CHAPTER 1

INTRODUCTION

A smart energy meter is an electronic device that measures and records the electricity consumption of a household or building in real-time and sends the data to the utility company for billing and analysis. Unlike traditional energy meters that require manual reading, smart meters use advanced communication technology to transmit energy usage data automatically to the utility company, providing a more accurate and efficient way to monitor and manage energy consumption.

Smart energy meters come with a range of features that enable users to better understand their energy consumption patterns and make decisions on how to reduce energy usage and save money. For example, smart meters may provide real-time information on energy usage, including daily, weekly, and monthly usage patterns, and alerts to indicate when energy consumption exceeds certain thresholds.

Smart energy meters also have the potential to support the integration of renewable energy sources such as solar panels, as they can provide real-time feedback on energy production and consumption, enabling users to optimize their energy usage and reduce their reliance on the grid.

Overall, smart energy meters offer numerous benefits, including more accurate billing, improved energy efficiency, and greater flexibility and control over energy usage.

1.1 Internet of Things (IoT):

IoT stands for the Internet of Things. It refers to a network of interconnected physical devices, vehicles, appliances, and other objects embedded with sensors, software, and network connectivity that enables them to collect and exchange data. The concept behind IoT is to create a vast network where these devices can communicate and interact with each other autonomously, leading to improved efficiency, convenience, and productivity in various domains.

IoT devices are typically equipped with sensors and actuators that allow them to gather data from their surroundings and perform actions based on that data. These devices connect to the internet or local networks, enabling them to transmit and receive data, as well as be remotely monitored and controlled.

The applications of IoT are diverse and span across industries such as healthcare, transportation, agriculture, manufacturing, smart homes, and cities. Some examples include:

- **Smart Home:** IoT-enabled devices like thermostats, lights, and security systems can be controlled remotely through smartphones or voice assistants, making homes more convenient and energy-efficient.
- **Healthcare:** Wearable devices and remote monitoring systems can collect patient data, transmit it to healthcare providers, and enable real-time monitoring of vital signs, improving patient care and enabling early detection of health issues.
- **Industrial Automation:** IoT devices in factories and industrial settings can monitor equipment performance, detect faults, and optimize processes, leading to improved efficiency, reduced downtime, and cost savings.
- **Agriculture:** IoT sensors can monitor soil moisture, temperature, and other environmental factors, enabling farmers to optimize irrigation, track crop health, and make data-driven decisions for increased productivity.
- **Smart Cities:** IoT systems can be used for traffic management, waste management, energy optimization, and improving public safety through real-time monitoring and analysis of data from various sensors and devices deployed throughout the city.

Advantages of IoT:

- **Access to low-cost, low-power sensor technology:** Affordable and reliable sensors are making IoT technology possible for more manufacturers.
- **Connectivity:** A host of network protocols for the internet has made it easy to connect sensors to the cloud and to other “things” for efficient data transfer.
- **Cloud computing platforms:** The increase in the availability of cloud platforms enables both businesses and consumers to access the infrastructure they need to scale up without actually having to manage it all.

- **Machine learning and analytics:** With advances in machine learning and analytics, along with access to varied and vast amounts of data stored in the cloud, businesses can gather insights faster and more easily. The emergence of these allied technologies continues to push the boundaries of IoT and the data produced by IoT also feeds these technologies.
- **Conversational artificial intelligence(AI):** Advances in neural networks have brought natural-language processing (NLP) to IoT devices (such as digital personal assistants Alexa, Cortana, and Siri) and made them appealing, affordable, and viable for home use.

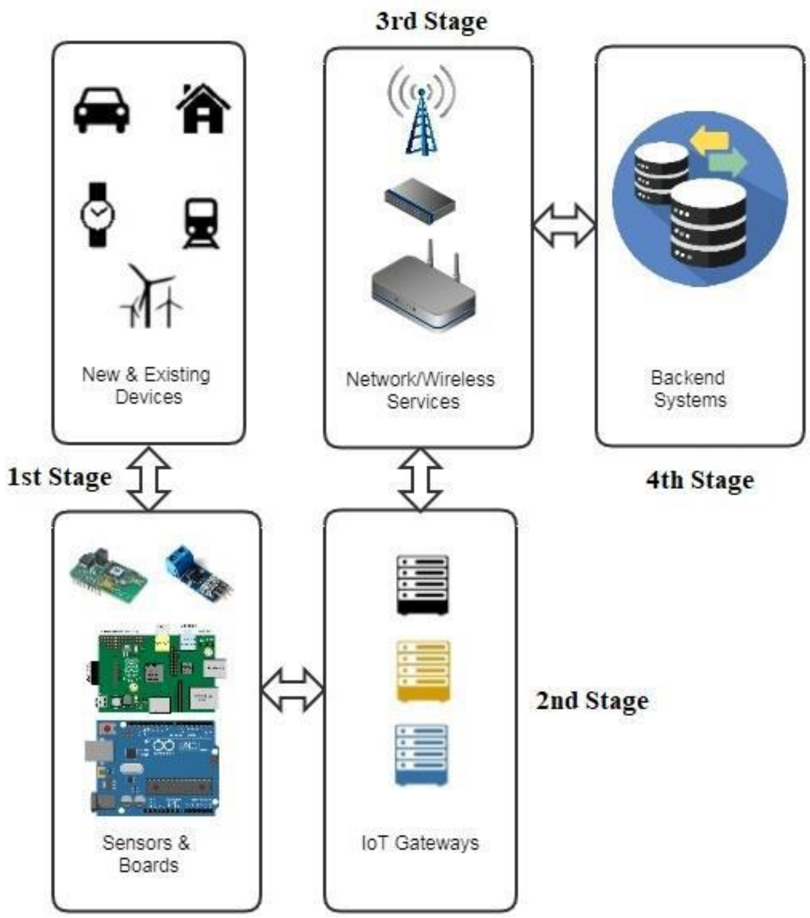


Fig. 1.1: Transmission of Data in IoT Devices

1.2 Machine Learning

Machine learning (ML) is a type of artificial intelligence (AI) that allows software application to become more accurate at predicting outcomes without being explicitly programmed to do so. Machine learning algorithms use historical data as input to predict new output values. Machine learning can help demystify the hidden patterns in IoT data by analysing massive volumes of data using sophisticated algorithms. Machine learning inference can supplement or replace manual processes with automated systems using statistically derived actions in critical processes. Application specification and the available computing resources, the ML models are developed to meet the specified requirements while optimizing the training processes in terms of the cost of time and computing resources. Next, the model deployment considers the difficulty of the heterogeneity of the IoT environment for running a set of composed ML models. Finally, ML-based IoT applications closely connect with people's lives and some applications such as autopilot require high reliability. Therefore, essential monitoring information has to be collected to improve the performance of the application in the next iteration of the lifecycle.

Energy meter billing is an important part of energy distribution. The use of manual systems is undesirable. Due to human errors at utility companies, it is problem for users to get them corrected. That is, customers have to stopover at the company offices, stand in a queue and get it corrected. There is a need to improve the accuracy of the bills. To avoid human intervention in the billing process, an automatic reading meter country can only measure and monitor electricity but do not allow remote access. The other problems with the system in that it requires a lot of manpower; It is time-consuming and prone to errors. "Smart Energy Meter" can solve these issues by providing services to the consumer through SMS along with other inbuilt features such as tamper-proof, fault detection, etc.

There's no guarantee you'll save money. A smart meter will only help you save money if you use it to monitor your energy use and make a positive decision to cut back. Smart meter is a device installed to automatically track electricity usage. It's connected to an home-display that shows you how much you're using and how much it's costing you. Best of all, a smart meter sends your meter readings to your energy supplier automatically, so there's no need for you to do it manually. With energy bills so high at the moment, it's more important than ever to try to cut costs where we can. A smart meter can help you take control. By better managing your daily energy consumption, you could save money on your energy bills. Smart meter will take a reading from your meter and automatically send it to your energy supplier. That means no more scrabbling around in a cupboard with a torch as you try to see the numbers.It also means your energy supplier won't need to pay someone to come out and read your meter. What they save in costs could be passed on to you, the customer. A smart meter will send an accurate reading of your exact energy use to the energy supplier either half-hourly, daily or monthly. This does away with estimated bills-so you'll only be charged for what you use. It comes with a handy In-Home Display unit that you can put anywhere, such as a kitchen wall. The display shows you how much energy you are using in real time.

