Smart Energy Monitoring System and Optimization of Energy Consumption

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A Final Year Design Project (FYDP) submitted to the Department of Electrical and Electronic Engineering in partial fulfillment of the requirements for the degree of B.Sc. in Electrical and Electronic Engineering

Electrical and Electronic Engineering
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[September] [2022]

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Declaration

It is hereby declared that

1. The Final Year Design Project (FYDP) submitted is my/our own original work while completing degree at Brac University.
2. The Final Year Design Project (FYDP) does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The Final Year Design Project (FYDP) does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. I/We have acknowledged all main sources of help.

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Ethics Statement

We have worked diligently on our Final Year Design Project titled “Smart Energy Monitoring System and Optimization of Energy Consumption” and firmly state that all the workings, results and data shown in this paper are our original work and have been organized accordingly. Additionally, the resources and materials used as references for our project collected from various sources have been cited according to the IEEE standards. The project has met the desired goals through our team’s hard work, efforts and notable support from our ATC (Academic Training Committee) members.

Abstract/ Executive Summary

We now place a high importance on energy efficiency, especially in light of the impending depletion of fossil resources. One way to accomplish this would be to utilize modern devices to monitor how much energy each room or building uses and to cut down on electricity waste. The designed system enables the customer to monitor their daily electricity consumption, assist them in managing their energy costs, and help them reduce their monthly electricity bill by optimizing their usage. The household's energy consumption is measured using various sensors. Based on the remaining pre-paid electric meter balance the smart device will send notifications to the consumer's mobile phone when the system calculates a low balance to make the user aware to recharge the meter. Additional notifications will remind them to switch off the appliances when not in use. This study shows how our designed system works on a prototype house model and compares the data obtained with an actual existing system to confirm our findings with readings from a conventional energy meter.

Keywords: Energy efficiency; pre-paid meter; IoT; Energy Monitoring; Tariff

Dedication

Even today, there are people in Bangladesh (ethnic groups), who still do not have proper electricity connections in their homes and have to spend nights in darkness. This paper is dedicated to all people with very limited access to electricity and those living in areas still detached from the main grid connection.

Acknowledgment

We would like to start by thanking the almighty whose blessings have made it possible for us to finish this project in due time. A special thanks to our supervisor Dr. Mohammed Belal Hossain Bhuian who has actively monitored our group throughout the FYDP, guided us and motivated us to develop a design that will positively impact our Energy sector. In addition, we would like to express our gratitude to Abdullah Hil Kafi, Lecturer at the Department of EEE, Brac University, for the guidance in the technical sections of our project, as well as Mahmudul Islam, Lecturer of EEE Department, Brac University, who has been supportive throughout the journey. Finally, we would like to thank our ATC (Academic Technical Committee) panel members for their invaluable assistance and direction during our FYDP (Final Year Design Project) journey.

Table of Contents

Declaration iii

Approval iv

Ethics Statement v

Abstract/ Executive Summary vi

Dedication vii

Acknowledgment viii

Table of Contents ix

List of Tables xv

List of Figures xvi

List of Acronyms xix

Chapter 1: Introduction- [CO1, CO2, CO3, CO10] 1

1.1 Introduction: 1

1.1.1 Problem Statement: 1

1.1.2 Background Study: 2

1.1.3 Literature Gap: 2

1.1.4 Relevance to current and future Industry: 3

1.2 Objectives, Requirements, Specification and Constraints 7

1.2.1 Objectives: 7

1.2.2 Functional and non-functional Requirements: 9

1.2.3 Specifications: 10

1.2.4 Technical and non-technical considerations and constraints in the design process: 12

1.2.5 Applicable compliance, standards and codes: 12

1.3 Systematic Overview / Summary of the proposed project: 13

1.4 Conclusion: 14

Chapter 2: Project Design Approach [CO5, CO6] 15

2.1 Introduction: 15

2.2 Identification of multiple design approaches: 15

2.2.1 Design Approach 01: 15

2.2.2 Design Approach 02: 16

2.2.3 Design Approach 03: 16

2.3 Description of multiple design approaches: 17

2.3.1 Design Approach 01: 17

2.3.2 Design Approach 02: 19

2.3.3 Design Approach 03: 21

2.4 Analysis of multiple design approaches: 23

2.5 Conclusion: 24

CHAPTER 3: Use of Modern Engineering and IT Tool [CO9] 25

3.1 Introduction: 25

3.2 Selection of appropriate Engineering and IT tools: 25

3.2.1: Software and comparison: 25

3.2.2: Hardware and coding: 27

3.3 Use of modern Engineering and IT tools: **27**

3.3.1 Comparison of the software for simulations: 27

3.3.2 For coding: 28

3.3.3 for hardware: 29

3.4 Conclusion: **29**

CHAPTER 4: Optimization of Multiple Design and Finding the Optimal Solution. [CO5, CO6, CO7] **30**

4.1 Introduction: **30**

4.2 Optimization of multiple Design approach: **30**

4.3 Identification of the Optimal design approach: **35**

4.4 Performance evaluation of developed solution: **36**

4.4.1: Implement the selected design solution: 36

4.4.2: Performing tests of the Implemented solution: 38

4.4.3: Evaluating the performance of the implemented solution: 40

4.5 Conclusion: **41**

Chapter 5: Completion of Final Design and Validation. [CO8] **42**

5.1 Introduction: **42**

5.2 Completion of the final design: **42**

5.2.1: House model system Design: 43

5.2.2: Individual hardware testing and system integration: 44

5.2.3: Blynk app for remote access: 45

5.2.4: Total system run test on house model: 46

5.3 Evaluate the solution to meet the desired need: 47

5.3.1: Sensor calibration: 47

5.3.2: App development (Blynk): 50

5.3.3: Keypad: 51

5.3.4: Display: 52

5.3.5: Calculations: 52

5.4 Conclusion: 57

CHAPTER 6: Impact Analysis and Project Sustainability. [CO3, CO4] 58

6.1: Introduction: 58

6.2: Assessment of impacts of the designed solution: 58

6.3: Evaluate the sustainability: 59

6.4: Conclusion: 60

CHAPTER 7: Engineering Project Management [CO11, CO14] 61

7.1: Introduction: 61

7.2: Define, plan and manage Engineering project: 61

7.2.1: Definition of project management: 61

7.2.2: planning of the Engineering project: 61

7.2.3: Project planning/Gantt chart: 65

7.3: Evaluate project progress: 68

7.4: Conclusion: 69

CHAPTER 8: Economical Analysis [CO12] 70

8.1: Introduction: **70**

8.2: Economic Analysis: **70**

8.3: Cost Benefit Analysis: **72**

8.4: Evaluate Economic and Financial aspects: **73**

8.4.1: Evaluate Economical aspects: 73

8.4.2: Evaluate Financial aspects: 77

8.5: Conclusion: **78**

CHAPTER 9: Ethics and Professional Responsibilities [CO13, CO2] **79**

9.1: Introduction: **79**

9.2: Identify ethical issues and professional responsibility: **79**

9.3: Apply ethical issues and professional responsibility: **79**

9.4 Conclusion: **81**

CHAPTER 10: Conclusion and Future work: **82**

10.1 Project summary/Conclusion; **82**

10.2 Future work: **82**

10.2.1 Introduce our project's future work possibilities 82

CHAPTER 11: Identification of Complex Engineering Problems and Activities **84**

11.1: Identify the attribute of complex engineering problem (EP): **84**

11.2: Provide reasoning how the project address selected attribute (EP): **84**

11.3 Identify the attribute of complex engineering activities (EA): **86**

11.4 Provide reasoning how the project address selected attribute (EA): **86**

References..**88**

Code: **91**

Logbook: **101**

List of Tables

Table 01: Functional and non-functional Requirements……………………………………..09

Table 02: System Requirements…………………………………………………………...10

Table 03: Component Specifications……………………………………………………...11

Table 04: Technical and non-technical considerations and constraints in design process…...12

Table 05: Comparison of the 3 Design approaches………………………………………..23

Table 06: Comparison of the Simulation Software………………………………………..26

Table 07: Comparison of the Simulation Software………………………………………..28

Table 08: Functional Verification of the 3 Design Solutions……………………………..30

Table 09: Comparison of alternate design approaches…………………………………....35

Table 10: Comparison between Arduino UNO and ESP 32…………………………...36,37

Table 11: Data collected during the experiment (at BRAC University)…………………….40

Table 12: Data obtained from testing the model at full load………………………………..54

Table 13: Values obtained in from the smart monitoring system vs the energy Meter data..56

Table 14: Contribution of individual group members………………………………………68

Table 15: Risk management system Analysis………………………………………………76

Table 16: Attribute of complex engineering problem (EP)…………………………………84

Table 17: Attribute of complex engineering activities (EA)………………………………..86

List of Figures

Fig 01: DESCO App User Interface……………………………………………………………04

Fig 02: DESCO online registered prepaid card……………………………………………...05

Fig 03: DPDC offline prepaid card……………………………………………………….06

Fig 04: DPDC web (Customer information for offline meters)……………………………..06

Fig 05: Block Diagram of Design Approach 01…………………………………………..…15

Fig 06: Block Diagram of Design Approach 02……………………………………………16

Fig 07: Block Diagram of Design Approach 03……………………………………………16

Fig 08: Block Diagram of Design Approach 01…………………………………………..…17

Fig 09: Schematic Diagram of Design Approach 01………………………………………..18

Fig 10: Block Diagram of Design Approach 02…………………………………………..…19

Fig 11: Schematic Diagram of Design Approach 02…………………………………...……19

Fig 12: Block Diagram of Design Approach 03…………………………………………..…21

Fig 13: Schematic Diagram of Design Approach 03………………………………………..21

Fig 14: Schematic Diagram of Design Approach 01……………………………………..….31

Fig 15: Schematic Diagram of Design Approach 02………………………………………..32

Fig 16: Schematic Diagram of Design Approach 03………………………………………..33

Fig 17: House Model Plan for a 2-bedroom flat…………………………………………….38

Fig 18: Wiring connections for the 2-bedroom flat House Model………………………….38

Fig 19: House Model on which the system was tested…………………………………..….39

Fig 20: The Energy Meter used in our project to verify the data…………………...……40

Fig 21: Blueprint of House Model Plan for a 2-bedroom flat…………………………...….43

Fig 22: Wiring connections for the 2-bedroom flat House Model………………………….44

Fig 23: ZMPT101B, Voltage sensor used in the smart monitoring system………………...44

Fig 24: ACS712_30A, Current sensor used in the smart monitoring system…………..……45

Fig 25: Initially designed house model for testing the monitoring system………………..…46

Figure 26: House Model updated after an actual house. …………………………..……..46

Fig 27: Graph representing the primary calibration of the current sensor…………….……..48

Fig 28: Graph representing the final calibration of the current sensor…………………..…..49

Fig 29: Data found after calibrating the Voltage sensor compared with multimeter reading..49

Fig 30: The User Interface we designed using the Blynk App………………………………50

Fig 31: The 4x4 Membrane Keypad we used in our project…………………………….....51

Fig 32: LM016L, a 16x2 Backlit LCD display………………………………………………52

Fig 33: Flowchart representing the tariff calculation used in coding……………………..…..54

Fig 34: Flowchart showing the overall structure of the code…………………………...…55

Fig 35: Some pictures of data obtained from the energy meter……………………….……..56

Fig 36: Flowchart representing the methodology of the project for FYDP P…………....…..62

Fig 37:Plan for identifying the problems to find appropriate design solutions to solve them.63

Fig 38: Planning for developing the hardware model of the identified optimal solution…....63

Fig 39: Planning for the implementation of the system to obtain data and verify them…….65

Fig 40: Gantt chart for FYDP_P …………………………………………………...…..65

Fig 41: Gantt chart for FYDP_D …………………………………………………….…...66

Fig 42: Gantt chart for FYDP_D (Updated version) ……………………………………..…66

Fig 43: Gantt chart for FYDP_C …………………………………………………...….67

Fig 44: Gantt chart for FYDP_C (Updated version)……………………………………..….67

Fig 45: phases of an engineering project ……………………………………………..….…71

Fig 46: standard deviation of any project through different phases…………………………71

Fig 47: Graph showing the evaluation and implementation of project phases…………….…..72

Fig 48: Cost influence through development of project……………………………………….73

Fig 49: Phases of project duration and budget……………………………………………....74

Fig 50: Continuous Evaluation of Project cost……………………………………………..….77

List of Acronyms

AC	Alternating current
APP	Application
BJT	Bipolar Junction Transistor
CAD	Computer-aided design
CBS	Cost Breakdown Structure
CO	Course Objectives
CPU	Central Processing Unit
DC	Direct current
DESCO	Dhaka Electric Supply Company Limited
DPDC	Dhaka Power Distribution Company
EA	Engineering Activities
EMS	Energy Management System
EP	Engineering Problems
EPA	Environmental Protection Agency
E-waste	Electronic products nearing the end of their useful life.
FYDP	Final Year Design Project
GDP	Gross Domestic Product
HTML	Hyper Text Markup Language
IoT	Internet of Things
IP	Internet Protocol
IT	Information technology
LabVIEW	Laboratory Virtual Instruments Engineering Workbench
LCD	Liquid Crystal Display
LED	Computer-aided design
MCU	Micro Controller Unit
MOSFET	Metal-Oxide–Semiconductor Field-Effect Transistor
MMU	Memory Management Unit
PCB	Printed Circuit Board

RAM	Random Access Memory
ROM	Read Only Memory
RMS	Root Mean Square
RTOS	Real-Time Operating System
SMS	Sending a Message to Someone
UI	User Interface
VAT	Value added tax
WBS	Work Breakdown Structure
Wi-Fi	Wireless Fidelity
Wh	Watt-hour

Chapter 1: Introduction- [CO1, CO2, CO3, CO10]

1.1 Introduction:

The world in which we live is filled with several kinds of energy. Notably, among the energies, electrical energy is one of the vital energies by which our life is being developed day by day. The lack of electricity generation is a very prominent concern in this age of digitization. Recently, in 2022 Bangladesh's Government announced their scarcity of Electricity generation due to many national and international issues. In order to reduce electricity waste, many coal-based power plants have been shut down, and the government has taken numerous notable measures, such as regular load shedding and adjusting office hours.
Therefore, it is evident that one of our nation's top priorities is to optimize electricity utilization. Hence, to meet up the demands of Electricity usage optimization, we are introducing our FYDP (Final Year Design Project) titled "Smart Energy Monitoring system and Optimization of Energy Consumption" which will help consumers to monitor the electricity usage of their prepaid meter via APP, SMS. . Additionally, this system would instruct customers on how much electricity they used in prior days so that they are more conscious of their electricity usage.

1.1.1 Problem Statement:

The five basic requirements for survival (food, clothing, accommodation, education, and health) have been surpassed by the utilization of electrical energy. We would not be able to do our daily chores if we did not have electricity. For a developing country like Bangladesh, the increasing demand for such a resource is very hard to meet and monitor.

The conventional way to measure electrical energy consumption in Bangladesh is through electric meters. These meters are permanently installed in a certain location and are typically clustered in areas where they are difficult to access or check on a regular basis. Due to lack of remote access the consumers may not always be able to monitor the remaining energy balance. As a result, a power outage might occur once the entire energy balance has been used up. Similarly, if a user wishes to keep expenses under control, he or she will fail because there is no easy way to remotely check daily usage.

There are times when we are utterly unconcerned with our energy usage and waste. There is no way to remotely track clients' daily electricity usage in Bangladesh. As a result, while the user is not near the meter, there is no way to tell him or her of the remaining amount for which, we routinely observe power outages that might happen at any time and the customer is unable to go to local vendors to quickly replenish the electric meter, resulting in lengthy load shedding.

1.1.2 Background Study:

According to Garcia et al [9], previous research in the field of energy generation and consumption indicates the technical, household, and commercial wastage of electricity worldwide which are approximately worth billions of dollars per year. Ueno et al. [10] installed an ECOIS energy monitoring system for residential homes. Their results showed the room temperature fell by 1 degree due to the proper use of home appliances from the notifications of the ECOIS system display allowing them to operate the appliances more effectively thus reducing wastage. A study by the School of Information Technology and Engineering [3] shows that if we are able to control the devices operating unnecessarily and reduce wasted electrical energy then the minimum energy preserved from every house within a block is sufficient enough to power up a small factory. A.R. Al-Ali [8] has represented an Energy Management System (EMS) for smart homes. In this system, each home device is interfaced with a data acquisition module that is an IoT object with a unique IP address resulting in a large mesh wireless network of devices. The data acquisition System on Chip module collects energy consumption data from each device of each smart home and transmits the data to a centralized server for further processing and analysis. Govindarajan et al [1] has introduced the SEMS method in which they have considered four different approaches and they have different outcomes. They have used four different systems that reported speed and time delay. From their experiment, we can see that the cloud-based can operate with the highest accuracy when compared with the other methods. And it is also faster than alternative systems such as ZigBee, Android, and IoT systems.

1.1.3 Literature Gap:

In every project, the term “Literature Gap” is commonly used due to the scope of future updates. Literature Gap has served as a detection mark for the project and its analysis procedure since the science is updated periodically. The "Literature Gap" in any project is mostly caused by the unexplored and underexplored scopes that are missing in this case due to a lack of information and sources. Eventually, our system also has certain "Literature-Gaps" where we can concentrate on our near future to update the system more accurately. As a result, we were able to identify 2 of the aspects that made up the literature gap.

- **<u>Web Scraping</u>:** Web scraping is a well-known technique in which we can use bots to legally extract and gather information from any website. The task is being done in this instance using HTML and Python code. Therefore, we need to learn more about these codes to Extract information from our targeted website to Sync the prepaid meter data information with our project's system. Finally, we anticipate that the concept of web scraping would develop for the project in the future.

- **<u>Algorithm</u>:** A widely common method for locating a desired result by configuring specific inputs is an algorithm. Algorithms are essentially described as some clearly specified instructions to produce the desired results for particular problems in the field of computer programming. As a result, if we incorporate algorithms into our codes, our system for monitoring energy will be more up-to-date. Here, using an algorithm, our system can read past electricity usage costs for our clients, and after analysis, the system can offer suggestions or advice on how the customer might maintain their electricity usage in the future. As a result, we firmly hope that this type of system update can prosper our energy monitoring system in near future.

-

1.1.4 Relevance to current and future Industry:

Engineering problem-based initiatives often have a heavy focus on their relevance to particular stakeholders, target audiences, current industries, and future industries. As a result, we can choose the project relevance criteria through extensive research and analysis of the current and future industries. Therefore, we have researched and found out the relevance of our project to the current and future industries.

- **<u>Current industry:</u>**

For the time being, the prepaid electricity users in Dhaka city are the stakeholders whom our project is targeting. We looked at a variety of areas and also surveyed users' specific data using a variety of criteria. We have chosen DPDC (Dhaka Power Distribution Company) as our stakeholder as a result. We have discovered that DPDC is one of the biggest electricity distribution providers in the city of Dhaka, and we have also found that their facilities may need some improvement.

First off, DPDC does not provide any APPs that allow customers to check their electricity usage and remaining balance remotely. If we contrast it with DESCO (Dhaka Electric

Supply Company Limited), they offer an APP in the Google Play store that allows consumers to monitor their meters' remaining energy balance.

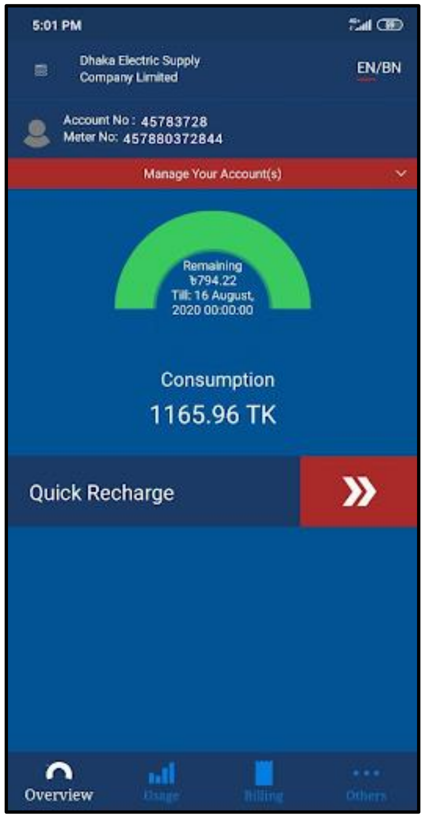


Fig 01: DESCO App User Interface

Secondly, DESCO company's APP is capable of recharging electricity prepaid meter balances through bkash, Nagad, Visa card, etc. they have updated and registered all of their prepaid cards on online platforms.

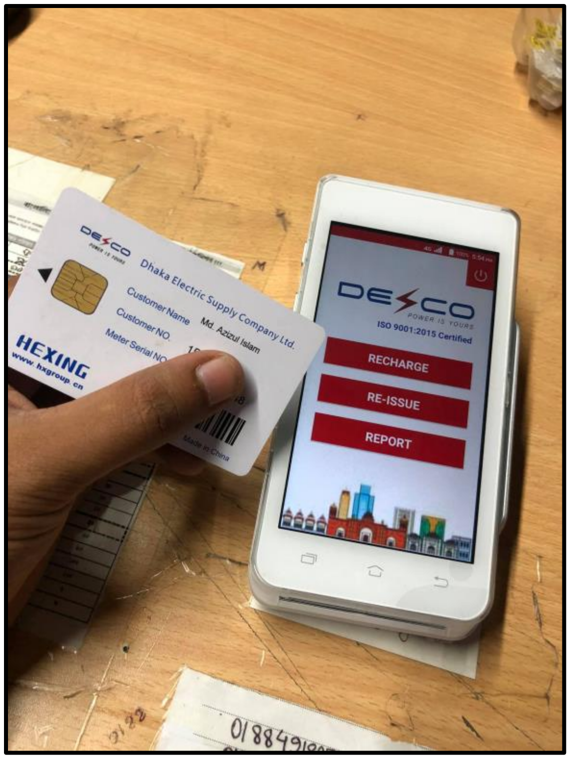


Fig 02: DESCO online registered prepaid card

On the other hand, DPDC also offers the option of recharging balances via their website (bKash, Nagad, Visa card, etc). Yet after doing some research, we find out that DPDC offers two different kinds of prepaid cards to its customers. One form of card is an online registered card, while the other is not. Because of this, holders of offline cards are unable to recharge their prepaid cards over any online platform; instead, they must manually recharge and put the card into the meter. Therefore, our energy monitoring system will help the offline prepaid card users of DPDC to be aware of their daily electricity usage and the remaining balance.

Fig 03: DPDC offline prepaid card

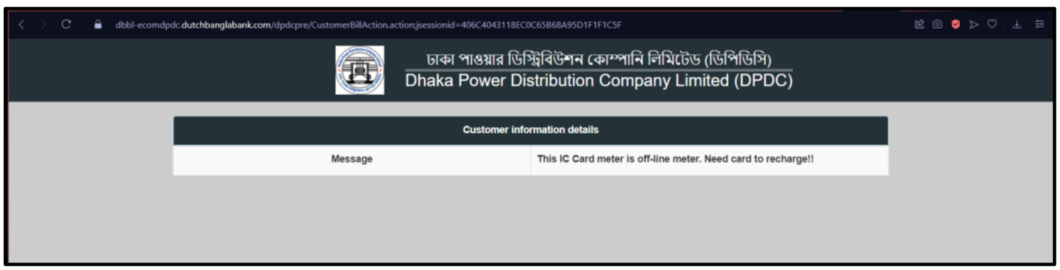


Fig 04: DPDC web (Customer information for offline meters).

Here, the Green colored DPDC prepaid card is offline. We can see that whenever we enter the customer number of a specific green prepaid card to recharge online then this message shows that the meter is an offline meter and the user needs to do the recharge manually. Therefore, the users of this type of card are getting deprived of many facilities.

- **Future industry:** Numerous potential future industries can use our energy monitoring system. In essence, we may link our energy monitoring system with automation systems by introducing a few characteristics within our system. As we all know, automation is a well-known method that requires some code integration. Therefore, the system on itself will be able to control various systems or devices to reduce human efforts and time to increase accuracy. As a result, we developed certain automation updates that would be strongly linked to the future energy generation sector by gathering information and doing research in the relevant field. The system's automatic update is as follows:

A) **Temperature sensor:** As our system is used for electricity energy monitoring, there are some cases where fire incidents could occur in the home from any source. As a result, adding a temperature sensor to our system would give consumers comfort because it would ensure that whenever a fire event occurs, an alert would be sent to them via an APP and a buzzing sound would be made from the Buzzer.

B) **Weather Data analysis:** Our project's name refers to smart energy monitoring. Therefore, we would like to incorporate weather data analysis into our project in the future so that it can provide consumers with smart advice by interpreting the weather data on its own. Eventually, through intensive research and updated coding, we can introduce this weather Data analysis feature to our project.

To conclude, our project has a strong relevant connection with the current and future industry where by improving and updating the system we can create a device that will be familiar to the smart home system.

1.2 Objectives, Requirements, Specification and Constraints

The goal of this project, requirements of the system, specifications from the user end, and specific details of the components used are discussed in the following subsections elaborately. We have also identified some of the limitations and constraints that the smart monitoring system will be facing in a real-world scenario.

1.2.1 Objectives:

Our effort is aimed toward a group of people who require help measuring their electricity usage in order to use less energy. The following are the objectives of our project:

- Monitor Electricity usage in real-time
- Display consumed units and remaining prepaid electricity balance
- Notification system for users using SMS or buzzer
- Provide suggestions to optimize electricity usage

Monitor Electricity usage in real-time: This part of our project aims to make it possible for users to monitor their usage and check their electric meter balance remotely using a smartphone.

Display consumed units and remaining prepaid electricity balance: The user may track their remaining electricity balance and become aware of their electrical wastage thanks to this component of the project, which also helps them reduce their monthly electricity cost.

Notification system for users using SMS or buzzer: This is an added feature in our system that alerts people when they have a low electric balance remaining in their meters. Unlike the traditional method, it does so even if the user is not physically present close to the meter.

