IOT BASED POWER MONITORING AND MANAGEMENT SYSTEM OF A DISTRIBUTION SUBSTATION

An Undergraduate CAPSTONE Project
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A CAPSTONE Project submitted to the Faculty of Engineering, American International University - Bangladesh (AIUB) in partial fulfillment of the requirements for the degree of Bachelor of Science in their mentioned respective programs.

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DECLARATION

This is to certify that the project titled "**IOT based Power Monitoring and Management System of a Distribution Substation**" is our own work. No part of this work has been submitted elsewhere partially or fully for the award of any other degree or diploma. Any material reproduced in this project has been properly acknowledged.

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APPROVAL

The CAPSTONE Project titled **IOT BASED POWER MONITORING AND MANAGEMENT SYSTEM OF A DISTRIBUTION SUBSTATION** has been submitted to the following respected members of the Board of Examiners of the Faculty of Engineering in partial fulfillment of the requirements for the degree of **Bachelor of Science in Electrical and Electronic Engineering** on **June 2023** by the following students and has been accepted as satisfactory.

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ABSTRACT

Remote monitoring and control of the substation is a critical issue for the power or energy management department, which is typically done manually or with the help of SCADA system. We proposed a system that is low cost, user friendly, and works in auto mode to avoid labor involvement and system loss. With the emergence of the internet and the computational era, a smart monitoring and trustworthy controlling system over the complete sub-station is extremely desirable, which may be accomplished by implementing Internet of Things (IoT) technology. Our own developed website is used in this paper as an IoT analytics platform service which lets the programmers collect, visualize and analyze incoming data streams to the cloud. The collected data is sent to the website, create instant visualization of live data related to the monitored station. We can monitor the power factor, supply voltage and total load current through this automation system. Engineers in charge of the station may monitor the progress of the station's operations from anywhere in the world using any internet connected device - a computer or a smartphone. Actually we want to distribute the load properly according to our load capacity and according to the importance of the place. There are three areas in our project based on different types of priority. When load demand increases more than available energy, automatically load shedding happens to the lesser priority areas. Here we have given first priority to hospitals followed by second priority to industrial areas and third priority to residential areas. The system applies a safety feature to completely close the power station in the event of a serious condition such as a fire. So, our main objective is reliable and safe power distribution properly where the entire system will be controlled through automation system.

Chapter 1

INTRODUCTION

1.1. Overture

A substation is a key part of electrical generation, transmission, and distribution systems. It transforms voltage from high to low or from low to high as necessary and dispatches electric power from generating stations to the consumption center. Substations can be generally divided into three major types according to voltage levels: Transmission substations, Sub-transmission substations, and Distribution substations. A distribution substation normally runs at voltage levels between 2.4 and 34.5 kV and provides electric power directly to commercial and residential customers. Power is delivered to consumers by distribution feeders from distribution substations. These feeders typically have a high number of branches and provide service to numerous locations. Distribution transformers convert the distribution voltage, typically ranging from 110 to 600 V, to the service level voltage utilized directly in homes and industrial facilities at the consumers premises.

The proposed IoT-based monitoring system of a power system substation consists of a data acquisition unit, a communication unit, and a data processing unit [1]. The data acquisition unit is responsible for collecting data from various devices and sensors in the substation, such as voltage and current sensors, power meters, and protection relays. The data is then transmitted to the communication unit, which uses a low-latency, high-speed communication protocol to transmit the data in real time to the data processing unit. The data processing unit is responsible for analyzing the data and providing real-time information to the system operators. This information can be used for monitoring the status of the substation, detecting potential issues, and making decisions for technical and financial matters. The system also includes a recording function to store the data for future analysis and troubleshooting [2]. The proposed IoT-based monitoring system can provide several benefits for the power system substation. Real-time monitoring of the substation can improve the reliability and stability of the power supply, reduce downtime, and increase revenue. The system can also be used to detect potential issues and prevent equipment failures, which can reduce maintenance costs. Additionally, the system can provide valuable data for analysis and planning, which can help improve the efficiency and cost-effectiveness of the power system. In conclusion, the proposed IoT-based monitoring system for a power system substation is a cost-effective and reliable solution for real-time monitoring and control of power systems [3]. The system can improve the reliability and stability of the power supply, reduce downtime, and increase revenue. Additionally, the system can provide valuable data for analysis and planning, which can help improve the efficiency and cost-effectiveness of the power system [4].

1.2. Engineering Problem Statement

The Engineering problem that this project is focused on is the efficient and reliable monitoring and management of power systems within a substation [5]. Specifically, the problem is to develop a system that can collect and analyze data from various power system components, such as transformers, switches, and power lines, in real-time to improve the overall performance and reliability of the substation. This includes addressing issues such as power outages, system downtime, and power theft. The specific problem statement could be:

"Design and develop an IoT based power monitoring and management system for a substation that can collect and analyze real-time data from various power system components, such as transformers, switches, and power lines, to improve the overall performance and reliability of the substation and reduce power outages, system downtime, and power thefts."

1.3. Related Research Works

Remote monitoring and control of substation equipment is a critical issue for the energy management department, which is typically done manually or with the help of an expensive PLC and SCADA system. A smart monitoring and trustworthy controlling system over the complete sub-station equipment is highly desirable in the age of the internet and computation, and this can be accomplished by implementing the Internet of Things (IoT) technology. The Internet of Things (IoT) is a network of physical objects with electronics, software, sensors, actuators, and network connectivity that can identify, gather, and exchange data. Each object has an embedded computing system that makes it individually identifiable, and it can interact with other things using the current internet infrastructure [5]. With the use of IoT-based systems, objects can be sensed or controlled from a distance using existing network infrastructure, which allows for broader integration into computer-driven systems and improves efficiency/accuracy and generates economic benefits through minimal human intervention.

1.3.1. Earlier Research

A smart substation auxiliary control system leveraging the Internet of Things is introduced to address the current issue of substations having separate auxiliary facilities that lack intelligent interaction capabilities (IOT). The IEC61850 communication protocol is used for internal coordination and remote information transfer in the system's management and monitoring of the production auxiliary systems of substations [6]. This system offers digitization, automation, and interactive support for smart substations by integrating all of the substation's auxiliary facilities, such as video monitoring, security, lighting, power supply, and optimal control subsystems [7].

In this research, the fundamental needs of the smart grid and examined how IOT technologies can be utilized to create a range of intelligent services. We discovered that by incorporating IOT into the smart grid, the overall development and functionality of the grid can be greatly improved [8]. Our study proposes a three-layer architecture for IOT in the smart grid in China, and examines the various information and communication techniques used in IOT for the smart grid. Specifically, we provide in-depth solutions for utilizing IOT in power transmission line monitoring, smart patrol, smart home, and electric vehicle management. This paper offers unique insights and practical applications for utilizing IOT in the smart grid to enhance its capabilities and performance [9].