With traditional non-smart meters, if you forget to submit a reading, your energy supplier will estimate your use based on past bills. Estimates can be notoriously inaccurate. With a smart meter you'll avoid estimate and the shock of a nasty final bill when you come to an end. Electricity theft is also a common issue. The main disadvantages of the 'ordinary' meter is that it is less reliable, less accurate and non – tamper proof. Even the present-day electronic energy meters are not completely tamper-proof. The proposed energy meter has features of detecting faults in the distribution system, which is done by checking the status of supply at a distribution transformer. The implementation of this project will help in better energy management, conservation of energy and also in doing away with the unnecessary hassles of incorrect billing. The billing system will keep track of consumption and solve any disagreements on consumption and billing.

Smart meter is the future because they have vast merits for both the consumers and the smart meters locally thus improving the number of electronic gadget's manufactured or made locally. The smart meters will, therefore, be able to counteract if not all, most of the demerits of the 'ordinary' meters, for instance; it must allow for remote access and be user-friendly, hence indicating if the amount of electricity used is high or low which leads to regulations and in turn saving energy. A microcontroller and the contactor will be the heart the design.

In this project, designing and building smart energy meter, the aim is to provide awareness to consumer about the power consumption. Power is being measured using Arduino programming sketch and voltage, current everything is displayed to LCD. Power of DC circuit and purely resistive AC circuit power is product of voltage and current and reactive AC current is called as apparent power (VA).

Arduino is an open-source single board microcontroller and it provided as open source, writing platform design to make the process of using electronics in multidisciplinary project. Arduino is flexible and easy understanding hardware cum software in our project we have used Arduino Uno microcontroller based on the Atmega 328.

1.3 Motivation

Smart energy meters are designed to replace traditional energy meters in homes and businesses. They are connected to the internet and can transmit data about energy usage in real-time to the energy provider. The motivation behind smart energy meters is to increase energy efficiency, reduce energy costs, and help individuals and businesses make better energy-related decisions.

Here are some of the key motivations behind smart energy meters:

- **Accurate billing:** Smart energy meters provide accurate readings of energy consumption, which helps to eliminate billing errors and ensure that customers are only charged for the energy they have used.
- **Real-time monitoring:** Smart energy meters allow customers to monitor their energy usage in real-time. This can help them identify ways to reduce energy consumption and save money on their energy bills.
- **Better energy management:** Smart energy meters can provide valuable insights into how energy is being used in a home or business. This information can help customers make more informed decisions about how to manage their energy usage, such as by adjusting their thermostat, turning off lights when not needed, and choosing more energy-efficient appliances.
- **Reduced carbon footprint:** By promoting energy efficiency, smart energy meters can help reduce the overall carbon footprint of a home or business. This is particularly important in the context of climate change, as reducing greenhouse gas emissions is a key priority for many governments and organizations.

Overall, the motivation behind smart energy meters is to promote energy efficiency, reduce energy costs, and help individuals and businesses make more informed decisions about their energy usage

Problem statement: ***"IoT based Smart energy meter reading, billing system and power management using ML"***

1.4 Objectives

The primary objective of a smart energy meter is to provide more accurate and detailed information about energy consumption in real-time, enabling both consumers and energy providers to better manage energy usage and reduce waste. Some of the specific objectives of Smart Energy Meters include:

- To build an efficient Smart Energy Meter to measure the electricity usage of the given device.
- To build a billing system that can generate the bill corresponding to the electricity usage.
- To build an efficient power conservation system.

1.5 Scope of the project

The scope of a smart energy meter project typically involves designing, developing, and deploying a system that can accurately and efficiently monitor the consumption of energy in households, buildings, or industrial settings. Smart energy meters are typically connected to a network and can provide real-time data on energy usage, enabling consumers to make more informed decisions about their energy consumption.

The scope of smart energy meters is quite broad and diverse, as they offer numerous benefits and applications for different stakeholders in the energy industry and society as a whole. Here are some of the most important scopes of smart energy meters:

- Designing and developing the hardware components of the smart meter, including sensors, microcontrollers, communication modules, and display interfaces.
- Developing the software that controls the smart meter and enables it to communicate with other devices and systems.
- Designing and implementing the communication infrastructure that allows the smart meter to transmit data to a central server or database.
- Developing software applications that enable consumers to access and analyze their energy usage data, and to make informed decisions about how to reduce their energy consumption.

- Integrating the smart meter system with other smart home or building automation systems, such as lighting, HVAC, or security systems.
- Testing and validating the system to ensure its accuracy and reliability, and to identify and fix any bugs or performance issues.
- Deploying the smart meter system to homes, buildings, or industrial facilities, and providing training and support to users.
- Energy Management: Smart energy meters provide consumers with detailed and accurate information about their energy usage. By monitoring and understanding their consumption patterns, individuals can make informed decisions about energy usage and take steps to reduce waste. This promotes energy conservation and helps to create a more sustainable future.
- Cost Savings: With real-time data on energy consumption, smart meters enable consumers to track their usage more effectively. This information allows them to identify areas of high consumption and make adjustments to reduce their energy bills. By promoting energy efficiency, smart meters can help households The scope of smart energy meters is expected to expand as the technology continues to evolve and become more sophisticated. With the growth of the Internet of Things (IoT) and advancements in data analytics and artificial intelligence, smart meters are likely to become even more valuable tools for energy management and grid optimization in the future.

1.6 Organization of report

The report is organized as follows. Chapter 2 includes Literature Survey where we have included the related works of our project. Chapter 3 includes System Analysis where we have compared the existing system and our proposed system. Chapter 4 consists of System Requirements Specification which includes Hardware and Software requirements of our project. Chapter 5 includes System Design which includes the system architecture. Chapter 6 includes System Implementation which includes the study about various methodologies used in the project. Chapter 8 includes Experimental Result and analysis of the project. Finally, Chapter 9 consists of Conclusion and Future Enhancement followed by References.

CHAPTER 2

LITERATURE SURVEY

The literature survey provides an overview of the research and development related to smart energy meter projects. The aim is to explore the current state of the art, identify key technologies, methodologies, and challenges, and highlight recent advancements in the field. The survey covers a wide range of academic and industry publications, including journal articles, conference papers, and technical reports. The findings of this survey will serve as a valuable resource for researchers, engineers, and policymakers involved in the design, implementation, and evaluation of smart energy meter projects.

In smart metering mechanism, the electronic power meter is utilized to fully remote control the appliances, anti-tampering or anti-theft mechanisms, diagnostics, consumption and power peak analysis, time-variable tariffs, fault alerts, and other possible instances. The use of the “Power-Line Communication”, known as PLC or relevant wireless and wired types of technologies for the connection of the service provider to the meter allows these aforementioned features compatible and realistic with the future protocols of smart grid.

Smart energy meters are typically digital meters that work in substitute for the old analog meters many homes use for the recording of their electrical use. Details of energy consumption can be transmitted by digital meters frequently to the utility as opposed to the conventional analog meters that need transmit the information using a meter reader. Home electric energy use is being recorded hourly or less. With smart meters, monitoring your consumption is easier and accurate to enable you make any informed decisions regarding the energy or controlling Public Information 10 the use of energy. Some feature sets of the meter are capable of notifying about power outage or enable the switching on or off of the electricity service of the utility.

Project Name: "Smart Energy Meter surveillance Using IoT"

Author Name: Anitha. k, Prathik et.al.

Year:2019

The foremost objective of this project is to create awareness about energy consumption and efficient use of home appliances for energy savings. Due to manual work, our existing electricity billing system has major drawbacks. This system gives the information on meter reading, power cut and the alert systems for producing an alarm where energy consumption exceeds beyond the specified limit using IoT. This idea is being implemented to reduce the human dependence to collect the monthly reading and minimize the technical problems regarding billing process. This project extends the design and implementation of an energy monitoring system with the pre-intimation of power agenda using Arduino microcontroller and a GSM (Global System for Mobile Communication) module.

Advantages:

The advantage of this system is that user can understand the power consumed by the electric appliance on the daily basis and can take further steps to control them and thus help in energy conservation.

Disadvantages:

It will give the data analysis of the appliances from the date they were installed.

Project Name: **"Raspberry pi based Smart Energy Meter"**

Author Name: Himanshu K. Patel et.al.

