information with the help of the display circuit consisting of a 16X2 LCD module. The control circuit contains a relay which helps to trip the circuit thereby cutting the power supply off from the circuit in times of a fault (overcurrent, overvoltage and under voltage). The Arduino sends the data to the server with the help of ESP 8266.

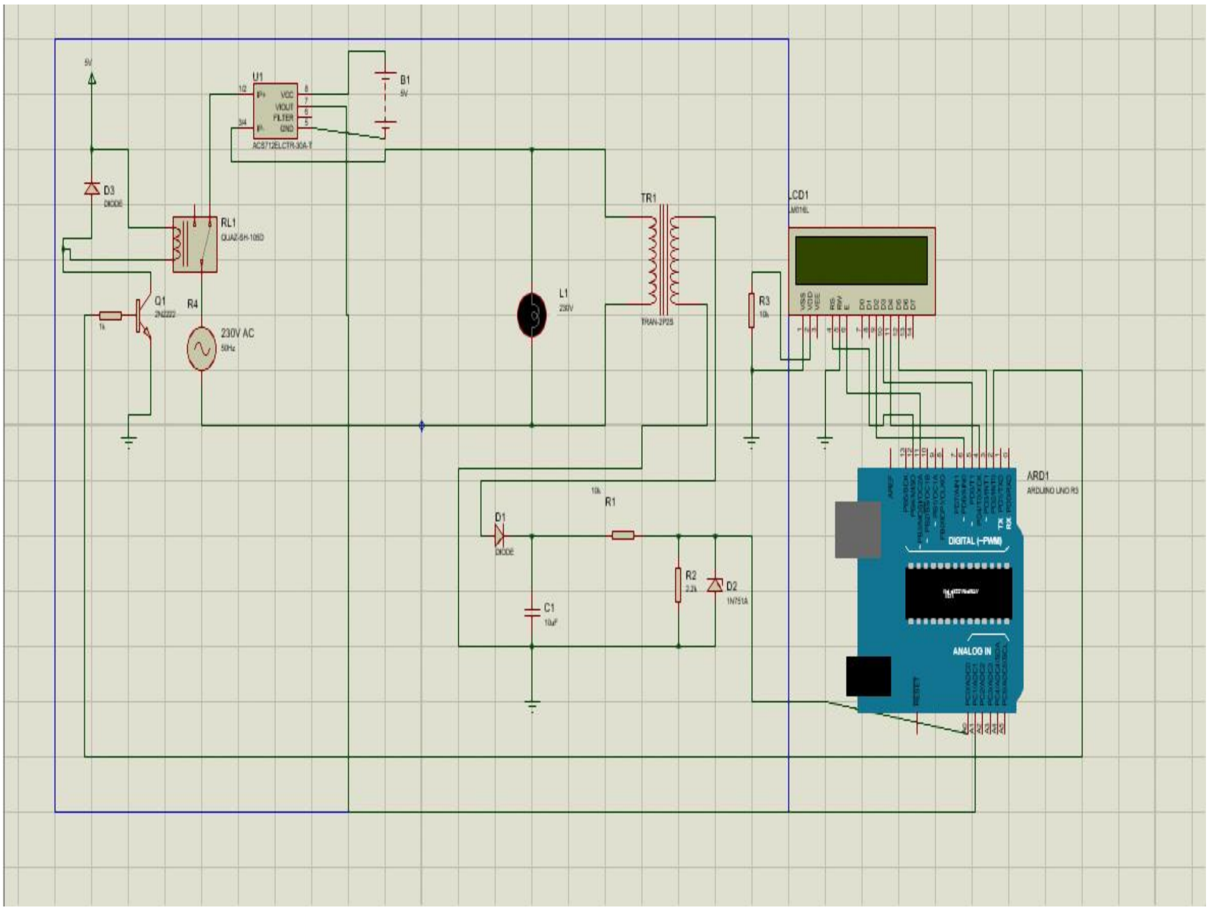
U1
B1
D3
RL1
Q1
R4
230V AC
L1
TR1
LCD1
R3
ARD1
D1
R1
R2
D2
C1
DIGITAL (~PWM)
ANALOG IN

Figure 2

MAIN COMPONENTS:

- **MICROCONTROLLER - ARDUINO UNO REV3:**

Arduino Uno is a microcontroller development board which is based on the ATmega328P of ATMEL. It consists of 14 digital Input/Output pins among which 6 may be used for PWM outputs. There are 6 analog inputs, a USB connection, a power jack, a 16 MHz quartz crystal, an ICSP header and a reset button. It contains a total development environment for the microcontroller. It can be connected to a computer very easily with a USB power cable. It can also be powered with an AC to DC voltage of 12V.

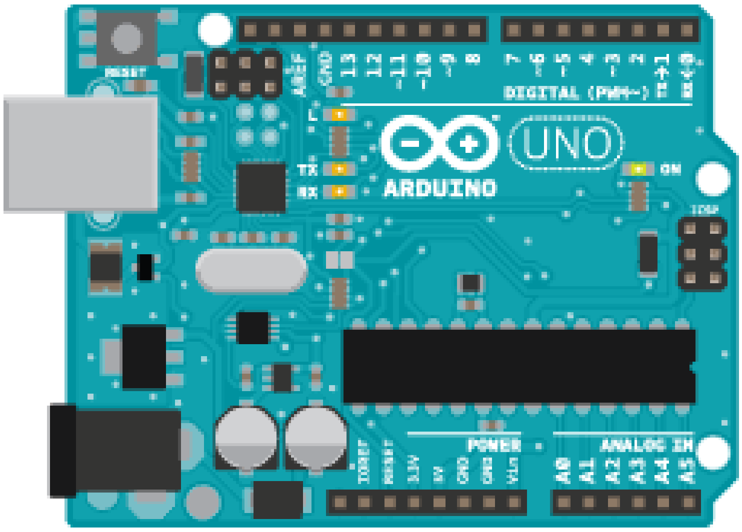

Figure 3

Features:

Microcontroller	:	ATmega328P
Operating Voltage	:	5V
Input Voltage (recommended)	:	7-12V
Input Voltage (limit)	:	6-20V
Digital I/O Pins	:	14 (of which 6 provide PWM output)
PWM Digital I/O Pins	:	6
Analog Input Pins	:	6

DC Current per I/O Pin	:	20 mA
DC Current for 3.3V Pin	:	50 mA
Flash Memory	:	32 KB
SRAM	:	2 KB
EEPROM	:	1 KB
Clock Speed	:	16 MHz
LED_BUILTIN	:	13
Length	:	68.6 mm
Width	:	53.4 mm
Weight	:	25 g

- **Wi-Fi MODULE –ESP8266-1E:**

The ESP8266 is a Wi-Fi module manufactured by Espressif Systems. It is known for its low cost and full TCP/IP stack commands

With the help of this small module, microcontrollers to connect to a Wi-Fi network and make simple TCP/IP connections using Hayes style commands. However, at the time there was almost no English documentation on the chip and the commands it accepted. The low price and the fact that there were very few external components on the module which suggested that it could eventually be very inexpensive in volume, attracted many hackers to explore the module, integrated chip, and the software on it, as well as to translate the documentation in Chinese to other languages like English.