Provide suggestions to optimize electricity usage: We have implemented some notification systems as opposed to conventional approaches to checking the meter. Customers will benefit from these notifications by using less electricity and saving money to the fullest extent feasible, which will lower their monthly electricity costs.

1.2.2 Functional and non-functional Requirements:

The Specifications of the system can be further classified into subcategories. These would be divided into Functional and Non-functional parts according to the User-end requirements.

User-end Requirements	Functional	Energy consumption monitoring
		Display total energy consumed
		Display Remaining balance
		Remote access (App based)
		Keypad for manual data entry
	Non-Functional	Casing Design
		System Water-proofing
		Kill Switch

Table 01: Functional and non-functional Requirements

1.2.3 Specifications:

In this section, we will be discussing the requirements and specifications of our system and give a detailed overview of the components used.

System Requirements	Specifications	Component Used
Can detect the current and unit consumed by the load. Can warn the user to take action.	Sensors for collecting data	Current Sensor - ACS712 Voltage Sensor - ZMPT101B
Can connect to the Wi-Fi or internet and able to send SMS	Wi-Fi Module to connect to the internet and send SMS using the online messaging system	Wi-Fi module built in the MCU
Able to gather information from the sensors, process data, and take decisions accordingly	Microcontroller Unit or Development Board	ESP-32 (Devkit v1)
Providing input values manually	Keypad to enter the data	Membrane Keypad (4x4)
Displays the user data	Display for visual output	LCD Display-LM016L with attached I2C

Table 02: System Requirements

Component Specifications:

SL No.	Component Name	Operating Voltage	Max Current Requirement	Manufacturer
1	ACS712_30A (Current Sensor)	5V	13mA	Allegro Microsystems
2	ZMPT101B (Voltage Sensor)	5V	20nA	Qingxian Zeming Langxi Electronic
3	ESP-32 (Devkit v1)	2.2V - 3.6V	40mA	Espressif Systems
4	Membrane Keypad (4x4)	Up-to 12V	30mA	Perfect Electronics
5	LCD Display- LM016L with attached I2C	4.7V - 5.3V	16mA	Mouser Electronics

Table 03: Component Specifications

1.2.4 Technical and non-technical considerations and constraints in the design process:

To run the project, we have to deal with various ordeals. In Our project, we have identified some of the problems which might arise. These mainly include:

Limitations/ Constraints of our design	Technical Constraints	Cannot synchronize with regular meter
		Wi-Fi connection setting is not automated
		Requires Internet connection for data synchronization with App
		Data loss due to load shedding
	Non-Technical Constraints	Making the casing for the monitoring system waterproof
		Multiple Casing colors of monitoring system to match user's wall
		Drilling holes in wall for setup

Table 04: Technical and non-technical considerations and constraints in the design process

1.2.5 Applicable compliance, standards and codes:

- **IEEE 802.11ba-2021:**
  This standard is to provide wireless connectivity for fixed, portable, and moving stations within a local area. This standard also offers regulatory bodies a means of standardizing access to one or more frequency bands for the purpose of local area communication.

- **IEEE 256-1963:**
  This Standard recommends and describes methods of measurement of the important electrical characteristics of semiconductor diodes. As we will be using a buck-boost converter for that BJT, MOSFET kind of element is needed which is also applicable.

- **IEEE 1703-2012:**
  The purpose of this standard is to define the network framework and means to transport the Utility End Device Data Tables via any Local area / Wide area network for use by enterprise systems in a multi-source environment. Our GSM module technique is also applicable to that standard.

- **IEEE 2050-2018:**
  This standard is a real-time operating system (RTOS) specification for small-scale embedded systems such as systems with a single chip microcomputer (single chip microcontroller) including 16-bit CPUs, systems with a small amount of ROM/RAM, and systems without a memory management unit (MMU). The main chip will need ROM for storing data. As well as managing reading falls under this standard.

1.3 Systematic Overview / Summary of the proposed project:

Bangladesh is regarded as a developing nation, and its achievements in the power sector are notable. However, we are currently experiencing a deficit in the production of power due to both global and local difficulties. In order to satisfy consumer needs, we have implemented a sophisticated technical project that will enable prepaid customers to remotely monitor their electricity usage and be aware of energy-saving opportunities. As a result, our method will have a good effect on the economy of the country and assist consumers in becoming more informed about how to use electricity.

1.4 Conclusion:

It is clear that maximizing the use of grid power is one of our country's main focuses. Therefore, in order to meet the demands of energy consumption efficiency, we are introducing our FYDP (Final Year Design Project), which will enable users to track the electrical consumption of their prepaid meters via APP and SMS. Customers would also receive information from this system about how much electricity they used in previous days, making them more aware of their utilization.

Chapter 2: Project Design Approach [CO5, CO6]

2.1 Introduction:

Our energy monitoring system is based on a few objectives, which helped us determine how important it was when designing the approaches. So that we could determine the three possible design approaches to meet the main goals of our project, we looked through a number of research review papers and software.

2.2 Identification of multiple design approaches:

2.2.1 Design Approach 01:

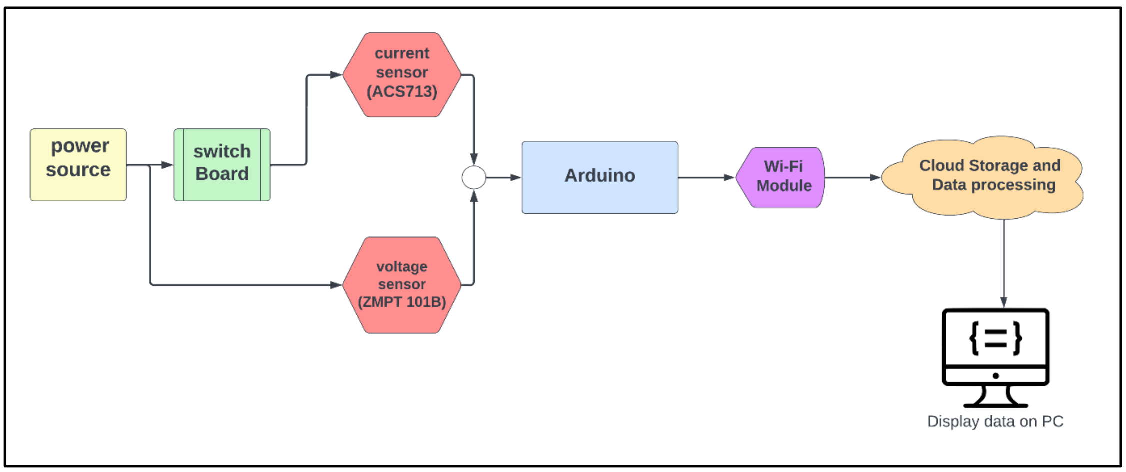


Fig 05: Block Diagram of Design Approach 01

- Current Sensors measure data for each appliance.
- Arduino Nano processes the data for each room.
- The processed Data is uploaded to a cloud storage using Wi-Fi shield.
- Users Getting Notification via Alarm system, Phone app.

2.2.2 Design Approach 02:

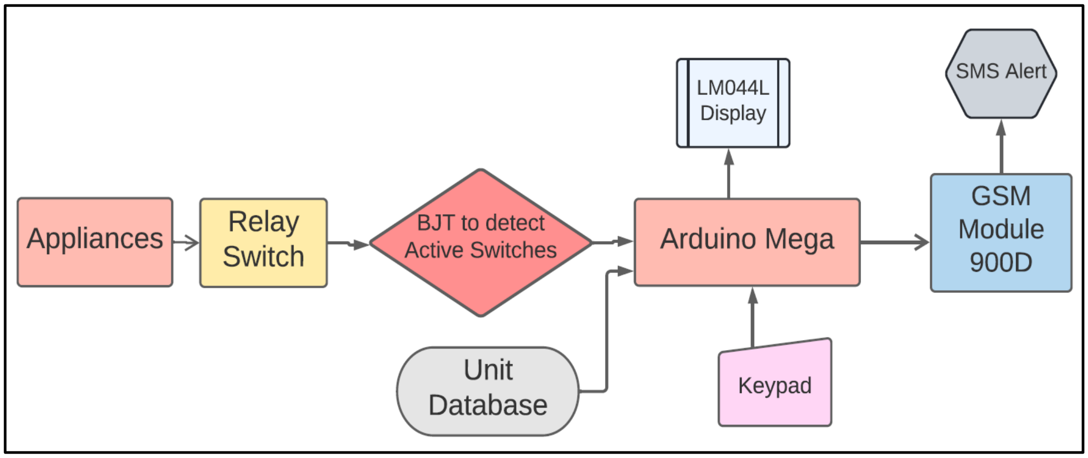


Fig 06: Block Diagram of Design Approach 02

- Transistors detect active relay switches and sends signal to MCU
- Arduino Mega (MCU) detects active switch and processes data regarding that switch
- Processed data is being shown LM044L Display
- Users provide input manually by keypad and receive Notifications via SMS

2.2.3 Design Approach 03:

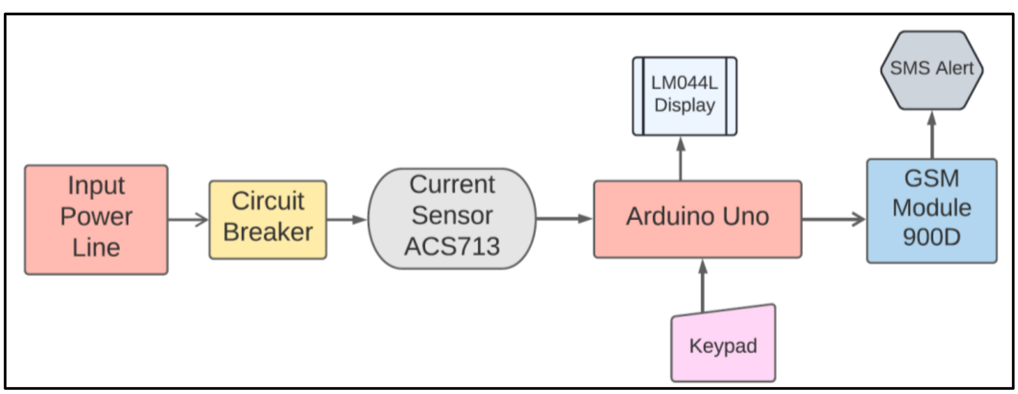


Fig 07: Block Diagram of Design Approach 03

- Current Sensor reads value from circuit breaker.
- Arduino Uno is used to read data and calculate tariff.
- Processed data is being shown into display (LM044L).
- Customers provide input manually by keypad and receive Notifications via SMS.

2.3 Description of multiple design approaches:

In the following pages, we have thoroughly described the Alternative design approaches possible for designing our system. This part was done to look for alternate solutions of the current problems that conventional meter users are facing.

2.3.1 Design Approach 01:

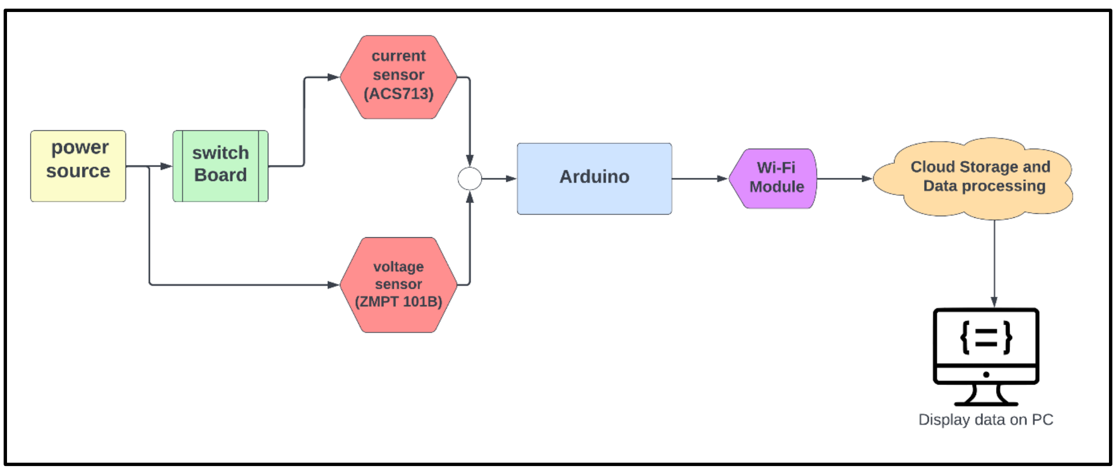


Fig 08: Block Diagram of Design Approach 01

- Current Sensor measure data for each appliance
- Arduino Nano processes the data for each room
- The processed Data is uploaded to a cloud storage using Wi-Fi shield
- Users Getting Notification via Alarm system, Phone app

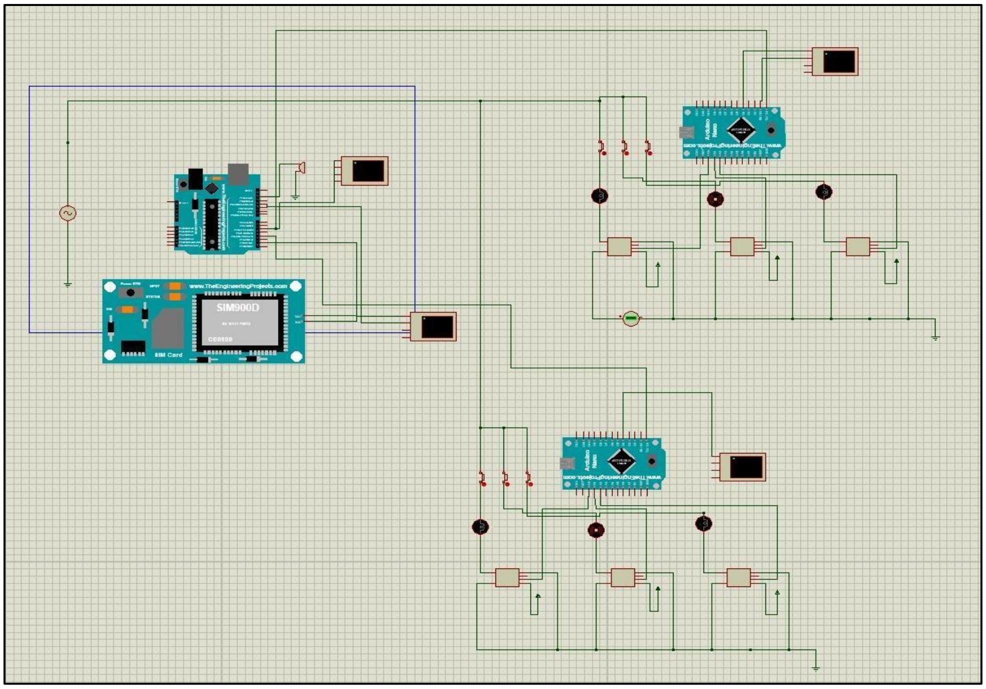


Fig 09: Schematic Diagram of Design Approach 01

In this design, each room is shown as a child circuit. The child circuit consists of a DC Motor representing a fan and 2 separate lamps depicting the light bulbs that we use in our house. These devices are connected in series with current sensors which record the current reading for each appliance separately. The reading for each room is checked by individual Arduino Nano placed in each room and it is here that using the sensor readings the Nano is able to tell whether an appliance is ON or OFF.

The total current reading, as well as the appliance activity, is processed and then sent to the Arduino UNO board from each room by the Nanos. The UNO receives this information and processes it to further make calculations that are used to measure the usage and bill of consumers. This data is then sent to a cloud using a GSM module which regularly updates the activities in the database and from here the consumer is able to monitor his/her activity via an app.

2.3.2 Design Approach 02:

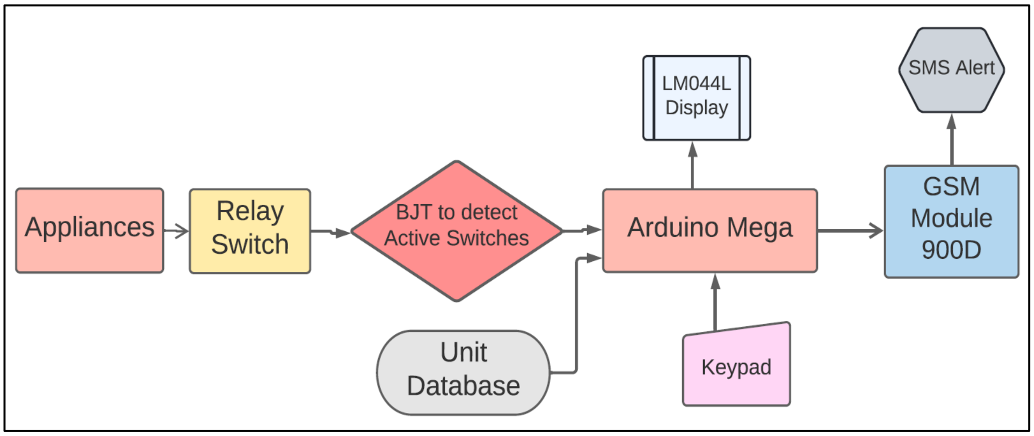


Fig 10: Block Diagram of Design Approach 02

- Transistors detect active relay switches and sends a signal to MCU
- Arduino Mega (MCU) detects active switch and processes data regarding that switch
- Processed data is being shown LM044L Display
- Users provide input manually by a keypad and receive Notifications via SMS

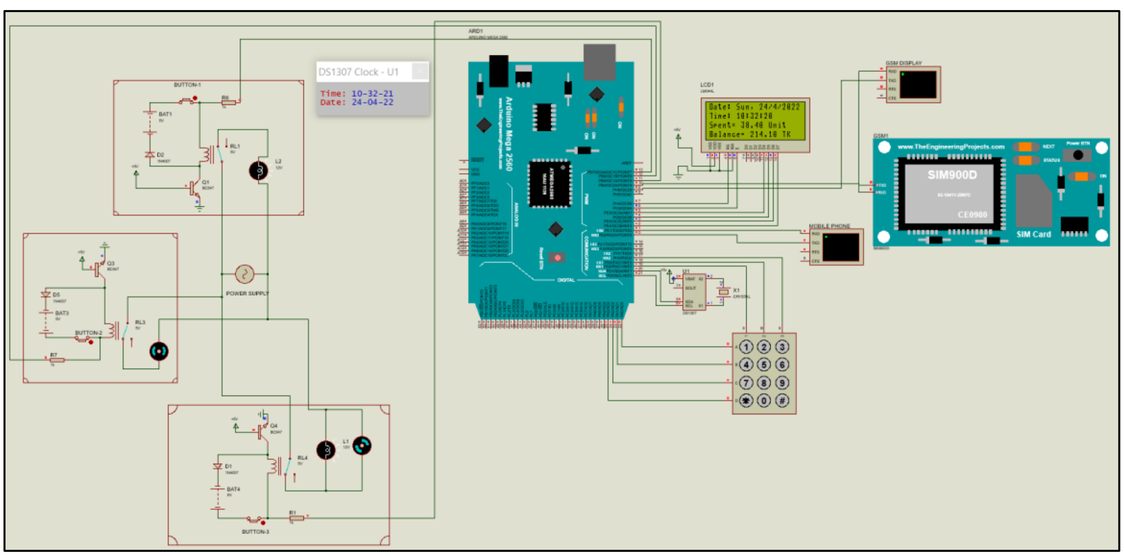


Fig 11: Schematic Diagram of Design Approach 02

We are implementing a relay with each load in this design process to distinguish which one is running and which one is not. We've linked the relay to each load's switch. When the switch is turned on, the relay is activated first, and then the load is activated. The operating data will be provided to Arduino during this time. The Arduino will then detect which switch is turned on and for how long. The data for each load is then pre-programmed on Arduino. As a result, Arduino calculates the balances that have been spent and those that have not been spent. A keypad is used to enter commands, and an LCD display (LM044L) is used to display them. On the screen, we can view the remaining balance, recharge amount, and usage history, among other things. Finally, the GSM module (900D) is available for sending text messages when the balance is at a low level. When the balance falls below 25%, a notification will be issued as an emergency reminder to recharge the device.

2.3.3 Design Approach 03:

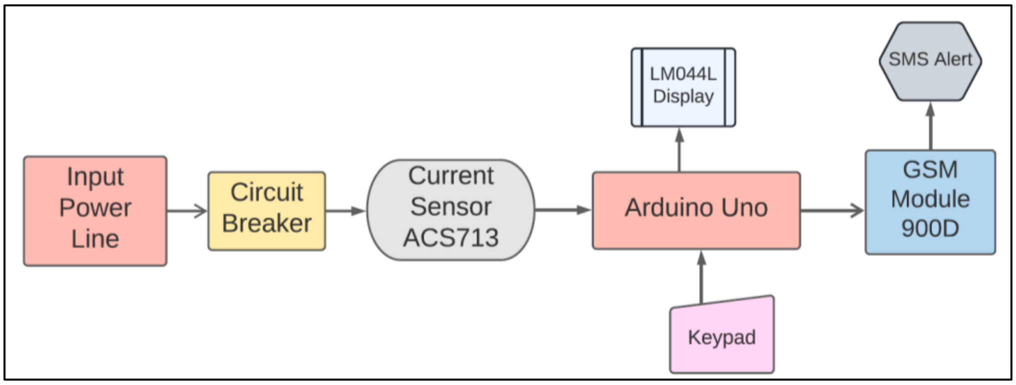


Fig 12: Block Diagram of Design Approach 03

- Current Sensor read values from circuit breaker
- Arduino Uno is used to read data and calculate tariff
- Processed data is being shown into the display (LM044L)
- Customers provide input manually by a keypad and receive Notifications via SMS

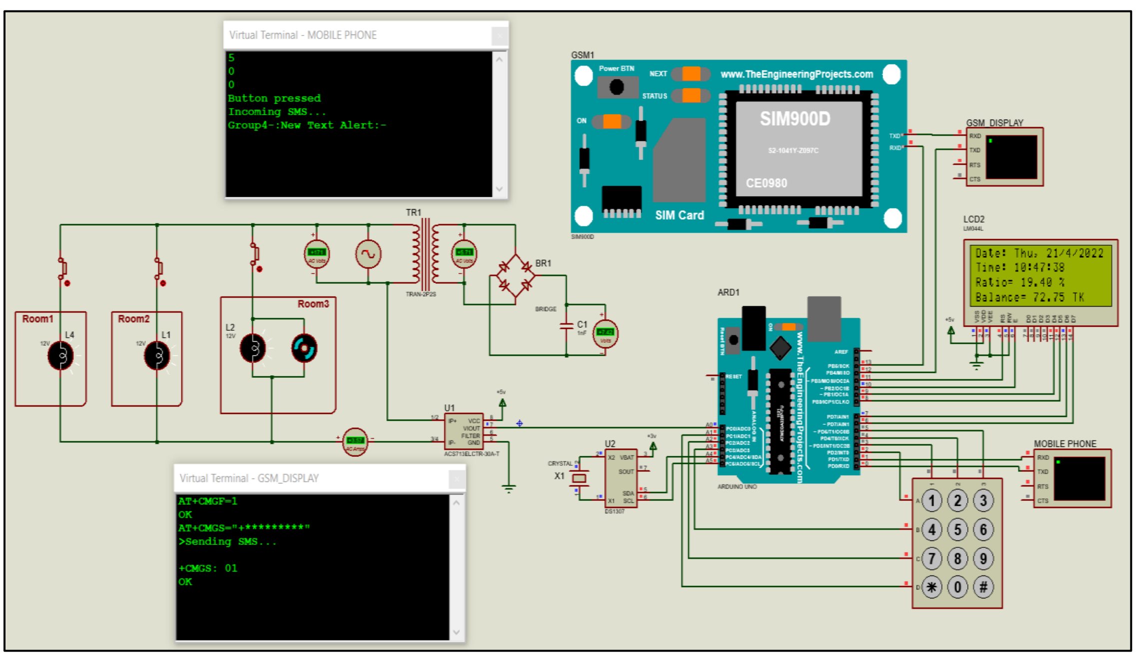


Fig 13: Schematic Diagram of Design Approach 03

We take the desired data from the circuit breaker through a circuit sensor in this design approach (ACS713). First and foremost, the sensor will send milliamps of data to Arduino right away. Our primary goal is to keep track of current data and convert it to amperes using Arduino code. Secondly, we have included a simple keypad system to collect user input and control the system. The necessary data is also displayed on a (LM044L) display. Finally, we prove that the units have been used and that there is still a balance in the meter by utilizing power and energy calculations. Although, for the time being, we are taking the balance input by asking the user how much he or she recharged. We are keeping the sanction load or demand rate as a constant rate of 60 BDT. Therefore, the system keeps calculating the data and through GSM module(900D) messages will be sent while the balance is about 50 percent left as well as 25 percent left.

2.4 Analysis of multiple design approaches:

Here to compare the three design approaches we have assessed them on several criteria and the results are tabulated below,

	Design 1	**Design 2**	**Design 3**
Component Efficiency	Uses multiple MCU and sensors to measure data in real-time.	Fixed appliance Unit ratings are taken from the database. Therefore, The transparency of output data is limited.	Uses a single Arduino UNO and sensors to measure data in real-time
Data accuracy	Error rate 14.28% (High error rate)	Error rate 4.3% (Moderate error rate)	Error rate 0.748% (Low error rate)
Manufacturability	The components are available, but a bit complex to build. Also, we can set the cloud storage data easily	This system is based on relay switch. Which will be dependent on database, there are less sensors	This is based on data from the circuit breaker. It requires digital sensors
Maintainability	There are more than 1 MCU, and the data is based on cloud storage. Here the maintenance is complicated.	Depending on transistors and relay, with each switch board. Which is easier compared to previous.	No internet connection in this system. Since the parameters are from the sensor, this system is simple to maintain.
Feasibility	This design has complexity. There are both nano and uno as MCU. And the code implementation is quite challenging.	The relay, BJT, pull down resistor's combination is a bit tough and there is only one MCU and the code direction is at a moderate level.	The current data is sensing and direct to the MCU. And its code is simple
Budget	9950	5600	4650

Table 05: Comparison of the 3 Design approaches

After the comparison, we have come to the decision to elect Design 3 to be our optimal design solution.