Year: 2019

The proposed scheme is to connect an LDR sensor with the blinking LED and send the data to microcontroller via GSM shield. RTC provides delay and acts an interrupt. The system includes a provision of sending an SMS to user for update on energy consumption along with final bill generation along with the freedom of load re-configuration via SMS. The disconnection of power supply on demand or due to pending dues was implemented using a relay. Hardware implementation results suggest that the accuracy of the proposed system is slightly greater than that of existing smart meters. The cost of system has been estimated to be less than the available smart meters, offering the same functionality. Bilateral communication between user and system sets it apart from the commonly available smart meters.

Advantages:

The system includes a provision of sending an SMS to user for update on energy consumption along with final bill generation along with the freedom of load re-configuration via SMS.

Disadvantages:

Higher implementation costs.

Project Name: **"Development of Energy Meter Monitoring System (EMMS) for Data Acquisition and Tampering Detection using IoT"**

Author Name: Aishwarya P. Kamatagi et.al.

Year: 2020

The main theme is to have a system which can be installed with existing electronic meters, instead of developing a new smart meter. Raspberry pi connected to the meter continuously monitors the data sent by energy meter, read the data and print the actual values of parameters. These actual values of parameters are further communicated along with decimals and appropriate SI units. GoDaddy's web server is developed and its database will store the data from the energy meter in front of its serial number. A multipurpose android application is designed to get the information regarding voltage ratings, current ratings, energy consumption and the meter tampering details which further can be useful to take actions against those customers. Upon providing the serial number of meter in the application, tampering status of energy meter is traced along with the basic parameter values.

Advantages:

Provide security from tampering.

Disadvantages:

Includes Raspberry pi which is costlier than Arduino uno.

Project Name: "Computer Vision Based Energy Monitoring System using Meter Image Capture System"

Author Name: Simran Bajaj et.al.

Year: 2020

This paper proposes a meter image capturing system (MICAPS). MICAPS is a image based technique for extraction of data. MICAPS is formed by integrating raspberry pi with raspberry pi camera. Python code is used to configure the camera and take the images and send it to cloud. This image is a seven-segment display. In order to convert a seven-segment display to text a computer vision optical recognition algorithm is used. The overall cost of the MICAPS is |4000 with which it is possible to monitor minimum 2 meters. One more advantage with MICAPS system is that remotely the operator will be able to change the granularity of the data based on the required. Thus, this MICAPS will help in monitoring the energy in a community-based distribution network.

Advantages:

All the meter readings will be stored in image form will be converted into text form and will be readily available whenever it is needed.

Disadvantages:

Doesn't have any features than capturing the meter readings.

Summary

This literature survey provides a comprehensive overview of the current state of smart energy meters, covering various aspects such as architecture, communication protocols, data analytics, benefits, challenges, case studies, and emerging trends. It serves as a valuable resource for researchers, practitioners, and policymakers interested in understanding the advancements and potential of smart energy meter projects.

CHAPTER 3

SYSTEM ANALYSIS

3.1 Existing System

The existing energy meter has been a reliable and widely-used technology for many years, but there are some disadvantages associated with its use. Here are some of the disadvantages of the existing energy meter:

- Manual reading: The existing energy meter requires manual reading by a meter reader, which can be time-consuming and expensive for energy suppliers. It can also lead to errors or mistakes in readings.
- Inaccurate measurements: The existing energy meter can sometimes provide inaccurate measurements due to wear and tear, tampering, or other factors. This can lead to incorrect billing for customers.
- No real-time data: The existing energy meter does not provide real-time data on energy consumption, which can make it difficult for customers to monitor their energy usage and make changes to reduce consumption.
- Limited functionality: The existing energy meter only measures electricity usage and does not provide information about gas or water usage. This can limit its usefulness for households that use other types of utilities.
- Lack of features: The existing energy meter does not have any advanced features or capabilities, such as the ability to communicate with other devices or systems.
- No ability to manage energy usage: The existing energy meter does not provide any tools or features to help customers manage their energy usage or reduce consumption.

Overall, while the existing energy meter has been a reliable and widely-used technology for many years, it does have some limitations and disadvantages that can be addressed by the use of smart energy meters.

3.2 Disadvantage of the System

While there are many advantages of using smart energy meters, there are also a few disadvantages that should be considered:

- Cost: The installation of smart energy meters can be expensive, and the cost is often passed on to the customer through their energy bills. In some cases, the cost of installation may outweigh the benefits of the meter.
- Privacy concerns: Smart energy meters collect detailed information about a household's energy use, which can be sensitive and personal data. There are concerns about who has access to this data and how it is used.
- Security risks: Smart energy meters are connected to the internet, which makes them vulnerable to cyber-attacks. Hackers could potentially gain access to a household's energy consumption data and use it for malicious purposes.
- Compatibility issues: The communication protocols used by smart energy meters can vary, which can cause compatibility issues with other devices in the household.
- Reliability issues: Smart energy meters can sometimes experience technical issues that can lead to inaccurate readings or even complete failure.
- Limited functionality: Smart energy meters typically only measure electricity usage and do not provide information about gas or water usage. This can limit their usefulness for households that use other types of utilities.

Overall, while the benefits of smart energy meters are significant, it is important to consider the potential disadvantages before deciding whether to install one.

3.3 Proposed System

The proposed smart energy meter system can Offer several benefits, such as accurate and reliable measurement of energy consumption, better control of energy usage, improved sustainability, and cost savings for customers. It also displays the live data of usage of energy consumption through which the users can monitor their energy usage.

3.4 Advantage of the System

Smart energy meters have several advantages over traditional energy meters:

- Accurate billing: Smart meters provide more accurate readings than traditional meters, reducing the risk of overbilling or underbilling.

- Real-time energy consumption monitoring: With a smart meter, consumers can track their energy usage in real-time, allowing them to identify patterns and make adjustments to reduce their energy consumption.
- Reduced carbon footprint: Smart meters help to reduce carbon emissions by enabling energy providers to more efficiently manage the energy grid, reducing waste and increasing the use of renewable energy sources.
- Remote monitoring and control: Smart meters can be remotely monitored and controlled, allowing energy providers to respond quickly to outages or other issues and minimizing downtime for consumers.
- Cost savings: By providing real-time information on energy consumption, smart meters help consumers identify opportunities to reduce their energy usage and save money on their energy bills over time.
- Improved customer service: With smart meters, energy providers can offer better customer service, responding more quickly to inquiries and addressing issues more efficiently.

Summary

In this chapter, we have discussed about the System analysis, in which we have discussed about the existing system that has been used by years. Various disadvantages of that system have been discussed. After analyzing the currently existing system and its disadvantages, we have tried to find the solutions to those problems in our project. After implementing those changes, we have discussed about our proposed system and its advantages over the existing system.

CHAPTER 4

SYSTEM REQUIREMENT SPECIFICATION

4.1 Introduction

Smart meter is a device installed to automatically track electricity usage. It's connected to a home-display that shows you how much you're using and how much it's costing you. Best of all, a smart meter sends your meter readings to your meter readings to your energy supplier automatically, so there's no need for you to do it manually. With energy bills so high at the moment, it's more important than ever to try to cut costs where we can. A smart meter can help you take control. By better managing your daily energy consumption, you could save money on your energy bills. Smart meter will take a reading from your meter and automatically send it to your energy supplier. That means no more scrabbling around in a cupboard with a torch as you try to see the numbers.it also means your energy supplier won't need to pay someone to come out and read your meter. What they save in costs could be passed on to you, the customer. A smart meter will send an accurate reading of your exact energy use to the energy supplier either half-hourly, daily or monthly.

4.2 System Requirements:

4.2.1 Hardware Requirements

- **ARDUINO UNO**

Arduino is open-source microcontroller and software development environment and easy to use and understand hardware and software. Arduino is a single board microcontroller has programming language is a simple C and C++ type programming language and C language is easy to learn. Arduino microcontroller is fast made by Interaction Design Institute Ivreal in Ivera, Italy; it has aim was design low cost and cheap microcontroller board. Arduino uses expansion circuit board knows as shield. It has facility to GPD, GDM, and Bluetooth, ZigBee, motor and other facility. This organization has developed 50,000 Arduino microcontroller boards in very short period. In 2011 Google announced the Arduino open accessories development kit, which enable

Arduino board to interfaced with Arduino mobile platform. In a market different Arduino board available for different requirement. They Arduino board are used for ATMGT microcontroller. The types of Arduino board are,

- Arduino Uno board,
- Arduino mega board and
- Arduino lily pad Arduino board.