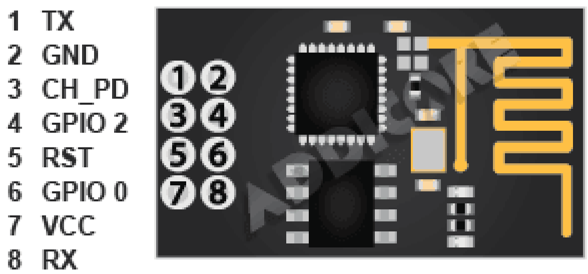

Figure 4

Specifications:

- Processor: L106 32-bit RISC microprocessor core based on the TensilicaXtensa Diamond Standard 106Micro running at 80 MHz†
- Memory:
  32 KB instruction RAM, 32 KB instruction cache RAM,80 KB user data RAM
  16 KB ETS system data RAM
- External QSPI flash: up to 16 MB is supported (512 KB to 4 MB typically included)
- IEEE 802.11 b/g/n Wi-Fi
- 16 GPIO pins
- I²S interfaces with DMA (sharing pins with GPIO)
- UART on dedicated pins, plus a transmit-only UART can be enabled on GPIO2
- 10-bit ADC (successive approximation ADC)

- **CURRENT SENSOR – ACS712-30A:**

Sensing and controlling current flow is a fundamental requirement in a wide variety of applications including, over-current protection circuits, battery chargers, switching mode power supplies, digital watt meters, programmable current sources, etc. The above named current sensor module uses an ACS712 sensor, which has the capability to detect AC or DC current accurately. Its maximum rating is 30A, and the current signal can be read via analog input/output port of Arduino u-controller. 5A and 20A versions of the same module are available in the market.

A precise, low-offset, linear Hall Effect sensor circuit with a copper conduction path located near the surface of the die is employed in this sensor. Applied current flowing through this copper conduction path generates a magnetic field which is sensed by the integrated Hall IC and converted into a proportional voltage. Optimization of device accuracy is done through the close proximity of the magnetic signal to the Hall transducer. A precise, proportional voltage is supplied by the low-offset and chopper-stabilized BiCMOS Hall IC which has been programmed for high level of accuracy. A positive slope is obtained from output of the device when an increasing current flows through the primary copper conduction path, which is used for current sensing.. The ACS712 comes in a small, surface mount SOIC8 package. The lead frame is plated with 100% tin, which is well-suited with standard lead free PCB assembly processes. Internally, the device is Pb-free, except for flip-chip high-temperature Pb-based solder balls, currently exempt from RoHS.

Figure 5

Features:

- Low-noise analog signal path
- Device bandwidth is set using the new FILTER pin
- output rise time in response to step input current is 5 μs
- Bandwidth of 80KHz
- Total output error of 1.5% at TA = 25°C
- Small footprint, low-profile SOIC8 package
- internal conductor resistance of 1.2 mΩ
- minimum isolation voltage from pins 1-4 to pins 5-8 is 2.1 kVRMS
- single supply operation of V
- output sensitivity of 66 to 185 mV/A
- Output voltage is proportional to AC or DC currents
- Extremely stable output offset voltage
- Nearly zero magnetic hysteresis
- Ratio metric output from supply voltage

- **16X2 LCD MODULE:**

LCD (Liquid Crystal Display) is an electronic display module which is used in a wide range of applications. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits. These modules are preferred over seven segment displays and other multi segment led displays. 16×2 LCD is named so because it has 16 columns and 2 rows. There are a lot of combinations available in the market like 8×1, 8×2, 10×2, 16×1, etc. but the most used one is the 16×2 LCD. So, it will have 32 characters in total and each character will be made of 5×8 pixel dots. Now, we know that each character has 40 pixels and for 32 characters we will have 1280 pixels. Further, the LCD should also be instructed about the arrangement of the pixels. Hence it will be a hectic task to handle everything with the help of microcontrollers, hence an interfacing IC like HD44780 is used, which is mounted on the backside of the LCD Module itself. The function of this IC is to get the commands and data from the microcontrollers and process them to display meaningful information onto our LCD Screen

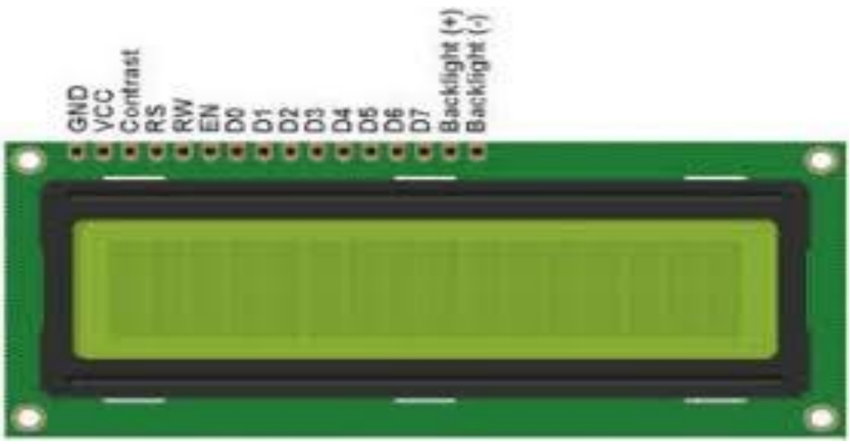

Figure 6

Features:

- Operating Voltage is between 4.7V and 5.3V
- Current consumption of 1mA without backlight
- LCD display can display both alphabets and numbers.
- It consists of two rows and each row can print 16 characters.
- Each character is built using a 5×8 pixel box
- It can work on both 4-bit and 8-bit mode
- It can also display any custom generated characters using the pixels properly.

- **RELAY- SRD-05VDC-SL-C:**

Relay is an electromagnetic device which facilitates immediate isolation two circuits electrically whenever a fault is detected by the sensors attached to it. They are very useful devices and allow one circuit to switch another one though they are completely separate. Relays are generally operated at lower voltages to switchover high voltage circuits. Thus a small sensor circuit can drive, say, a fan or an electric bulb. A relay switch can be divided mainly into two parts: input and output. The input section consists of a coil which can generate magnetic field whenever a small voltage from an electronic circuit energises it. This voltage is termed as operating voltage. Relays are available in different configuration of operating voltages like 5V, 6V, 9V, 12V, 24V etc. which are used quite commonly. The output section consists of contactors which connects or disconnects mechanically. A typical basic relay consists of three contactors namely normally open (NO), normally closed (NC) and common (COM). At no input state, the common is connected to normally close. When the operating voltage is applied, the relay coil gets energized and the common changes contact to normally open. Different relay configurations are available like SPST, SPDT, DPST, DPDT, etc. which have different number of changeover contacts. The electrical circuit can be switched on and off by using proper combination of contactors

Figure 7

Features:

- Operating Voltage of 5V.
- Max Current is 20mA.
- Relay Current Capacity at AC250V is 10A.
- Relay Current Capacity at DC30 is 10A.
- 1 Normally Close contact and 1 normally open contact.
- Triode drive, increasing relay coil.
- High impedance for the controller pin.
- Pull down circuit is provided for avoidance of malfunction.
- Lamp for power supply indication.
- Lamp for control indication.
- Relay output status is indicated.
- It can be control various appliances & other equipment with large current.
- The module is compliant with international safety standards, control and load areas.

<u>METHODOLOGY:</u>

The main project is divided into two main phases:

PHASE I: The development of a basic digital meter of load capacity of 1-3 KW with an error of 5% or less.

PHASE II: Integration of IOT based system on the basic meter and development of cloud based infrastructure for monitoring and analysis of meter data.

a) <u>Schematic aspect</u>: At first the schematics of the project is to be finalised. For this the architecture of the project is designed. The schematic diagram is to be designed using PROTEUS DESIGN SUITE 8.0 PROFESSIONAL. In that the individual circuits are to be simulated part by part using PROTEUS DESIGN SUITE 8.0 PROFESSIONAL. Then, the whole circuit is to be simulated using TINKERCAD.

b) <u>Sourcing of sub materials</u>: During this period all the materials are to be sourced. The components for sub circuits like voltage measurement circuit, current measurement circuit, display circuit, control circuit like relay, ACS712 sensor IC, 220/6v step down transformer, bridge rectifier, LCD, etc. are to be sourced and a budget plan is to be prepared for the project. The total cost estimation is set to be +/- 40% of the initial cost estimation.

c) <u>Prototype Design and measure the I/O system:</u> During this period the different circuits are to be assembled individually. The input and output (load) to the meter is to be designed. Then the whole meter is to be integrated inside a single enclosure with provision for connection and disconnection of load and supply during time of installation and maintenance.

d) <u>Trial Testing:</u> During this period, the sub circuits are to be tested and calibrated to minimise error (targeted to achieve less than or equal to 5%). If any component is faulty or malfunctions then that component is to be replaced. Then the total circuit is integrated and tested as a whole using a standard load.

e) <u>Finalisation and Reporting:</u> After successful trail and testing, the whole meter is to be calibrated to achieve desired accuracy and meter is prepared for final product development. The report containing the details about the project is to be prepared, proof read and finalised.