SWOT Analysis of the Optimal Design Solution:

- **Strengths:**
  I. Is able to display the usage history of the user in detail for the running month.
  II. Users will be notified using the SMS system so they do not need to check meters regularly and can get notified remotely.
  III. Providing suggestions to optimize electricity usage

- **Weaknesses:**
  I. Current fluctuation as AC to DC converter is used which reduces accuracy.
  II. Sensors consume a small amount of energy which is not calculated

- **Opportunities:**
  I. Cloud storage to monitor the data Remotely
  II. App based to make it more user-friendly

- **Threats:**
  I. Data loss due to load shedding
  II. Damage due to water droplet accumulation
  III. System can be tampered

2.5 Conclusion:

To conclude, we have gone through several aspects of mathematical reasoning, analytical skills, and complex engineering problem issues. In order to choose the best design approach (Design Approach-3) for our system, we compared the functionality phases of the 3 separate design approaches we came up with after completing these tasks.

CHAPTER 3: Use of Modern Engineering and IT Tool [CO9]

3.1 Introduction:

The phrase "modern Engineering Tools" is frequently used in the engineering field. Research, analysis, and comparison are the best ways to choose a “modern” engineering tool. In essence, using a modern engineering tool requires extensive research so that the user can select the best for the task. Therefore, we have done several types of research, literature review, and comparison to select the Modern Engineering tools (Hardware, Software, Simulation) for our “energy monitoring System” project.

3.2 Selection of appropriate Engineering and IT tools:

In any complex engineering problem, we need to research and examine certain criteria for selecting the appropriate modern Engineering Tools. As a consequence, we have found some cutting-edge engineering tools that will be utilized for our complex engineering project's hardware and software phases.

3.2.1: Software and comparison:

Through some research and browsing various websites over the internet, we have identified some of the software that allows us to perform the simulations of the design approaches. We have analyzed each individual software and compared them to select an ideal platform for us to work.

Sci-lab: Sci-lab is free and open-source software which is used for testing algorithms or numerical computation. Also, it can be used for signal processing, statistical analysis, image enhancement, fluid dynamics simulations, numerical optimization, and modeling, simulation of explicit and implicit dynamical systems, and (if the corresponding toolbox is installed) symbolic manipulations. This software has extensive tools with a great support base. Scientists and engineers use MATLAB a lot. Scilab, unfortunately, is not remotely compatible with MATLAB. As long as Scilab is not the most popular of its kind, compatibility will always be an issue. Hence, we have skipped the software.

LabVIEW: LabVIEW (Laboratory Virtual Instruments Engineering Workbench) is a system engineering software for applications that require measurement, testing, and control with rapid access to hardware and data insights. The LabVIEW software offers a graphical programming approach that helps to visualize every aspect of the application, including hardware configuration, measurement data, and debugging. This visualization makes it simple to integrate measurement hardware from any vendor, represent complex logic on the diagram, develop data analysis algorithms, and design custom engineering user interfaces. LabVIEW is the best tool available in the market for real-time control. It can connect with multiple devices to acquire data from sensors and control actuators based on processed data.

PSPICE: It is a general-purpose analog circuit simulator that is used to verify circuit designs and predict circuit behavior. However, it has so many limitations. Such as, it is restricted to circuits with 10 transistors only, doesn't support iterative methods, unavailability of distortion analysis, cannot be used to synthesize the circuit elements, and so on. As it has so many limitations, we are not using this software.

Proteus: This software integrates circuit simulation, PCB design, and single-chip simulation. By providing the best real-time display effects, it also supports the compiling, editing, and source-level simulation of the assembly language of the microcontroller, with built-in assembly compilers of 8051, AVR, PIC, etc. However, insufficient data calculation of the circuit is the limitation of it. As it is more compatible than any other software for us, we've selected Proteus software for our project simulation.

The comparison has been shown in the table below:

Software Name	Portable	PC Specs Moderate	Import facilities	Free to use	Crash issue	Graphs	Pulse	Component Naming	Library Resources
Proteus	√	√	√	×	√	√	√	√	High
Sci-lab	×	×	×	×	×	√	√	√	Moderate
LabVIEW	√	√	√	×	×	√	√	√	High
TINKERCAD	×	√	√	√	×	×	×	√	Moderate
PSpice	×	√	×	×	×	×	×	√	Moderate

Table 06: Comparison of the Simulation Software

By comparing various criteria, we see that Proteus has the most available resources and online forums with a very user-friendly interface. Thus, we have selected to work on Proteus 8 Professional (v8.11) for the simulation part

3.2.2: Hardware and coding:

ESP32 Microcontroller: This is the microcontroller that reads the data from the sensors and processes the data by integrating the code. This MCU has memory storage of 32Mbit and it operates at 3.3V.

ACS712 Current Sensor: To measure the current we are using a digital meter that gives us a definite rating with an error of 1.5%. The rating for this module is sufficient for our project i.e. it is capable of reading currents up to 21 amps.

ZMPT101B Voltage Sensor: The sensor is capable of measuring ac voltage directly from the main source or meter line that enters our house. With high precision, the sensor can measure a peak voltage value of 280V.

LCD Display: The output data is displayed on the LCD monitor. After the calculation is completed in the MCU, the data is transferred to the LCD, which displays the processed data output.

ACTIVE BUZZER: this tool is used for warnings and notifications by creating a sound through the speaker. The model we have used has an operating voltage of 5 V.

3.3 Use of modern Engineering and IT tools:

3.3.1 Comparison of the software for simulations:

We have used proteus software for our simulation. The following table represents the comparison of the softwares which we have identified previously.

Software Name	Portable	PC Specs Moderate	Import facilities	Free to use	Crash issue	Graphs	Pulse	Component Naming	Library Resources
Proteus	√	√	√	×	√	√	√	√	High
Sci-lab	×	×	×	×	×	√	√	√	Moderate
LabVIEW	√	√	√	×	×	√	√	√	High
TINKERCAD	×	√	√	√	×	×	×	√	Moderate
PSpice	×	√	×	×	×	×	×	√	Moderate

Table 07: Comparison of the Simulation Software

By comparing various criteria, we see that Proteus has the most available resources and online forums with a very user-friendly interface. Thus, we have selected to work on Proteus 8 Professional (v8.11) for the simulation part.

3.3.2 For coding:

The platform for the Arduino development environment is "Arduino IDE." It is a quick and effective open source program that makes it simple to develop code and upload it to the device. This application is compatible with all versions of Arduino, ESP, etc. The software has many tools to make coding more user-friendly, including a text editor for creating code. The software connects to the Arduino or ESP hardware to upload programs and communicate with them using the USB ports.

3.3.3 for hardware:

We have used certain hardware components for our project after analyzing the features and criteria that relate to our project appropriately. Therefore, the description of the hardware components is as follows,

ESP32 Microcontroller: This is the microcontroller that reads the data from the sensors and processes the data by integrating the code. This MCU has memory storage of 32Mbit and it operates at 3.3V.

ACS712 Current Sensor: To measure the current we are using a digital meter that gives us a definite rating with an error of 1.5%. The rating for this module is sufficient for our project i.e. it is capable of reading currents up to 21 amps.

ZMPT101B Voltage Sensor: The sensor is capable of measuring ac voltage directly from the main source or meter line that enters our house. With high precision, the sensor can measure a peak voltage value of 280V.

LCD Display: The output data is displayed on the LCD monitor. After the calculation is completed in the MCU, the data is transferred to the LCD, which displays the processed data output.

ACTIVE BUZZER: this tool is used for warnings and notifications Via creating a sound through the microphone. The model we have used has an operating voltage of 5 V.

3.4 Conclusion:

In the end, we have gone through several research papers and analyses to select the appropriate modern engineering tools for our “energy monitoring system” project’s hardware and software part. We have selected the sensors and other equipment that were available in the local market.

CHAPTER 4: Optimization of Multiple Design and Finding the Optimal Solution. [CO5, CO6, CO7]

4.1 Introduction:

To choose the best design approach for our project's multiple design approaches, we have chosen a few criteria. Here, our key purpose was to identify the most appropriate and suitable proposed design that would satisfy our needs, requirements, and specifications.

4.2 Optimization of multiple Design approach:

We have gone through some test cases to optimize the multiple design approaches. The following test are given below,

Design-1	Design-2	Design-3
- **Error rate** of ACS712 = 1.5% - No. of ACS712 for 2 room system=9 So, **Total error** = (1.5*9)=13.5%	At 55.7 unit - Remaining balance = 233.383 - Balance used = 141.617 *True value = 135.52 So, Error Rate = ((141.617-135.52)/141.617)*100 = 4.3%	At 35.3 unit - Remaining balance = 227.1 - Balance used = 146.8 *True value = 147.907 So, Error Rate = ((147.907-146.8)/147.907)*100 = 0.748%

Table 08: Functional Verification of the 3 Design Solutions

The table above compares the error rate for each individual approach. By comparing the 3 designs we see that Design 3 has the least error rate in comparison to the other 2 Designs.

Design 01:

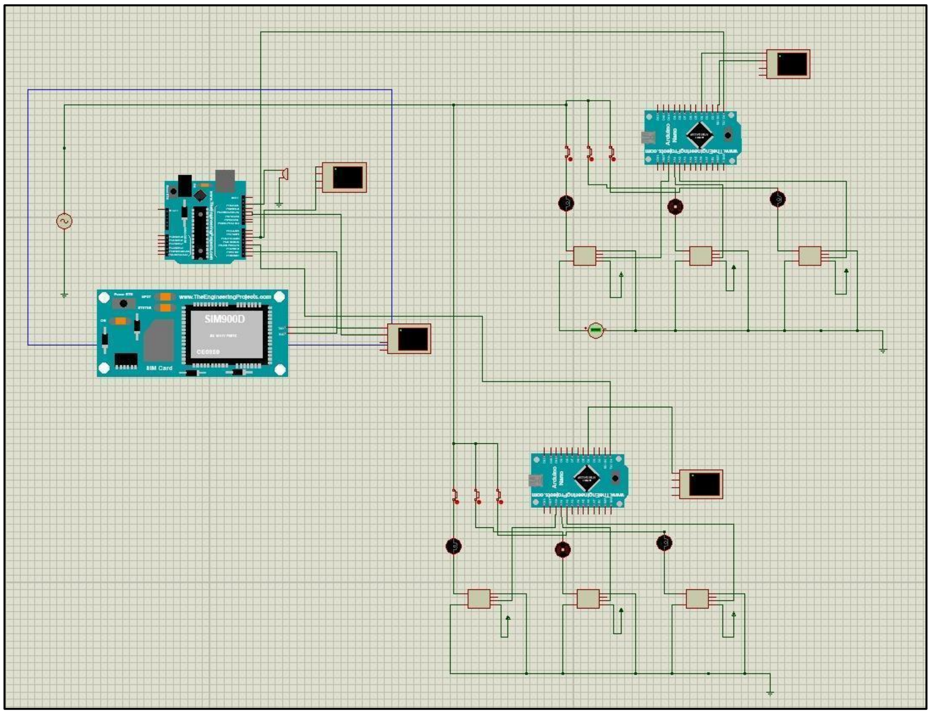


Fig 14: Schematic Diagram of Design Approach 01

We used a microcontroller to store and combine data with the slave Arduino in this technique. The data will subsequently be shown via a mobile app created using a computer programming language. The user will be able to control the data and examine the desired output, as well as a report for the previous 10 days or a month.

[Note: Some modules in Proteus exist as dummy blocks. Hence the processes were not shown in the Proteus Simulations**]**

Design 02:

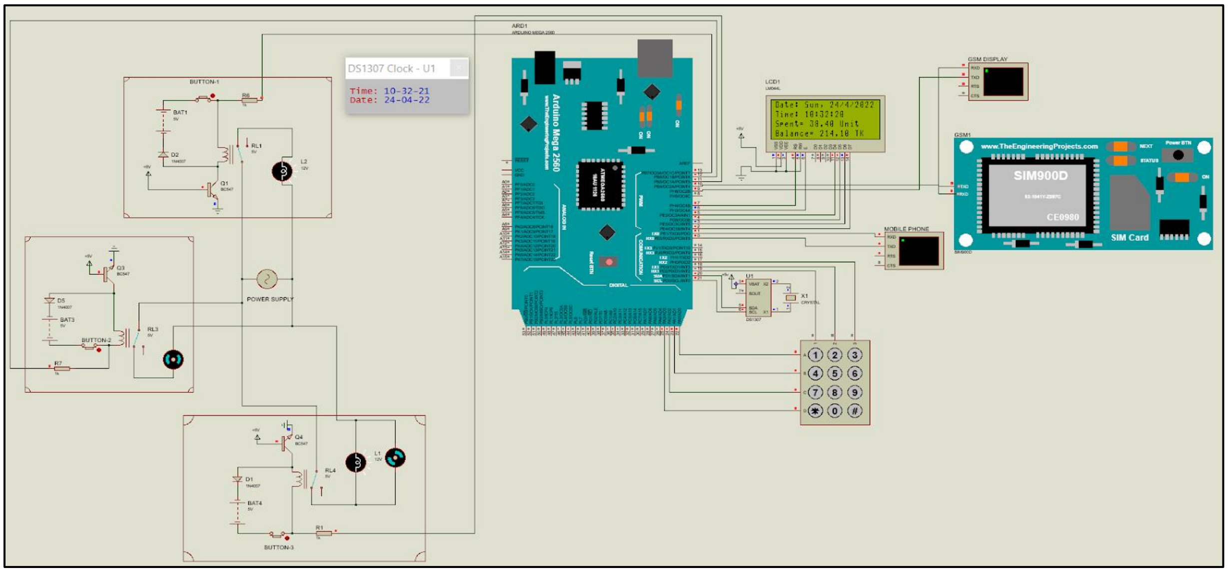
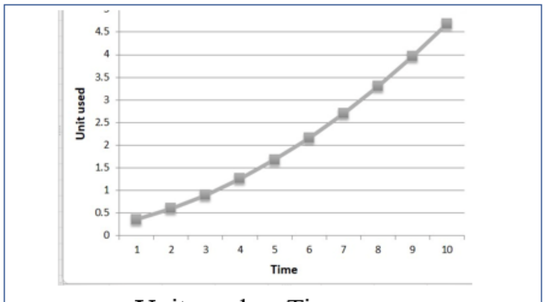
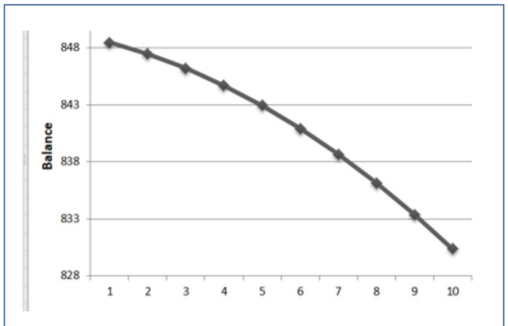


Fig 15: Schematic Diagram of Design Approach 02

Design 2 is based on relay switching. which is being checked by the Arduino that is the load is connected or not. Then it tracks the watt rating and depending on that, it provides the unit, energy as well as remaining balance.



Unit used vs Time



Balance vs Time

The data is being collected from the unit which has been used as spending and plotting it minute by minute accordingly. Also, we are showing the balance decreasing flow from time to time.

Design 03:

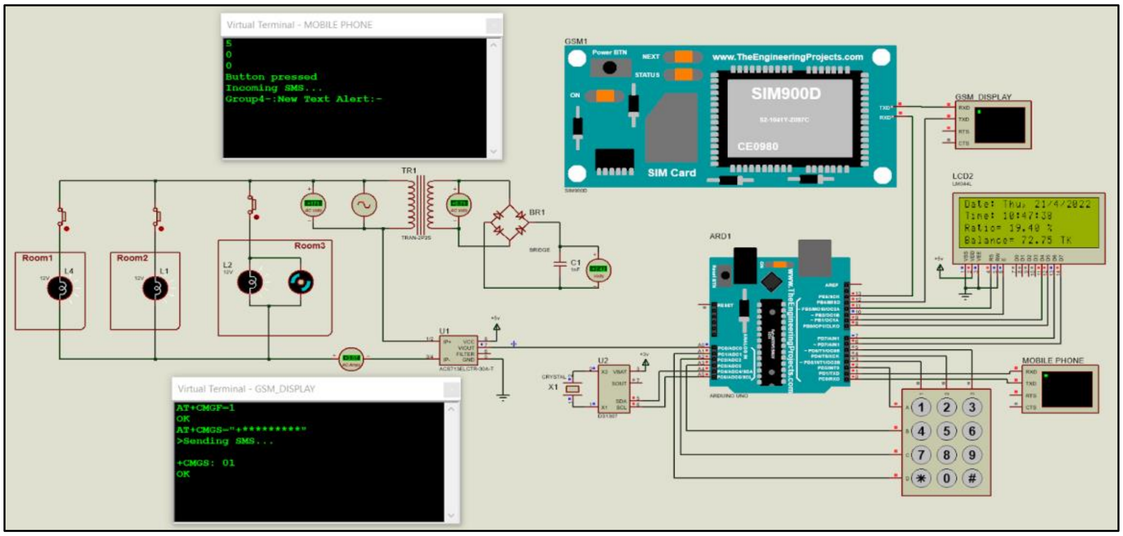
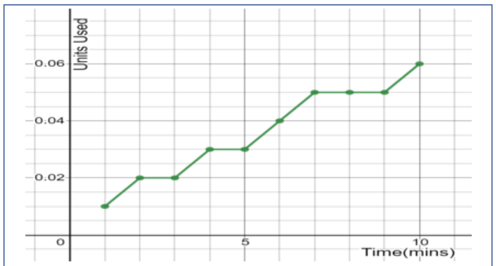


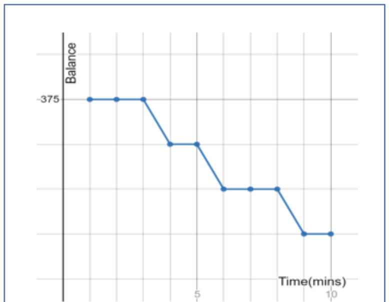
Fig 16: Schematic Diagram of Design Approach 03

As we have predefined that our system is, based on notification through gsm module and taking the data from the circuit breaker. So, we have used Arduino code and this calculation is given below to measure unit, energy, and remaining balance.

This design can show us the current usage value from time to time. It gives us notifications when the remaining balance reaches at 50% and 25%. It sends a message, as a signal to the user so that he or she can be notified when the remaining balance is low. Therefore, our design's functional verification is validated where we are able to show the remaining balance, consumed energy units, and notify the user via SMS when there is low amount of balance is present.



Unit used vs Time



Balance vs Time

In design-3, the data is also being collected (as previously in design-2) from the unit that has been used and plotting it. minute by minute accordingly same as design-2 graph. Also, we are showing the balance decreasing flow from time to time.

4.3 Identification of the Optimal design approach:

We have selected various criteria for our project's design approaches considering cost, efficiency, usability, manufacturability, impact, sustainability, maintainability, etc. Therefore, we have compared these criteria with the 3 design approaches which helped us to select the Optimal design approach for our 'Energy Monitoring System'.

Here to compare the three design approaches we have assessed them on several criteria and the results are tabulated below,

	Design 1	**Design 2**	**Design 3**
Component Efficiency	Uses multiple MCU and sensors to measure data in real-time.	Fixed appliance Unit ratings are taken from the database. Therefore, The transparency of output data is limited.	Uses a single Arduino UNO and sensors to measure data in real-time
Data accuracy	Error rate 14.28% High error rate	Error rate 4.3% Moderate error rate	Error rate 0.748% Low error rate
Manufacturability	The components are available, but bit complex to build. Also, we can set the cloud storage data easily	This system is based on relay switch. Which will be dependent on database, there are less sensors	This is based on data from circuit breaker. It requires digital sensors
Maintainability	There are more than 1 MCU, and the data is based on cloud storage. Here the maintenance is complicated.	Depending on transistors and relay, with each switch board. Which is easier compared to previous.	No internet connection in this system. Since the parameter are from the sensor so this system is simple to maintain.
Feasibility	This design has complexity. There are both nano and uno as MCU. And the code implementation is quite challenging.	The relay, BJT, pull down resistor's combination is a bit tough and there is only one MCU and the code direction is in moderate level.	The current data is sensing and direct to MCU. And its code is simple
Budget	9950	5600	4650

Table 09: Comparison of alternate design approaches

After the comparison, we have come to the decision to elect Design 3 to be our optimal design solution as it outshines the other two designs in more than one category.

4.4 Performance evaluation of developed solution:

For the implementation of the optimal design solution, we had to make some changes in the hardware section as we came to know about many alternative devices which are better performing, cheaper, and come with a number of built-in systems.

4.4.1: Implement the selected design solution:

In our optimal design solution, Design Approach 3, we have selected an Arduino UNO to be the microcontroller unit (MCU) of the system. However, a further search led us to the ESP32 Devkit, a different MCU that performs better and uses fewer parts than the one we originally planned to utilize in our design.

The comparison of the two MCUs for which we made the adjustment can be found in the following table

		Arduino UNO Rev3	**ESP32 DevKit**
General	**Dimensions**	2.7¨ x 2.1¨	2¨ x 1.1¨
	Pricing	800-1100 tk	750-950 tk
Connectivity	**I/O Pins**	14	36
	PWM Pins	6	16
	Analog Pins	6	Up to 18 *
	Analog Out Pins (DAC)		2
Computing	**Processor**	ATMega328P	Xtensa Dual-Core 32-bit LX6 microprocessor

	Flash Memory	32 kB	4 MB
	SRAM	2 kB	520 kB
	EEPROM	1 kB	-
	Clock speed	16 MHz	Upto 240 MHz
	Voltage Level	5V	3.3V
	USB Connectivity	Standard A/B USB	Micro-USB
Communication	**Hardware Serial Ports**	1	3
	SPI Support	Yes (1x)	Yes (4x)
	CAN Support	No	Yes
	I2C Support	Yes (1x)	Yes (2x)
Additional Features	**Wi-Fi**	-	802.11 b/g/n
	Bluetooth	-	v4.2 BR/EDR and BLE
	Touch Sensors	-	10

Table 10: Comparison between Arduino UNO and ESP 32

Some slight modifications to Design 3 were made such as the use of a Voltage sensor (ZMPT101B) to compare the monitor voltage in real-time. The current sensor available in the market during the development of the project is ACS712 which works the same as ACS713. The ACS 712 model comes with three different ratings and for our project, we decided to use the 30A rated Model as it was the highest rated current sensor. Rather than using a GSM Module for sending SMS to individual users, we found an Internet-based SMS system that was more efficient.

4.4.2: Performing tests of the Implemented solution:

We have chosen to build a model of a typical two-bedroom house in order to test how the designed model operates. To create the house model, a design of a real house model was acquired, and the accessories like lights, fans, switches, circuit breakers, etc. were bought. Below is an overview of the house model's design and wiring.

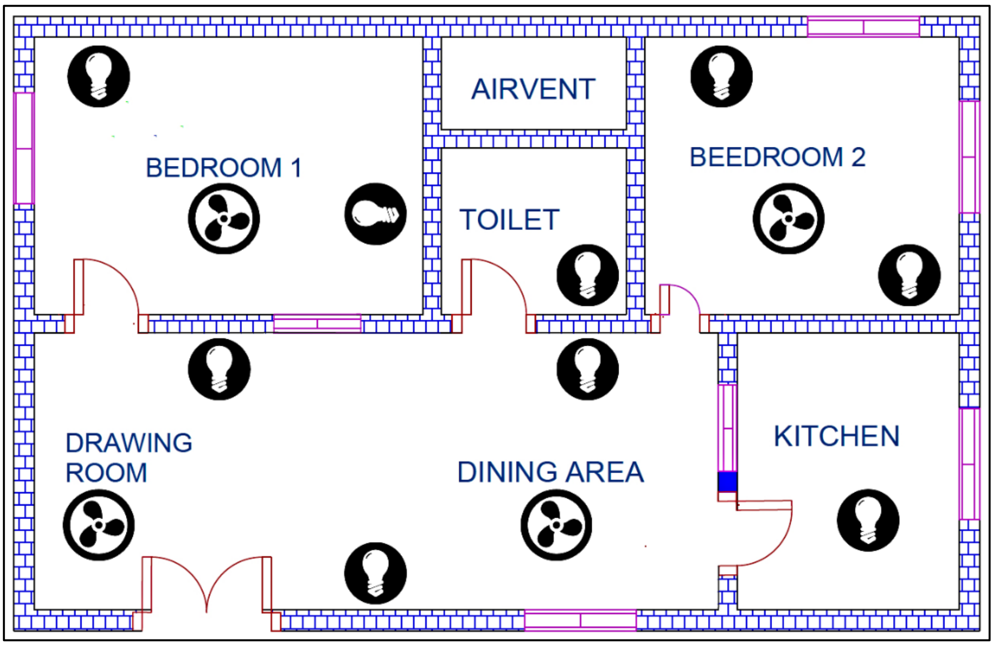


Fig 17: House Model Plan for a 2-bedroom flat

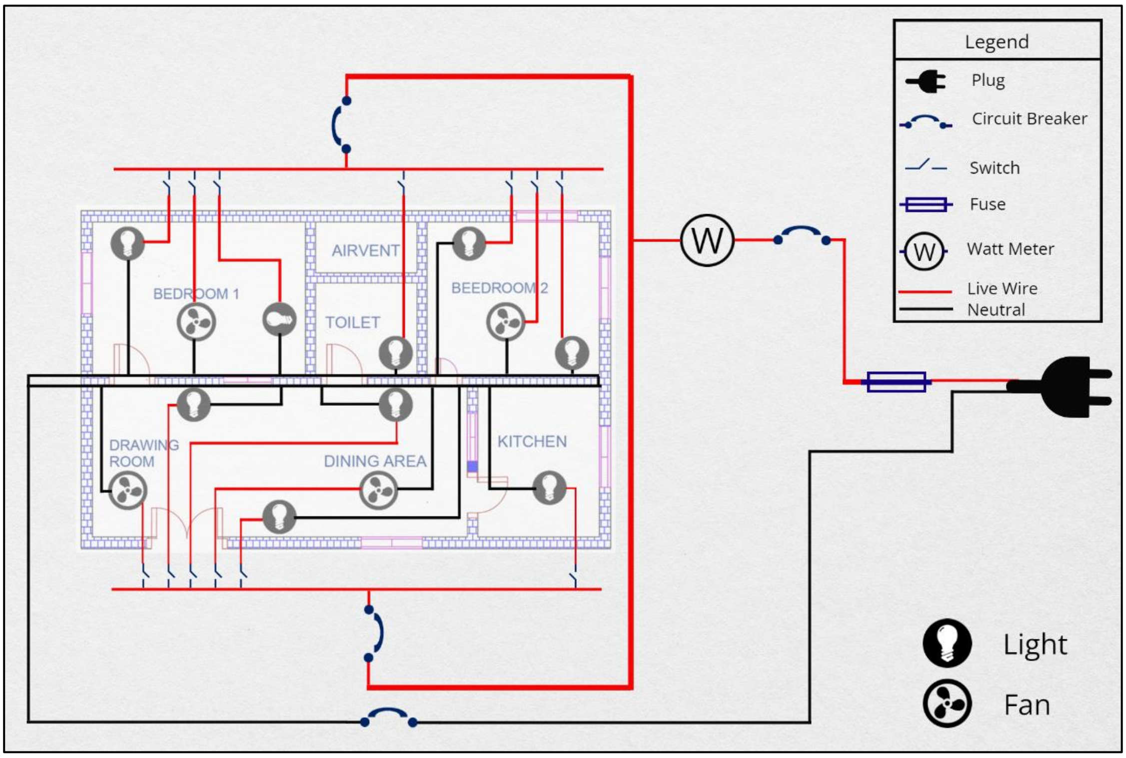


Fig 18: Wiring connections for the 2-bedroom flat House Model

We have connected our sensors with the housing model and obtained readings from that to see whether the design can actually perform for an actual system. Here for the light bulbs, we used LED bulbs of 5W each and we purchased some mini AC fans, each rated 30W.