In our project we have used Arduino Uno board, has a digital input / output pin, six analog inputs, 6 PWM pins and 16Mhz ceramic resonator a power jack on OICSP heady and a reset button it has on board one USB to serial convert and connect to computer using USB cable.

Features of Arduino Uno board-

- It is based on AI mega 328 microcontroller
- Input voltage range is 7.12V.
- Digital I/O pins is 14 (of which 6 pin provide PWM output)
- 6 analog input pins.
- 32KB flash memory 0.5KB used by boot leader.
- 16MHz clock speed.
- **Reset pin-** This pin enables to reset Arduino microcontroller board.
- **IOEF-** This pin act as a reference to the input given to the Arduino board.
- Arduino has 6 analog pins A0 to A5.
- There are 14 digital pins from 0-13 among these (3,5,9,1,11) are PMW Pins from which analog output taken from the Arduino board.

There is inbuilt LED on Pin 13.

- **AREF**- This pin is acting as a reference to analog input.
- **RXTX** – used for receiving and transmitting serial data.
- **ICSP** (In circuit serial programming) - this pin enables the use to programmed the chips on the circuit.

- **ACS 712**

ACS712 current sensor is based on the principle of Hall-effect, which was discovered by Dr Edwin Hall in 1879. According to this principle, when a current carrying conductor is placed into a magnetic field, a voltage is generated across its edges perpendicular to the directions of both the current and the magnetic field. ACS712 device is provided in a small, surface mount SOIC8 package. It consists of a precise, low-offset, linear Hall sensor circuit with a copper conduction path located near the surface of the die. When current is applied through the copper conductor, a magnetic field is generated which is sensed by the built-in Hall element. The strength of the magnetic field is proportional to the magnitude of the current through the conduction path, providing a linear relationship between the output Hall voltage and input conduction current.

- **RELAY**

This is a 5V 4-channel relay interface board, and each channel needs a 15-20mA driver current. It can be used to control various appliances and equipment with large current. It is equipped with high-current relays that work under AC250V 10A or DC30V 10A. It has a standard interface that can be controlled directly by microcontroller.

- **LED**

LED stands for "Light Emitting Diode". It is a semiconductor device that emits light when an electric current is passed through it. LEDs have become increasingly popular in recent years as they are energy-efficient, long-lasting, and can produce a range of colours. LEDs are commonly used in lighting, displays, and electronic devices such as televisions, computers, and smartphones. They are also used in traffic lights, automotive lighting, and for architectural and decorative purposes.

- **JUMPER WIRES**

Jumpers are tiny metal connectors used to close or open a circuit part. They have two or more connection points, which regulate an electrical circuit board. Their function is to configure the settings for computer peripherals, like the motherboard. Suppose your motherboard supported intrusion detection. A jumper can be set to enable or disable it. Jumper wires are electrical wires with connector pins at each end. They are used to connect two points in a circuit without soldering. You can use jumper wires to modify a circuit or diagnose problems in a circuit. Further, they are best used to bypass a part of the circuit that does not contain a resistor and is suspected to be bad. This includes a stretch of wire or a switch. Suppose all the fuses are good and the component is not receiving power; find the circuit switch. Then, bypass the switch with the jumper wire.

- **LCD DISPLAY**

LCD (Liquid Crystal Display) screen is an electronic display module and find a wide range of devices and circuits. These modules are preferred over seven segments and other multi segment LEDs. A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix.

4.2.2 Software Requirements

Arduino- Software (IDE): Arduino IDE is an open-source software, designed by Arduino.cc and mainly used for writing, compiling and uploading code to almost all Arduino modules. It is an official Arduino software, which makes code compilation so easy that even a layperson can get their feet wet with the learning process. It is available for all operating systems i.e., MAC, Windows, Linux and running on Java. A platform that comes with inbuilt functions and commands that play an important role in debugging, editing and compiling code. The main code, also known as a sketch, created on the IDE platform will eventually generate a hex file that is then transferred and uploaded to the on-board controller. An IDE environment mainly consists of two basic parts: the editor and the compiler where the former is used. Used to write the required code and later compile and upload the code to the given Arduino module. This environment supports both C and C++ languages.

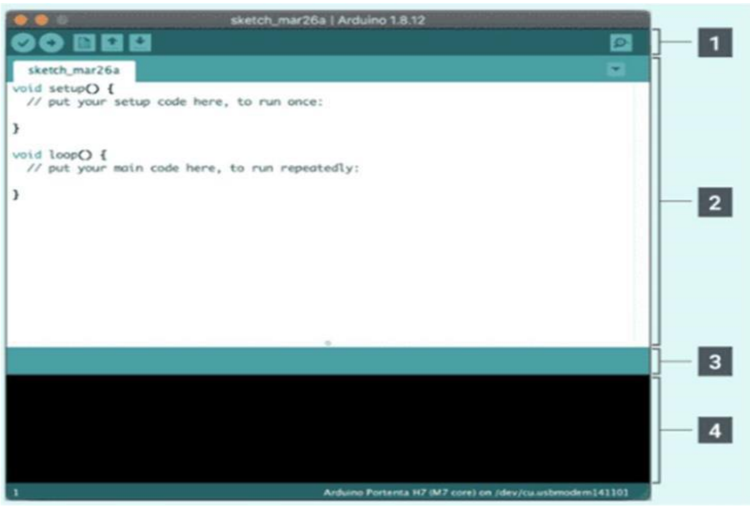


Fig 4.1 Arduino IDE

4.3 About the tool Used

- **ARDUINO UNO**

Arduino Uno R3 is a microcontroller board based on the ATmega328P microcontroller chip. The ATmega328P is an 8-bit microcontroller with 32KB of flash memory, 2KB of SRAM, and 1KB of EEPROM. The board has 14 digital input/output pins, 6 analog inputs, a 16MHz quartz crystal, a USB connection, a power jack, and an ICSP header. The digital input/output pins can be used to control and read digital signals, while the analog inputs can be used to read analog signals, such as sensors or potentiometers. The 16MHz quartz crystal provides the clock signal for the microcontroller, which runs at a clock speed of 16MHz. The USB connection can be used to program the board and communicate with the microcontroller. The power jack can be used to power the board with a DC power supply, while the ICSP header can be used to program the microcontroller using an in-circuit programmer. The Arduino Uno R3 can be programmed using the Arduino programming language, which is based on C/C++. The Arduino IDE (Integrated Development Environment) provides a simple and easy-to-use interface for writing, compiling, and uploading code to the board. The board is widely used in various applications, including robotics, home automation, and Internet of Things (IoT) projects. Its ease of use and versatility make it an ideal choice for beginners and advanced users alike.

- **ACS 712**

ACS712 current sensor is based on the principle of Hall-effect, which was discovered by Dr. Edwin Hall in 1879. According to this principle, when a current carrying conductor is placed into a magnetic field, a voltage is generated across its edges perpendicular to the directions of both the current and the magnetic field. ACS712 device is provided in a small, surface mount SOIC8 package. It consists of a precise, low-offset, linear Hall sensor circuit with a copper conduction path located near the surface of the die. When current is applied through the copper conductor, a magnetic field is generated which is sensed by the built-in Hall element. The strength of the magnetic field is proportional to the magnitude of the current through the conduction path, providing a linear relationship between the output Hall voltage and input conduction current.

- **RELAY**

This is a 5V 4-channel relay interface board, and each channel needs a 15-20mA driver current. It can be used to control various appliances and equipment with large current. It is equipped with high-current relays that work under AC250V 10A or DC30V 10A. It has a standard interface that can be controlled directly by microcontroller.

- **LED**

LED stands for "Light Emitting Diode". It is a semiconductor device that emits light when an electric current is passed through it. LEDs have become increasingly popular in recent years as they are energy-efficient, long-lasting, and can produce a range of colours. LEDs are commonly used in lighting, displays, and electronic devices such as televisions, computers, and smartphones. They are also used in traffic lights, automotive lighting, and for architectural and decorative purposes.

- **JUMPER WIRES**

Jumpers are tiny metal connectors used to close or open a circuit part. They have two or more connection points, which regulate an electrical circuit board. Their function is to configure the settings for computer peripherals, like the motherboard. Suppose your motherboard supported intrusion detection. A jumper can be set to enable or disable it. Jumper wires are electrical wires with connector pins at each end. They are used to connect two points in a circuit without soldering. You can use jumper wires to modify a circuit or diagnose problems in a circuit. Further, they are best used to bypass a part of the circuit that does not contain a resistor and is suspected to be bad. This includes a stretch of wire or a switch. Suppose all the fuses are good and the component is not receiving power; find the circuit switch. Then, bypass the switch with the jumper wire.