TIME FRAME:

a) Schematic aspect -1.5 months

b) Sourcing of sub materials (Current sensor, Voltage sensor, Micro Controller, etc) - 30 Days

c) Prototype Design and measure the I/O system -1.5 Months (for Phase I)

d) Trial Testing - 10 days (Phase I)

e) Finalisation and Reporting - 7 days

COST ESTIMATATION:

S. No.	NAME Of THE COMPONENTS/ITEM	COST OF THE COMPONENTS/ITEM(₹)
01.	Current Sensor(ACS-712)	250.00
02.	Voltage Sensing Circuit	100.00
03.	Arduino Uno Microcontroller	500.00
04.	Display Circuit	300.00
05.	Relay Circuit	100.00
06.	Test Load	150.00
07.	Miscellaneous	200-300
08.	Total Estimated Cost of The Meter	1600-1700

The total estimated cost for this project is estimated to be around Rs1600 to 1700.

The stipulated cost should be +/- 40% of the initial estimated cost.

So, the stipulated cost is estimated to be around 1000-2000, where lower end is for bulk production and higher end is for very small scale manufacturing with a lot of interruptions.

FABRICATION:

CURRENT MEASUREMENT CIRCUIT:

The current measurement circuit measures the current consumed by the load and sends the data to the arduino microcontroller. It consists of a ACS 712-30A current sensing module. It is connected in series to the load. It can measure up to 30 A load current. A 5V supply is connected between the VCC (pin8) and GND (pin 5) pin to enable biasing voltage to the ACS712 IC. VOUT (pin 6) is connected to the analog pin of the arduino. IP+ (pin 1&2 shorted together) and IP- (pin 3&4 shorted together) are connected to the supply and load terminals respectively. ACS 712-30A chip has a current sensitivity of 66mv per ampere. Arduino is capable of sensing between 0 to 5V, which will give a corresponding current of 0A to 30A.

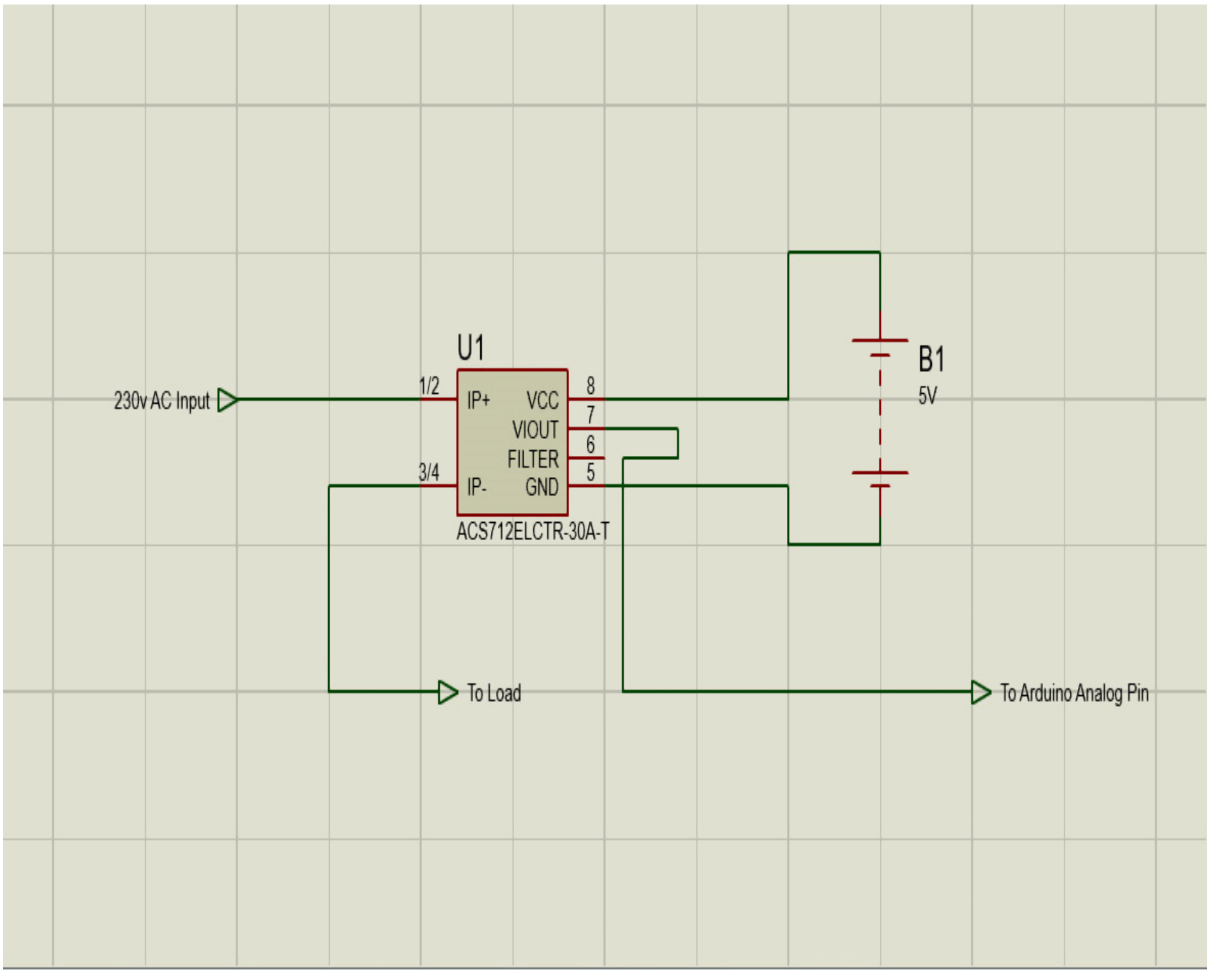

Figure 8

VOLTAGE SENSING CIRCUIT:

The voltage sensing circuit consists of three main parts the first being the voltage transformer, the second one is DC rectification and the third one is voltage divider circuit. The voltage transformer steps down the voltage from the 220 V AC to 6V AC. Then a diode bridge rectifier is used to rectify the negative part of the voltage. A 10 microfarad capacitor is attached to compensate the ripples contained in the output of the bridge rectifier. ADC of arduino is only rated for voltages between 0 and +5V. But when we are rectifying 6V AC, the output voltage of the bridge rectifier is more than 5V. So a voltage divider circuit consisting of a 2.2Kohm and 10Kohm resistor are connected in series which divides the voltage in 1:5 ratio. A zener diode is connected in parallel to the 10Kohm resistor which assures the safety by keeping the voltage under 5V. The output voltage across the 10Kohm resistor is then fed to the analog pin of arduino.