In this study, a brand-new smart power management system for the smart grid is introduced. The system is broken down into five primary parts: smart grid power system failure analysis, smart power system modeling, real-time power system monitoring, system engineering database collection and management [10]. By combining historical engineering data with real-time monitoring data in a single system, analyzing scenarios through a variety of modules, and enabling accurate real-time data collection, monitoring, and control, the Smart Power Management System enables effective grid management and visualization. Regulations, requirements for grid management, and operational guidelines are taken into account when designing the smart power system. To fit the unique requirements and circumstances of the grid, several scenario modules can be modified. In order to tackle critical problems in power system engineering, design, grid operation, maintenance, and management, the system also contains neural networks for intelligent modeling. For the convenience of the maintenance crew, the system's intelligent features can also be accessible remotely using wireless channels, including cell phones [11]. Field maintenance and grid operation can also receive real-time alerts of problematic system indications as needed.

1.3.2. Recent Research

A work in the energy management department's challenge of remotely monitoring and controlling sub-station equipment. With the advent of the internet and computational era, a smart, reliable system is highly sought after. By incorporating Internet of Things (IOT) technology, the objective can be achieved. IOT is a network of physical devices embedded with electronics, software, sensors, actuators, and network connectivity that have the ability to identify, collect, and exchange data. Each device is uniquely identifiable and able to interoperate within the existing internet infrastructure [13]. The paper proposes an IOT-based network strategy for monitoring and controlling sub-station equipment to improve efficiency, accuracy, and economic benefit with minimal human intervention. The proposed system allows objects to be sensed or controlled remotely through existing network infrastructure, resulting in direct integration of the physical world into computer-based systems [14]. A prototype system has been implemented and tested to evaluate the effectiveness of the proposed model.

Managing power plants requires monitoring a wide range of data and parameters in real-time. With the advancement of technology, the Internet of Things (IOT) has made it possible to remotely control and monitor the performance of power plants using digital data. In this study, an IOT system using a Wi-Fi development kit called Photon was implemented to remotely monitor and control the University of Mosul power plant [15]. The system was able to track important parameters such as Power Factor, supplied voltage, and total load current for each substation within the university. Additionally, the system had a safety feature that would automatically shut down the power plant in the event of a critical situation such as a fire. The data collected by the Photon devices was sent to Thing Speak, an IOT analytics platform, which allowed engineers to visualize and analyze the data in real-time [16]. This feature enabled the engineers to monitor the performance of the power plant from any location and make necessary adjustments to the system while it was still in operation.

1.4. Critical Engineering Specialist Knowledge

In order to successfully and effectively implement an IOT-based power monitoring and management system for a substation, several specialist knowledge areas are required. These include:

Knowledge of power systems and substation design: This is essential for understanding the various components of the substation, their functions and how they interact with each other. It also allows for the proper design and implementation of the IOT system to monitor and control the substation.

Knowledge of IOT technology: The IOT system used in this project is based on Photon Wi-Fi development kit and Thing Speak IOT analytics platform. Knowledge of these technologies is necessary for programming and configuring the devices to collect and transmit data to the cloud.

Knowledge of cloud computing and data analytics: The collected data is sent to the cloud for storage and analysis. Understanding how to analyze and visualize the data in real-time is crucial to effectively monitoring the performance of the substation.

Knowledge of electrical safety: Implementing a safety feature to completely shut down the power plant in the event of a serious condition such as a fire requires knowledge of electrical safety and the ability to properly design and implement the safety feature.

Knowledge of communication protocols and networking: The IOT system relies on communication protocols and networking to transmit data from the substation to the cloud. Knowledge of these technologies is necessary to ensure that the data is transmitted securely and reliably.

Knowledge of software development: The system can be reprogrammed during operation, if necessary, which requires knowledge of software development for making the necessary changes.

Overall, a combination of knowledge in power systems, IOT technology, cloud computing, electrical safety, communication protocols, and software development is required to effectively implement an IOT-based power monitoring and management system for a substation.

1.5. Stakeholders

An IOT-based Power Monitoring and Management system of a substation would have a variety of stakeholders, each with their own specific requirements. Some potential stakeholders and their requirements include:

Power Utility Companies: These companies would have a primary interest in the system as they would be responsible for the operation and maintenance of the substation. They would require accurate and real-time monitoring of the substation's power usage, as well as the ability to control and manage the substation remotely.

Regulators: Regulators such as government agencies and industry associations would require the system to comply with industry standards and regulations. They would also be interested in the system's ability to improve the overall reliability and efficiency of the power grid.

Customers: Customers, such as residential and commercial users, would require the system to provide them with accurate and transparent information about their power usage, as well as the ability to control their own power usage.

Equipment Manufacturers: Equipment manufacturers would be interested in the system's ability to integrate with their equipment and provide them with valuable data and insights about their products' performance.

Researchers and academics: Researchers and academics would require the system to provide them with data and insights for their research projects and publications.

Cybersecurity experts: With the implementation of IoT, cyber security experts would require the system to have robust security measures in place to protect against cyber-attacks and to ensure the system operates securely.

Project Managers: Project managers would require the system to be implemented on time, within budget and to the required specifications.

It is important to have a clear understanding of the stakeholders and their requirements to ensure the project meets the needs of all parties involved.

1.6. Objectives

The objective of an IOT based Power Monitoring and Management system of a substation is to monitor and manage the power distribution and consumption of a substation in real-time using Internet of Things (IoT) technology. This system aims to improve the efficiency and reliability of the power distribution network by using sensors and communication devices to collect data on the substation's power usage and status. The data is then transmitted to a central management system, where it can be analyzed and used to optimize the power distribution and identify potential problems. This system can also be used to remotely control and adjust the substation's power distribution, allowing for more efficient management of the power grid. Additionally, it also helps to avoid power outages, reduce costs and improve the overall performance of the substation. Overall, the goal of this system is to provide real-time monitoring, management and control of the substation's power distribution network, leading to more efficient and reliable power supply for the end-users.

The primary and secondary objectives of the project are summarized below:

1.6.1. Primary Objectives

- Real-time monitoring of key electrical parameters such as voltage, current, and power factor
- Automated data collection and analysis to identify potential issues and improve overall system efficiency
- Remote control and management of substation equipment, including the ability to remotely switch on/off breakers, adjust tap positions, and perform other functions
- Improved system reliability and availability through predictive maintenance and advanced fault detection and diagnosis
- Enhanced security through the use of secure communication protocols and access control mechanisms.
- Integration with other systems and data sources to provide a more comprehensive view of the power system.

1.6.2. Secondary Objectives

- Improved energy management and optimization through real-time monitoring and analysis of energy consumption
- Better decision-making through the use of historical data and analytics
- Improved communication and collaboration between substation personnel and other stakeholders, such as utilities and regulatory bodies
- Reduced downtime and maintenance costs through predictive maintenance and advanced fault detection and diagnosis
- Enhanced regulatory compliance through the use of automated data collection and reporting
- Increased scalability and flexibility to accommodate future growth and changes in the power system.