- **LCD DISPLAY**

LCD (Liquid Crystal Display) screen is an electronic display module and find a wide range of devices and circuits. These modules are preferred over seven segments and other multi segment LEDs. A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix.

4.4 About the Programming language

Embedded C:

Embedded C is a set of language extensions for the C language that makes it more suitable for embedded applications. A technical report detailing these language extensions was released in 2004, with a revised edition of the same report released in 2016. As a low-level programming language, Embedded C gives developers more hands-on control over factors like memory management. This is useful for programming embedded microcontrollers that frequently face power usage and memory constraints. Embedded C also introduces the in port and outport functions for I/O, along with features like fixed-point arithmetic, hardware addressing, and multiple memory areas.

It is most popular programming language in software field for developing electronic gadgets. Each processor used in electronic system is associated with embedded software. Embedded C programming plays a key role in performing specific function by the processor. In day-to-day life we used many electronic devices such as mobile phone, washing machine, digital camera, etc. These all-device working is based on microcontroller that are programmed by embedded C. Embedded C is an extension that provides support for developing efficient programs for embedded devices**.** Yet, it is not a part of the C language. The embedded C programming language uses the same syntax and semantics as the C programming language. The only extension in the Embedded C language from normal C Programming Language is the I/O Hardware Addressing, fixed-point arithmetic operations, accessing address spaces, etc.

Summary

In this chapter, we have discussed about the System requirements, which includes the information regarding the various Hardware and software components that has been used in the project. A brief description regarding the programming language used in the project has been discussed.

CHAPTER 5

SYSTEM DESIGN

Introduction

In this chapter, we will discuss the various design constraints and available option for implementing the various stages of the smart energy metering. The Arduino programming was used for the design of this project. This chapter focuses on the design steps of the energy meter implementation. Moreover, the embedded system is an essential and digital system having a dedicated operation within a massive electrical system or mechanical system, usually having real-time computing limitations. It is incorporated as one of the complete devices, which usually include mechanical and hardware parts. On the contrary, a personal computer or the general-purpose computer is made flexible to satisfy the different needs of the end-users. Most of the devices used nowadays are controlled by the embedded systems.

The modern embedded systems' operations are on the basis of microcontrollers alongside peripheral interfaces and/or the integrated memory, while the ordinary microprocessors (with the use of external chips for the peripheral interface circuits and memory) remain popular, particularly in complex systems. In any of these cases, there are different types of the processor(s) applied, which include the general-purpose ones and the extremely specialized ones in specific computation categories, or including the custom designed for the underworking application.

Generally, an energy or electric meter measures the quantity of consumed electric energy by an entity (electrically powered device, residence or business). Typically, energy meters have calibration in billing units – kilowatt-hour (kWh). The energy consumed and billing cycles are set up by the periodic readings of the electricity meters amid a cycle. For the choice of energy savings for a particular time, the settings of the meters can be used for the demand measurement, including the maximum power used for a particular interval. Electric rates are allowed by "time of day" metering to change during the day, for usage recording amid the off-peak lower-cost intervals or the peak high-cost intervals. Additionally, other types of meters are designed with demand response load, which shed amid peak load intervals. Since the 1880s when electric energy spread commercially, it turned out extremely essential that an electric energy meter, just like the gas meters around, was necessitated to appropriately get customers billed for the energy costs, rather than being billed for a particular fixed lamp number each month.

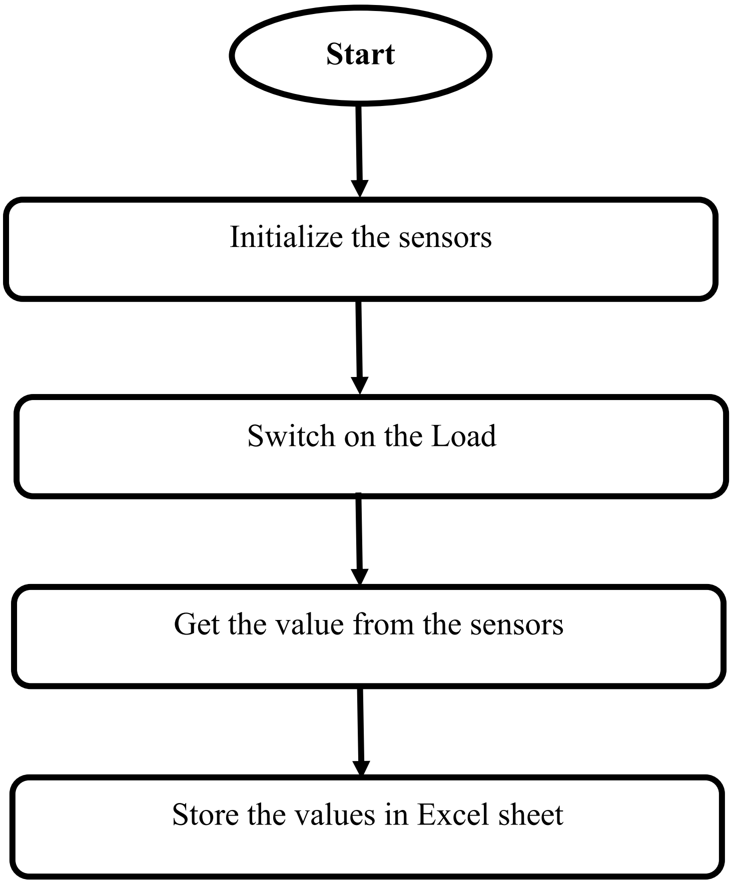


Fig 5.1: Smart Energy Meter Flow Chart

CHAPTER 6

SYSTEM IMPLEMENTATION

The various design stages and relevant hardware implementation is discussed in this section.

6.1 Methodology

Module 1

- **Arduino Uno**

The Arduino Uno is one of the most popular and widely used development boards in the Arduino ecosystem. It is based on the ATmega328P microcontroller and provides a range of features and capabilities for building electronic projects. Here are some key aspects of the Arduino Uno:

- **Microcontroller:** The Arduino Uno is powered by the ATmega328P microcontroller, which has 32KB of flash memory for storing code, 2KB of SRAM for data storage, and 1KB of EEPROM for non-volatile storage.
- **Digital and Analog I/O:** The Uno has 14 digital input/output (I/O) pins, of which 6 can be used as PWM (Pulse Width Modulation) outputs. It also has 6 analog input pins that can be used to read analog sensor values.
- **Communication Interfaces:** The Uno features a USB port for serial communication with a computer, enabling code uploading and serial communication with other devices. It also has an ICSP (In-Circuit Serial Programming) header for advanced programming and debugging.
- **Power Supply:** The Uno can be powered via USB connection, an external power supply (7-12V DC), or by using the onboard voltage regulator with a 5V power source. It can also be powered from the Vin pin or the barrel jack.
- **Programming:** Arduino Uno is programmed using the Arduino programming language, which is a simplified version of C/C++. The Arduino IDE provides a user-friendly environment for writing, compiling, and uploading code to the Uno.
- **Expansion Shields:** The Uno is compatible with a wide range of expansion shields, which are add-on boards that extend its functionality. These shields can provide

additional features like Ethernet connectivity, Wi-Fi, Bluetooth, motor control, and more.

- **Community and Ecosystem:** The Arduino Uno has a large and active community of users, makers, and developers. There is a wealth of documentation, tutorials, libraries, and projects available online, making it easy to get started and find support when working with the Uno.
- The Arduino Uno is suitable for beginners, students, and hobbyists who want to learn electronics and programming or build small to medium-scale projects. Its versatility, ease of use, and vast ecosystem make it a popular choice for a wide range of applications, including robotics, home automation, IoT prototyping, and educational projects.