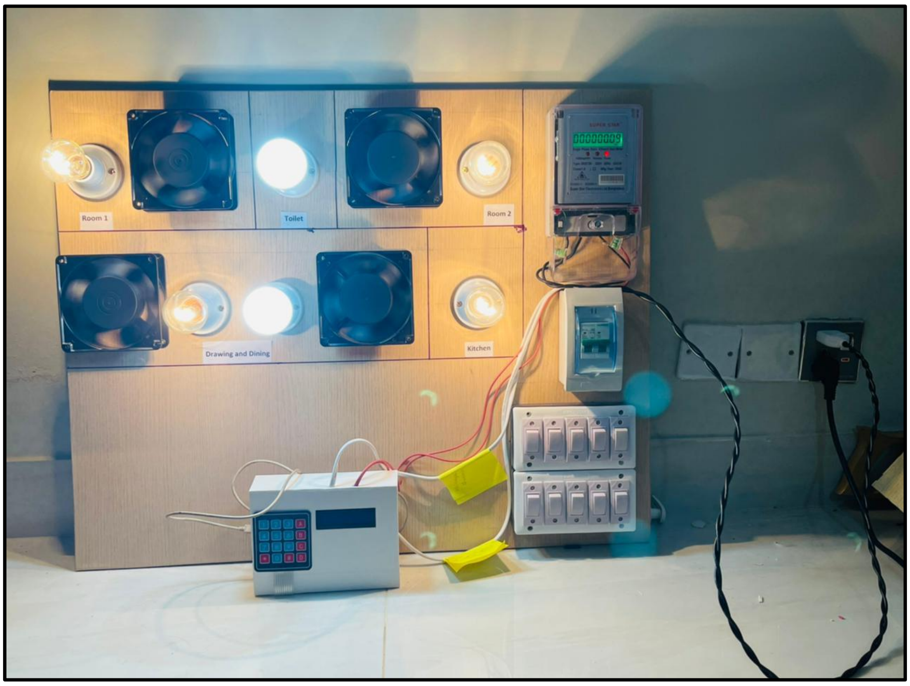


Figure 19: House Model on which the system was tested.

4.4.3: Evaluating the performance of the implemented solution:

To determine whether the numbers acquired from our system were reliable, we compared the readings we obtained from the sensors with an energy meter for the evaluation of the monitoring system.

Fig 20: The Energy Meter used in our project to verify the data

To check the accuracy of our system, the voltage sensor's calibration was completed, and the findings were compared with a multimeter reading.

We also put our system to the test by having it run throughout a specific time of day. As a result, we were able to determine if the system would still work as intended during prolonged, continuous use. We observed the data as the test ran to look for any irregularities.

Duration (min)	15	30	45	60	75	90
Voltage Reading (V)	229.87	230	227.90	231.34	230	230
Power Consumed (KWh)	0.04	0.07	0.11	0.16	0.19	0.23

Table 11: Data collected during the experiment (at BRAC University)

We discovered throughout the testing that the voltage swings and is not constant. During the testing, it was discovered that different places have varying voltage ratings, even though this fluctuation was extremely low (less than 5V) and the voltage reading was roughly 230 V. While performing such an experiment we found that some areas have a voltage supply as low as 207V (Niketon Housing Society) but it does not increase above 237 V in any areas.

4.5 Conclusion:

According to the market analysis, several changes to the final design were necessary, and some components were substituted for more effective ones. To ensure that we obtained accurate data for our monitoring system, the sensors were calibrated, and test results were compared with the actual or practically used equipment. We have also developed the housing model after an actual 2 bed-room designed flat to run our tests.

Chapter 5: Completion of Final Design and Validation. [CO8]

5.1 Introduction:

For the completion of the smart monitoring system, we divided the tasks into several categories to make the workflow smooth. We did some literature review and datasheet analysis of the components that we are using followed by the calibration of individual sensors and components used for the system. After that, we moved on to full system integration, and then finally we tried to link the system with an app so that the house model can be monitored remotely.

5.2 Completion of the final design:

The actions that need to be taken to implement the smart monitoring system have been identified by our team. To keep track of all the advancements made and to update as necessary, a work breakdown structure was developed. A logbook was kept to provide a clearer picture of the development. Since testing our system in a real room would be difficult and could result in circuit breakers tripping repeatedly if wires are not connected properly, we obtained a real house design to be developed and tested on. The user will have issues if the system is tested in the real room before being tested on a model or prototype, and there is a significant risk of sensor damage if this is done without first understanding the entire load capacity of the user's equipment.

5.2.1: House model system Design:

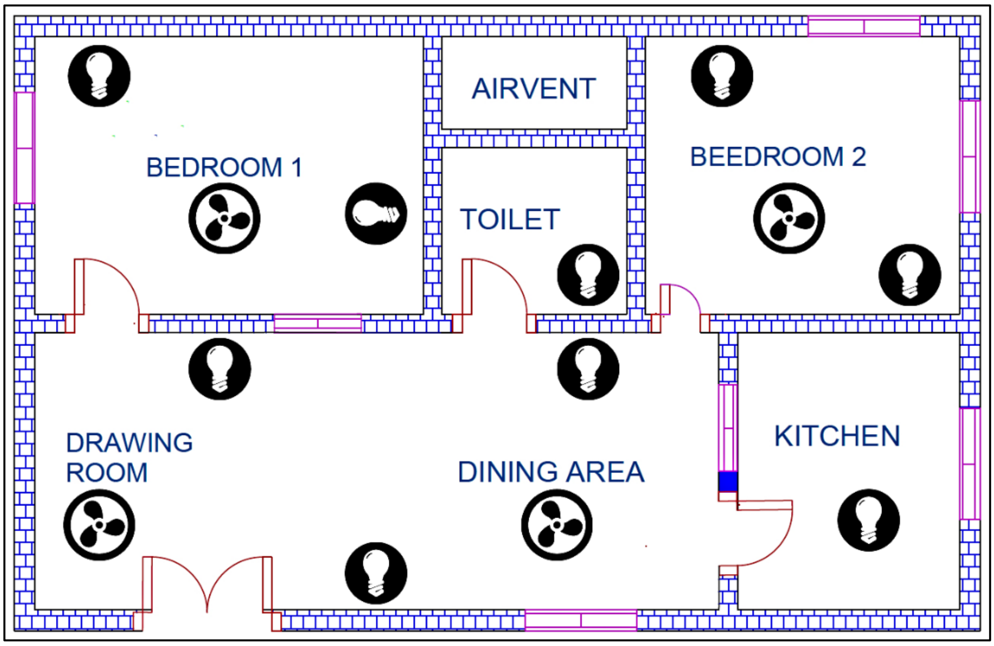


Fig 21: Blueprint of House Model Plan for a 2-bedroom flat

The blueprint of the house model represents a typical 2-bedroom house that most of our targeted stakeholders live in. The type of flat they live in was identified by performing a survey where they shared with us their living conditions, types of equipment they regularly use, their monthly electricity bill, and how it would help them if they could track their daily electrical usage.

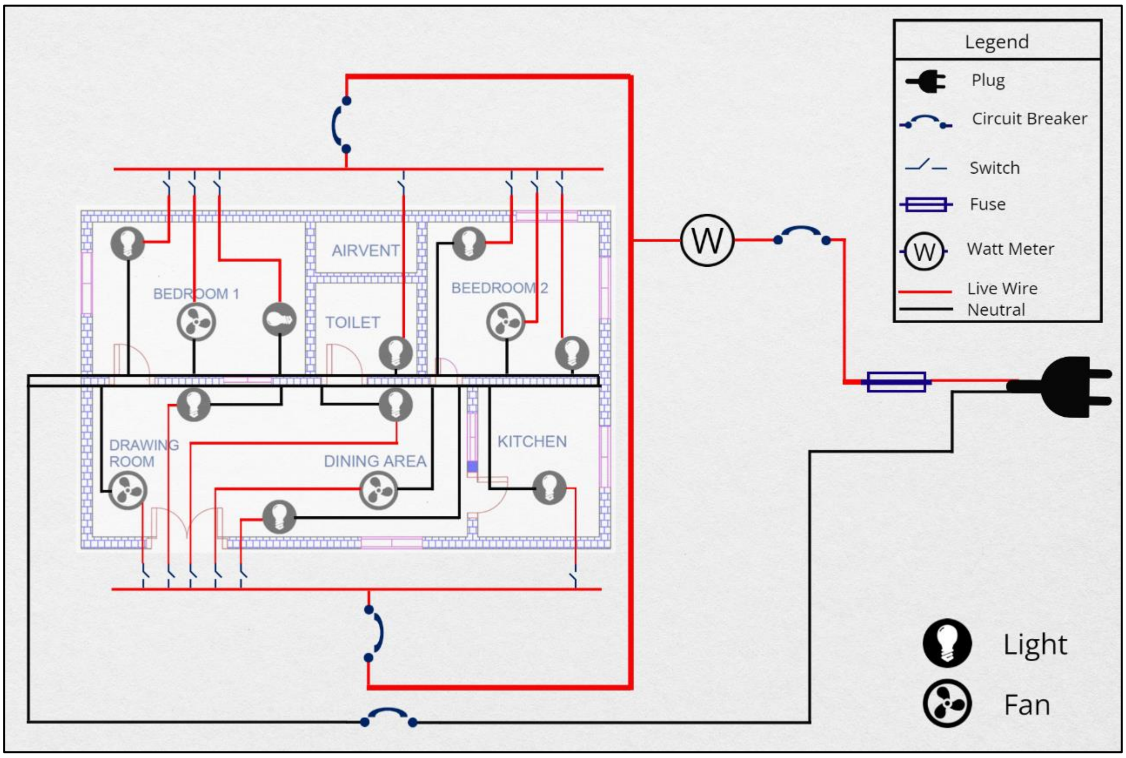


Fig 22: Wiring connections for the 2-bedroom flat House Model

We then counted the total number of lights and fans a household contains and created a minimalistic design accordingly. For the lights, we used LED bulbs of 5W and for the fans, we substituted them with mini AC cooling fans rated 30W.

5.2.2: Individual hardware testing and system integration:

The voltage sensor (ZMPT101B) and the current sensor (ACS712 30A) were the sensors that underwent calibration.

Calibration of Voltage Sensor (ZMPT101B): To establish the supplied load voltage for the dwelling in Bangladesh, we searched the internet. It is claimed that the load voltage delivered by the distributor is in the range of 220-240V at a frequency of 60 Hz.

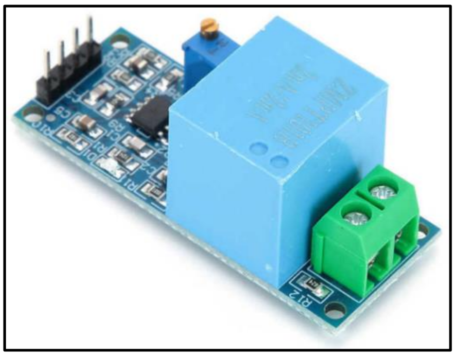


Fig 23: ZMPT101B, Voltage sensor used in the smart monitoring system.

However, it differed in multiple locations. The lowest number we noticed was a measurement of 207V for several regions where the load was verified to be below 220V. (according to the digital multimeter reading). On the other hand, because the highest value we could find was 236.5V, the maximum load voltage observed did not exceed 240V.

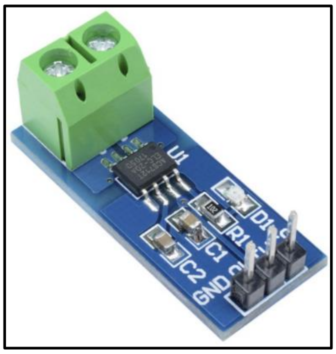


Fig 24: ACS712_30A, Current sensor used in the smart monitoring system.

Current Sensor (ACS712 30A): For the current sensors, we calibrated it using the small ac fans that were purchased as it was problematic to connect an ammeter directly in series with an ac load. The fans' rated current is around 0.14A. To get the rated value, we first linked the sensor to a single fan, watched the readings, and further calibrated it. We were able to achieve a current reading between 0.13-0.17A, even though the results we obtained wouldn't stay constant because of the fluctuating ac current supplied at home. We compared the readings of the current sensors when the fan was switched off to observe values at no load condition.

5.2.3: Blynk app for remote access:

We have integrated the Blynk App into our system to enable remote access. The data is read from the microcontroller (Esp-32) and calculated here using the predefined codes. The App also computes power usage, energy consumption, and prepaid meter balance. By linking the phone to the Blynk server, the user can utilize the internet to remotely monitor the meter's detailed info from any location.

5.2.4: Total system run test on house model:

Fig 25: Initially designed house model for testing the monitoring system.

We first adjusted the sensor readings before installing the monitoring system on the house model to obtain precise data. A 5W LED bulb connected in parallel was tested after it had initially been tested on a small ac fan. Then, as fans consume a higher current than lights do, we connected two more small fans in tandem to test our system. By turning on many loads at once, we tested our system's ability to tolerate an in-rush current of up to 33A before implementing it on the designed house model.

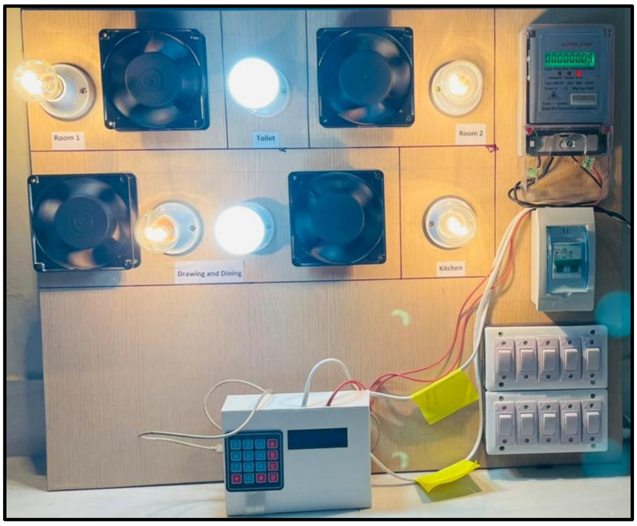


Fig 26: House Model updated after an actual house.

5.3 Evaluate the solution to meet the desired need:

Our design aims to make it possible for the user to remotely check their remaining electric balance. We needed our system to operate with extreme precision and very little margin for error to accomplish this. Further calibration of the sensors was necessary to obtain such results.

5.3.1: Sensor calibration:

The data obtained from our project was fine-tuned to meet the users' requirements and be used for further calibration. We checked the values of our system by comparing them with results obtained from practically used equipment.

ACS712 Current Sensor:

Following the completion of the initial computations, we examined the raw data and calibrated the ACS712 sensor to determine the most recent readings of the entire house model. However, background noise from other electronic equipment was present in the data because of interference. Due to this, even when all of the components in our housing model were turned off, the sensors continued to report readings higher than "0”.

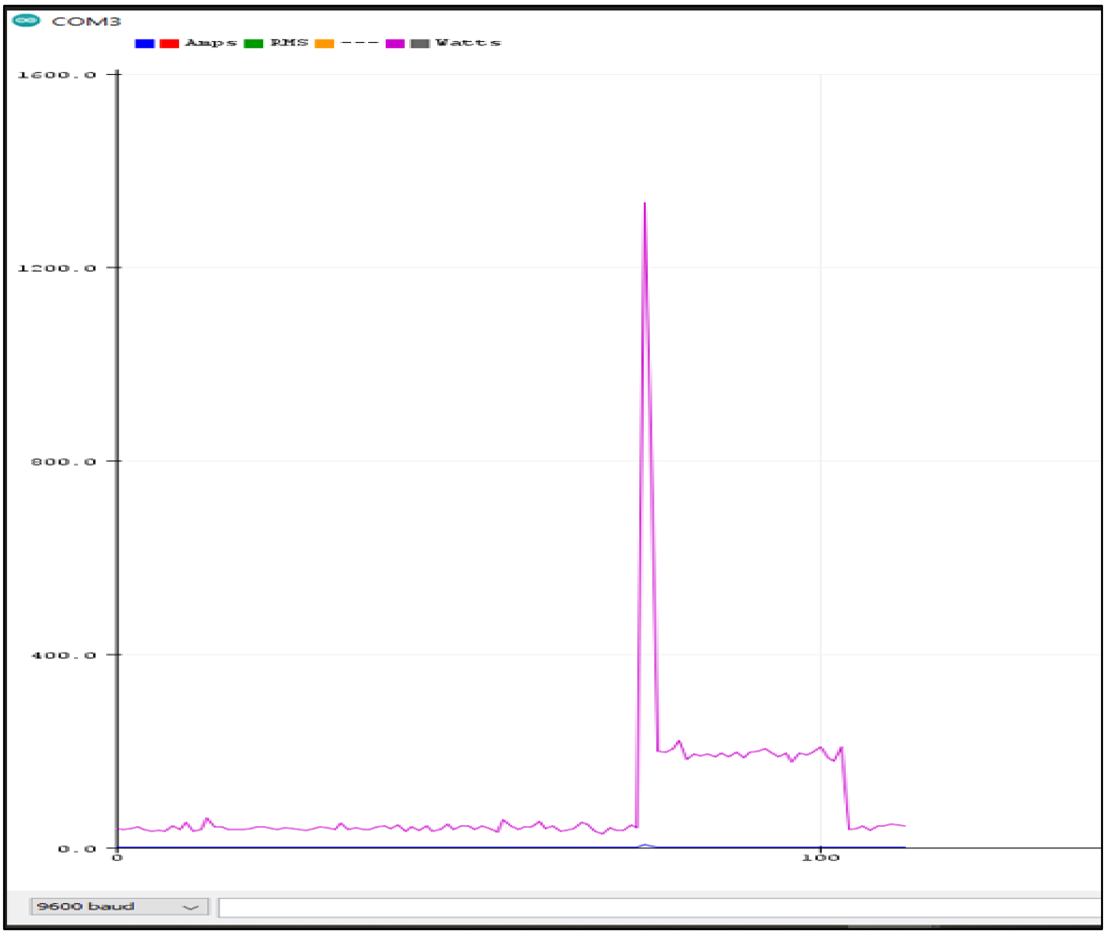


Fig 27: Graph representing the primary calibration of the current sensor

We observed the data at no load condition to find out the peak value it gives and adjusted our calibration factors accordingly. Not only we were able to receive a clean feed but we managed to reduce the fluctuations that our sensors were giving earlier. The graph below is a representation of the data found.

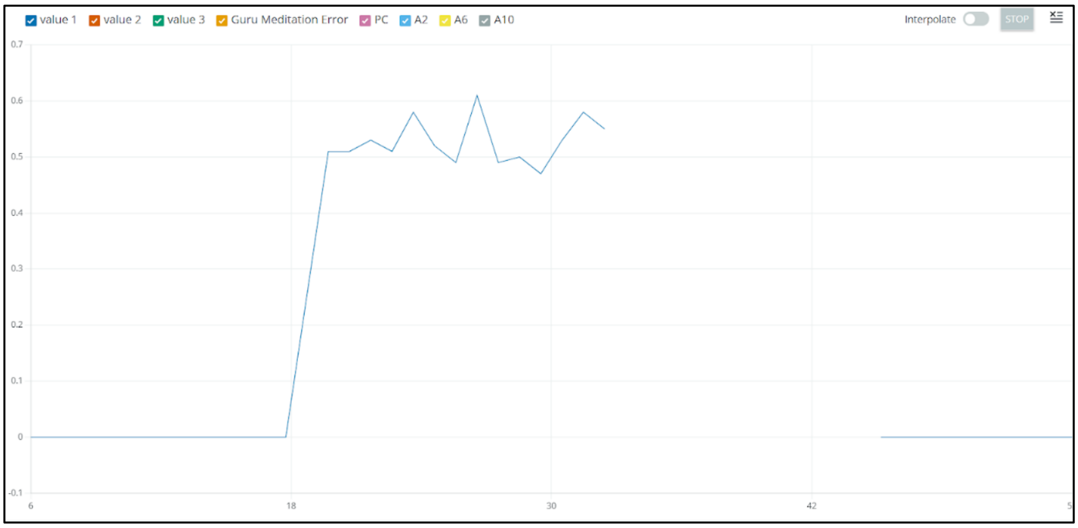


Fig 28: Graph representing the final calibration of the current sensor

Voltage Sensor: In comparison to the current sensor, the ZMPT101B voltage sensor was much easier to set up and values obtained from it were precise enough to be included in calculations. However, we were required to test it on various loads to check and see if the calculations matched the readings of a Digital Multimeter.

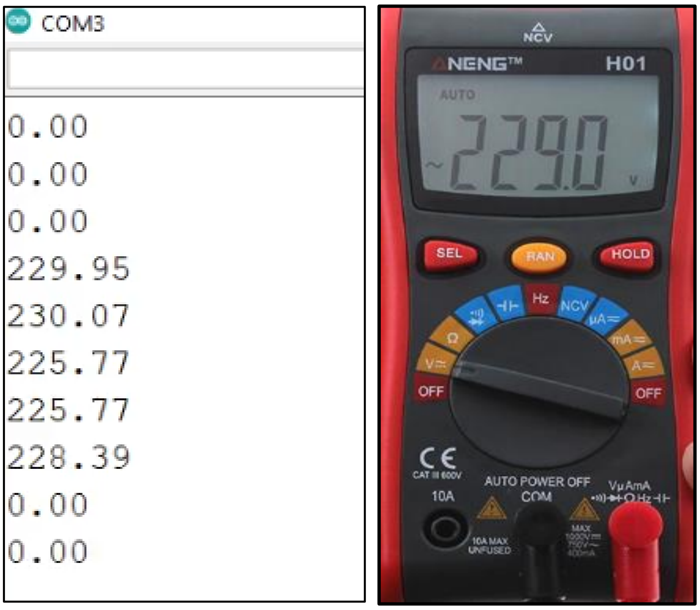


Fig 29: Data found after calibrating the Voltage sensor compared with multimeter reading

5.3.2: App development (Blynk):

We made use of Blynk's app feature to let the user keep track of their electricity bill. The app's user interface was developed with the stakeholders in consideration. The main goal of the app was to make it possible for customers to use their smartphones to check the balance on their electric meters and to create a notification system that would inform users when their balance was low and they needed to recharge. We have included various features in the app.

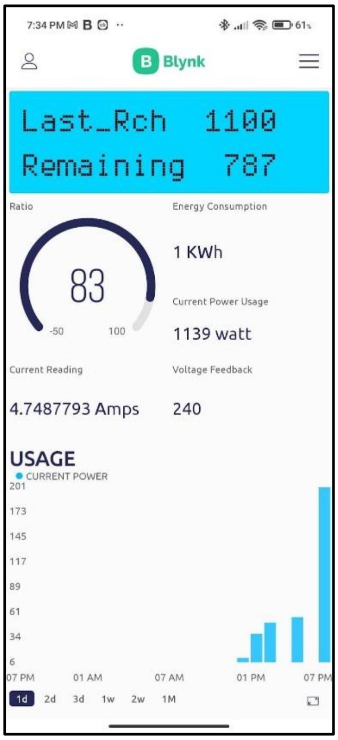


Fig 30: The User Interface we designed using the Blynk App

1. **Showing remaining balance:** the user will now be able to to check how much money they have remaining using their mobile phones without the need to go and check the meter every time.

2. **Showing consumed energy:** This feature allows them to check their total energy expenditure in KWh just like a conventional meter.

3. **Showing bar chart for last 7 days usage:** This is a bonus feature we have designed for the user that will allow them to check their daily usage and make them aware to use electricity efficiently so that they are able to reduce wastage.
4. **Suggesting usage for different phases of balance (50%, 25%, 10%): Continuous real time monitoring (Voltage):** Like a normal house electricity meter, our system is able to show the real-time voltage to the consumers.

5. **Remaining percentage of the balance recharged:** A secondary goal of our project is to make the recharged amount last longer by allowing the user to control their wastage and spread awareness. In order to do so we have set up a ratio that shows the remaining balance as a percentage. The user can see the percentage of the remaining balance (similar to displaying battery percentage) in their app and some notification systems have been set for certain percentages.

6. **Recharge History:** This feature is to show the user their last recharge amount and the date and time of recharge.