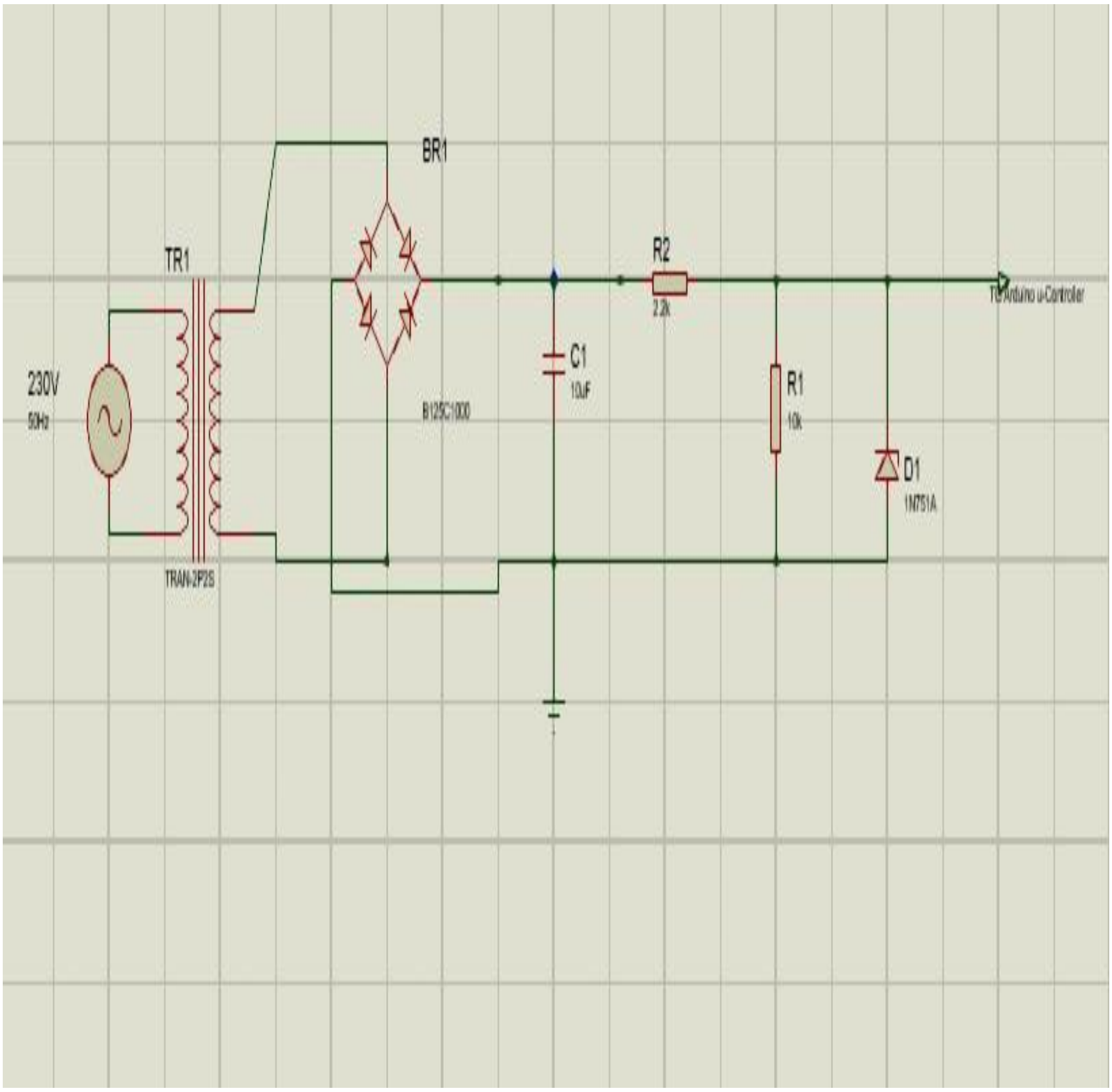

Figure 9

CONTROL CIRCUIT:

This circuit will connect and disconnect the load with respect to the requirement. It consists of a 5V relay which is controlled from the arduino. As soon as the microcontroller senses any fault (overcurrent, overvoltage and undervoltage) it trips the circuit. The COM and NC (normally close) contacts are connected to the supply and current sensor respectively. A diode is connected between the GND and INPUT terminals (2 ends of the excitation coil). A transistor is connected in for triggering the excitation coil on and off. The transistor is operated in saturation region where it functions as a switch.

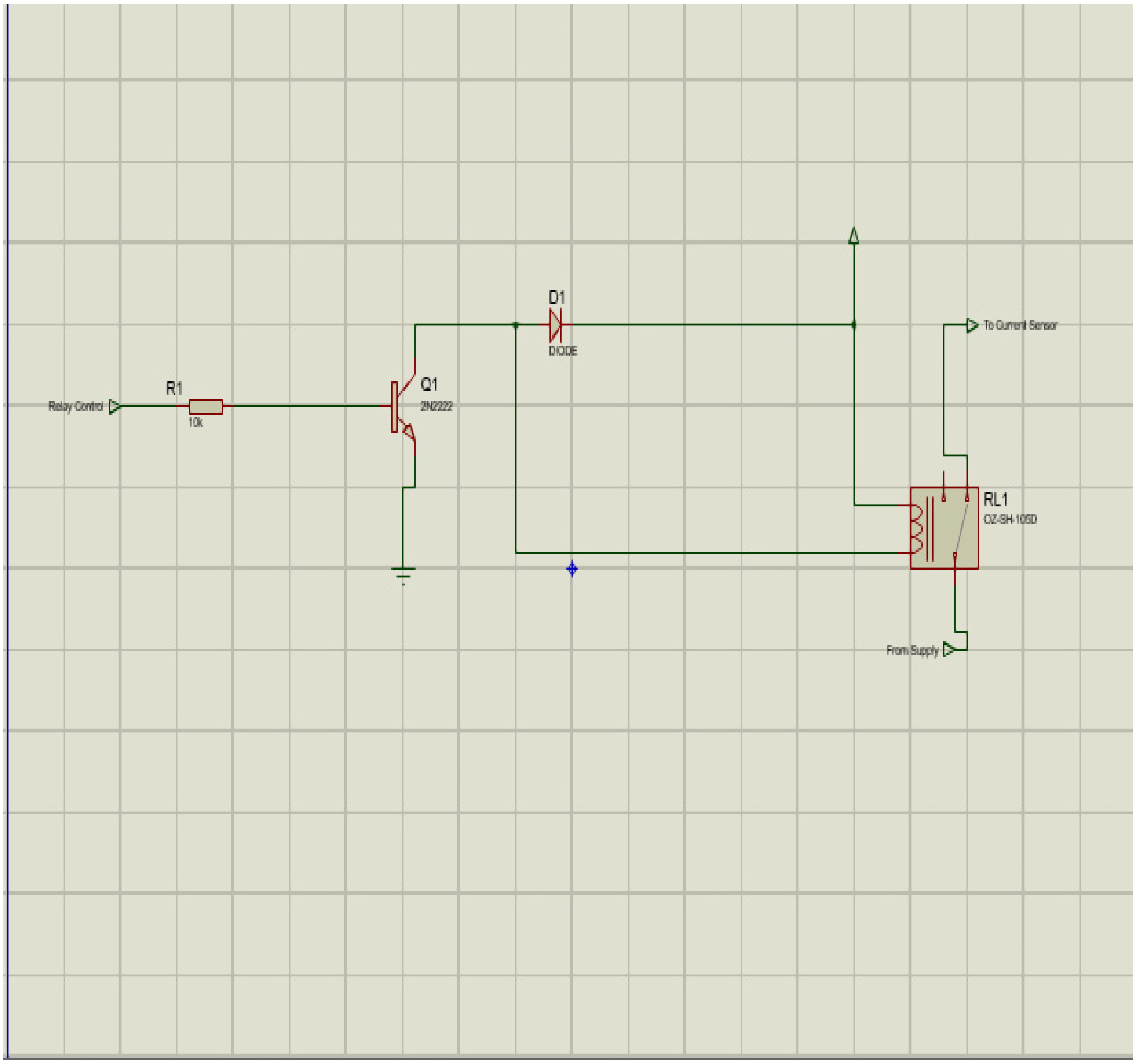

Figure 10

DISPLAY CIRCUIT:

The display circuit contains a 16x2 LCD module which displays the various electrical quantities consumed such as voltage, current, power and energy. The LCD module has 16 pins. The GND (pin1) and VCC (pin2) are connected to the 5V and GND pin of arduino. A 10Kohm potentiometer is connected in between the GND and 5V and its wiper is connected to the CONTRAST (pin 3) of the LCD. RS (pin4) and E (pin 6) are connected to arduino digital pins. LCD has 2 data transmission process – 4bit and 8bit. Here, 4bit data transmission is used. So out of D0 to D7, only D4, D5, D6 and D7 are connected to the arduino. The RW (pin 5) is grounded.