1.7. Organization of Book Chapters

Chapter 2: Project Management

In this section, we focus on the cost analysis, management of the project, S.W.O.T. analysis, P.E.S.T. Analysis, and project lifecycle.

Chapter 3: Methodology and Modeling

This chapter discusses the methods that are going to use to implement the project. Some flowcharts, models are going to provide to show how the whole project is going to implement.

Chapter 4: Project Implementation

Project implementation is a significant term for all kinds of projects. In this project, various components are included and each of them has its own particular work.

Chapter 5: Results Analysis & Critical Design Review

In this part, the results & the data we have found are going to analysis and compare with the traditional measure data. The outcome of the whole project is going to elaborate in this chapter.

Chapter 6: Conclusion

At the end of this chapter, we conclude by saying different drawbacks of the device, future scopes, and the impact of the project on society.

Chapter 2

PROJECT MANAGEMENT

2.1. Introduction

Project management is defined as a methodical approach to initiating, planning, strategies, executing, monitoring, and communicating projects. A project is a short-term activity that involves the creation of a one kind of product or service. To achieve a project's goal, the team in charge must carry out a specific set of actions. Before starting a project, the strength, weakness, opportunities, and threats (S.W.O.T analysis) must be evaluated. Furthermore, the project timeline must be met, which necessitates task planning. Of course, project cost estimating is one of the most important duties to complete. In addition to that possibility, the project's socioeconomic and environmental consequences must be considered before proceeding. Furthermore, professional duties as project engineers must be considered. This chapter addresses all of the aforementioned concerns.

2.2. S.W.O.T. Analysis

SWOT analysis is a useful planning and analysis procedure that examines a project’s strengths, weaknesses, opportunities and threats. It’s a strategic tool for identifying both positive and negative factors. Those variables are both helpful and hindering in accomplishing the project’s goal. [17].

2.2.1. Strength

Here are a few potential strengths of an IoT-based power monitoring and management system for a substation:

Real-time monitoring: The system can continuously collect and transmit data on various parameters such as voltage, current, power, and energy consumption, allowing for real-time monitoring and analysis of the substation's performance.

Remote access and control: The system can be accessed and controlled remotely through a web-based interface or mobile app, allowing operators to monitor and manage the substation from anywhere at any time.

Improved efficiency: The system can provide detailed insights into the substation's energy consumption, helping operators identify areas for improvement and optimize the substation's performance.

Increased reliability: By continuously monitoring the substation's performance, the system can detect and alert operators to potential issues before they become critical, helping to prevent equipment failures and power outages.

Predictive maintenance: The system can analyze data on equipment usage, temperature, vibration, and other factors to predict when maintenance will be needed, allowing operators to schedule maintenance at the most convenient times and avoiding unplanned downtime.

Increased safety: By providing real-time monitoring of the substation's performance, the system can help to ensure that the substation is operating within safe limits and alert operators to any potential safety hazards.

Cost savings: By providing real-time monitoring and control of the substation, the system can help to reduce energy consumption, minimize downtime, and improve the overall efficiency of the substation, resulting in significant cost savings.

2.2.2. Weakness

Here are some potential weaknesses of an IOT-based power monitoring and management system for substations:

Security: If the system is not properly secured, it may be vulnerable to hacking or other cyber-attacks, which could compromise the safety and integrity of the power grid.

Scalability: As the number of devices and sensors connected to the system increases, it may become increasingly difficult to manage and process the large amount of data generated.

Interoperability: If the system is not designed to work with existing substation equipment and protocols, it may not be able to effectively integrate with existing systems.

Reliability: If the system is not designed to withstand harsh substation environments, it may not be able to operate reliably.

Cost: Implementing an IOT-based power monitoring and management system can be expensive, especially if it requires upgrading or replacing existing substation equipment.

Maintenance: IOT devices require regular updates, maintenance, and troubleshooting which can be costly.

Data Analysis: The system generates a lot of data, so the data analysis and interpretation can be challenging, and require highly skilled and trained professionals.

2.2.3. Opportunities

Here are some opportunities for an IOT based Power Monitoring and Management system of Substation:

- Remote monitoring and control of substation equipment, such as transformers, breakers, and switchgear, to improve efficiency and reduce the need for on-site maintenance.
- Real-time monitoring of power usage and distribution, allowing for more efficient energy management and cost savings.
- Early detection and prediction of equipment failures, reducing the risk of outages and power loss.
- Automated control of substation equipment to optimize power distribution and reduce transmission losses.
- Integration with other smart grid technologies, such as Advanced Metering Infrastructure (AMI) and Distribution Automation (DA), to improve overall grid reliability and resiliency.
- Improved data analysis and visualization capabilities, providing better insights into power usage patterns and enabling more effective decision making.
- Remote Accessibility to the substation which reduces the need of human intervention and increases the security of the substation.

- Enabling the integration of renewable energy sources into the power grid by monitoring and controlling their output.

2.2.4. Threats

Here are some potential threats for an IOT based Power Monitoring and Management system of a substation:

Physical Security Risks: Substations are physical infrastructure and susceptible to vandalism, theft or natural disasters.

Security Breaches: As the system relies in interconnected devices and networks, there could be a risk of security breaching that includes unauthorized access, data breaching or any cyber-attack.

Data Privacy Concerns: The system collects and processes a significant amount of data that includes operational and sensitive information. Inadequate data protection or unauthorized data sharing could result in privacy violations.

Network Vulnerabilities: The IoT system involves various network components and communication protocols. Weakness in network infrastructure such as insecure wireless communication, lack of encryption or poor access controls could expose the system to unauthorized persons.

Equipment Malfunction: The IoT devices and sensors used in the substation monitoring system may experience technical issues such as hardware failures, software or cloud glitches or communication interruptions. These factors could impact the accuracy and reliability of data and could lead to incorrect decision-making.

2.3. Schedule Management

Schedule management suggests that the method of developing a project, maintaining a project, and human action project schedules for time and a few resources [18]. Schedule Management implies that the method of creating the policies for the project, some procedure for implementation, and documentation for the project for designing, managing, executing, developing, and dominant the project management schedule. Table 2.1 shows the project timeline of our project, where you can see a detailing task and their deadlines.