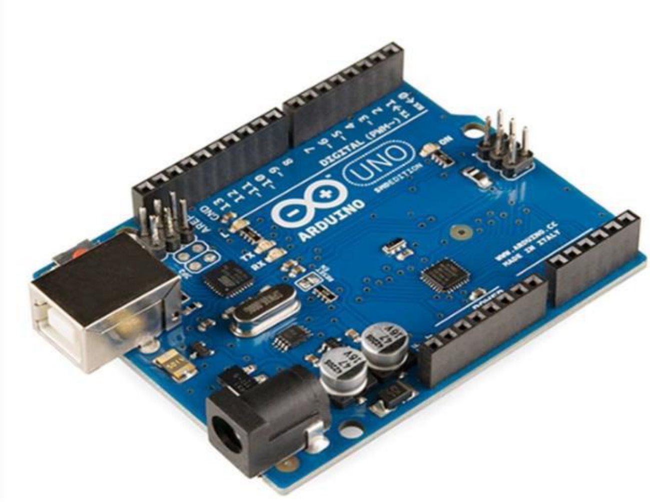


Fig 6.1 Arduino Uno

- **Software**

Arduino IDE (Integrated Development Environment) is an open-source software platform used for programming and developing applications for Arduino microcontrollers. It provides a simple and user-friendly interface for writing, compiling, and uploading code to Arduino boards. Here are some key aspects of the Arduino IDE.

- Code Editing: Arduino IDE offers a text editor where you can write code using the Arduino programming language. It supports basic features like syntax highlighting, auto-indentation, and code completion to assist in writing code more efficiently.
- Code Compilation: The IDE compiles the written code into a binary file that can be executed by the Arduino board. It leverages the Arduino core libraries and compiler toolchain to generate the appropriate machine code.

- Board and Port Selection: Arduino IDE supports a wide range of Arduino boards. You can select the specific board model and configure the appropriate communication port to establish a connection between the IDE and the Arduino board.
- Uploading Code: Once the code is compiled, you can upload it to the connected Arduino board using a USB cable or other supported communication methods. The IDE handles the transfer of the compiled code to the board's microcontroller.
- Library Management: Arduino IDE provides a library manager that allows you to search, install, and manage libraries. Libraries contain pre-written code that extends the functionality of Arduino boards, enabling you to easily integrate various sensors, actuators, and communication modules into your projects.
- Serial Monitor: The IDE includes a built-in serial monitor tool that allows you to communicate with the Arduino board via the serial port. It enables you to send and receive data for debugging purposes or to interact with your application.
- Example Code: Arduino IDE offers a collection of example codes that demonstrate the usage of different functionalities and components. These examples serve as a starting point for beginners and provide reference material for more complex projects.
- Community Support: Arduino has a large and active community of developers who share their knowledge, projects, and troubleshooting tips. The Arduino forums and online resources provide assistance and guidance for using the IDE and working with Arduino boards.
- Arduino IDE is widely used in the maker community and is suitable for beginners and hobbyists looking to develop projects with Arduino microcontrollers. However, there are also alternative IDEs available that offer more advanced features and enhanced development capabilities for experienced users.

Module 2

- **16*2 LCD:**

In our project, we had to add LCD. The LCD stand for Liquid Crystal Display. There are many types of LCDs, but the one we were concerned about is the 16x2 LCD, which displays 2 lines each with 16 characters. We preferred this one over the other displays such as 7-seqments and other segments LEDs. The reason is that we can easily program it with the Arduino which allows us to display both numbers and letters in addition to the symbols.

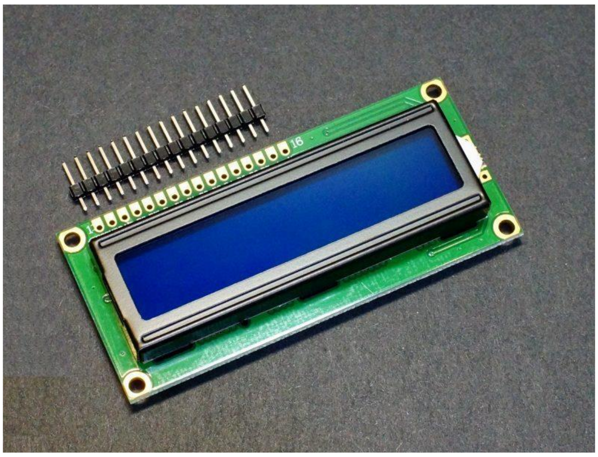


Fig 6.2 LCD Display

A 16x2 LCD display is a common type of alphanumeric display module that can display up to 16 characters on each of its two rows, for a total of 32 characters. It is widely used in many electronic projects and devices such as digital clocks, thermometers, and small embedded systems.

The display consists of two rows of 16 characters each, with each character being made up of a matrix of pixels. The display is controlled by an integrated circuit that communicates with a microcontroller or other device via a parallel or serial interface. The interface allows the microcontroller to send commands and data to the display, which then displays the information on the screen.

Overall, a 16x2 LCD display is a simple and reliable way to display text in a wide variety of electronic projects and devices.

- **ACS712 Current Sensor:**

The ACS712 Module uses the ACS712 IC for current measurement by using the principle of the Hall Effect. The module gets its name from the IC(ACS712) used in the module, so for final products use the IC directly instead of the module.

The ACS712 is a Hall Effect-based current sensor module that can be used to measure both AC and DC current. The sensor uses a Hall Effect sensor to measure the magnetic field generated by the current flowing through a nearby conductor. The output of the sensor is proportional to the current flowing through the conductor.

Fig 6.3 ACS712 Current Sensor

The ACS712 sensor is available in several different versions with different current ranges, such as 5A, 10A, 20A, and 30A. The sensor also has built-in protection features such as overcurrent detection and thermal shutdown to help prevent damage to the sensor and the circuit.

Overall, the ACS712 is a useful and versatile sensor for measuring current in a variety of electronic applications.

- **I2C_LCD**

I2C_LCD is an easy-to-use display module; it can make display easier. Using it can reduce the difficulty of make, so that makers can focus on the core of the work. We developed the Arduino library for I2C_LCD, user just need a few lines of the code can achieve complex graphics and text display features.

Summary

In this chapter, the System implementation has been discussed, which includes various methodologies and components used in the project.

CHAPTER 7

SYSTEM TESTING

7.1 Introduction

Testing is the process of evaluating a system or its component(s) with the intent to find whether it satisfies the specified requirements or not. Testing is executing a system in order to ide System testing is a type of software testing that is performed on a complete, integrated system to evaluate its compliance with specified requirements and user expectations. The purpose of system testing is to identify defects or issues that arise when different components of the system are combined and tested as a whole.

The primary goal of system testing is to verify that the system meets its functional and non-functional requirements. This involves testing all system components and subsystems together to ensure that they interact correctly and that the system behaves as expected. It also involves testing the system's performance, security, reliability, and other non-functional aspects to ensure that the system meets the user's expectations.

7.2 Testing Principle

Before applying methods to design effective test cases, a software engineer must understand the basic principle that guides software testing. All the tests should be traceable to customer requirements.

7.3 Testing Methods

There are different methods that can be used for software testing. They are:

- Black-Box Testing: The technique of testing without having any knowledge of the interior workings of the application is called black-box testing. The tester is oblivious to the system architecture and does not have access to the source code. Typically, while performing a black-box test, at ester will interact with the system's user interface by providing inputs and examining outputs without knowing how and where the inputs are worked upon.
- White-Box Testing: White-box testing is the detailed investigation of internal logic and structure of the code. White-box testing is also called glass testing or

open-box testing. In order to perform white-box testing on an application, a tester needs to know the internal workings of the code. The tester needs to have a look inside the source code and find out which unit/chunk of the code is behaving in appropriately.

7.4 Levels of Testing

There are different levels during the process of testing. Levels of testing include different methodologies that can be used while conducting software testing.

Functional Testing: This is a type of black-box testing that is based on the specifications of the software that is to be tested. The application is tested by providing input and then the results are examined that need to conform to the functionality it was intended for. Functional testing of software is conducted on a complete, integrated system to evaluate the system's compliance with its specified requirements. There are five steps that are involved while testing an application for functionality.

- The determination of the functionality that the intended application is meant toper form.
- The creation of test data based on the specifications of the application.
- The output based on the test data and the specifications of the application.
- The writing of test scenarios and the execution of testcases.
- The comparison of actual and expected results based on the executed testcases.

Non-functional Testing: This section is based upon testing an application from its non-functional attributes. Non-functional testing involves testing software from the requirements which are non-functional in nature but important such as performance, security, user interface, etc.