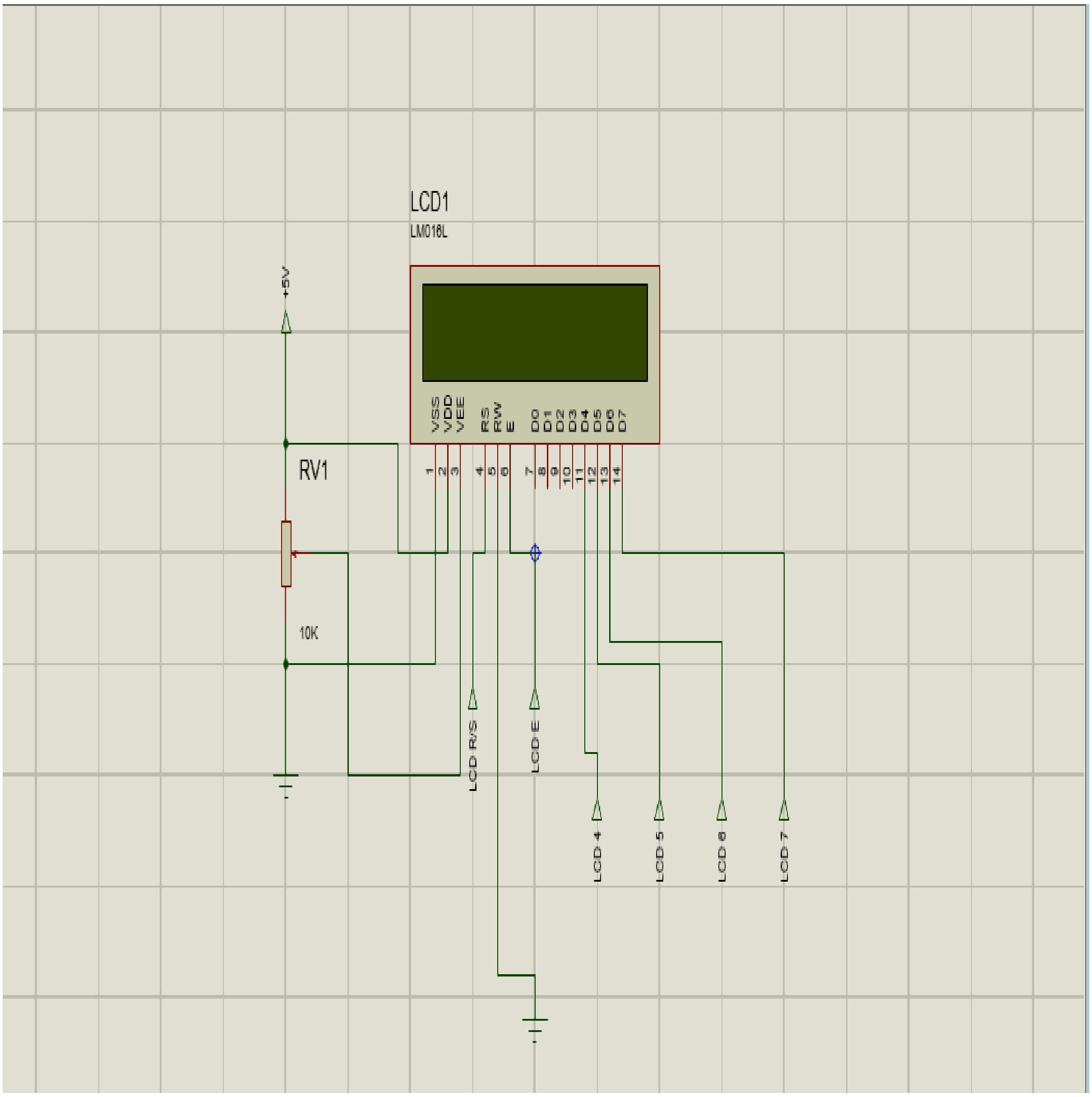
LCD1
LM016L
+5V
RV1
10K
VSS
VDD
VEE
RS
RW
E
D0
D1
D2
D3
D4
D5
D6
D7
LCD R/S
LCD E
LCD 4
LCD 5
LCD 6
LCD 7

Figure 11

TRIAL AND TESTING:

- **Simulation phase:**

For simulation of the circuit, PROTEUS DESIGN SUITE 8.0 PROFESSIONAL and TINKERCAD were used. All the individual modules were simulated at first using the Proteus and then whole circuit was simulated using Tinkercad. As Tinkercad do not have ACS712 and transformer in it, so a signal generator was connected to the analog pins of the arduino and voltage signal between 0 to 5V was sent for simulating.

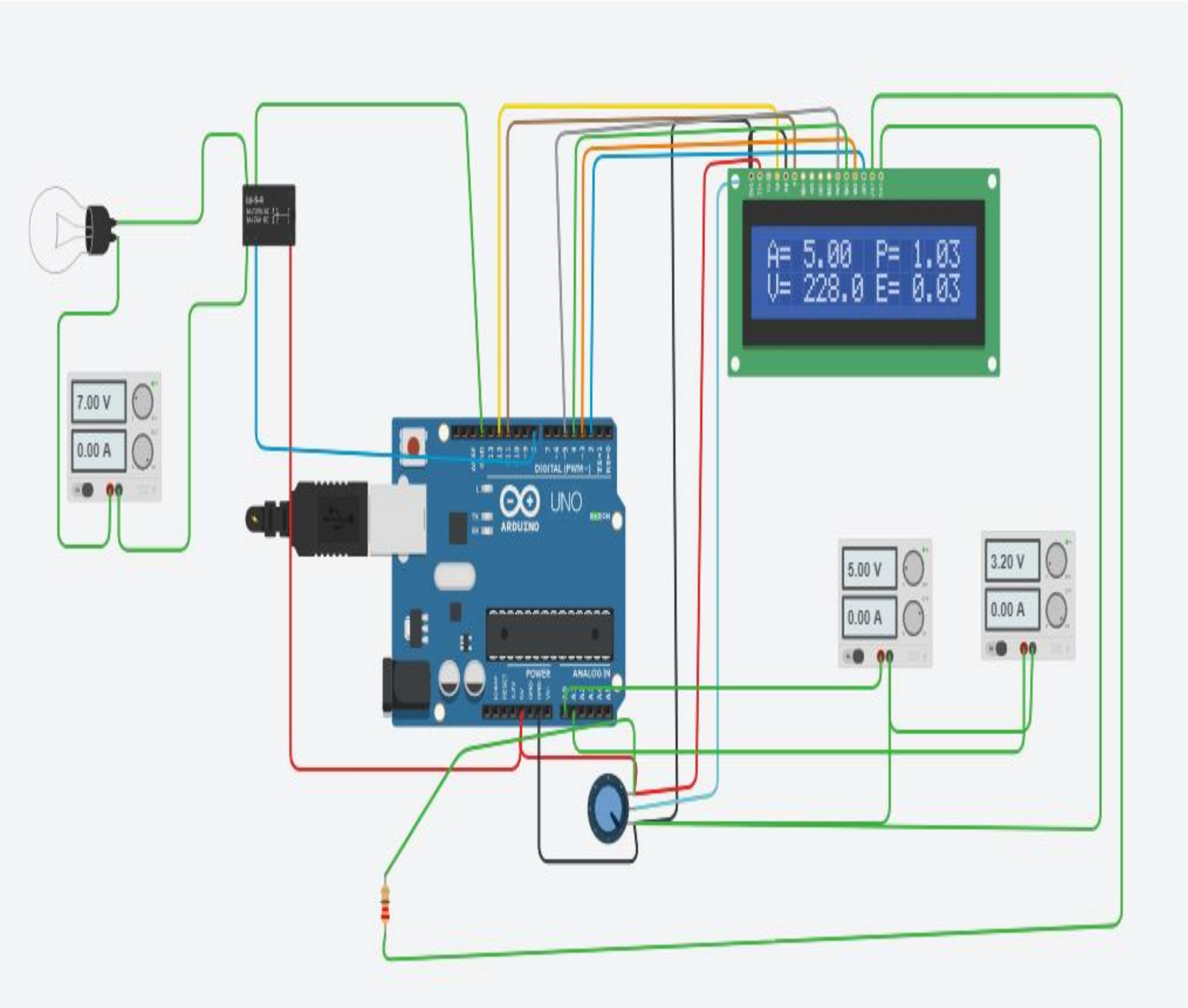

Figure 12

- **<u>Individual Circuit Testing:</u>**

At first, all the individual modules (current measurement circuit, voltage measurement circuit, LCD display circuit and relay circuit) were tested connected them to arduino. For testing a supply of 230V and a load of 1KW (5 x200 W incandescent lamp) was connected. As this is a resistive load so no power factor correction was required.