5.3.3: Keypad:

Here, a 4X4 Membrane keypad has been installed. The keypad's function is to allow manual entry of the recharge amount into our monitoring system. We used a keypad at the time because we could not sync the information about the actual meter balance with our system. The user must enter the balance using this keypad.

Fig 31: The 4x4 Membrane Keypad we used in our project

The A,B,C and D keys are used as special command keys which function as the following:

A → Current Power Usage

B → Balance Remaining

C → Consumed Units

D → Date of Last Balance Recharge and Recharge amount.

5.3.4: Display:

Here we have used the LM016L display which is a 16x2 Backlit LCD display. Like the conventional method, we have decided to display some of the information by using this LCD.

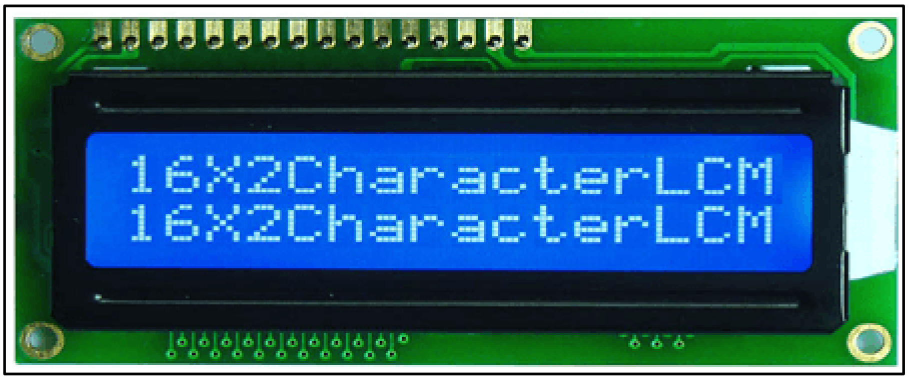


Fig 32: LM016L, a 16x2 Backlit LCD display

5.3.5: Calculations:

The Bill Calculation: After some browsing and searching books, we have identified all the equations that are necessary for calculating the electricity bill. The following list of equations lists all of them that we used.

Power calculation:
P = V x I

V= Voltage RMS Value

I= Current Value Acquired from the sensor

Energy calculation:
E = P x t (Wh)

E = P x t ÷ 1000 (kWh)

Energy Cost = Energy Used in kWh x Time in Hours

Cost Per Hour = kWh x Unit Price

VAT calculation:
Fixed 5% VAT will be deducted from the calculated total energy cost

Meter charge (once a month)

Meter rent per month is = 40 taka

Demand charge:

Per KW sanction load is = 30 taka

Overall sanction load = sanctioned load *30 taka

Tariff Calculation: We have also looked at the updated circulars for Tariff calculations provided by the government of Bangladesh and the costing of individual Electricity Provider Services. After analyzing all the data which we found, we then moved on with the coding part for balance calculations using values obtained from the sensors of the monitoring system.

First Slab: 01 to 75 units	4.19 Taka
Second Slab: 76 to 200 units	5.72 Taka
Third Slab: 201 to 300 units	6.00 Taka
Forth Slab: 301 to 400 units	6.34 Taka
Fifth Slab: 401 to 600 units	9.91 Taka
Sixth Slab: Above 600 units	11.46 Taka

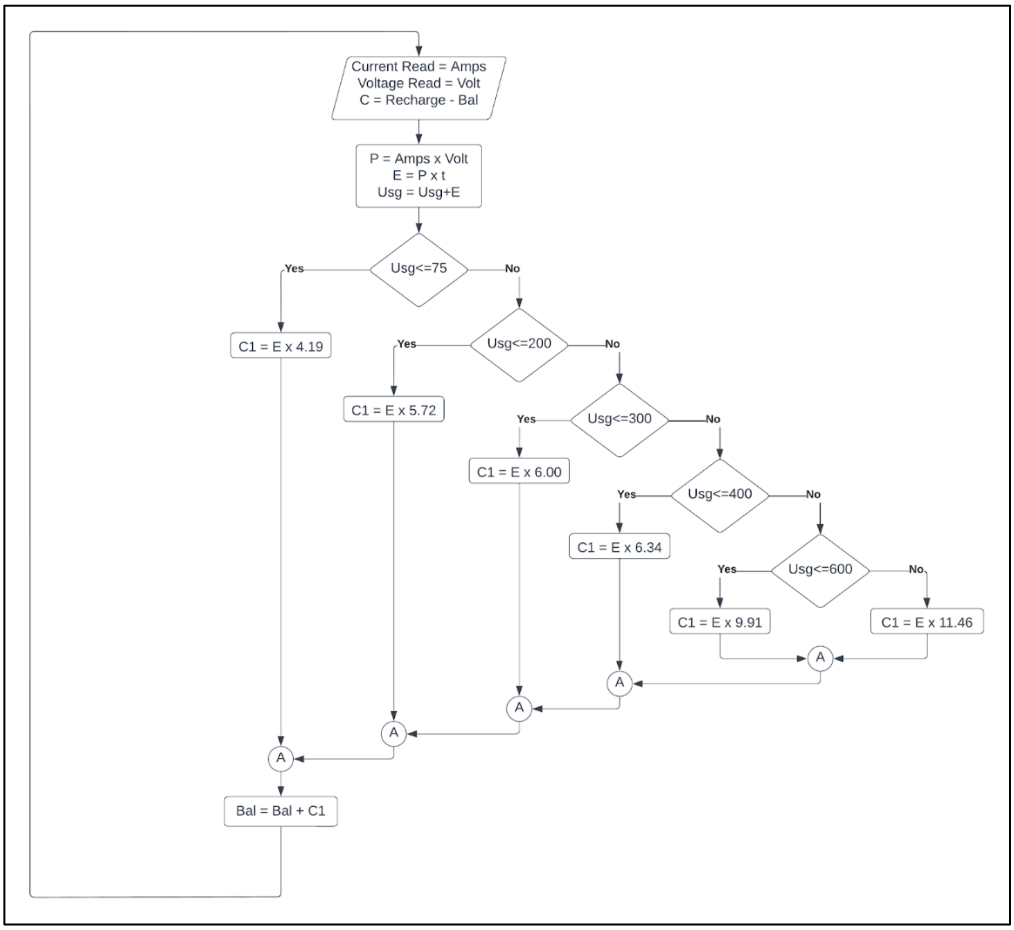


Fig 33: Flowchart representing the tariff calculation used in coding

The code for the Monitoring System: A simplified framework is used to explain the overall code in the flowchart that follows.

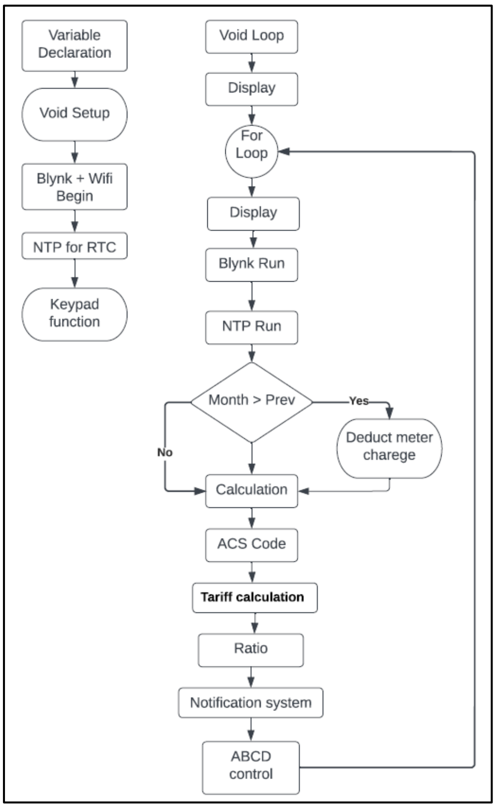


Fig 34: Flowchart showing the overall structure of the code

Data obtained from the system: After the full monitoring system integration was finished, we ran a test on the house model. All of the lights and fans in the house model were turned on during our full load test, and the monitoring system's results were recorded in a spreadsheet.

Per Day Testing		
Hour	Unit Consumed	Balance
0	0	500(Recharge)
0	0	375(Charge Reduction)
1	0.15	374.3715
4	0.6	372.486
6	0.9	371.229
7	1.05	370.601
10	1.5	368.715
16	2.4	364.944
18	2.7	363.687
20	3	362.43

Table 12: Data obtained from testing the model at full load.

Data obtained from the monitoring system vs the actual data from the energy meter:

To verify the accuracy of the data obtained from the system, we compared the total energy consumption reading of our system with the data obtained from the actual energy meter used for the model.

Fig 35: Some pictures of data obtained from the energy meter

The following table is the set of recorded data from the house model by both the energy meter and the smart monitoring system. The table allows us to compare the data for a better understanding of the readings we obtained and the error rate.

	Weekly testing Feedback							
	Day	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Device Data	**Unit Consumed**	3	2.02	2.7	2.98	0.75	1.4	0.97
	Device Balance	362.43	353.966	342.65	330.167	327.024	321.158	317.094
Watt Meter Data	**Watt Meter (Units)**	2.98	2.02	2.69	2.96	0.75	1.37	0.96
	Manually calculated Balance	362.514	354.05	342.778	330.376	327.234	321.493	317.471
Analysis	**Error Rate (%)**	0.02312	0.02373	0.03736	0.0633	0.06422	0.10431	0.11892
	Avg E/R (%)	**0.062137021**						

Table 13: Values obtained in from the smart monitoring system vs the energy Meter data

Here, from the table, we see the data found by running the device for 7 days and comparing the results found from the smart energy monitoring system with that found from the energy meter. After comparison we see that the values obtained are very close with an error of 0.06214% approximately.

5.4 Conclusion:

We split the tasks into different categories for the smart monitoring system's completion in order to facilitate a seamless workflow. Before calibrating individual sensors and system components, we reviewed some relevant literature and examined the datasheets of the components we are implementing. Then, we advanced to complete system integration, and ultimately, we sought to connect the system with an app so that the house model could be observed from a faraway. For sensor calibration, we had to go through the readings over and over again to filter out any noise from the system and calculated the balance of the electric meter using the final values obtained. We designed the User Interface of the app to make the system user-friendly and designed the notification system in a specific way so that the user can remain cautious of their electric meter balance and avoid any disconnection due to using up all the balance.

CHAPTER 6: Impact Analysis and Project Sustainability. [CO3, CO4]

6.1: Introduction:

Like all initiatives, our project is vital to society and will have an impact on a range of areas, including the economy, ecology, and more. Keeping in mind the effects our project would have on the users' lives, we have made an effort to ensure the users' safety when using it in their homes. We have also considered how to make this initiative sustainable.

6.2: Assessment of impacts of the designed solution:

The impacts of our project is carefully analyzed according to the cultural context of our country are divided into different categories and are mentioned below

Economic impact:

Smart monitoring systems provide additional benefits to the user, energy production company, and our environment. This system minimizes the chance of a mistake. It achieves accuracy in the calculation of cost and provides previously unavailable transparency into energy usage. Moreover, users can track their consumption in real-time and can identify waste points, and control spending.

Environmental impact:

According to the United States Environmental Protection Agency (EPA), buildings in the U.S. produce 30% of carbon dioxide partially responsible for climate change. However, some studies show that it is much higher for Bangladesh due to its dense population. Our system aims to notify the customers about their usage so that they can control their habits and reduce electric wastage. In doing so, carbon emissions can be reduced thus decreasing the carbon footprint.

Safety impact:

Since the main goal of our project is to notify users remotely about their daily electricity consumption and remaining balance, they won't need to physically check their daily electricity status by going close to the meter, which will help to prevent them from suffering an electric shock due to the numerous wire connections surrounding the meter.

Societal impact:

As our system notifies about the usage and helps to get the updates of the bill, it assists the user to use less amount of electricity when the usage is too much. As a result, it makes the cost limited and beneficial for society. We are in an era where fossil fuels are almost depleted and there is a gap in electricity demand and electricity generation more than ever. Our project will help customers to use this energy more efficiently and thus reduce the gap between the amount supplied and demanded.

Health impact:

Due to the controlled electricity usage of the concerned users, the carbon emission will be reduced which is harmful to our health. Moreover, the remote monitoring system reduces the chance of receiving a shock from the meter and in some cases will motivate the user to live a healthy lifestyle by altering their habits using the notification system.

6.3: Evaluate the sustainability:

We anticipate that the system we have created will last 10–12 years. We can make sure the system is functioning and capable of producing outcomes with a minimum level of error by using the right protection mechanisms and doing routine inspections. We have conducted surveys of the current systems in addition to testing the product longevity, and we then structured the project to maximize user advantage such as

Economically: Electricity is an expensive resource and users are depending on it for performing their daily activities. But the current system available in our country does not allow customers to monitor their daily energy expenditure. Our project records this information in real-time and assists users in analyzing their consumption. By doing so, consumers can determine their overall costs and expenses, as well as optimize their usage thus reducing the total expenditure.

Environmentally: The device can help the environment because by enabling users to use electricity more effectively, we are reducing E-waste, which can affect the environment. Additionally, consumers will be able to reduce their electricity waste by improving their habits, which will reduce carbon emissions, by managing their energy consumption.

Societal: This initiative was created to conserve electricity in homes by minimizing the use of superfluous appliances because there is currently less electricity being produced due to the shutdown of most coal-based power plants. This energy can be supplied when needed by minimizing wastage in one home, bringing equity to rural areas.

6.4: Conclusion:

We have examined the potential effects of our project in this part on the environment, society, user safety, and how it would affect their health. We have also discussed sustainability issues including the economic and environmental ones. By evaluating the sustainability of this project on a number of criteria, we can contribute to its lifespan, improve society, and thus look toward a better future for our nation.

CHAPTER 7: Engineering Project Management [CO11, CO14]

7.1: Introduction:

Engineering project management is a very vital terminology where the main aim is to keep the project on time, on budget, and aligned with all relevant specifications. Here, we looked into and analyzed a number of engineering project management-related topics, made a Gantt chart, assigned tasks fairly among the group members, and assessed the project's success using a set of criteria.

7.2: Define, plan and manage Engineering project:

Any engineering project contains a management sector where the work, time, and responsibilities have been distributed according to the plan. Here, we have done the same for our FYDP (Final Year Design project) management.

7.2.1: Definition of project management:

The engineering project management contains project planning, and communication with the stakeholders as it involves the identification of project objectives, requirements, and specifications. The main motive of engineering project management is to secure and complete the project within the due time, on budget and meet the demands of the consumers. Here, the basic criteria/skills that are needed to complete the project within the due time are given as follows,

- Risk management
- Stakeholder management
- Procurement
- Quality assurance
- Process integration
- Timing, cost, and scope of the project
- Communications

7.2.2: planning of the Engineering project:

We have planned a WBS (Work Breakdown Structure) for planning our “energy monitoring system”. Here, this process helped us to conduct our project in the 3 phases within due time,

Flow Chart of the project:

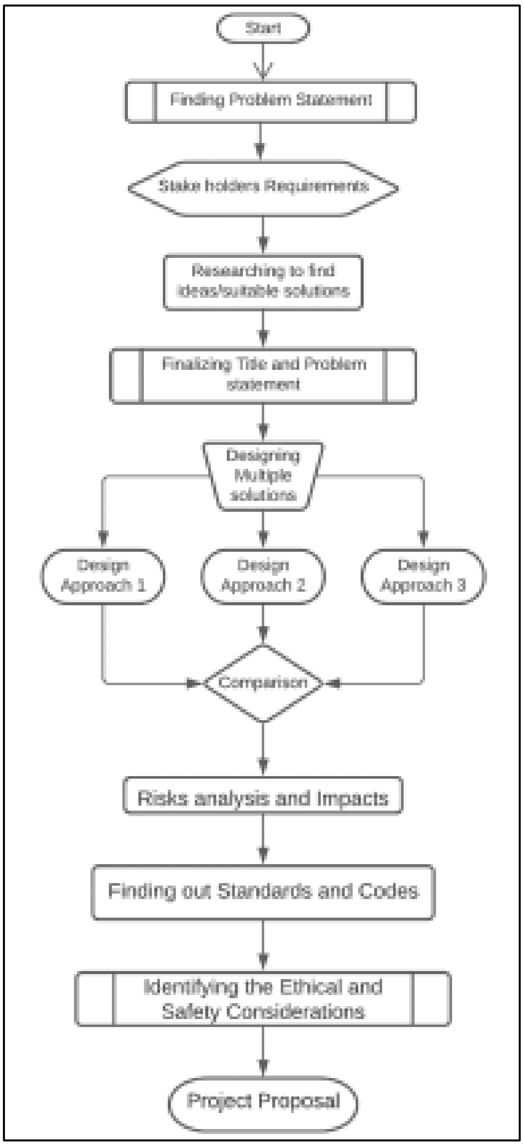


Fig 36: Flowchart representing the methodology of the project for FYDP P

Our FYDP project's flowchart diagram begins with the phase of determining the problem statement based on a real-life complex engineering problem. Then we spoke with potential project stakeholders and inquired about their needs and expectations. Following that, we looked through research articles in order to come up with some possible answers to the topic we are working on. Finally, we have come up with some viable options and have decided on a project and problem description. Furthermore, we have chosen three design methods as our project solution and compared them, analyzing the risk and repercussions that may arise during the implementation of this project. After that, we looked into the standards and codes which are related to our project, and also, we identified some ethical considerations and safety measurements before finalizing the project proposal. In the end, we submitted our project proposal report.

We have divided our work for the project into 3 phases. These stages include the following

Phase 1:

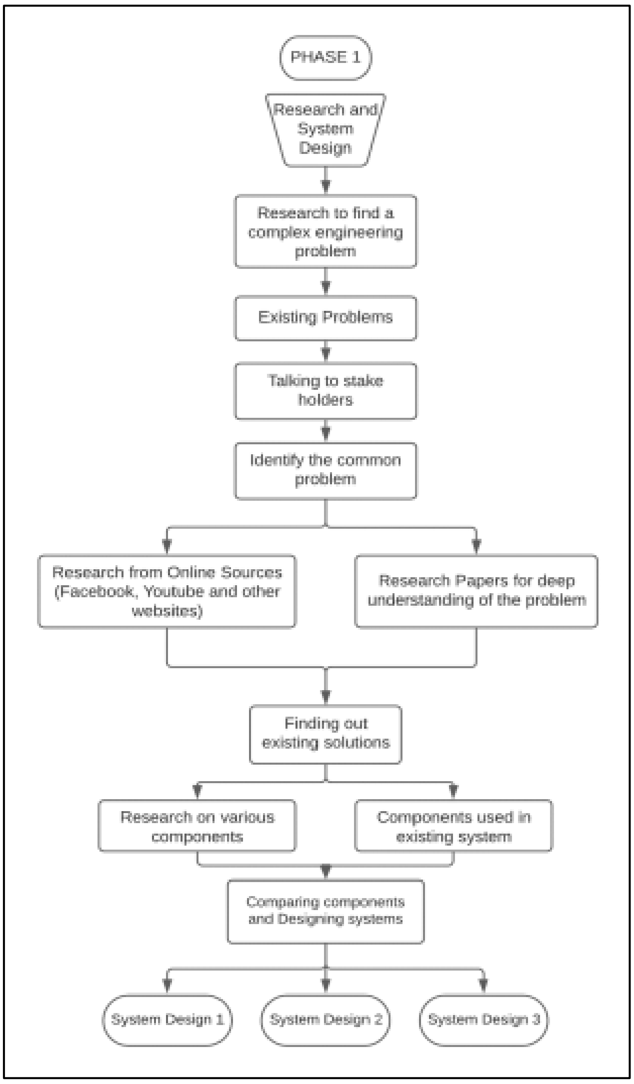


Fig 37: Plan for identifying the problems to find appropriate design solutions to solve them

In this phase of our project, we have researched a few papers to get a complex engineering problem. Then we talked to the stakeholders about what type of problems they are facing and we tried to find some existing solutions. Following that, we compared components and design systems and we came up with 3 system designs.

Phase 2:

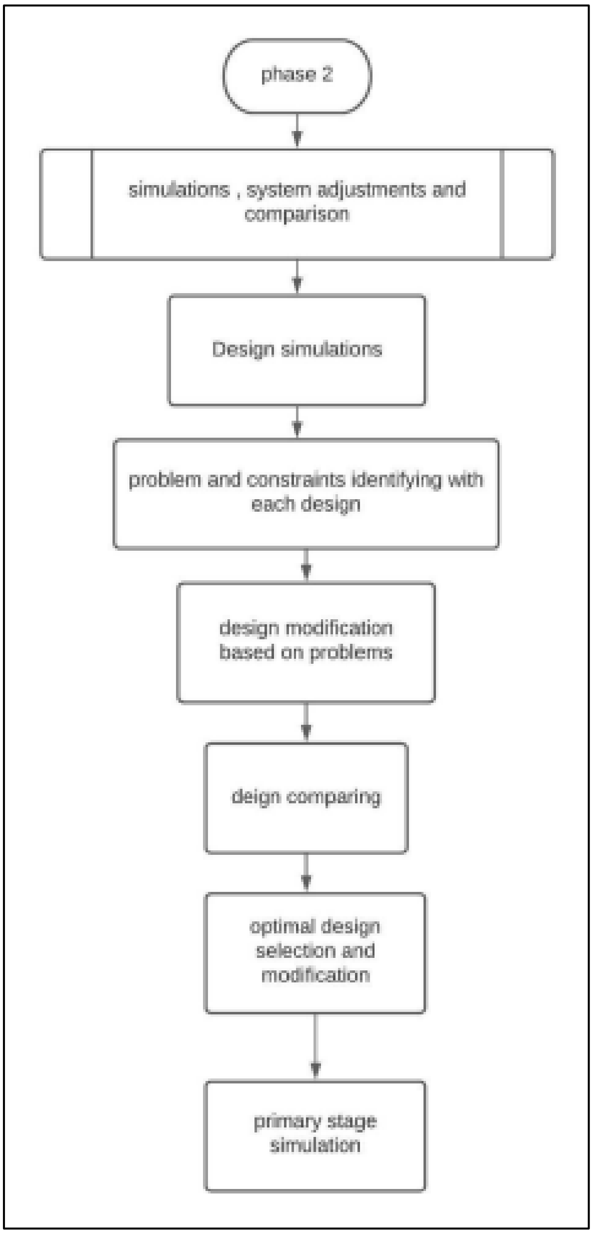


Fig 38: Planning for developing the hardware model of the identified optimal solution

In this phase, we will simulate and adjust our designs. Then we will figure out problems and constraints with each of our designs. After that, we will be modifying our designs based on the problems we have identified. Then we will be comparing our designs and select the optimal design. Now, we will start our primary stage simulation.

Phase 3:

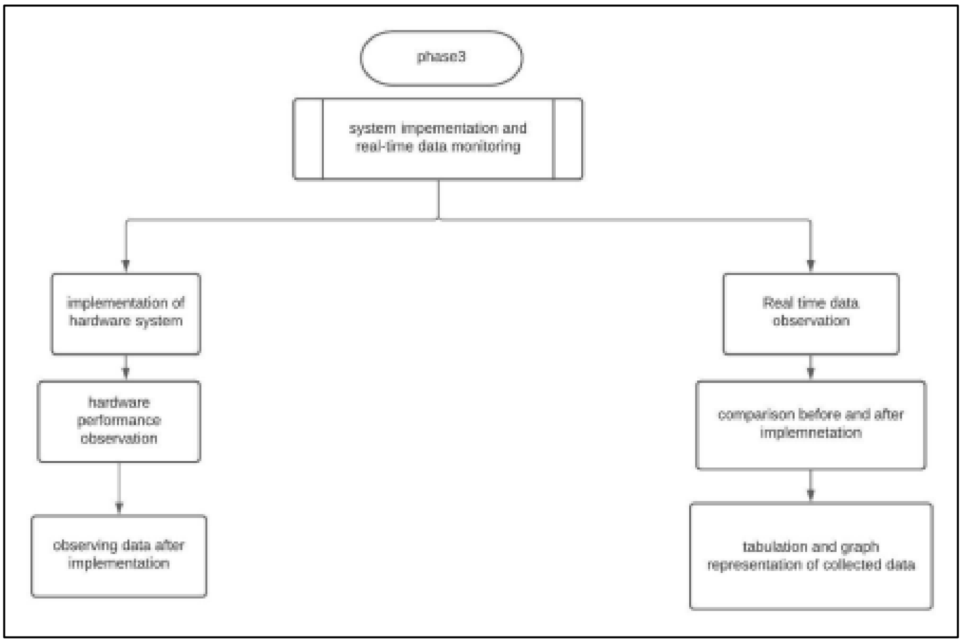


Fig 39: Planning for the implementation of the system to obtain data and verify them

In this phase 3 of our project, we will implement the system and monitor real-time data. Then, we will compare the data before and after the implementation of the system.

7.2.3: Project planning/Gantt chart:

We have created a Gantt Chart for each semester of our project. In general, Gantt Chart is a process where we distribute our work for the whole semester in-group members and also in dates.