(1) Gantt Chart

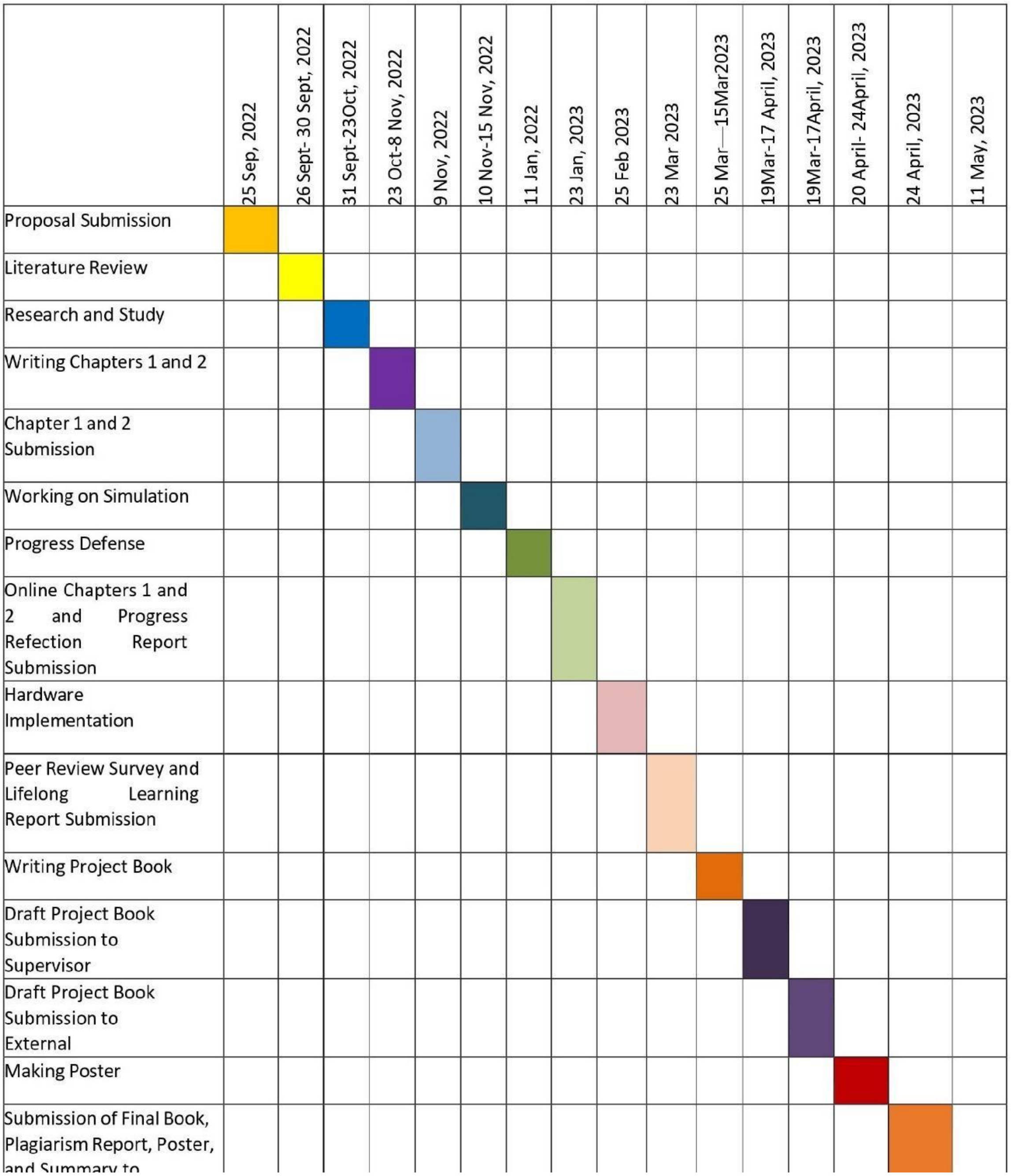


Figure 2.1: Project Timeline

2.4. Cost Analysis

We assess all potential costs that can be generated from our project as part of the cost-analysis process to verify that our budget is sufficient to cover the costs.

The positive square root of the variance is the standard deviation. One of the fundamental approaches of statistical analysis is standard deviation. The standard deviation is frequently abbreviated as SD and denoted by 'o' and it reveals about the value how far it deviates from the mean value. A low standard deviation indicates that the values are close to the mean, whereas a large standard indicates that the values are distant from the mean. [19]

$$S = \sqrt{\frac{\sum_{i=i}^{n}(x_i - \bar{x})^2}{(n-1)}}$$

s → Sample Standard Deviation

n → Total number of sample elements

$\bar{x}$ → Sample mean

Table 2.1: Project Budget Estimation

Serial	Components	Quantity	Estimated Price	Actual Price
01	ESP32 W-ROM Development Board	1	600	650
02	MQ2 Smoke/LPG/CO Gas Sensor	1	150	150
03	20 x 4 LCD Display	1	400	470
04	AC Voltage Sensor Module	1	200	280
05	10A on/off Red Color Rocker Switch	1	20	20
06	5V 1 Channel Red color Relay	3	350	390
07	Hall Current Module	4	600	640
08	Arduino Uno	1	800	850
09	DC Power Supply	1	800	950
10	25 W light	3	100	90
11	Holder	3	50	90
12	Regulator	3	100	150

Table 2.1 (contd.)

13	2 Pin Plug	1	20	20
14	Load		100	100
15	Connecting wire		200	200
`16	Others		500	900
		Total	4990	5950

Table 2.2: The Standard Deviation for the Project's Estimated Cost

Estimated Price (Xi)	**Mean (Xi)**	**(Xi-X)**	**(Xi-X)^2**	**SD**
600	4990/16= 311.88	288.12	83013.134	316.34
150		-161.88	26205.134	
400		88.12	7765.1344	
200		-111.88	12517.134	
20		-291.88	85193.934	
350		38.12	1453.1344	
600		288.12	83013.134	
800		488.12	238261.13	
800		488.12	238261.13	
100		-211.88	44893.134	
50		-261.88	68581.134	
100		-211.88	44893.134	
20		-291.88	85193.934	
100		-211.88	44893.134	
200		-111.88	12517.134	
500		188.12	35389.134	

Table 2.3: The Standard Deviation for the Project's Actual Cost

Estimated Price (Xi)	Mean (Xi)	(Xi-X)	$(Xi-X)^2$	SD
650	5950/16= 371.88	278.12	77350.734	375.41
150		-221.88	49230.734	
470		98.12	9627.5344	
280		-91.88	8441.9344	
20		-351.88	123819.53	
390		18.12	328.3344	
640		268.12	71888.334	
850		478.12	228598.73	
950		578.12	334222.73	
90		-281.88	79456.334	
90		-281.88	79456.334	
150		-221.88	49230.734	
20		-351.88	123819.53	
100		-271.88	73918.734	
200		-171.88	29542.734	
900		528.12	278910.73	

2.5. P.E.S.T. Analysis

P.E.S.T. is a form of strategic research used to analyze the effects on political, economic, social, and technological factors that a plan could have [20]. It requires a person to know the surrounding world before initiating a project.