Current sensing circuit: The current sensing circuit was connected to supply and load and the readings were measured in arduino (microcontroller) serial monitor. When the supply was switched off (0V), the load should draw no current. At that point, a current of 0.13 ampere was flowing through it. During switching operation a sudden surge is noticed for one sec which can be ignored. After that it gave a steady current of 4.63 amperes. The current measured by ammeter during similar conditions was measured to be 4.54 amperes.

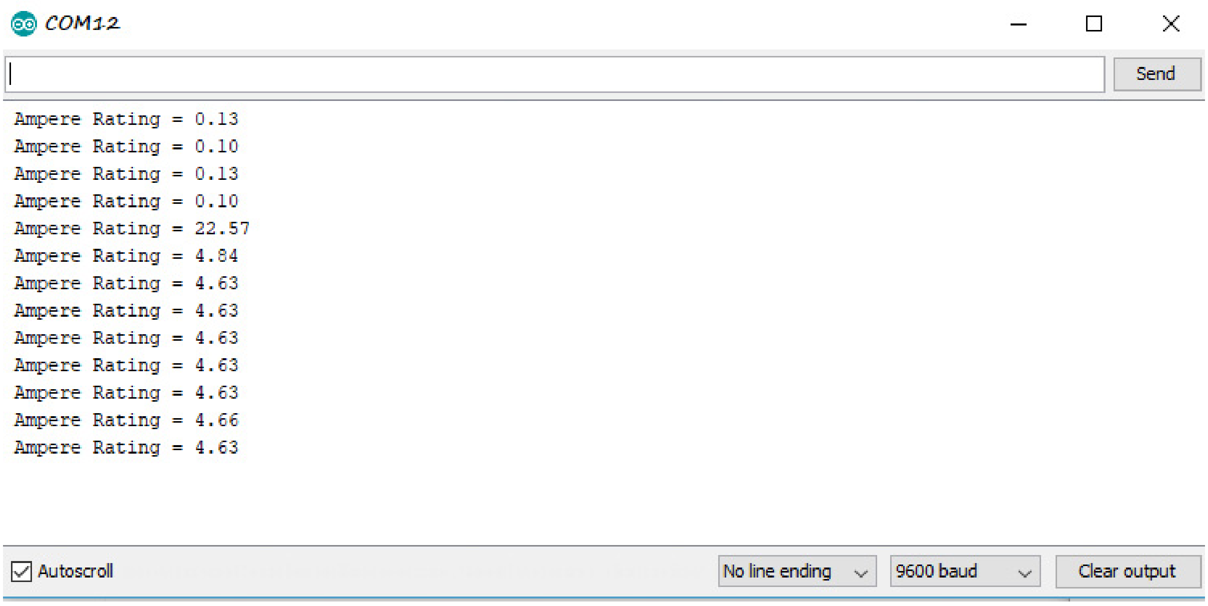

Figure 13

Voltage sensing circuit: The voltage sensing circuit was connected in parallel to the load and the readings were measured in arduino (microcontroller) serial monitor. When the supply is switched off (0 V), the voltage was measured to be around 5-7 volts. When the supply was switched on, the voltage was measured to be around 231 volts whereas the voltage when measured by voltmeter was found to be varying between 230 to 232 volts. Again when the supply was switched off, a surge reading of 68.74 volts was seen for one second and then the voltage again dropped between 5 and7 volts.

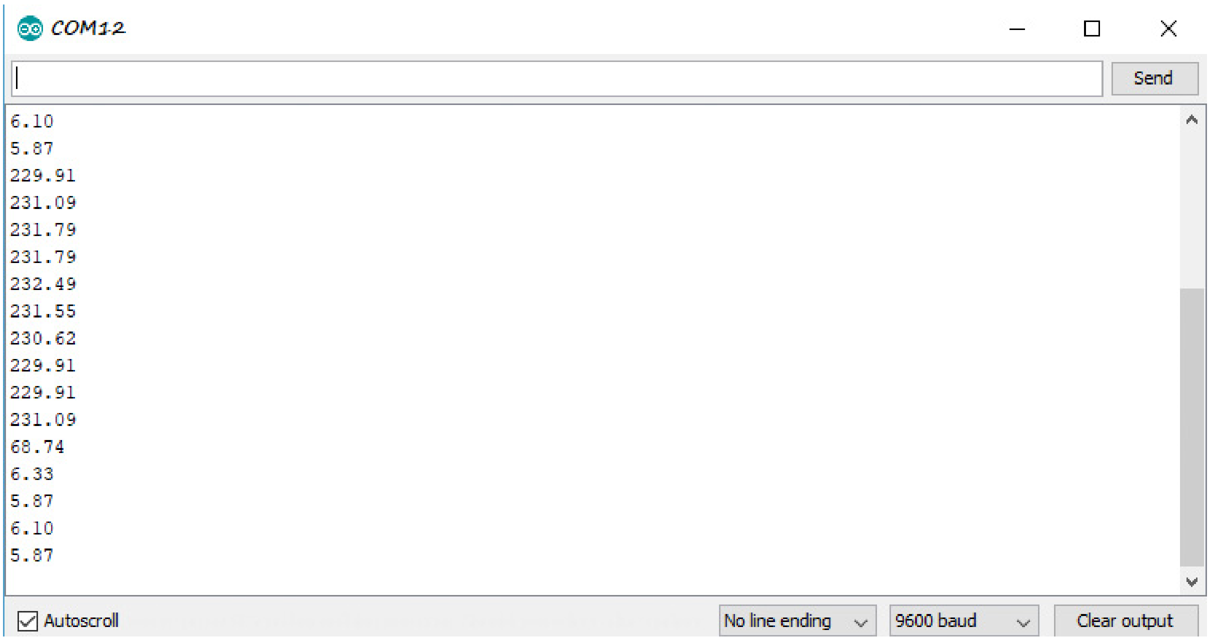

Figure 14

Control circuit: The control circuit was connected in series with one end connected to the live wire of supply side and other end connected to the current sensor. The relay was switched on for one seconds and switched off for the next second. The functioning of the relay was ensured by the operation of the led indicator.