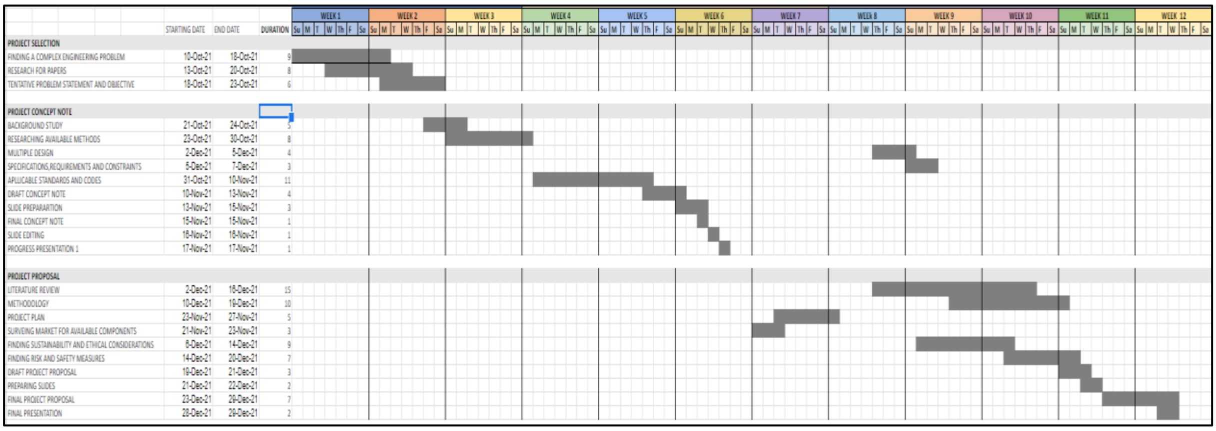


Fig 40: Gantt chart for FYDP_P

EEE400D Gantt chart:

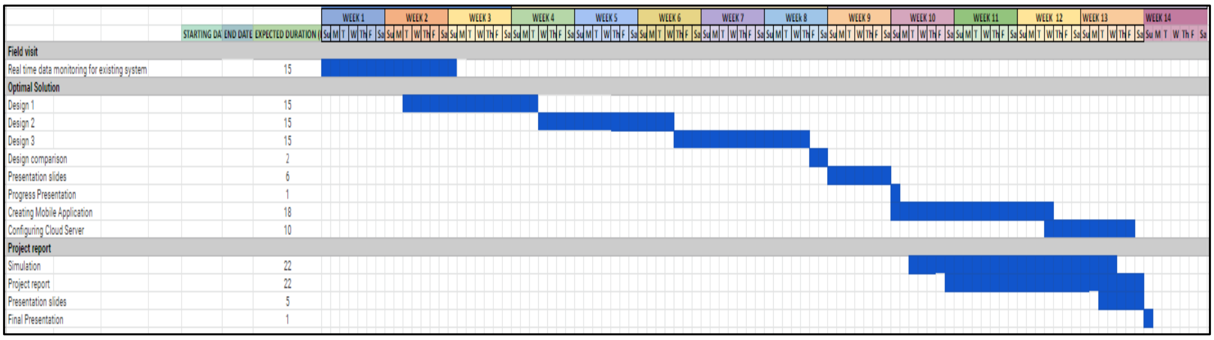


Fig 41: Gantt chart for FYDP_D

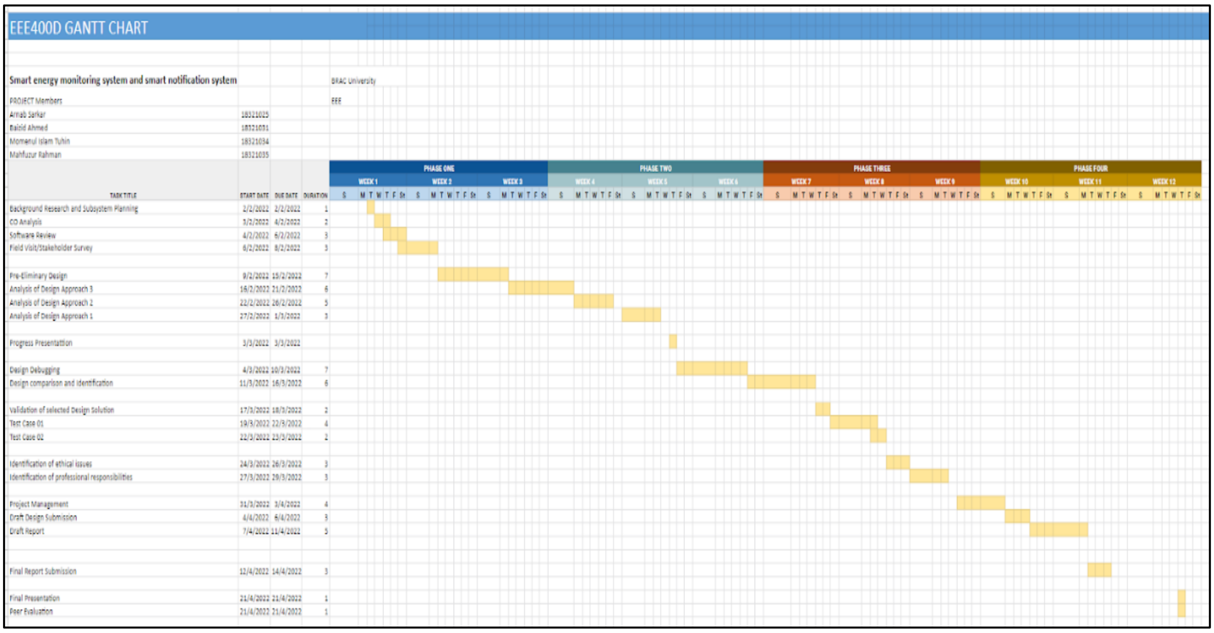


Fig 42: Gantt chart for FYDP_D (Updated version)

EEE400C Gantt chart:

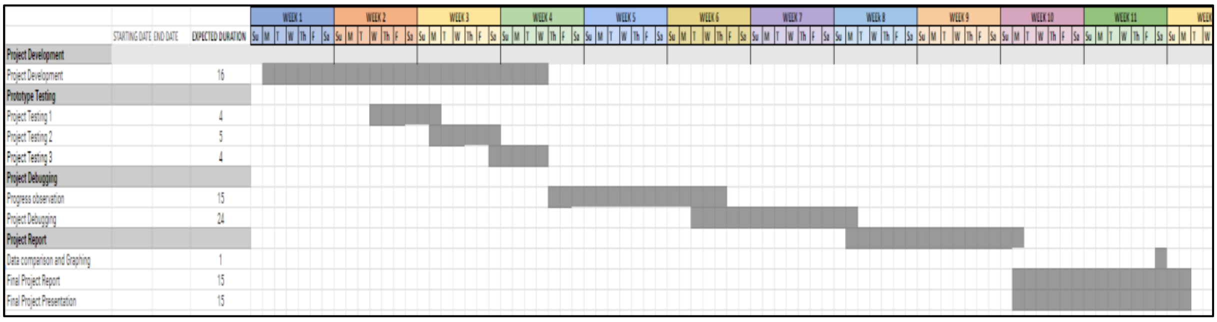


Fig 43: Gantt chart for FYDP_C

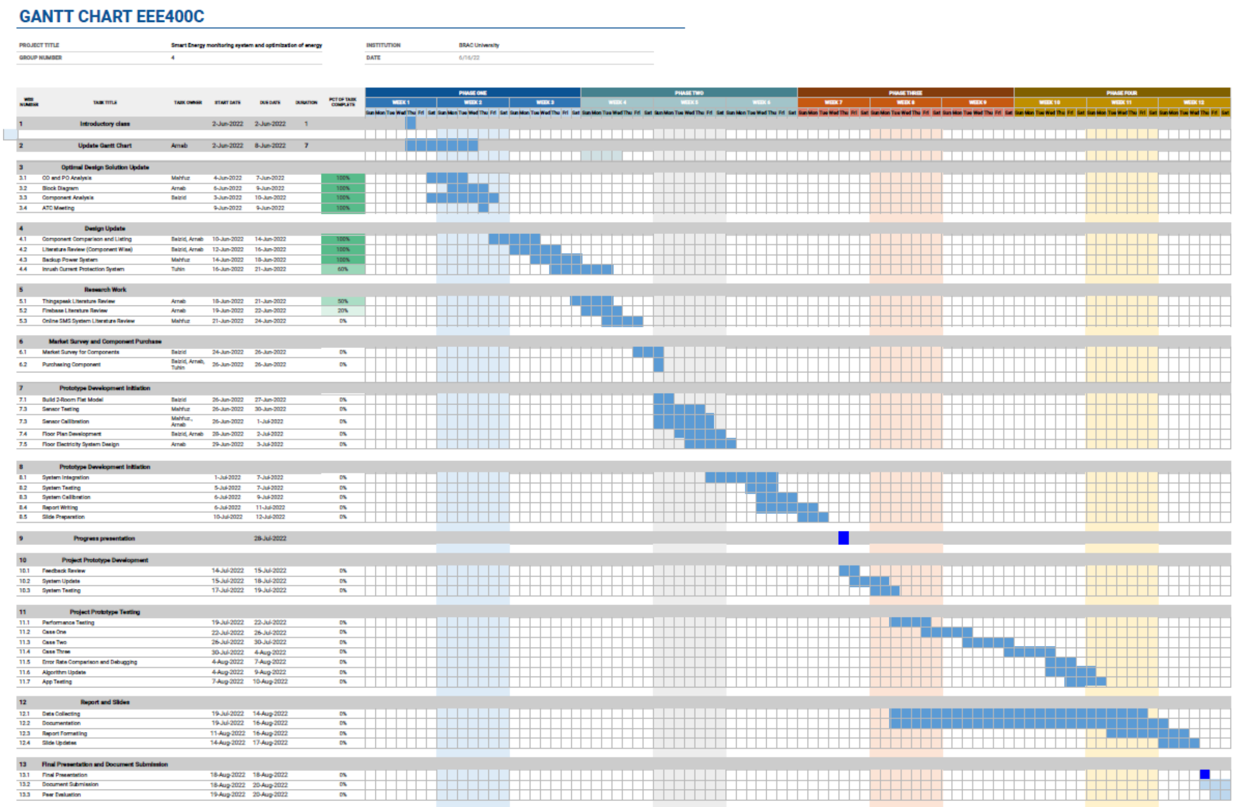


Fig 44: Gantt chart for FYDP_C (Updated version)

7.3: Evaluate project progress:

We have done various tasks to build the project. Here, throughout the 3 semesters, we have distributed our project work among the individual group members. Therefore, we have followed several works to organize the project work accordingly.

- WBS(Work Breakdown Structure) for project framework.
- Gantt Chart to complete work in due time.
- Maintaining Logbook to track members' activeness towards their responsibility.
- Completing Peer-evaluation forms in each semester to evaluate each group member's contribution in the project.

FYDP_EE400C_TEAM_04			
Responsibilities			
-Arnab -Baizid	-Arnab -Mahfuzur	-Arnab -Baizid	-Mahfuzur - Arnab
House Model Completion	Sensor Calibration	Report and Slide Writing	BLYNK App
Using 6 Lights (5W) and 4 Fans (33W)	ACS712(Current sensor) Calibration check	Writing Draft Report Following the instructions accordingly	Observations
Developing housing Model for prototype testing	Voltage sensor (ZMPT101B) precision check	Writing down the final report chapter wise	-Real-time data -Daily electricity usage -Voltage outputs -Total power usage -Bar chart showing Energy usage of past 1 month
Manually Calculate Total power calculation	Selecting commands for Keypad		
	Buzzer connection with the main System		

Table 14: Contribution of individual group members

7.4: Conclusion:

To conclude, we have analyzed the terms of project management skills and criteria, and we have incorporated those points into our FYDP (Final Year Design project) . Therefore, by maintaining Logbook, Gantt Chart, Peer evaluation form we have distributed our project's work fairly to complete the project in due time, and on budget.

CHAPTER 8: Economical Analysis [CO12]

8.1: Introduction:

Engineering economics is the study of whether a project is worthwhile. Here, the expenditures are incurred immediately, which is the primary issue. A specified set of economic analysis requirements must be met for an engineering project to be completed. Therefore, a project developer might detect the economic impact on his project by analyzing and evaluating those factors. Therefore, we have gone through various factors to make our “energy monitoring system” project more economical and cost-friendly.

8.2: Economic Analysis:

In any engineering project, there are various aspects that help the manufacturer of the project to determine the relation of economical factors. The analysis points are as follows,

- **Concept of macroeconomics:**

  Macroeconomics is a bigger view as it's a system of the overall performance of global and national economics. Here, it also covers the larger areas of the engineering field, like GDP, Fiscal policy, etc. Basically, the external factors of economics related to an engineering project are emphasized.

- **Concept of microeconomics:**

  Microeconomics is a smaller aspect of economic analysis where it is related to the comparisons of initial and final product features and their effect on the local dealer, stakeholders and service providers. Here, Land, Labor, Capital, etc.

- **Phases of the project to estimate budget:**

  The engineering project contains certain phases where it helps the engineer to estimate the project overall budget.

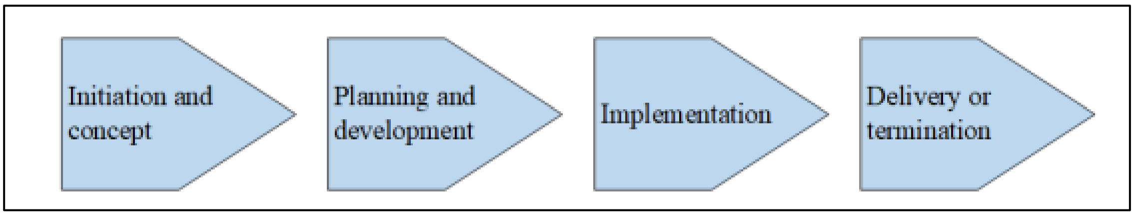


Fig 45: Phases of an engineering project

- **Economical Planning:**

This part includes various factors which help us to determine and analyze the economic aspects of any engineering project.

1. **Cost estimation:** the cost estimation is an estimation that engineers do at the beginning of the project. Here, throughout the developing process information, data and actual scenarios the cost estimation is being created.

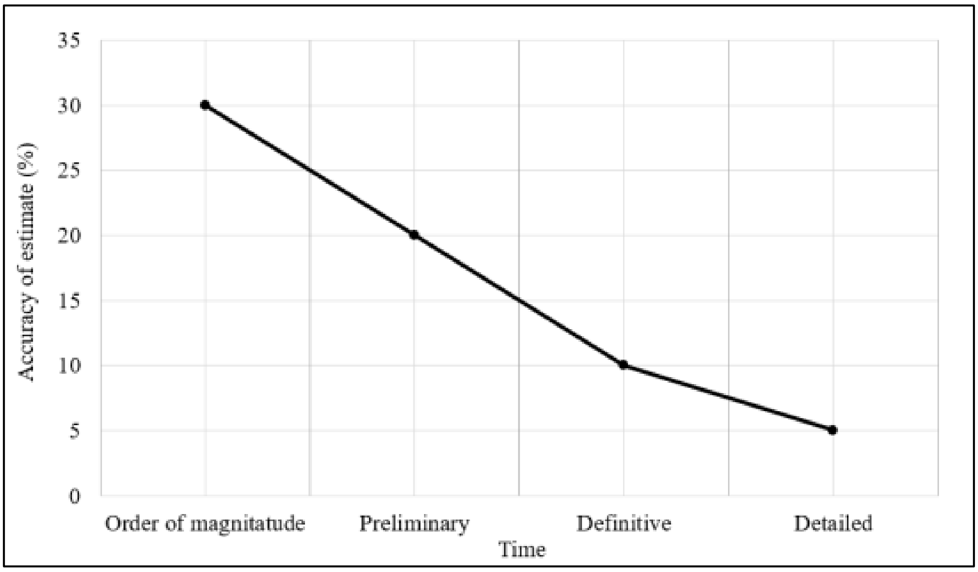


Fig 46: Standard deviation of any project through different phases.

2. **Cost breakdown structure:** In any engineering project the cost estimation is based on the CBS (Cost Breakdown Structure) by which the engineer determines the budget of the project. Each cost code can for instance refer to materials, labor, equipment, etc.

3. **Risk management system:** In every project, uncertainty and risk are always present while conducting the project. Therefore, engineers should consider backup plans if the project faces uncertainty.

4. **Continuous evaluation:** After setting up the budget and overall cost of the project, the engineer should constantly monitor the ups and downs of the estimated cost. Therefore, they can use a chart to track the project's overall cost

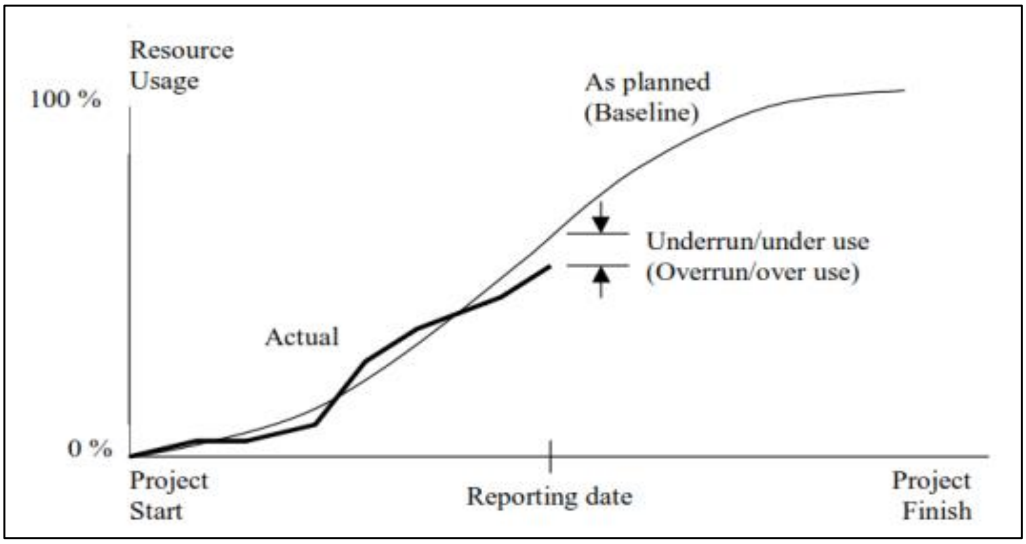


Fig 47: Graph showing the evaluation and implementation of project phases

8.3: Cost Benefit Analysis:

Cost-benefit analysis of any engineering project is a systematic approach in which proposals are analyzed to determine whether the benefits outweigh the costs, and by what margin. Here, we need to consider some factors while analyzing the cost benefit of any engineering project.

- **Balance sheet:** The systematic approaches and well organization is considered as the key factor to complete a project successfully. Here, to make a project Cost beneficial the engineers must make a Balance sheet and Budget sheet where they can track the expenses and costs happening throughout the whole process.

- **Cost influence through the development process:** The engineers must analyze the development process and understand the influence of the cost throughout the completion of the project.

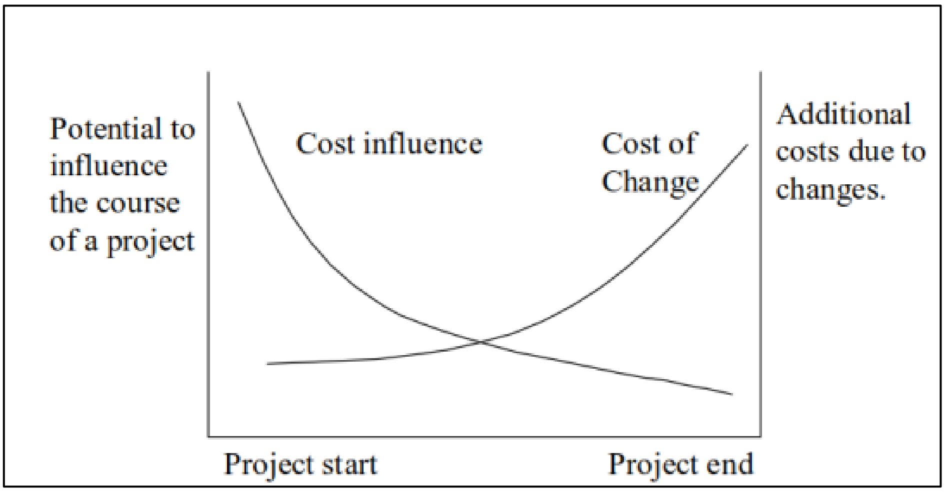


Fig 48: Cost influence through development of project

8.4: Evaluate Economic and Financial aspects:

We evaluated the economic and financial aspects of our FYDP (final year design project). As a result, we have analyzed research articles on engineering project economics and costs and have chosen some criteria to assess the economic and financial features of our "smart energy monitoring System" project.

8.4.1: Evaluate Economical aspects:

- **Concept of macroeconomics:** Macroeconomics is regarded as the external and more significant part of the economic sector in any engineering project, thus these external factors are also included in our project.

  Here, the shortage of electricity production in Bangladesh is directly tied to our "Smart Energy Monitoring" project. Furthermore, the fundamental goal of the Government of Bangladesh's significant initiatives to reduce electricity waste is to stabilize the business conditions of our nation. Therefore, by alerting the users, our system's major goal is to eliminate electricity waste and optimize electricity usage. So, The user will be more aware of how to use electricity wisely via an app and email. As a result, our project will have a positive impact on our nation's macroeconomics, which will optimize the use of electricity and create a stable economical situation for the people of the country.

- **Concept of microeconomics:** The interaction between the local dealer, service providers, and stakeholders of any given engineering project is discussed in terms of "microeconomics." The emphasis placed on the initial and ultimate products of any project, as well as how they affect the economic phase, is another important aspect of this sort of economic factor.

As a consequence, in our FYDP project, we related these facts in the context of financial considerations and assessed them in light of needs. Here, the primary objective of our project is to track the electricity usage of a residential home and inform prepaid meter users of their specific electricity usage information using an app, or email, Therefore, middle-class consumers need to be very cautious about their everyday expenses and are the appropriate stakeholders. Additionally, the cost of an electrical bill is very expensive right now, so if they can remotely check their electricity usage and keep their appliance usage at its best, it will help them stabilize their financial situation. Moreover, we have selected DPDC (offline prepaid card meters) as our service provider company. Here, improving the features of the App and suggestions of previous usage history will help the consumer to be frugal.

In conclusion, our “Smart Energy Monitoring System” satisfies the factors of the microeconomics both in service provider level and stakeholder level.

- **Phases of the project to estimate budget:** To complete a successful project, the organized project phases are very important to estimate the Budget for the whole period of the project duration. From the beginning to the end, we separated our project into different sections. Additionally, we thoroughly examined the phases to determine our project budget and periodically update it.

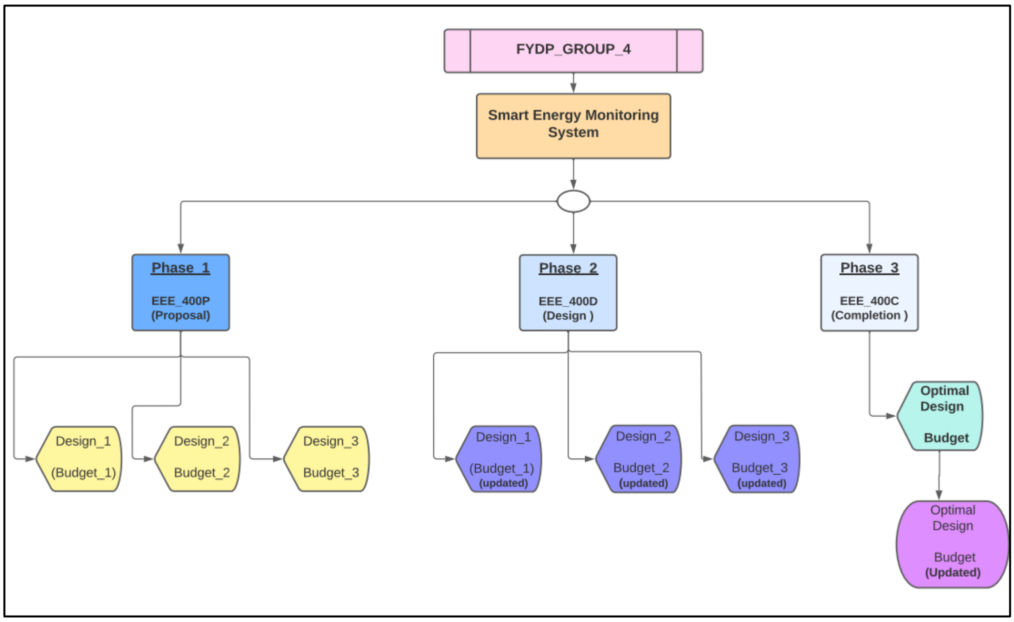


Fig 49: Phases of project duration and budget

Therefore, By analyzing the project phases we were able to organize our project budgets to meet the objectives of our project.

- **Cost estimation:** We estimated the overall project cost for our FYDP project from semester to semester. Here, as the project moves forward, the cost of our project varies occasionally as a result of data, certain unexpected events (Sensor burst, broken components), and market instability for componentry. Moreover, the cost estimation of the engineering project is created by the CBS(Cost Breakdown Structure). This technique was used in this instance to estimate our project's costs.

- **Risk management system:** While conducting any project, the project developers always take account of the unexpected occurrences that could occur during the progress process of the project. Therefore, As we are doing a project on “Smart Energy Monitoring System” which is directly related to electricity connection, as a result, many hardware and components related malfunctions, faults, and even loss of components can happen during the project. We have observed these scenarios and implemented them in our project progress period from the first day to the end of the project work. Therefore, we have assigned group members to deal with unexpected scenarios related to economic issues.

Risk Management System			
Incident	**Description**	**Backup Plan**	**Responsible person**
Faulty component	Malfunctioned and faulty components can be bought because of not checking it properly. Therefore, it will increase the budget because it is not usable.	Keeping All the purchasing receipts of the shop because if any components are faulty then we can replace or get the compensation money from the shop.	Baizid Arnab Mahfuzur
Scarcity of components in the market	Due to various reasons the components availability can differ in the market for which the price of the components can increase.	To avoid high priced components, we have analyzed and searched for shops and websites to buy the components at a reasonable price.	Arnab Baizid
Component Burst	While taking data and experimenting our system, due to Short circuit, our components can Get burst which will create problem for our project budget	As it's evident that this kind of incident can occur during the project. Therefore, we have kept extra components to avoid any unexpected situations	Baizid Arnab Tuhin
Hardware Material Finding	As per our house model, we needed to buy a hardboard and for that reason we needed to buy the exact size of hardware to avoid double buying if its not fit for the house-model	We have analyzed and measured various aspects to buy the perfect size hardboard for our house-model	Arnab Baizid

Table 15: Risk management system Analysis

Therefore, by taking these necessary steps we avoided the risks as much as possible, that can occur during our project and thus managed to stabilize our budget.

- **Continuous evaluation:** In our FYDP (Final Year Design Project), we initially chose a budget for three design approaches, following which we began to update the budget those. Therefore, after selecting our optimal design , We periodically tracked the budget and expenditures using an excel balance sheet that we had constructed. Moreover, as an engineering project, we have maintained and updated our balance sheet to be cost-efficient and evaluate our projects' previous and present budgets.