2.5.1. Political

Political factors can play a significant role in the implementation and success of an IOT based Power Monitoring and Management system of a substation in Bangladesh. The government of Bangladesh have laws and regulations in place that govern the implementation and operation of such systems. It is important to ensure compliance with these regulations. The government have policies in place that incentivize or discourage the use of IOT technology in the power sector. These policies may affect the implementation and success of the system. Political stability in the country can affect the implementation and success of the system. Unrest or instability may make it difficult to implement or maintain the system, or may make it more vulnerable to attack. Corruption can be a significant problem in Bangladesh and can affect the implementation and success of the system. It is important to ensure that the system is implemented and maintained in a transparent and accountable manner to minimize the risk of corruption. The government support will be crucial for the implementation and success of the system. The government support can be in terms of financial support, policy support, legal support etc.

2.5.2. Economical

By monitoring and managing power transmission and distribution in real-time, the system can help identify and address issues more quickly and effectively, leading to improved efficiency and reliability of the power grid. The system can help identify and address power loss due to transmission and distribution issues, leading to significant reduction in energy loss. To monitor the condition of equipment in real-time, the system can help predict and prevent equipment failures, reducing the need for costly repairs and maintenance. By providing real-time monitoring and management of power transmission and distribution, the system can help improve customer service by addressing issues more quickly and effectively. In Bangladesh, electricity production is mostly based on natural gas, coal and a small amount of hydroelectricity. So, by implementing the IOT-based Power Monitoring and Management system, the power generation companies will be able to optimize the usage of these sources, reduce wastage and increase their revenue.

2.5.3. Social

IOT based Power Monitoring and Management systems have the potential to bring significant benefits to the power sector in Bangladesh, including improved efficiency, reliability, and cost savings. However, as with any new technology, there are also potential challenges that need to be considered. One potential social challenge is the lack of awareness and understanding of the technology among stakeholders. This could include government officials, power companies, and consumers. Without a sufficient understanding of the benefits and limitations of the technology, stakeholders may be less likely to support or invest in its implementation. Another potential challenge is the lack of infrastructure and resources to support the technology. The implementation of an IOT based power monitoring and management system requires a reliable and secure network infrastructure, as well as trained personnel to operate and maintain the system. In Bangladesh, the availability and quality of infrastructure and resources may be limited, which could impede the implementation of the technology. Additionally, privacy and security concerns may arise. With the collection and storage of large amounts of data, there is a risk that this information could be compromised or used for malicious purposes. It's important to ensure that the system is designed and implemented with robust security measures to protect the data and prevent unauthorized access. Finally, the cost of implementing such system could be a significant challenge for Bangladesh. The cost of setting up the system and maintaining it could be high, especially for small and medium-sized power companies. It's important to consider these potential challenges in order to develop effective strategies for overcoming them and successfully implementing IOT based Power Monitoring and Management systems in Bangladesh.

2.5.4. Technological

An IoT based Power Monitoring and Management system of a substation in Bangladesh could potentially face several technological challenges. These challenges could include:

Limited infrastructure: Bangladesh has a limited infrastructure for IoT implementation, including limited availability of high-speed internet, power supply, and device connectivity. This could make it difficult to implement a robust and reliable IoT system.

Lack of standardization: The IoT industry in Bangladesh is still in its early stages, and there is a lack of standardization in terms of device compatibility, communication protocols, and data format. This could make it difficult to implement a system that can seamlessly integrate with existing infrastructure.

Limited device availability: The availability of IoT devices in Bangladesh is limited, which could make it difficult to find suitable devices for the substation monitoring and management system.

Limited skilled workforce: Bangladesh has a limited number of skilled workers with experience in IoT implementation, which could make it difficult to find the necessary personnel to design, implement, and maintain the system.

Limited data security: Bangladesh lacks a comprehensive data security framework, which could make it difficult to secure the data generated and transmitted by the system.

Limited power supply: Bangladesh often faces power shortages, which can affect the normal functioning of the IoT devices. Limited budget: The cost of implementing such a system can be high, and the budget for such projects may be limited in Bangladesh.

It's important to note that these are just examples of potential challenges and the actual challenges will depend on the specific implementation and the location where the substation is located.

2.6. Professional Responsibilities

Engineers are responsible for making sure the system is built in accordance with all safety and legal requirements, including OSHA, IEEE, and NERC standards. The system's reliability and reliability must be assured by the engineers to satisfy the requirements of substation operations. Engineers must make sure the system is designed to be secure against cyber risks including malware infections, unauthorized access, and data breaches. Implementing security mechanisms like firewalls, encryption, and authentication methods falls under this category. To fulfill future operational needs for the substation, engineers must make sure the system is built to be expandable. The system must be developed to meet the performance standards of the substation operations, according to engineers. To prevent operational conflicts, engineers must make sure the system is built to be compatible with other systems already in the substation. To offer a complete monitoring and management solution, engineers must make sure the system is built to be interconnected with other systems in the substation.

2.6.1. Norms of Engineering Practice

Engineering practice is the application of scientific, mathematical, and practical knowledge to design, build, and maintain systems, structures, and equipment. In the context of an IoT based Power Monitoring and Management system of a substation, the general engineering practice would involve applying the principles of electrical engineering and computer science to design, implement, and maintain the system.

To follow engineering guidelines in this project, the following steps could be taken:

Define the project requirements: The first step is to clearly define the requirements of the project, including the goals, objectives, and constraints of the system.

Conduct a feasibility study: A feasibility study should be conducted to determine if the project is technically and economically viable. This study should include an analysis of the infrastructure, technology, and regulations that will be required for the project.

Design and development: The design and development phase of the project involves creating a detailed design for the system, including the selection of hardware, software, and communication protocols. The design should also consider security, scalability, and reliability.

Testing and validation: The system should be thoroughly tested and validated to ensure that it meets the requirements and works as intended. This includes functional testing, performance testing, and security testing.

Implementation and commissioning: The system should be implemented and commissioned in accordance with the design and test results. This includes installing and configuring the hardware and software, and ensuring that the system is properly integrated with the existing infrastructure.

Maintenance and support: The system should be maintained and supported to ensure that it continues to operate correctly and to address any issues that arise. This includes regular monitoring, troubleshooting, and updating the system as needed.

Compliance with regulations: The system should be designed and implemented in compliance with relevant regulations and standards, such as safety, security, and data privacy regulations.

By following these general engineering practice, the project will ensure that the power monitoring and management system is designed, developed, and maintained in a safe, secure, and efficient manner.

2.6.2. Individual Responsibilities and Function as Effective Team Member

2.6.2.1. The tasks of Member (MOSTAK, MD. SAKLINE):

- Conducting Necessary Surveys.
- Calibrating Simulation, Analyzing findings and Results.
- Writing Chapter 1 & 5 of the Project Book.
- Preparing Poster.
- Making of project pre-defense PowerPoint presentation.
- Presented the slide during the project’s pre-defense.
- Made the book formatting.

- Helped in the buying of hardware components.
- Made in the process of hardware implementation.