Testing can be done in different levels of SDLC. Few of them are:

Unit Testing: Unit testing is a software development process in which the smallest testable parts of an application, called units, are individually and independently scrutinized for proper operation. Unit testing is often automated but it can also be done manually. The goal of unit testing is to isolate each part of the program and show that individual parts are correct in terms of requirements and functionality. Test cases and results are shown in the Tables. Unit Testing Benefits

- Unit testing increases confidence in changing/ maintaining code.
- Codes are more reusable.
- Development is faster.
- The cost of fixing a defect detected during unit testing is lesser in comparison to that of defects detected at higher levels.
- Debugging is easy.
- Codes are more reliable.

Table 1: Functional Testing

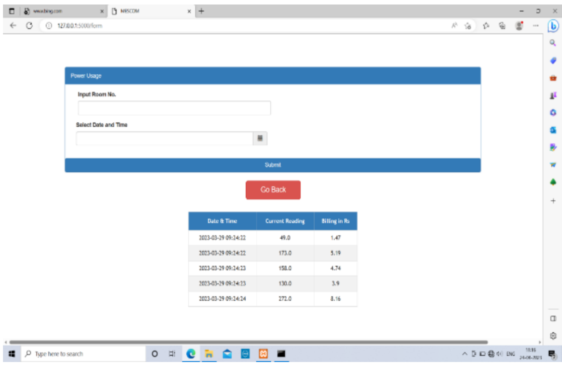
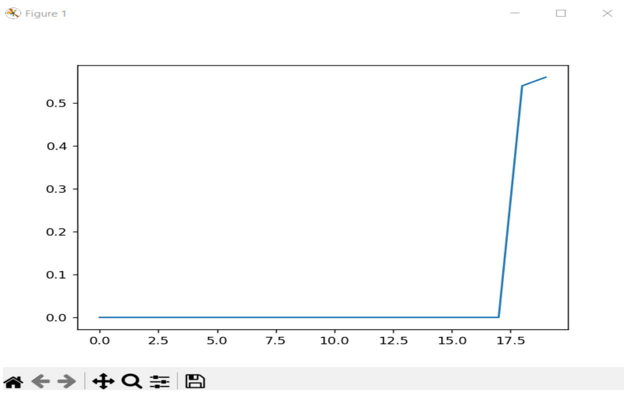
Test Case Description	**Expected Result**
Functional Testing	
Test if the smart energy meter can measure the amount of energy consumed.	The smart energy meter accurately measures and displays the amount of energy consumed. 
Test meter's ability to display real-time energy usage data.	Real-time energy usage data displayed accurately in the form of graph. 

Table 2: Performance testing

Test Case Description	Expected Result
Performance Testing	
Test if the smart energy meter can handle a high volume of energy consumption data.	The smart energy meter can handle a high volume of energy consumption data upto 12 Watt.
Verify if the smart energy meter can operate for an extended period without any interruptions or failures.	The smart energy meter operates without interruptions or failures for an extended period.

Table 3: Usability testing

Test Case Description	Expected Result
Usability Testing	
Test if the smart energy meter has a user-friendly interface.	The smart energy meter has a user-friendly interface that is easy to navigate and understand.

Table 4: Security testing

Test Case Description	Expected Result
Security Testing	
Verify if the smart energy meter has adequate security measures to protect against unauthorized access.	The smart energy meter has adequate security measures to protect against unauthorized access.

Summary

The system testing process typically involves creating a test plan that outlines the scope of the testing, the testing objectives, the testing techniques, the testing schedule, and the acceptance criteria. Test cases are then designed and executed to evaluate the system's performance against the acceptance criteria. Defects or issues identified during testing are then logged and reported to the development team for further analysis and resolution. Overall, system testing is a crucial step in the software development process that helps to ensure the quality and reliability of the system.

CHAPTER 8

EXPERIMENTAL RESULT AND ANALYSIS

Introduction

After powering on the meter, the measurement circuit current and voltage were observed by the sensors. The Arduino was used to compute the sensors' signals, adhering to the programmed algorithm. The data processed regarding voltage, and current showed results on the LCD display provided on the power meter. The measurement of the voltage requires current sensor of the Hall Effect to get the current obtained by the load. The LCD display the results.

8.1 Screenshots

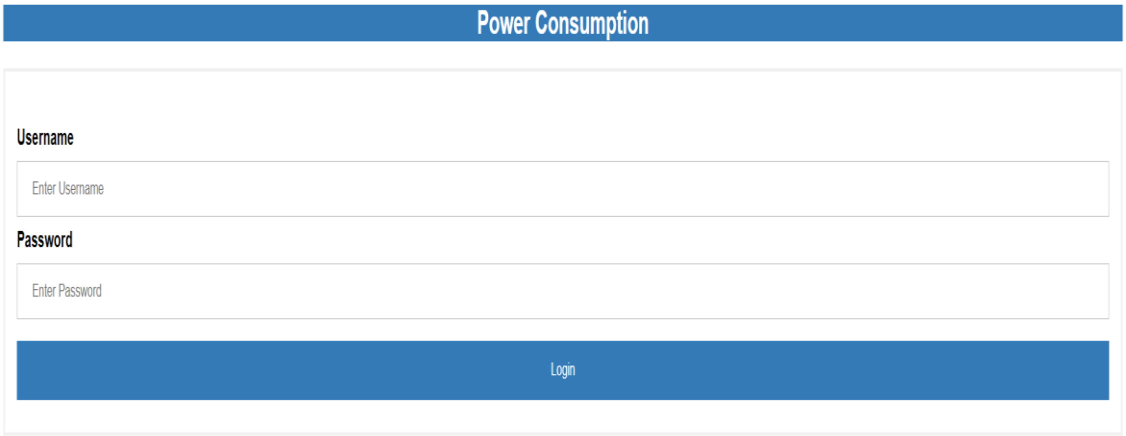


Fig 8.1 Login Page

Fig 8.1 shows the login page of the user portal where user can login using his login credentials.

Smart energy meter is different from normal traditional meters in many ways.One of the main feature is it maintains privacy of the user.The user will be provided with the login portal where he can login and check his energy usage using his login credentials.

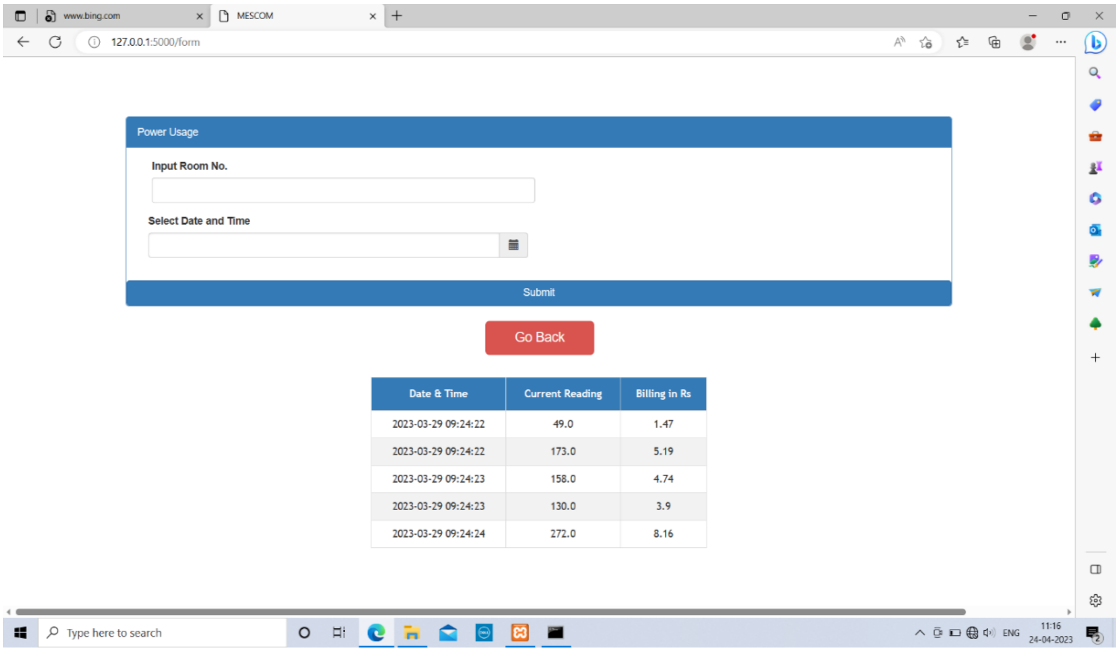


Fig 8.2 Previous data

Fig 8.2 shows the previous data of usage of electricity with it's corresponding billing.