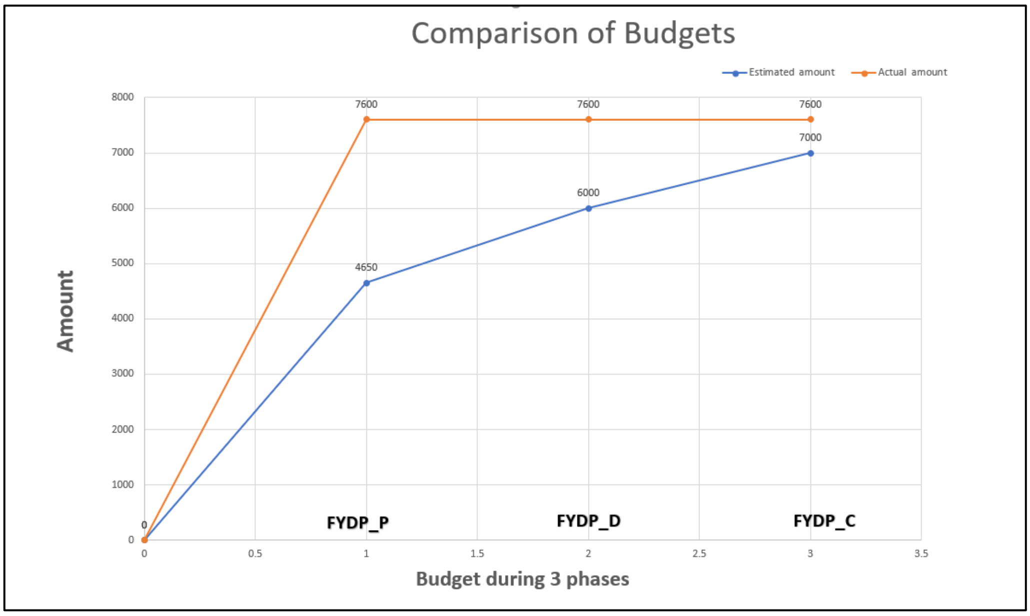


Fig 50: Continuous Evaluation of Project cost

Therefore, this is the process we have analyzed our project’s budget, comparing our optimal solution in the 3 phases of our project and comparing it with the final cost of our system.

8.4.2: Evaluate Financial aspects:

In every engineering project, we have to analyze the perspectives of the stakeholders of our project. Here, we have figured out some aspects of our project where it will help the consumers in various ways to maintain their financial aspects.

- **Remote Monitoring:**

  Remotely monitoring electricity use is one of our major purposes. Here, we have been able to display the prepaid meter user consumption history via email and an app. As a result, users will easily be able to keep track of their electricity balance and usage. Additionally, users will be able to promptly reload their prepaid meter card to prevent any power outages.

- **Consumer is aware about bill and use electricity effectively:**

  In our “Smart Energy Monitoring System” project, we have targeted middle-class families and the offline prepaid card users of the DPDC service provider. In essence, consumers would be able to track their usage via an app, increasing their awareness of their electricity use, lowering their electricity costs, and maintaining a stable financial situation.

- **Consumers will be able to track their electricity expenditure:** Given that our target audience consists of middle-class residential families who must be thrifty with their daily spending, energy usage is one of the essential costs on their list. Additionally, by keeping tabs on their monthly electricity usage, they can gain insight into how to optimize their usage, which will help them create a bill for the days ahead.

8.5: Conclusion:

To conclude, we have created an engineering project that considers service providers, stakeholders, and the economic and financial aspects of the country. Additionally, because of the lack of electricity production, our project will have a positive influence on consumer lifestyle and behavior regarding electricity use and will aid in stabilizing the country's economic situation.

CHAPTER 9: Ethics and Professional Responsibilities [CO13, CO2]

9.1: Introduction:

In any engineering project, Ethics and professional responsibilities are well-known terms where certain criteria are being measured to determine the project's acceptability from this side of the engineering project sector. Therefore, For our FYDP (Final Year Design project) we have gone through several criteria. Like, such as professional ethics, professional responsibilities, applicable code, standards, etc. These criteria helped us to design our project more accurately throughout the 3 semesters of our FYDP (Final Year Design project).

9.2: Identify ethical issues and professional responsibility:

Every engineering project should take into account a few fundamental factors when determining the ethical issues that are relevant to the stakeholder's requirements. When creating an engineering project, the developer should take into account user privacy and security, sustainability, and safety concerns.

In the sector of professional responsibility in any engineering project, the developer should consider certain attributes to meet the requirements of the stakeholders. To ensure that the project is compliant with the relevant authorities, the manufacturer must uphold all applicable codes of standards, professional codes, and regulatory requirements.

Hence, we have gone through these criteria while determining our “smart energy monitoring system” projects concerned with ethical issues and responsibilities throughout the process, development, and service of the system.

9.3: Apply ethical issues and professional responsibility:

In our FYDP (Final Year Design project), we analyzed the criteria that are necessary to select the related ethical issues and professional responsibilities of our project.

- **Ethical Consideration:**

  Electricity plays a crucial role in the energy and power industry. So, to monitor the electricity we implemented this system. Because these meters are entirely computerized and include measuring and collecting data, they help to improve the efficiency of electricity networks. But in doing so, certain concerns arise which question them from using the system. We have looked at some of these concerns.

A**ssuring significance for both businesses and society:**

As compared to traditional electric meters, smart energy monitoring systems maintain transparency with regards to bill generation between consumers and electric companies. There is no risk to the source if this system is implemented. By assuring more significant benefits, the project will benefit both businesses and society.

- **No personal security breach:**

  We will treat everyone's data as confidential, so to maintain privacy we will ensure data safety. The design will only be able to access data that is coded for a particular house. Without proper authorization from the admin, data access will be denied.

- **Minimizing human and animal harm:**

  This project means no harm to any survival, Since, we are using the sensors, and connections will be covered with plastic elements. And we will be using authentic wires and hardware. So, there will be no threats for humans and animals.

Applicable Standards and Codes

- **IEEE 802.11ba-2021:**

  This standard is to provide wireless connectivity for fixed, portable, and moving stations within a local area. This standard also offers regulatory bodies a means of standardizing access to one or more frequency bands for the purpose of local area communication.

- **IEEE 256-1963:**

  This Standard recommends and describes methods of measurement of the important electrical characteristics of semiconductor diodes.

  As we will be using a buck-boost converter for that BJT, MOSFET kind of element is needed which is also applicable.

- **<u>IEEE 1703-2012:</u>**

  The purpose of this standard is to define the network framework and means to transport the Utility End Device Data Tables via any Local area / Wide area network for use by enterprise systems in a multi-source environment.

- **<u>IEEE 2050-2018:</u>**

  This standard is a real-time operating system (RTOS) specification for small-scale embedded systems such as systems with a single chip microcomputer (single chip microcontroller) including 16-bit CPUs, systems with a small amount of ROM/RAM, and systems without a memory management unit (MMU). The main chip will need ROM for storing data. As well as managing reading falls in this standard

9.4 Conclusion:

In conclusion, through the three stages of our complex engineering project, we have gathered knowledge and information to identify the ethical issues and professional responsibilities where we prioritize the needs, safety, and privacy of the customer in order to help them create an environment that is eco-friendly and less polluted.

CHAPTER 10: Conclusion and Future work:

10.1 Project summary/Conclusion;

As the human race continues to advance and develop in the modern period, where electricity is one of the essential resources, so does our nation. However, we are experiencing some difficulty in producing enough electricity as a result of different effects and issues. As a result, in order to satisfy the needs, we have developed a project that will have a significant and beneficial impact on how effectively and efficiently energy meter customers use electricity. Here, we have chosen a few objectives and requirements, and in order to satisfy them, we have finished creating a project that will be beneficial for both our society and the country as a whole. Therefore, after completion of this project, the users have certain advantages which are given below,

- Real-time tracking of electricity usage.
- Show the number of units consumed as well as the remaining prepaid electricity balance.
- APP, Mail, and buzzer notification system for users.
- Make recommendations for reducing electricity consumption.

10.2 Future work:

As science is an aspect that is constantly advancing, the word "Future work" is heavily tied to every complex engineering problem. As a result, every project might include Future Works where it can be updated and modified in both hardware and software aspects. Eventually, our ‘energy Monitoring System’ project has some future work scopes where it can get more updated and worthwhile for the users.

10.2.1 Introduce our project’s future work possibilities

- **Temperature detection:**
  By integrating a temperature sensor with our "energy monitoring system," we can add a temperature detection feature that will allow the system to detect the current temperature and provide recommendations about how to use appliances.

- **Weather forecasting:**
  In order for the sensor to read the data and anticipate the weather for the next few days, we would like to include a weather forecasting component in our project. Additionally, this will enable the users to lead more modern lives.

- **Fire detection:**
  In our homes, fire-related incidents occur frequently. Bangladesh too has a high rate of fire-related fatalities. Therefore, we are planning to incorporate a fire detection system in our system by which the user can be notified Via the App and Buzzer if any fire ignites.

- **Individual machine learning for different house models and appliances:**
  Today, machine learning has a significant and positive impact on engineering projects. We intend to integrate machine learning into our system in this FYDP project. Our technology can automatically scan the load data and include its features because different residences have different types of loads.

CHAPTER 11: Identification of Complex Engineering Problems and Activities

11.1: Identify the attribute of complex engineering problem (EP):

	Attributes	**Putting tick (√) as appropriate**
P1	Depth of knowledge required	√
P2	Range of conflicting requirements	
P3	Depth of analysis required	√
P4	Familiarity of issues	√
P5	Extent of applicable codes	√
P6	Extent of stakeholder involvement and needs	√
P7	Interdependence	

Table 16: Attribute of complex engineering problem (EP)

11.2: Provide reasoning how the project address selected attribute (EP):

P1: Depth of knowledge:

We gathered a few papers and extensively reviewed them. We learned about our requirements and the specifics of our project. Moreover, by evaluating those articles, we learned that there would be some drawbacks that we may encounter when implementing the project and that we will be able to arrive at an optimal solution in a more timely and reasonable manner. Finally, we may visualize the project's outcomes by obtaining the depth of knowledge from the journals that we have studied. As a result, we will be able to choose the optimal solution for the complex engineering problem on which we have been working.

P3: Depth of analysis required:

In this project, for getting the depth of analysis we have gone through several research papers.

Then we looked for reasonable components to incorporate in our system's design, thus we came up with three different design approaches. Furthermore, by examining the research articles, we discovered how energy monitoring systems contribute to the efficiency of energy usage. As a result, the depth of analysis is important to our project.

P4: Familiarity of the issue:

In our day-to-day lives, electricity is one of the most important assets we have. The most alarming issue that consumers face is that they frequently experience power outages due to insufficient monitoring of the electricity balance. As a result, this type of unexpected blackout is extremely inconvenient for consumers. Another big issue is that without appropriate monitoring of electrical operations at residences, a lot of unnecessary electricity usage happens, resulting in higher electricity bills. Eventually, this became a very familiar issue for us, in which a lack of energy conservation results in wasteful electricity consumption and power outages.

P5: Extent of applicable codes:

The project we will be working on has a variety of components, modules, and other elements. Here, we will consider all applicable codes, rules, and limitations from the authorities of various organizations that are involved in our project. As a result, we shall use appropriate components to avoid any possible conflicts with the applicable codes.

P6: Extent of stakeholder involvement:

The major goal of our project is to notify users of their energy use and the working condition of their electrical appliances. We have been thinking of adding more features to our project, and we will need a lot of involvement from the stakeholders to do so.

11.3 Identify the attribute of complex engineering activities (EA):

	Attributes	Putting tick (√) as appropriate
A1	Range of resource	√
A2	Level of interaction	√
A3	Innovation	
A4	Consequences for society and the environment	√
A5	Familiarity	√

Table 17: Attribute of complex engineering activities (EA)

11.4 Provide reasoning how the project address selected attribute (EA):

A1: Range of resources:

We studied a few research papers, publications, and journals to see how we could construct our project. These papers provided us with a wide range of options for how we may create our project, and we came up with three design approaches from which we would choose the optimal one to build it.

A2: Level of interaction:

The amount of interactive activity is considered critical in this project. As a result, we have met with some of the users in person and produced a Google form to collect data and information from the project's stakeholders.

A4: Consequences for society and the environment:

By receiving notifications from our system, our project plays a critical role in informing consumers to be more sincere about consuming electricity. Furthermore, warning customers of needless appliance usage might reduce the use of electrical appliances, resulting in reduced heartburn from electrical appliances. As a result, it will have a positive impact on the environment.

A5: Familiarity:

Our project deals with the familiarity issue of sudden power cuts due to inappropriate electricity monitoring systems. We have planned to use some ways to get notified by SMS module, App-based system, or LCD display-based system. By these engineer activities, we will be able to get a notification to the user appropriately. In addition, the user will be able to lower the cost.

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Code:

```
double a=0;
double cval=1;
double Balance = 0;
double Balance75 = 0;
double Balance200 = 0;
double Balance300 = 0;
double Balance400 = 0;
double Balance600 = 0;
double Balancefinal = 0;
char customKey = 0;
String Day;
String Month;
String Year;
int initial_m = 0;
int current_m = 0;
int changes = 0;
int check = 0;

#define BLYNK_TEMPLATE_ID   "TMPLXlvgjoFt"
#define BLYNK_DEVICE_NAME   "FYDP EMS"
#define BLYNK_AUTH_TOKEN    "SDLDjTAvbFpImww2pqV-PrLFfGb1o0YK"

// Comment this out to disable prints and save space
//#define BLYNK_PRINT Serial

#include <LiquidCrystal_I2C.h>
LiquidCrystal_I2C lcd(0x27,16,2);
#include <Keypad.h>

//blynk+ wifi starts//
#include <WiFi.h>
#include <WiFiClient.h>
#include <BlynkSimpleEsp32.h>

char auth[] = BLYNK_AUTH_TOKEN;

char ssid[] = "POCO X3 Pro";
char pass[] = "00000000";

// blynk pertially done//

//NTP for RTC
#include "NTP.h"
```

```
WiFiUDP wifiUdp;
NTP ntp(wifiUdp);
//NTP for RTC declaration

//keypad code//
#define ROW_NUM     4 // four rows
#define COLUMN_NUM  4 // four columns

char keys[ROW_NUM][COLUMN_NUM] =
 {
  {'1', '2', '3', 'A'},
  {'4', '5', '6', 'B'},
  {'7', '8', '9', 'C'},
  {'*', '0', '#', 'D'}
 };

byte pin_rows[ROW_NUM]      = {13, 12, 14, 27}; // connect to the row pins
byte pin_column[COLUMN_NUM] = {26, 25, 33, 32}; // connect to the column pins

Keypad keypad = Keypad( makeKeymap(keys), pin_rows, pin_column, ROW_NUM,
COLUMN_NUM );

unsigned long loopCount;
unsigned long startTime;
String msg;

//keypad breaks//

void setup()
 {
  Serial.begin(115200);
  lcd.init(); // initialize the lcd
  lcd.backlight();

  Blynk.begin(auth, ssid, pass);  //Blynk
  Blynk.run();

  Serial.print("Connecting to ");
  Serial.println(ssid);
  WiFi.begin(ssid, pass);

  while (WiFi.status() != WL_CONNECTED) {
   delay(500);
   Serial.print(".");
  }
  Serial.println("");
```

```
    Serial.println("Connected");
    lcd.setCursor(0,0);
      lcd.print("Connected");

    ntp.ruleDST("CEST", Last, Sun, Mar, 2, 360); // last sunday in march 2:00, timetone
+120min (+5 GMT + 1h summertime offset)
    ntp.ruleSTD("CET", Last, Sun, Oct, 3, 300); // last sunday in october 3:00, timezone
+60min (+5GMT)
    ntp.begin();
  }

//keypad continue//
long getKeypadIntegerMulti()
{
  int cnt = 7;
  long value = 0;                              // the number accumulator
  long keyvalue;                                   // the key pressed at current moment
  int isnum;

  do
  {Blynk.run();
    keyvalue = keypad.getKey();                      // input the key
    isnum = (keyvalue >= '0' && keyvalue <= '9');        // is it a digit?
    if (isnum)
    {cnt++;

      Serial.print(keyvalue - '0');
        lcd.setCursor(cnt,0);
        lcd.print(keyvalue - '0');
      value = value * 10 + keyvalue - '0';              // accumulate the input number
    }

  } while (isnum || !keyvalue);                       // until not a digit or while no key pressed

  return value;
}
//keypad partially end

void loop()
{
  Blynk.run();

  //keypad output with initial display
  lcd.begin(16,2);
  lcd.clear();
  lcd.setCursor(0,0);
```

```
  lcd.print("Balance:");

lcd.setCursor(0,1);
  lcd.print("Press * to run");
  int val= getKeypadIntegerMulti();

lcd.setCursor(8,0);
  lcd.print(val);

  Blynk.virtualWrite(V0,val," Taka");
  Blynk.virtualWrite(V7,val);
  Blynk.logEvent("Notification", "Balance has been recharged successfully");

//keypad ends

   // balance calc
double pval= val*0.05;             //5% vat
double mval= val-40.0-pval;         //monthly bill deduction
double dload = mval-60.0;      //sanction load/demand charge
   // balance calc ends

for (int t = 1; t >= 1; t++)
   {
     Blynk.run();

     //RTC using NTP
     ntp.update();

       //Serial.println(ntp.formattedTime("%d. %B %Y")); // dd. Mmm yyyy
       //Serial.println(ntp.formattedTime("%A %T")); // Www hh:mm:ss

       Day = ntp.formattedTime("%d");
       Month = ntp.formattedTime("%m");
       Year = ntp.formattedTime("%Y");
       /*Serial.print(Day);
       Serial.print(", ");
       Serial.print(Month);
       Serial.print(", ");
       Serial.print(Year);
       Serial.println("");
       */
     //RTC code ends

     //Monthwise calc
     current_m = Month.toInt();
```

```
if(check == 0){
initial_m = current_m;
check = 1;
}

changes = current_m - initial_m;

if(changes == 0){
  //No changes
}
else if(changes > 0){
  Balance = Balance - 100;
  check = 0;
}
//monthwise calc ends

//ACS
     float result;
     int readValue;
     int maxValue = 0;
     int minValue = 4096;

     uint32_t start_time = millis();
     while((millis()-start_time) < 1000) //sample for 1 Sec
     {
         readValue = analogRead(34);
         // see if you have a new maxValue
         if (readValue > maxValue)
         {
             /*record the maximum sensor value*/
             maxValue = readValue;
         }
         if (readValue < minValue)
         {
             /*record the minimum sensor value*/
             minValue = readValue;
         }
     }

     // Subtract min from max
     result = ((maxValue - minValue) * 5)/4096.0; //ESP32 ADC resolution 4096

     if(result < 0.59){
       result = 0;
     }
     else{
```

```
      result = result - 0.59;
    }

//ACS ends

//calculations
cval = result;
Serial.println(cval);
 Blynk.virtualWrite(V5,cval, " Amps");

double Power= (240*cval)/1000;           //in KW
int cpower = Power * 1000;
 Blynk.virtualWrite(V4,cpower, " watt");
 Blynk.virtualWrite(V8,cpower);

double Energy= Power*(t/36);
int BlynkEnergy = Energy;
 Blynk.virtualWrite(V3,BlynkEnergy, " KWh");

double Spent= a+Energy;

Balance75 = Balance;
Balance200 = Balance;
Balance300 = Balance;
Balance400 = Balance;
Balance600 = Balance;

  if (Spent >= 0 && Spent < 76)
   {
     Balance75 = dload-(Spent*4.19);
     Balance = Balance75;
    }

  else if (Spent > 75 && Spent < 201)
    {
      Balance200 = Balance75-((Spent-75)*5.72);
      Balance = Balance200;
     }

  else if (Spent > 200 && Spent < 301)
    {
      Balance300 = Balance200-((Spent-200)*6.0);
      Balance = Balance300;
     }

  else if (Spent > 300 && Spent < 401)
```

```
  {
     Balance400 = Balance300-((Spent-300)*6.34);
     Balance = Balance400;
    }

 else if (Spent > 400 && Spent < 601)
  {
     Balance600 = Balance400-((Spent-400)*9.94);
     Balance = Balance600;
    }

 else {
       Balancefinal= Balance600-((Spent-600)*11.46);
       Balance = Balancefinal;
      }

    int BlynkBal = Balance;

// ratio calc
double Ratio = (Balance/dload)*100.0;
Blynk.virtualWrite(V2,Ratio);


//GSM continue

 if (Ratio == 50.0)
 {
  Blynk.logEvent("Notification", "50% of Balance has been used");
  //SendSMS();
 }

 else if (Ratio == 25.0)
 {
  Blynk.logEvent("Notification", "25% of Balance remaining");
  //SendSMS();
 }

 else if (Ratio == 10.0)
 {
  Blynk.logEvent("Notification", "10% of Balance remaining, Recharge ASAP");
  // SendSMS();
 }

 else if (Ratio == 5.0)
 {
  Blynk.logEvent("Notification", "You have 5% Left, Recharge Immediately");
```

```
  //SendSMS();
 }

 else if (Ratio == 0.0)
 {
  Blynk.logEvent("Notification", "No balance left");
  //SendSMS();
 }


//GSM partially ends

 lcd.setCursor(0, 1);
  lcd.print("Left= ");

 lcd.setCursor(6, 1);
  lcd.print(Balance);
  lcd.print(" TK");

 Blynk.virtualWrite(V1,BlynkBal, " tk");
 Blynk.virtualWrite(V7,Balance);

 delay(1);

a = Spent; //for summing the energy
//ABCD control
 customKey = keypad.getKey();

if (customKey)
 {
    Serial.println(customKey);
    if(customKey == 'A')
    {
      Serial.println("Current Power Usage");
      Serial.println();

      lcd.setCursor(6, 1);
       lcd.print("Power= ");

      lcd.setCursor(0, 1);
       lcd.print(cpower);
    }

    else if(customKey == 'B')
    {
     Serial.println("Balance");
```

```
  Serial.println();

  lcd.setCursor(6, 1);
    lcd.print("Left= ");

  lcd.setCursor(0, 1);
    lcd.print(Balance);
}

else if(customKey == 'C')
{
  Serial.println("Total Energy Consumption");
  Serial.println();

  lcd.setCursor(6, 1);
    lcd.print("Unit= ");

  lcd.setCursor(0, 1);
    lcd.print(Energy);
}

else if(customKey == 'D')
{
  lcd.setCursor(6, 1);
    lcd.print(ntp.formattedTime("%d. %B %Y"));

  lcd.setCursor(0, 1);
    lcd.print(ntp.formattedTime("%A %T"));

  Serial.println(ntp.formattedTime("%d. %B %Y")); // dd. Mmm yyyy
  Serial.println(ntp.formattedTime("%A %T")); // Www hh:mm:ss
}

else if(customKey == '#')
{
  Serial.println("Back to Home");
  Serial.println();

  lcd.setCursor(6, 1);
    lcd.print("Left= ");

  lcd.setCursor(0, 1);
    lcd.print(Balance);
}

else if(customKey == '*')
```

```
        {
         val = getKeypadIntegerMulti();
         dload = val + Balance;
         Balance = val + Balance;
         double vat_deduct = val*0.05;
         Balance = Balance - vat_deduct;

         Blynk.virtualWrite(V0,val," Taka");
         Blynk.logEvent("Notification", "Balance has been recharged successfully");
         Serial.print("New= ");
         Serial.println(Balance);
        }
    }
    //ABCD control ends
   }

}
```

Logbook:

Title: Smart Energy Monitoring System and Optimization of Energy Consumption

	Final Year Design Project (P) Summer 2021		
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Chair			
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Date/Time/ Place	**Attendee**	**Summary of Meeting Minutes**	**Responsible**	**Comment by ATC**
8.11.2021 (4:45 – 5:45pm) ATC Meeting-1	1. Dr. Belal Bhuian 2. Mahmudul Islam 3. Arnab 4. Baizid 5. Tuhin 6. Mahfuz	1. How to find problem statement 2. Need to find stakeholders specifications 3. Developing Ideas about reverse engineering	Task 1: Arnab, Baizid, Tuhin, Mahfuz Task 2: Arnab, Baizid, Tuhin, Mahfuz Task 3: Arnab, Baizid, Tuhin, Mahfuz	N/A as it was an introductory meeting.
				.
12.11.2021 (8:50– 10:50pm) Group Meet-1	1. Arnab 2. Baizid 3. Tuhin 4. Mahfuz	1. Share Ideas 2. Gather information 3. Identify a possible problem	Task 1: Arnab, Baizid, Tuhin, Mahfuz Task 2: Arnab, Baizid, Tuhin, Mahfuz Task 3: Arnab, Baizid, Tuhin, Mahfuz	
16.11.2021 (5:50 – 6:50pm) ATC Meeting-2	1. Dr. Belal Bhuian 2. Mahmudul Islam 3. Arnab 4. Baizid 5. Tuhin 6. Mahfuz	1.Need to finalize the title. 2.Need to finalize the problem statement. 3.Need to prepare a draft concept note	Task 1: Arnab, Baizid, Tuhin, Mahfuz Task 2: Arnab, Baizid, Tuhin, Mahfuz Task 3: Arnab, Baizid, Mahfuz	More discussion on topic selection, Reverse Engineering of solution to find problem.
18.11.2021	1. Arnab	1. Preparation for 1st presentation	task 1:Arnab, Baizid	Topic title is negative (Abdur Rahim Sir)