2.6.2.2. The task of Member (ALAM, S.M TANVIRUL)

- Conducting Necessary Surveys.
- Writing Chapter 3 of the Project Book.
- Making of project pre-defense PowerPoint presentation.
- Presented the slide during the project’s pre-defense.
- Helped in the making of the project Block Diagram.
- Helped in the buying of hardware components.
- Listing and collecting Project Components.
- Analyzing Project finance.
- Made the project Gantt Chart.
- Made in the process of hardware implementation.

2.6.2.3. The tasks of Member (RAHMAN, MD. HASIBUR):

- Writing Chapter 2 & 4 of the Project Book.
- Making of project pre-defense PowerPoint presentation.
- Helped in the buying of hardware components.
- Listing and collecting project components.
- Analyzing Project finance.
- Proteus Simulation.
- Made the project survey questions.
- Analyzing Survey.
- Made the book formatting.
- Helped in the process of hardware implementation.

2.6.2.4. The tasks of Member (DAS, PRITOM)

- Writing Chapter 6 of the Project Book.
- Analyzing Survey.
- Made the project survey questions.
- Making of project pre-defense PowerPoint presentation.
- Helped in the buying of hardware components.
- Proteus Simulation.
- Helped in the process of hardware implementation.
- Preparing summary.
- Listing and collecting Project Components.

2.7. Management Principles and Economic Models

An IoT based Power Monitoring and Management system of a substation project would likely involve several engineering managements models and principles to ensure the project is completed successfully and cost-effectively.

One example of a management principle that could be applied in this project is the Project Management Body of Knowledge (PMBOK) framework. This framework provides a structured approach to managing projects, including planning, execution, monitoring and controlling, and closing phases. This framework could be used to establish a project plan, assign tasks, monitor progress, and identify and resolve issues throughout the project.

Another example of a management principle that could be applied in this project is the agile methodology. Agile methodology emphasizes flexibility, adaptability, and customer satisfaction by breaking the project into small chunks and delivering them iteratively. This methodology could be used to ensure that the project meets the needs of the stakeholders and adapts to changing requirements.

In terms of economic models, the Total Cost of Ownership (TCO) could be used to evaluate the cost-effectiveness of different solutions. TCO takes into account not only the initial cost of the solution, but also the ongoing costs such as maintenance, energy consumption, and replacement costs. This model can be used to evaluate different solutions to find the most cost-effective one.

Another economic model that could be used in this project is the Benefit-Cost Analysis (BCA). BCA is a method used to determine the economic viability of a project by comparing the benefits and costs of a proposed solution. This model can be used to evaluate the economic benefits of the project, such as improved power supply, reduced downtime, and increased revenue.

To demonstrate competency in completing an individual engineering project based on relevant management principles and economic models, it is important to document the project management approach and the economic models used throughout the project. This could include:

- Detailed project plan and timeline
- Regular progress updates
- Identification and resolution of issues

Final report summarizing the management approach and economic models used in the project.

It is also important to demonstrate an understanding of the various engineering management models and principles and how they were applied in the project. This could include explaining how the project was broken down into smaller chunks and delivered iteratively using the agile methodology, or how the project plan was established and executed using the PMBOK framework.

In addition, it is important to demonstrate an understanding of the economic perspective and models used in the project, such as how the TCO and BCA models were used to evaluate the cost-effectiveness and economic viability of the proposed solution.

2.8. Summary

This chapter mainly describes the management procedure of our project. We have discussed possible strengths, weaknesses, opportunities and threats of our work. Political, Economic, Social and Technological factors have been also discussed in this chapter. According to S.W.O.T and P.E.S.T analysis, we realized that the scopes and factors affecting the project. The cost analysis of the IOT based Power Monitoring and Management system of Distribution Substation is briefly presented here. The chapter also demonstrates project lifespan as a conclusion.

Chapter 3

METHODOLOGY AND MODELING

3.1. Introduction

In this project, several basic engineering theories and methods were implemented to design and develop the Power Monitoring and Management (PMM) system. These theories and methods serve as the foundation for understanding and optimizing the electrical system's performance. Firstly, electrical engineering principles were employed to ensure the accurate measurement and analysis of electrical parameters. This includes applying Ohm's law, which relates voltage, current, and resistance, to calculate and monitor power consumption. Additionally, knowledge of electrical circuit analysis, such as series and parallel circuits, aided in designing efficient and reliable connections within the PMM system. Power systems analysis techniques were crucial for studying and evaluating the behavior of the electrical network. Load flow studies were conducted to analyze power flow and voltage levels, while fault analysis helped identify and mitigate potential electrical faults. Transient analysis aided in understanding the system's response to sudden changes or disturbances. By applying these methods, engineers could optimize the PMM system's design and performance, ensuring stable and efficient power management. Data acquisition and communication principles played a vital role in collecting and transmitting real-time data from various sensors and components in the PMM system. Understanding sensor technologies, signal conditioning, and communication protocols enabled engineers to select appropriate sensors, ensure accurate data measurement, and establish reliable data transmission between devices. Control systems engineering was applied to regulate and optimize power usage within the PMM system. This system monitoring such as load shedding, voltage, current and power factor. These control strategies helped maintain the system's stability and efficiency.