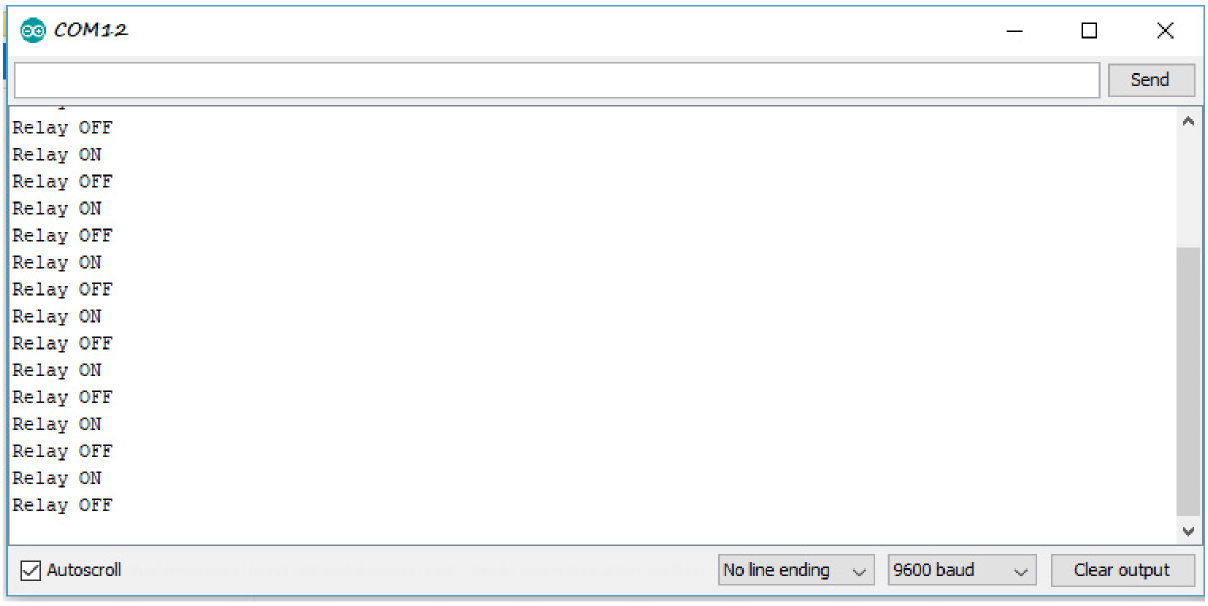

Figure 15

Display circuit: The display circuit was connected to the arduino and a string of "SMART ENERGY METER" was sent to be printed during the initial starting of the meter. Then after one second current, voltage, power and energy were displayed in two columns.

Figure 16

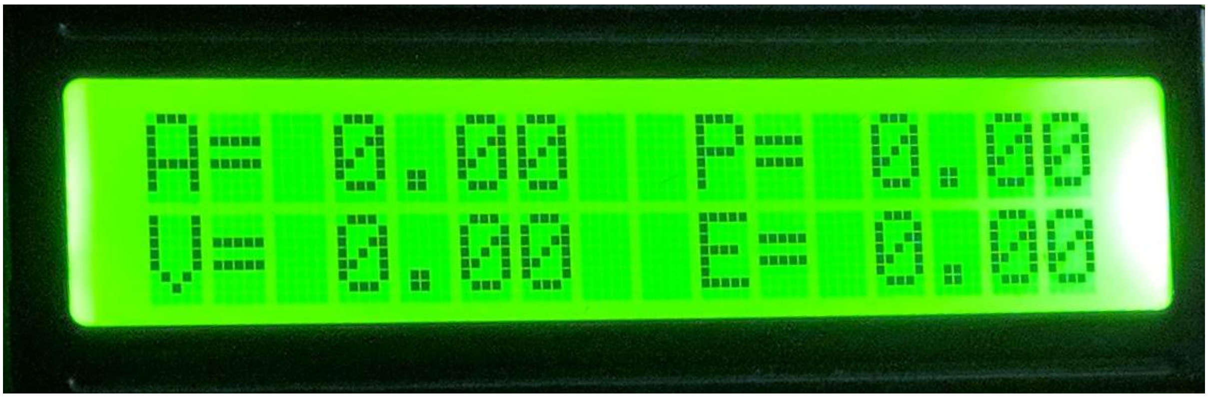

Figure 17

- **Integrated meter testing:** After all the parts of the meter was integrated the meter was tested using a standard load of 1KW and a predefined power factor of 0.9 was used.

Figure 18

CALIBRATION:

Calibration of voltage sensor circuit: For the calibration of voltage sensing circuit, different ac inputs were provided and the rectified current across the output of the voltage sensing circuit was measured and a graph was plotted.

SL.NO	SUPPLIED AC VOLTAGE	MEASURED DC VOLTAGE
1	0	0
2	50	0.57
3	100	1.67
4	150	2.81
5	200	3.95
6	230	4.54

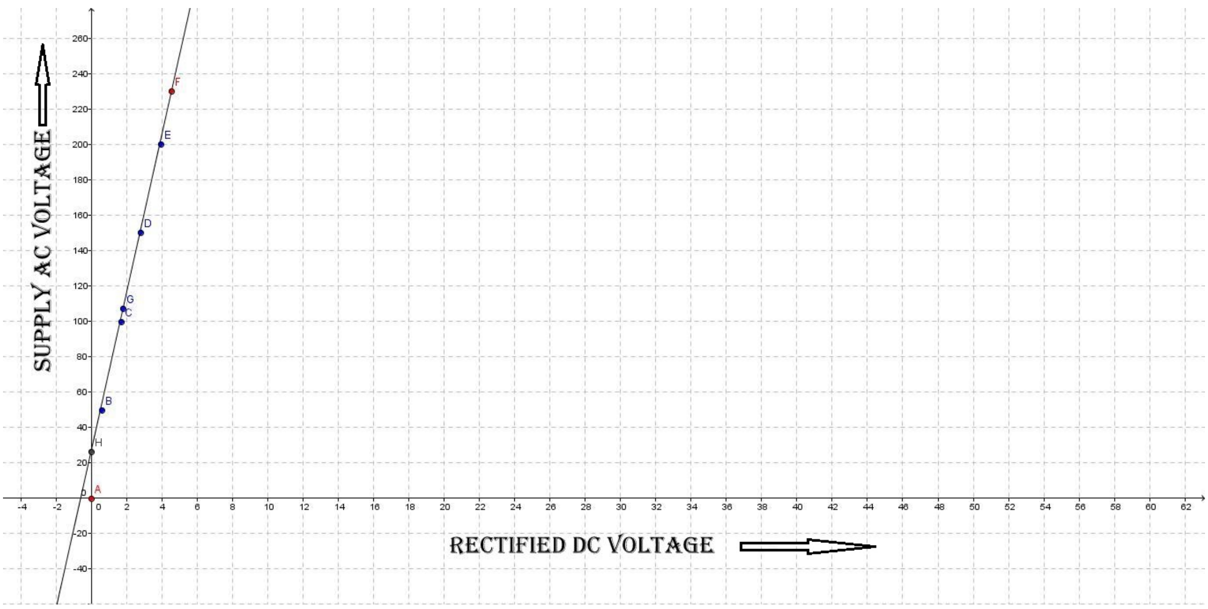

Figure 19

From the graph, the corresponding ac supply voltage for 5V rectified voltage was found to be 240 volts. So, the arduino can measure currents upto 5V. Thus overvoltage trip of relay was set at 240 volts

MARKETABILITY OF SMART METERS IN INDIA-:

A smart meter is an electronic device which records the electricity consumption for short intervals of time and communication of that data for the monitoring and billing purpose. As per the Global Investment in technology it is expected that the market as well as research in India will be worth of 19 billon dollar in the year 2018-19.

The smart meter work is under process in some states of India like Uttar Pradesh and Haryana. The Energy Efficiency Service Ltd. (EESL) is the government agency which is responsible for running the energy efficiency program in this area. The staring project is to installing 4 millions of smart meters in this two states.

The Smart meter is among the steps taken by Govt. of India that is UDAY (Ujjwal Discom Assurance Yojana) to improve the financial health of the power distribution companies in India. The government of India also announced a plans to subsidise the cost of smart meter for energy saving point of view. As per the news the Ministry of Power is planning to give subsidy to the advance meter system which also reduce the price of smart meters so that consumer have access to the real time data regarding the way they use energy.

The government will also subsidised the rate of smart meter from Rs10000 to Rs1000 and also permitted for the manufacture of the smart meter locally so that it will reduce the cost of the smart meter and it also satisfy the “DIGITAL INDIA” and “MAKE IN INDIA” initiatives of the government which implies empowering India digitally as well as to set a good marketing competition in India. This will also help to solve a large amount unemployment problem in India.

Under the efforts to increase the consumer energy efficiency, the government is planning a number of initiative such as implementation of “UJJALA” scheme to produce a huge amount of electricity in India for which there is a need of good monitoring system. Henceforth, Ministry of Power decided take initiatives towards the smart metering infrastructure.