The above figure shows the energy consumption of the user and the corresponding billing on the basis of dates. In the traditional meters we will get the electricity meter on the monthly basis. So it will be difficult for us to guess how much electricity each device is consuming. But in the smart energy meter we can get the bill date wise so it will be helpful in keep track of our energy usage.

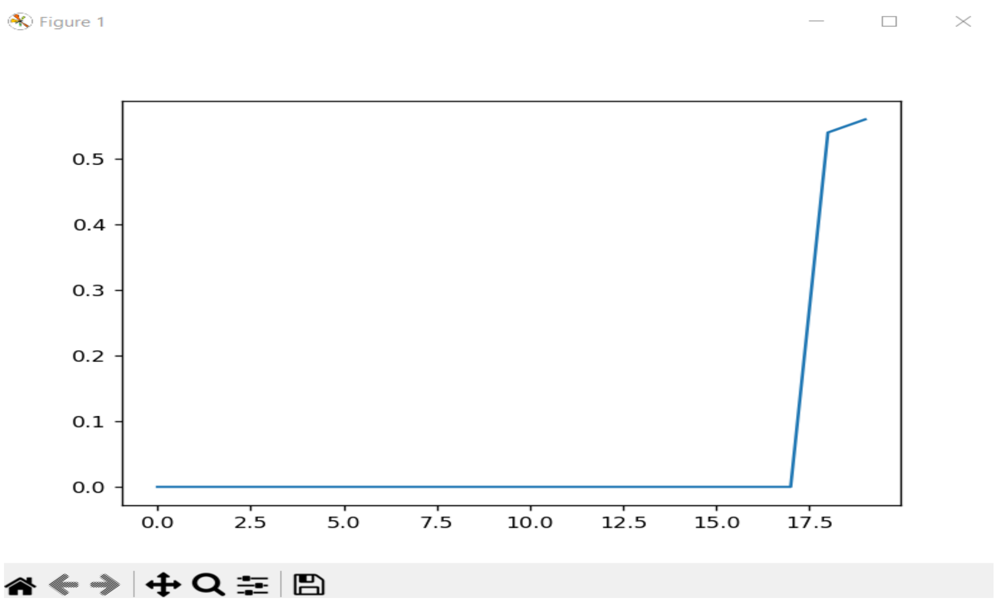
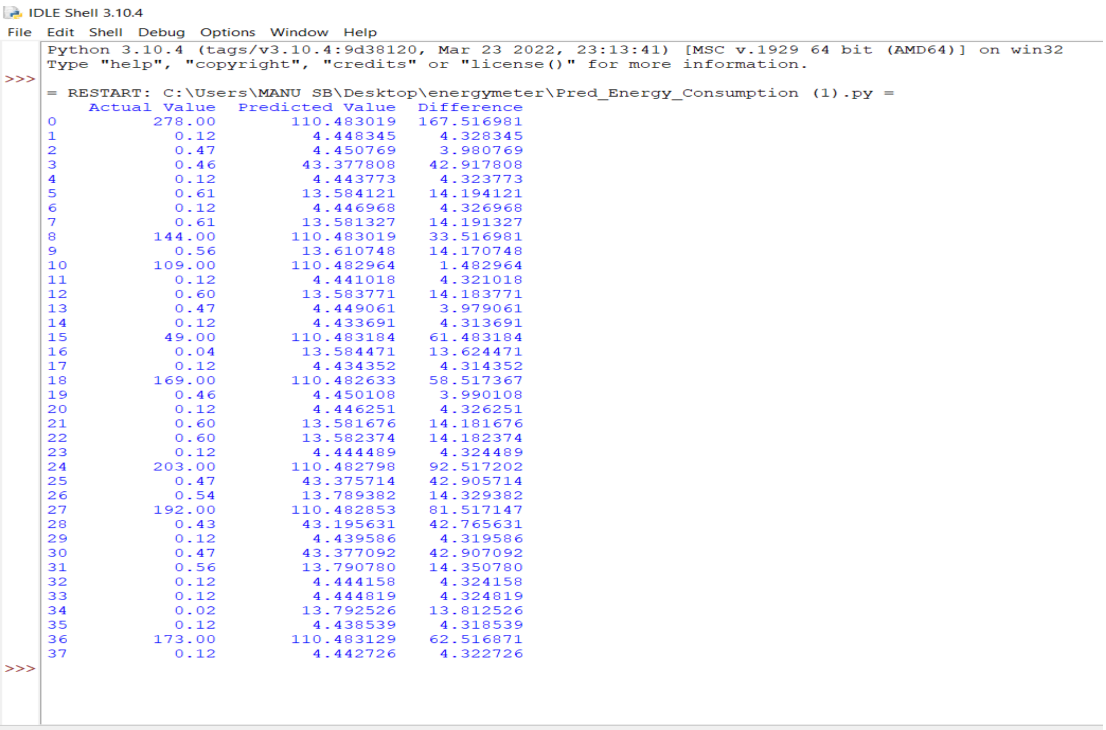


Fig 8.3 Live data

Fig 8.3 shows the live data which consists the graph of current vs time.

The above figure shows the Live data of energy consumption. In the traditional meters we will get the energy units consumption in the meters. Since they will be installed on the walls it will be difficult for us to record those values. But in smart energy meter the lcd display can be installed in any place and we can get the Live data regarding energy consumption. Here we are representing the Live data in the form of current vs time graph.



```
IDLE Shell 3.10.4
File  Edit  Shell  Debug  Options  Window  Help
Python 3.10.4 (tags/v3.10.4:9d38120, Mar 23 2022, 23:13:41) [MSC v.1929 64 bit (AMD64)] on win32
Type "help", "copyright", "credits" or "license()" for more information.
>>>
= RESTART: C:\Users\MANU SB\Desktop\energymeter\Pred_Energy_Consumption (1).py =
    Actual Value  Predicted Value  Difference
0         278.00       110.483019  167.516981
1           0.12         4.448345    4.328345
2           0.47         4.450769    3.980769
3           0.46        43.377808   42.917808
4           0.12         4.443773    4.323773
5           0.61        13.584121   14.194121
6           0.12         4.446968    4.326968
7           0.61        13.581327   14.191327
8         144.00       110.483019   33.516981
9           0.56        13.610748   14.170748
10        109.00       110.482964    1.482964
11          0.12         4.441018    4.321018
12          0.60        13.583771   14.183771
13          0.47         4.449061    3.979061
14          0.12         4.433691    4.313691
15         49.00       110.483184   61.483184
16          0.04        13.584471   13.624471
17          0.12         4.434352    4.314352
18        169.00       110.482633   58.517367
19          0.46         4.450108    3.990108
20          0.12         4.446251    4.326251
21          0.60        13.581676   14.181676
22          0.60        13.582374   14.182374
23          0.12         4.444489    4.324489
24        203.00       110.482798   92.517202
25          0.47        43.375714   42.905714
26          0.54        13.789382   14.329382
27        192.00       110.482853   81.517147
28          0.43        43.195631   42.765631
29          0.12         4.439586    4.319586
30          0.47        43.377092   42.907092
31          0.56        13.790780   14.350780
32          0.12         4.444158    4.324158
33          0.12         4.444819    4.324819
34          0.02        13.792526   13.812526
35          0.12         4.438539    4.318539
36        173.00       110.483129   62.516871
37          0.12         4.442726    4.322726
>>>
```

Fig 8.4 Power Conservation

Fig 8.4 shows the power conservation data using logistic regression.

The above figure shows the data regarding energy conservation using logistic regression. The actual value will be the data we are getting from the live data usage. We need to compare the actual value with the predicted value in order to find the amount of energy we are wasting. This will be helpful in energy conservation.

CHAPTER 9

CONCLUSION AND FUTURE ENHANCEMENT

In this project, a smart energy meter system is designed and built using Arduino UNO microcontroller with current and voltage sensors. The measured energy is displayed on the 16 x 2 Lcd using I2C modules. The smart meter is used to replace the mechanical energy meter that has several advantages over the mechanical one. In addition, smart meter has the ability to give us the voltage and current reading at the given instance of time. The proposed device can be utilized to measure the amount of electric power consumed by Bulb along with the monitoring and the consumption of electric energy usage by measuring both current and voltage signal from power system.

In future work, we suggest expanding the smart meter to work with three-phase system and to replace the display module with another has the ability to display the results as a graphics form. Following changes are recommended to be implemented in this project to make it more accurate and reliable.

- Graphical display
- Increase LCD size

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