(11 – 1.10pm) Group Meet-2	2. Baizid 3. Tuhin 4. Mahfuz			Add block diagrams (Mohaimenul Sir) Design Approach not clear (Belal Sir) Methodology not added (Mohsin Sir)
22.11.2021 (11 – 1.10pm) Group Meet-3	1. Arnab 2. Baizid 3. Tuhin 4. Mahfuz	1. Gathering ideas from feedback 2. Literature Review collection	task1: Arnab, Baizid, Tuhin, Mahfuz task2: Arnab	
1.12.2021 (4:40 – 5:40pm) ATC Meeting-3	1. Dr. Belal Bhuian 2. Mahmudul Islam 3. Arnab 4. Baizid 5. Tuhin 6. Mahfuz	1.Need to finalize the title. 2.Need to finalize the problem statement. 3.Need to prepare a draft concept note	task 1: Arnab, Baizid, Tuhin, Mahfuz task 2: Arnab, Baizid task 3: Mahfuz, Baizid, Arnab	Title problem decided, Alternative design approach techniques, Change Specification format, Edit the title from optimization to notification system.
1.12.2021 (9:30 – 11:30pm) Group Meet-4	1. Arnab 2. Baizid 3. Tuhin 4. Mahfuz	1. Work Distribution 2. Progress Planning	task1: Arnab task2: Baizid	
2.12.2021 (10.00am- 11.00 am) group meet -5	1.arnab 2. baizid 3. mahfuz 4. tuhin	1. need to find more literature review paper on our problem 2.need to complete the concept note	task 1: Arnab, Tuhin task 2: Arnab, Baizid, Mahfuz	
4.12.2021 (11.00pm- 12.12am) group meet-6	1.arnab 2. baizid 3. mahfuz	1.collect research papers 2.shared our collected papers with group mates .	task 1: Arnab, Baizid, Tuhin task 2: Arnab, Baizid, Tuhin, Mahfuz	

5.12.2021 (2.30pm-4.00pm) group meet-7	1.arnab 2. baizid 3. mahfuz 4. tuhin	1.discussion on concept note 2.discussion on literature review paper . 3. discussion about project related components.	task 1: Arnab, Baizid, Tuhin, Mahfuz 2: Arnab, Mahfuz, Baizid Tuhin (partially completed) task 3: Arnab, Baizid, Mahfuz	(feedback given on concept note via e-mail) Add system specification Title edit
6.12.21 (10.00pm- 12.00pm) Group meet-8	1. Baizid 2. Mahfuz 3. Tuhin	1. discussion about project related components. 2. finding constraints 3. Specs and Requirements	task 1: Arnab 2: Baizid, Mahfuz (partially completed) task 3: Mahfuz, Arnab, Baizid (partially completed)	
7.12.2021 (7.00pm - 9.00pm	1. Baizid 2. Mahfuz 3. Arnab 4. Tuihn	1. finding constraints 2. Specs and Requirements	task 1: Baizid, Mahfuz, Arnab task 2: Arnab, Baizid	
29.12.2021 (11.00pm-3.00am) Group meet-9	1. Baizid 2. Arnab 3. Mahfuz	1. Gantt chart 2. Literature review summary 3. Discussion on draft proposal report	task1: Arnab task2: Arnab, Baizid, Mahfuz task3: Arnab, Baizid	
29.12.2021 (11.00AM- 1.00PM) Group meet-10	1. Arnab 2. Baizid 3. Mahfuz 4. Tuhin	1. Gantt Chart 2. Discussion on draft proposal report	task1: Arnab (400P) task2: Baizid, Tuhin (400D) task3: Mahfuz (400C)	
31.12.2021 (2.00pm - 5.00pm) Group meet-11	1. Baizid 2. Arnab	1. Discussion on final proposal 2. Design approach	task1: Arnab (Design01) task2: Arnab (Design02) task3: Baizid (Design03)	Designs not in sync with the project title. Safety and Ethical considerations not mentioned clearly.
1.1.2022 (9.00 am - 2.00pm)	1. Baizid 2. Arnab 3. Mahfuz	1. Discussion on final proposal 2. Gantt Chart	task1: Arnab, Baizid, Tuhin, Mahfuz task2: Mahfuz (partially completed)	

Group Meet-12				
2.1.2022 (4.00pm-12.00am) Group Meet-13	1. Mahfuz 2. Baizid 3. Arnab 4. Tuhin	1. Final Proposal_draft 2. Gantt Chart	task1: Arnab, Baizid task2: Tuhin, Mahfuz	
3.1.2022 (3:30pm-7:00pm) Group Meet-14	1.Baizid 2.Mahfuz	1. Final Proposal report_draft	task1: Arnab, Baizid, Tuhin, Mahfuz	
4.1.2022 (11.00am- 2.00pm) ATC Meeting-4	1. Dr. Belal Bhuian 2. Mahmudul Islam 3. Arnab 4. Baizid 5. Tuhin 6. Mahfuz	1.Feedback for proposal Draft		Specification editing, Separate points for constraints and risk management, Design Comparison
5.1.2022 (12.00am -2.00pm) Group Meet-15	1. Mahfuz 2. Baizid 3. Arnab 4. Tuhin	1.Final report 2. Slide compilation	task1: Arnab, Baizid, Tuhin, Mahfuz task2: Arnab, Baizid, Mahfuz	

	Final Year Design Project (D) Spring 2022		
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Date/Time /Place	Attendee	Summary of Meeting Minutes	Responsible	Comment by ATC
02.02.2022	1.Arnab 2.Baizid 3.Tuhin 4. Mahfuz	1. Discussion on Design Approaches. 2.Assign Background Research and Component Comparison 3.Subsystem Planning	Task 2: Everyone Task 3: To be asked in ATC meeting	N/A as it was an introductory meeting.
06.02.2022	1.Arnab 2.Baizid 3.Tuhin 4. Mahfuz	1.Disscussion on software (Modern IT Tools) 2.Review on Background Research (Projects similar to ours) 3. Making Slide to show progress to ATC	Task 2: Everyone-partially completed Task3: Everyone-completed	
08.02.2022	1. Belal Sir 2. Arnab 3.Baizid 4.Tuhin 5. Mahfuz	1.Detailed Overview of 400D 2.Discussion on what to do to avoid losing marks 3.Slide Presented to ATC Panel 4. Queries asked	Task3: Everyone-Completed Task4: Everyone-Completed	
10.02.2022	1.Arnab 2.Baizid 3.Tuhin 4. Mahfuz	1. Discussion of Project COs (dividing the tasks to identify the terms) 2. Software Analysis/Review (Researching the advantages and disadvantages of several softwares) 3. Creating Survey form	Task1: Arnab-CO5, CO9, CO11 Baizid- CO9, CO11, CO13 Tuhin- CO9, CO11, CO15 Mahfuz- CO6, CO9, CO15 () Task 2: Everyone - completed Task 3: Mahfuz, Tuhin	Task 1: Completed Task 2: Completed Task 3: Incomplete
13.02.2022	1.Arnab 2.Baizid 3.Tuhin	1. Progress discussion on assigned tasks 2. Creating Survey form	Task 1: Arnab-partially done Baizid- partially done Tuhin- not started yet	Task 1: Partially completed Task 2: Incomplete

	4. Mahfuz		Mahfuz- Done Task 2: Mahfuz, Tuhin, Baizid	
18.02.2022	1.Arnab 2.Baizid 3.Tuhin 4. Mahfuz	1. CO term discussion 2. Software review 3. Creating Survey form	Task 2: Everyone Task 3: Mahfuz	Task1: Completed Task 2: Partially completed Task 3: Partially completed
20.02.2022	1.Arnab 2.Baizid	1. Completing Survey form	Task1: Arnab, Baizid	Task 1: Completed
23.02.2022	1.Arnab 2.Baizid 3.Tuhin 4. Mahfuz	1.CO Analysis 2.Software Review 3.Collecting Equations for Project 4. Gantt Chart	Task1: Everyone-Completed Task 2: Everyone-Partially completed Task 3: Arnab, Baizid-Partially completed Task 4: Mahfuz, Tuhin- Partially completed	
24.02.2022	1.Arnab 2.Baizid 3.Tuhin 4. Mahfuz	1.Software Review 2.Collecting Equations for Project 3. Gantt Chart 4.WBS Structure 5.Simulation	Task1: Everyone-completed Task 2: Arnab, Baizid-Partially completed Task3: Mahfuz, Arnab, Baizid-Completed Task 4: Arnab, Baizid, Tuhin- Completed Task 5: Mahfuz, Tuhin- In progress (Design3)	
25.02.2022	1.Arnab 2.Baizid	1.Progress Slide 2.Survey Response Review 3.House Model Plan	Task1: Everyone-completed Task2: Arnab, Baizid, Mahfuz- Completed	

		4.Simulation 5.Software Comparison	Task3: Arnab, Baizid- Completed Task 4: Mahfuz, Tuhin- In progress (Design3) Task 5: Baizid- Completed	
26.02.2022	1. Belal Sir 2.Mahmudul Sir 3. Arnab 4.Baizid 5.Tuhin 6. Mahfuz	1. Progress Update 2. Queries on CO and Software 3. Queries about Upcoming Presentation	Task1: Everyone- Completed Task2: Asked Task3: Asked	1.Redo Survey based on pre-paid system. 2.Detailed flowchart for alternative designs to be shown. 3.Collect all required equations to identify variables. 4.Change House Plan to a smaller design 5.Work on data collection from Arduino part.
27.02.2022	1.Arnab 2.Baizid	1.Creating new Survey Form	Task1: Arnab, Baizid- Completed	
28.02.2022	1.Arnab 2.Baizid 3.Mahfuz	1. Recheck Survey form 2. Review Survey feedback 3.Slide Preparation	Task1: Everyone- Completed Task2: Everyone- Partially Completed Task3: Mahfuz, Baizid- Partially completed	
01.03.2021	1.Baizid 2.Mahfuz	1. Prepare Slide for Progress presentation 2. Simulation Progress	Task1: Mahfuz, Baizid- Partially done Task2: Mahfuz, Baizid -In Progress	
02.03.2022	1.Arnab 2.Baizid	1. Prepare Slide for Progress presentation	Task1: Everyone – completed	

	3.Tuhin 4.Mahfuz	2. Simulation Progress 3. Slide update mailed to ATC	Task2: Mahfuz – In Progress Task3: Arnab - completed	
05.03.2022	1.Arnab 2.Mahfuz	1. Simulation Progress presented to Belal Sir	Task1: Update given	1.Include Slab Calculations. 2.Look into energy rates for peak and off-peak hours.
08.03.2022	1.Arnab 2. Baizid	1.Discussed design approach with Mohaimenul Sir.		1.Using relay to take readings for voltage sensor. 2.Present test cases to run simulation.
24.03.2022	1.Arnab 2.Baizid 3.Tuhin 4.Mahfuz	1.Discussed and reformed progress plan. 2. Update on Design approach 2	Task1: Completed Task2:Baizid, Tuhin-Partially done	
30.03.2022	1.Arnab 2.Baizid 3.Tuhin 4.Mahfuz	1.Update on Design approach 1 2.Update on Design approach 2 3.Update on Design approach 3	Task1:Mahfuz-Updated Task2:Tuhin-No update Task3:Baizid, Arnab, Mahfuz- Updated	
05.04.2022	1.Arnab 2.Baizid 3.Mahfuz	1.Update on Design approach 1 2.Update on Design approach 3 3.Task assigned for finding equations, app development	Task1:Mahfuz-Updated Task2:Baizid, Arnab, Mahfuz- Updated Task3: Assigned	
07.04.2022	1.Arnab 2. Baizid 3. Mahfuz	1. Collect and evaluate all calculations to show energy cost and tariff. 2. Update Design Approach 2	Task1: Baizid, Arnab - Completed Task 2: Mahfuz - Updated	
08.04.2022	1. Belal Sir 2.Mahmudul Sir	1. Show Progress 2. Discuss problems on Design approach 1	Task1- Completed Task 2- Completed Task 3- Completed	1.Use Xbee to show wireless communication

	3. Arnab 4.Baizid 5.Tuhin 6. Mahfuz	3. Discuss problem for tariff calculation		2. Use nested loop for the tariff calculations.
09.04.2022	1.Arnab 2.Baizid 3.Tuhin 4.Mahfuz	1. Design Approach 1 Xbee update 2. Design Approach 2 relay switch update 3. Design Approach 3 calculation update	Task 1- Arnab,Baizid- No Update as Xbee block is a dummy block Task 2- Mahfuz, Tuhin- Updated Task 3- Mahfuz, Baizid- Updated	
14.04.2022	1.Arnab 2. Baizid 3. Mahfuz	1. Calculation Modifications 2. Code Update	Task 1- Baizid- Modified Task 2- Mahfuz, Arnab- Updated	
17.04.2022	1.Arnab 2. Baizid 3. Mahfuz	1. Update design approach 1 and 3 2. Report Update	Task 1- Arnab- Updated Task 2-Baizid- Partially Updated	
20.04.2022	1.Arnab 2.Baizid 3.Tuhin 4.Mahfuz	1. Report Update 2. Final Presentation Slide	Task 1- Baizid, Tuhin, Mahfuz- Partially Updated Task 2-Arnab, Baizid- Partially Updated	
23.04.2022	1.Arnab 2.Baizid 3.Tuhin 4.Mahfuz	1. Report Update	Task 1- Partially done	
24.04.2022	1.Arnab 2.Tuhin 3.Mahfuz	1. Test case for 3 design approach 2. Finding error for all designs 3. Draft Report submission	Task 1- Completed Task 2- Partially Done Task 3- Completed	

27.04.2022	1. Belal Sir 2.Mahmudul Sir 3. Arnab 4.Baizid 5.Tuhin 6. Mahfuz	1. Update Slide on feedback	Task 1-Completed	1.Survey results not needed in final presentation 2. Update design comparison based on separate criteria
28.04.2022	EEE400D (All ATC Panel and stedents)	1. Final Presentation	Task 1- Completed	1.Add notification system to reduce electricity wastage. 2. Predict monthly expense based on previous usage.

Final Year Design Project (C) Summer 2022			
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Member 3	Mahmudul Islam	mahmudul.islam@bracu.ac.bd	

Date/Time/ Place	Attendee	Summary of Meeting Minutes	Responsible	Comment by ATC
29.05.2022 (Online Meeting)	1.Arnab 2.Baizid	1. Need to make floor plan electrical Layout 2. Find papers on home electricity meters	Task 1: Baizid Task 2: Arnab	N/A as it was an introductory meeting.
03.06.2022 (Online Meeting)	1.Arnab 2.Baizid	1. Floor plan initial electrical system layout 2. Selecting safety devices for the protection of the system	Task 1:Baizid (Partially done) Task 2: Arnab (Completed)	
04.06.2022 (Physical Meeting/Thesis LAB, UB5)	1. Arnab 2. Baizid 3. Mahfuzurur	1. Complete the floor electrical layout 2. Component specification and current price listing 3. System Layout Design	Task 1: Arnab (Completed) Task 2: Baizid (Completed) Task 3: Mahfuzurur (partially done)	
05.06.2022 ATC Meeting (Physical Meeting/LASSET LAB, UB4)	1. Kafi Sir 2. Arnab 3. Baizid 4. Mahfuzurur	1. Show the floor electrical layout 2. Show component specification 3. System Layout Design	Task1: Everyone Task2: Everyone Task3: Everyone	1. Check ESP instead of Arduino as MCU 2. Gather information about the server accessing meter data from SSL. 3. Check online messaging procedures. 4. Show a complete system block diagram.
09.06.20 ATC Meeting (Physical Meeting/Belal Sir's Room, UB5)	1. Belal Sir 2. Mahmudul Sir 3. Arnab 4. Baizid 5. Mahfuzurur	1. Study the COs and POs 2. Update about the project progress	Task1: Everyone Task2: Everyone	1. Explained the COs 2. Provide Literature review in the next meeting 3. Full System block diagram to be shown next week. 4. Gantt Chart

12.06.2022 (Physical Meeting/ LAB, UB4)	1. Arnab 2. Baizid	1. Full system diagram update 2. Update the Gantt chart for 400C	Task 1: Arnab (Partially done) Task 2: Baizid (Partially done)	
13.06.2022 (Physical Meeting/ LAB, UB4)	1. Arnab 2. Baizid	1. Full system diagram update 2. Update the Gantt chart for 400C	Task 1: Arnab (Partially done) Task 2: Baizid (Partially done)	
13.06.2022 (Physical Meeting/ LAB, UB4)	1. Arnab 2. Baizid	1. Full system diagram update 2. Update the Gantt chart for 400C	Task 1: Arnab (Completed) Task 2: Baizid (Partially done)	
16.06.2022 ATC Meeting (Physical Meeting/Belal Sir's Room, UB5)	1. Belal Sir 2. Arnab 3. Baizid 4. Mahfuzurur 5. Tuhin	1. Component Listing and Pricing 2. Gantt Chart Update 3. Market Survey and Component Purchasing	Task 1: Baizid, Arnab, Mahfuzur (Completed) Task 2: Tuhin (Partially done) Task 3: Arnab, Baizid, Tuhin (Partially done)	Update on Block diagram, Gantt chart, and literature to be shown in the following ATC meeting.
19.06.2022 (Physical Meeting/ LAB, UB4)	1. Arnab 2. Baizid 3. Mahfuzur	1. Gantt chart Update 2. Task distribution (Research Work, Inrush current reducing system, Back-up power system, Component listing for house model) 3. Maintaining Component Bill sheet	Task 1: Mahfuzur, Arnab (Completed) Task 2: Arnab (Completed) Task 3: Baizid (Partially Done)	
20.06.2022 (Online Meeting)	1. Baizid 2. Arnab	1. Maintaining Component Bill sheet 2. Contact SSL Wireless for Data transferring System information	Task 1: Baizid, Arnab (Completed) Task 2: Baizid (Partially Done)	[Note from SSL Wireless: Mail Operation management for further details]
28.06.2022 (Physical Meeting/ LAB, UB4)	1. Baizid 2. Arnab	1. House Model plan component selection. 2. Component listing for purchase	Task 1: Baizid, Arnab (Completed) Task 2: Baizid, Arnab (Done)	

30.06.2022 ATC Meeting (Physical Meeting/Belal Sir's Room, UB5)	1.Belal Sir 2.Arnab 3.Baizid 4.Mahfuzurur 5.Tuhin	1. ESP connection with Blynk 2. Market survey	Task 1: Mahfuzur (Partially done) Task 2: Arnab, Baizid, Tuhin (Completed)	Mock presentation on Breadboard model, Final presentation must be done using PCB design. [Speak with Kafi Sir regarding algorithm]
01.07.2022 (Physical Meeting/ Arnab's House)	1. Arnab 2. Baizid 3. Mahfuzur	1. Slide Preparation 2. Voltage sensor Calibration 3. Current Sensor calibration 4. System Integration	Task 1: Everyone (Partially Done) Task 2: Everyone (Partially Done) Task 3: Arnab, Mahfuzur (Partially Done) Task 4: Arnab Mahfuzur (Partially Done)	
EID Vacation & MID Week- Hence no meetings were held during this time				
21.07.2022 (Physical Meeting/ Arnab's House)	1. Arnab 2. Baizid 3. Mahfuzur	1. Material purchasing for Demo House Model 2. Demo House Model building	Task 1: Everyone (Completed) Task 2: Arnab, Baizid (Completed)	
26.07.2022 (Physical Meeting/UB5, Thesis LAB)	1. Arnab 2. Baizid	1. Sensor Data read from House model (Current Sensor) 2. Slide Update for Progress Presentation	Task 1: Arnab, Baizid (Completed- Sensors need more calibration) Task 2: Baizid (Partially Done)	
27.07.2022 (Physical Meeting/ Arnab's House)	1. Arnab 2. Baizid 3. Mahfuzur 4. Tuhin	1. Sensor Data read from House model 2. Slide Update for Progress Presentation	Task 1: Everyone (Completed) Task 2: Everyone (Completed)	
28.07.2022	**Progress Presentation**			

30.07.2022 (Online Meeting)	1. Arnab 2. Baizid 3. Mahfuzur	1. Report Preparation of the progress Update	Task 1: Everyone (Completed)	
03.08.2022 ATC Meeting (Physical Meeting/Belal Sir's Room, UB5)	1. Belal Sir 2. Arnab 3. Baizid 4. Mahfuzur	1. Progress Update 2. Problem Discussion	Task 1: Everyone Task 3: Everyone	1. Current sensor calibration - Check for load readings using a multimeter and compare them with ACS712 sensor readings. 2. Compare AC current sensor (SCT013) data with DC current sensor (ACS712) data and verify which type of sensor gives precise readings. 3. Tariff calculation: Show block diagram Show flow chart of tariff calculation. 4. Show App flow diagram. 5. Literature review on Residential Power factor(PF=1) 6. Test case on power factor to show the fluctuation effect on the energy consumption. (Tariff calculation by considering PF=1 and if PF<1) 6. Explaining why our targeted stakeholders need our system? - our targeted stakeholder is lower middle-class families 7. Verifying sensor output readings with the

				watt meter to compare it with the real house system.
04.08.2022 (Physical Meeting/UB5, Thesis LAB)	1. Arnab 2. Baizid	Task 1: Revise Progress Planning Task 2: Remodeling Demo House-plan Task 3: Logic for SMS	Task 1: Arnab-Completed Task 2: Arnab-Partially Complete Task 3: Arnab-Partially Complete	
06.08.2022	1. Baizid 2. Mahfuzur	Task 1: Component Purchase	Task 1: Baizid, Mahfuzur - Completed	
09.08.2022 (Physical Meeting/UB5, Thesis LAB)	1. Arnab 2. Baizid 3. Mahfuzur	Task 1: Sensor Calibration Task 2: GSM connection Task 3: Blynk Notification System	Task 1: Arnab, Mahfuzur-Completed Task 2: Arnab-(GSM not receiving power) Task 3: Mahfuzur-Completed	
11.08.2022 ATC Meeting (Physical Meeting/Belal Sir's Room, UB5)	1.Belal Sir 2. Mahmudul Sir 3.Arnab 4.Baizid 5.Mahfuzurur 6.Tuhin	Task 1: Progress Update	Task 1: Everyone (Completed)	1. Add sensor calibration in report. 2. Show tariff calculation as a flowchart. 3. Real-time Voltage vs Peak voltage comparison. 4. Keypad button control set-up 5. Web Scraping literature Review 6. Proper Economical Analysis
14.08.2022	1. Arnab 2. Baizid	Task 1: Draft Report	Task 1: Baizid, Arnab (Patially done)	

(Online Meeting)				
16.08.2022 (Online Meeting)	1. Arnab 2. Baizid	Task 1: Draft Report Task 2: Flow-chart of tariff calculation	Task 1: Baizid, Arnab (Patially done) Task 2: Arnab (Completed)	
18.08.2022 ATC Meeting (Physical Meeting/Belal Sir's Room, UB5)	1.Belal Sir 2.Arnab 3.Baizid 4.Tuhin	Task 1: Tariff calculation flowchart. Task 2: Web Scraping Literature Review Task 3: Updated House Model design of Prototype Task 4: Peak Voltage vs Actual Voltage	Task 1: Arnab (Completed) Task 2: Baizid, Arnab (Completed) Task 3: Baizid, Arnab (Updated) Task 4: Mahfuzur, Tuhin (not done)	1. Show the data comparison between Real-time Voltage vs Peak voltage 2. Skip values for inrush current when showing data for sensor calibration. 3. Update Economical Analysis.

21.08.2022 (Physical Meeting/UB4, LASSET LAB)	1. Kafi Sir 2. Arnab	Task 1: Algorithm check for the system	Task 1: Arnab (Update Given)	1. Work on the notification System for the Blynk App
22.08.2022 (Physical Meeting/UB5, Thesis LAB)	1. Arnab 2. Baizid	Task 1: Draft Report Task 2: Voltage data obtained and compared (Real-time vs Peak Voltage)	Task 1: Baizid, Arnab (Updated) Task 2: Arnab, Baizid (Completed)	
24.08.2022 (Physical Meeting/ Arnab's House)	1. Arnab 2. Baizid 3. Tuhin	Task 1: Draft Report Task 2: System Integration and further Testing Task 3: House Model Wiring	Task 1: Baizid, Tuhin (Updated by Baizid) Task 2: Arnab (Partially Done) Task 3: Arnab, Baizid (Partially Done)	
25.08.2022 Additional Consultation (Physical Meeting/Belal Sir's Room, UB5)	1. Belal Sir 2. Mahmudul Sir 3. Arnab 4. Tuhin	Task 1: Data comparison of Voltage data obtained (Real-time vs Peak Voltage) Task 2: Draft Report	Task 1: Arnab (Update Given) Task 2: Tuhin (No update done)	1.Since the difference is very little, work with peak voltage value for calculations, Show real-time voltage in the App.
26.08.2022 (Physical Meeting/ Arnab's House)	1. Arnab 2. Baizid	Task 1: Calculation Re-check Task 2: System Integration and wiring check Task 3: House-Model Wiring Task 4: Draft Report Update	Task 1: Arnab, Baizid (Completed) Task 2: Arnab, Baizid (Completed) Task 3: Arnab (Completed) Task 4: Baizid (Updated)	
27.08.2022	1. Arnab 2. Baizid	Task 1: Draft Report Update Task 2: Presentation Slide	Task 1: Arnab, Baizid (Updated)	

(Physical Meeting/ Arnab's House)	3. Mahfuz	Task 3: Observation of data for anomaly	Task 2: Mahfuz (Partially done) Task 3: Baizid (Values Noted)	
28.08.2022 (Physical Meeting/ Arnab's House)	1. Arnab 2. Baizid	Task 1: Draft Report Update Task 2: Observation of data for anomaly	Task 1: Arnab, Baizid (Updated) Task 2: Arnab (Values Noted)	
30.08.2022 (Physical Meeting/ Arnab's House)	1. Arnab 2. Baizid 3. Mahfuzur 4. Tuhin	Task 1: Draft Report Update Task 2: Observation of data for anomaly Task 3: Presentation Slide Task 4: Blynk Notification System Update	Task 1: Arnab, Baizid (Updated) Task 2: Tuhin (Values Noted) Task 3: Mahfuzur, Tuhin (No Update) Task 4: Mahfuzur (Updated)	
31.08.2022	1. Arnab 2. Baizid 3. Mahfuzur 4. Tuhin	Task 1: Draft Report Update Task 2: Observation of data for anomaly Task 3: Presentation Slide Task 4: Blynk Notification System Update	Task 1: Arnab, Baizid (Updated) Task 2: Arnab (Values Tabulated) Task 3: Arnab (Completd) Task 4: Mahfuzur (Completed)	
01.08.2022	**FYDP C Final Presentation and Project Showcasing**			