It is mostly expected that the market of the smart meter will reach up to 21 billion dollar in the year 2022. There will be a high demand of the smart meter in the future due to the advanced features of this metering system and energy saving property which will increase the demand of this product in future. As per the economic survey of India, the growth of smart meter market will be 9.38% in the year 2022.

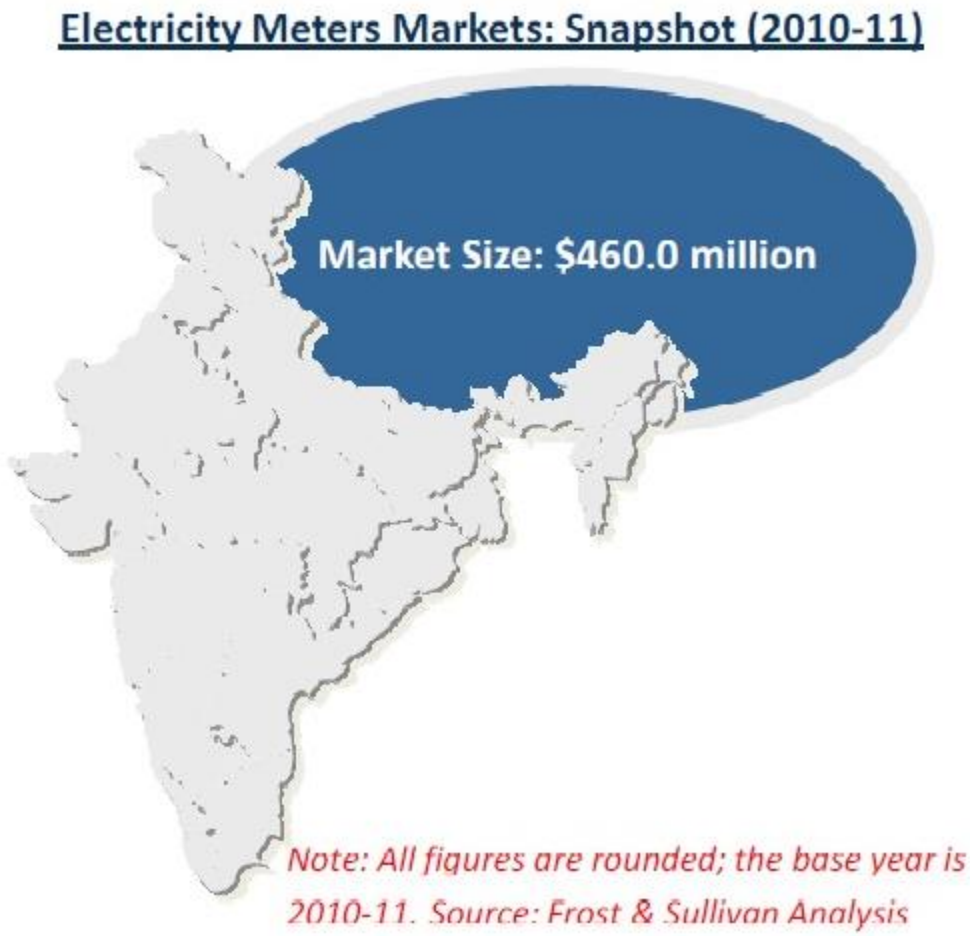

Figure 20

This smart meter has also come into pictures in many organisations working in the industrial, commercial and residential sector. Factories such as NTPC, SAIL, BHEL, etc. are using smart meter for measuring their consumption in many of their manufacturing units. Not only government organisations but also a lot of private organisations are also installing a smart meter as well as developing smart metering infrastructure for more convenience. For India, smart meter may turn out as a possible game changer for the many distribution companies.

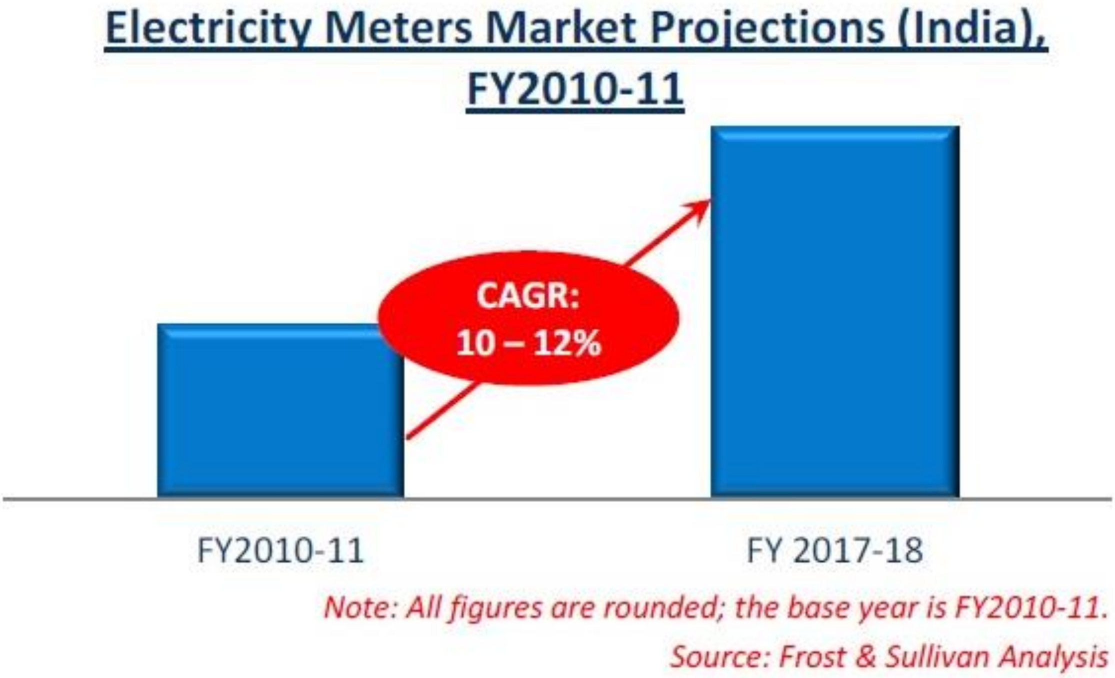

Figure 21

In most parts of India, power distribution companies are losing money on each unit of the power sold due to theft, meter tampering, lack of proper billing and are compelled to sell electricity below cost to poor and agricultural consumers. 21 states in India decided to start the project on this field to increase so that India could installed 15 million meter by 2020 which make India digitally empowered.

EESL which is a joint venture between India's Ministry of power and state-backed companies as well as power sector unit such as Power grid corp. of India ltd, NTPC, Rural Electrification Crop., etc. and numerous other private organisations and start-up industries are coming forward in this particular field for development of Smart meters.

CONCLUSION:

The smart energy meter was integrated and tested using a standard resistive load of 1KW and a predefined power factor of 0.9. The current was observed to be 4.63A and the theoretical calculation gave a current value of 4.54A when the circuit was switched on. When the circuit was switched off a current of 0.13A was observed which should theoretically 0A. Thus, an error of around 2% was noticed in the current measurement. The voltage was observed to be deviating around 3-4V when the circuit was switched on and around 7V when the circuit was switched off which should be theoretically 0V. Thus an error of 2-3% was observed in voltage measurement. The power was measured to be varying between 0.97KW and 1.02KW which should be 1KW as 1KW load is connected. Thus, an error of around 3% was observed. For energy measurement, the meter was switched on for 10 minutes ad 1KW load was connected to it. According to theoretical calculation, Energy consumption should be 0.167 unit and the energy consumption observed was 0.158. Thus, it can be concluded that the energy meter was built with an error of less than 5%. So, phase I was completed.

For phase II, IOT based system has to be integrated to the energy meter and cloud server has to be set up for storage and monitoring of the electrical parameter data and its analysis. There is a huge future scope for this project.

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