3.2. Block Diagram and Working Principle

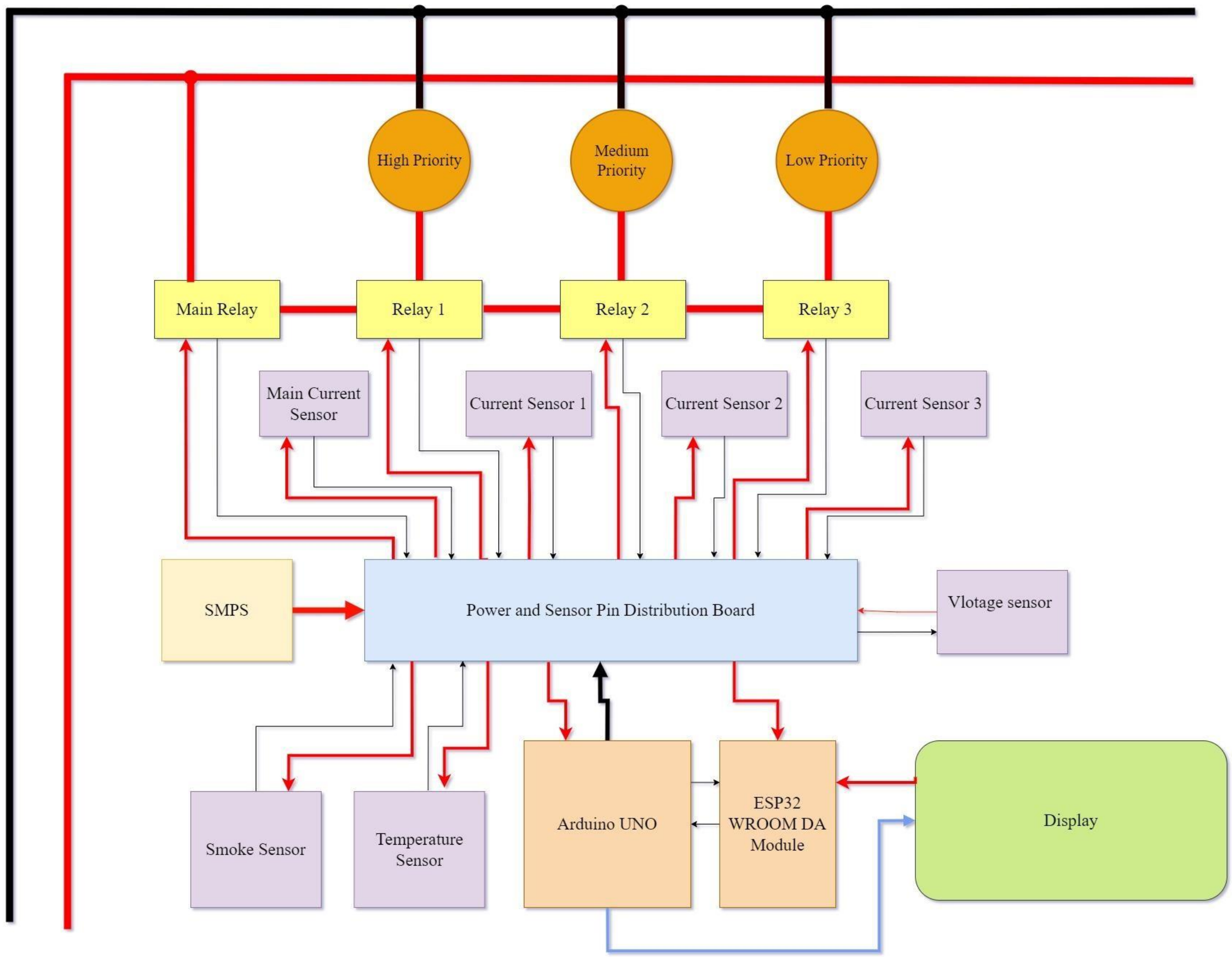


Figure 3.1: System Block Diagram

The block diagram of the Power Monitoring and Management (PMM) system showcases the interconnection of various components and divisions to efficiently monitor and manage power consumption. Take steps to examine the block diagram and its operation in further more detail:

Starting with the switch, it serves as the primary input device that controls the flow of electrical current in the system. The current sensor is connected to the switch and measures the current passing through the circuit. This sensor provides valuable data about the current consumption, a critical parameter for power monitoring. Following the current sensor, the voltage sensor is connected. This sensor measures the electrical voltage in the circuit, offering insights into the voltage level. By measuring the voltage, the system can monitor and analyze power-related characteristics accurately. The output from the voltage sensor is then connected to a Switched Mode Power Supply (SMPS) and a display unit. The SMPS plays a crucial role in converting the incoming voltage to the desired level required for powering the system components. This conversion ensures that the system operates with the appropriate voltage and power supply. The display unit, connected to the SMPS, provides visual feedback to users. It presents real-time information about power-related parameters such as current readings, voltage readings, power factor, or energy consumption. The display unit allows users to monitor and analyze power usage effectively.

Moving on, the ESP32 WROOM-32 acts as the central processing unit in the system. It receives data from the current and voltage sensors, processes the information, and controls the overall functionality of the PMM system. The ESP32 WROOM-32 is responsible for collecting and analyzing power data, making decisions, and triggering actions based on the measured parameters. In terms of safety measures, the ESP32 WROOM-32 is connected to both a fire alarm and a smoke sensor. This integration enables continuous monitoring of power-related parameters, ensuring prompt response to abnormal power conditions. In the event of dangerous situations such as high current or voltage fluctuations, the ESP32 WROOM-32 can trigger the smoke alarm and activate the smoke sensor, enhancing safety precautions and timely alerting. Moreover, the PMM system is divided into three distinct areas. Each area consists of specific components and functionalities. In each area, a relay is employed to control the flow of electrical current to the devices within that specific section. The relay is followed by a current sensor, which measures the current consumed by the devices in that particular area. This allows for precise monitoring and management of power usage within each section. Furthermore, a fan regulator is incorporated to control the speed of the fan in each area. This regulation ensures optimal ventilation and cooling based on the power requirements and environmental conditions. Additionally, a 25W light is connected within each area, providing illumination. The power consumption of the light can be monitored and managed as part of the overall power management system.

In summary, the block diagram demonstrates the systematic integration of components in the PMM system. It starts with the switch and current sensor, followed by the voltage sensor, SMPS, and display unit, all connected to the ESP32 WROOM-32. The ESP32 WROOM-32 is further linked to the fire alarm and smoke sensor for enhanced safety measures. The system is divided into three areas, each comprising a relay, current sensor, fan regulator, and a 15W light. This design allows for efficient power monitoring, management, and control, ensuring optimized power consumption and safety in each section.

3.3. Modeling

The 3D design is created in Fusion 360 for the Power Monitoring and Management (PMM) system incorporates an optimized layout and integration of its components. explore the 3D design in detail:

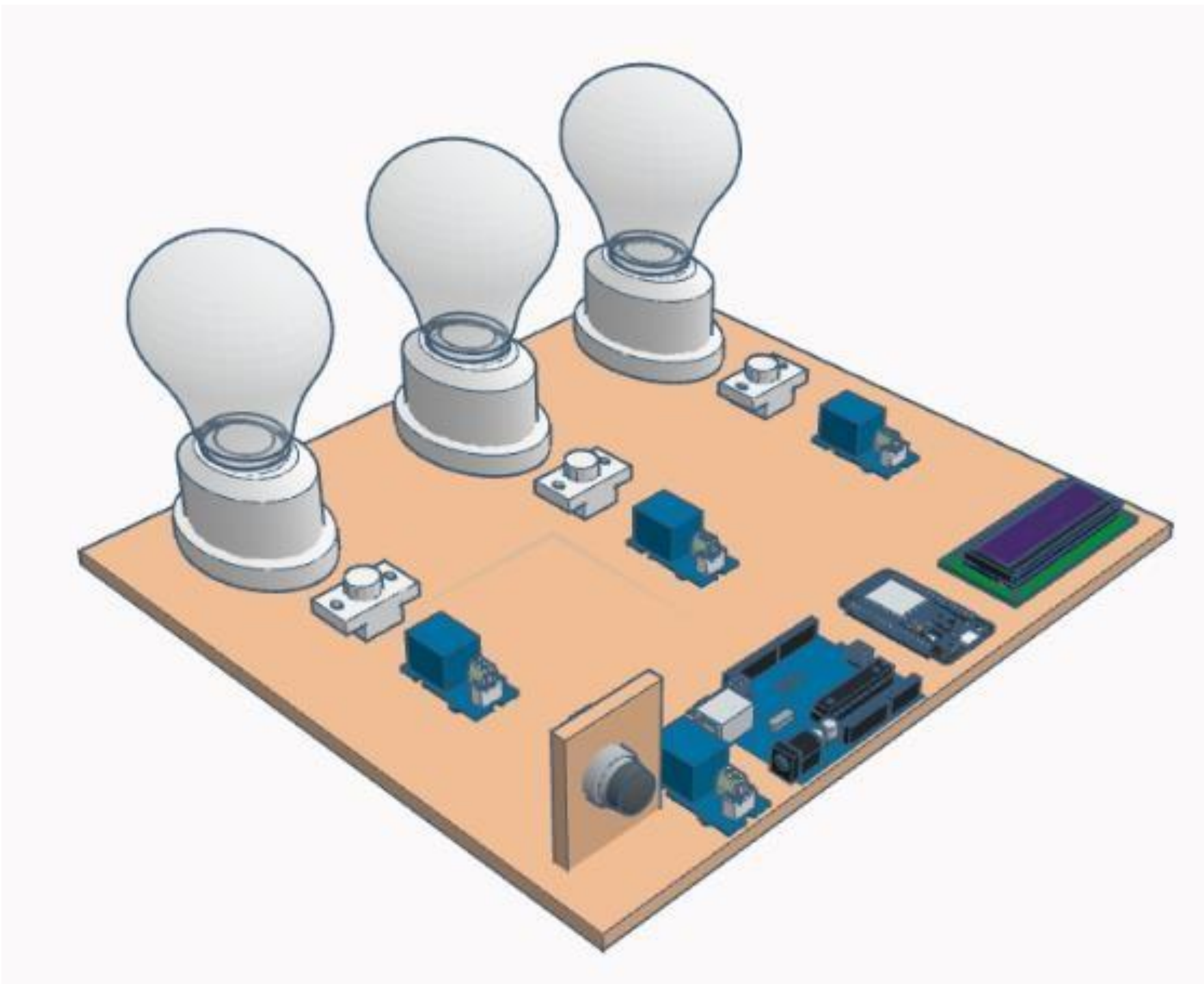


Figure 3.2: 3D Model of the Project

The system includes a switch connected to a current sensor, followed by a voltage sensor. The 3D design ensures the proper placement of these components, allowing for efficient routing of electrical connections and optimal space utilization. The design incorporates a Switch Mode Power Supply (SMPS) and a display unit, which are interconnected. The SMPS is positioned strategically within the 3D model to efficiently convert the incoming voltage to the desired level for powering the various components of the PMM system. The display unit is placed in a location that ensures clear visibility and accessibility for users to monitor real-time power-related information.

The ESP32 WROOM-32, serving as the central processing unit, is connected to the SMPS and the display unit. In the 3D design, the placement of the ESP32 WROOM-32 is carefully considered to facilitate smooth communication with the sensors and other components. This integration enables the ESP32 WROOM-32 to process data, control the system's functionality, and provide the necessary intelligence for power management. In addition to the ESP32 WROOM-32, the 3D design incorporates connections to the fire alarm system and the smoke sensor. These safety components are strategically positioned within the design to ensure effective monitoring and prompt response to hazardous conditions. The integration of the fire alarm and smoke sensor enhances the system's ability to detect and respond to potential fire incidents associated with power abnormalities.

Furthermore, the PMM system is divided into three areas within the 3D design. Each area consists of specific components and functionalities to cater to individual requirements. The design ensures proper segregation and organization of these areas, allowing for efficient power monitoring and management within each section. In each area, the components are arranged in a logical sequence. Starting with a relay, which controls the flow of electrical current, it is followed by a current sensor to measure the power consumption of devices within the specific area. A fan regulator is integrated to enable precise control of the fan's speed, ensuring optimal ventilation and cooling based on the power requirements and environmental conditions. Additionally, a 25W light is connected within each area to provide illumination, and its power consumption is monitored and managed as part of the overall power management system.

To summarize, the 3D design created in Fusion 360 for the PMM system optimizes the arrangement and integration of components. The placement of the switch, current sensor, voltage sensor, SMPS, display unit, ESP32 WROOM-32, fire alarm, and smoke sensor is carefully considered to ensure efficient routing of connections and effective utilization of space. The design also includes three distinct areas, each comprising a relay, current sensor, fan regulator, and a 15W light, enabling efficient power monitoring and management in each section. This 3D design approach enhances the functionality and performance of the PMM system, promoting effective power monitoring, management, and safety measures.

3.4. Summary

In summary, the Power Monitoring and Management (PMM) system was designed using a combination of engineering theories, methods, and 3D modeling techniques. The final model incorporates various components and divisions to effectively monitor and manage power consumption. The modeling process began with the identification and arrangement of components in a block diagram. The system consists of a switch, current sensor, voltage sensor, SMPS, display unit, ESP32 WROOM-32, fire alarm, smoke sensor, relays, fan regulators, and 15W lights. Each component was strategically positioned within the 3D design to optimize space utilization, connectivity, and accessibility. The modeling steps involved the creation of a 3D design in Fusion 360, ensuring accurate placement and interconnection of the components. The 3D design visualized the physical layout of the PMM system, allowing for effective analysis, evaluation, and refinement of the design. The final model showcases the integration of the components and their functionality. The switch controls the flow of electrical current, which is measured by the current sensor. The voltage sensor provides insights into the electrical voltage level. The SMPS converts the voltage to the required level, while the display unit presents real time power-related information.

Chapter 4

PROJECT IMPLEMENTATION

4.1. Introduction

Project implementation is a significant term for all kinds of projects. In this project, various components are included and each of them has its own particular work. These components are selected based on circuit consistency, work capacity and cost. The hardware implementation is done by using different types of equipment to implement the project because of specific functional tasks. Various components were selected based on circuit reliability and function. The purpose of an AC Hall Current Module is, to measure the amount of electrical current flowing to a conductor over a specified period. The ac hall current module is a device that is used to track current usage in ampere. It helps, not just in monitoring consumption incurred on electricity and also energy consumption. This module is commonly used in various applications where accurate current measurements are required. The purpose of an AC voltage sensor module is to provide accurate voltage measurements in order to monitor a typical voltage for the households, industries and commercial buildings. AC voltage sensors provides a non-invasive method for measuring AC voltage. The module is designed with a high level of accuracy and precision. In our work, This AC voltage module helps to measure the input and output voltage of the devices and conductors. A smoke sensor is a device that senses the presence of smoke, gas or other LPGs in the environment. The smoke sensor is placed in the room where all the power plant devices is integrated. It sends information about the presence of smoke if there have any fire hazards and the WROOM trip the system automatically. A rocker switch is a type of electrical switch that is designed to be operated by rocking it back and forth, typically with a finger. The purpose of a rocker switch is to control the flow of electrical current in a circuit by making and breaking the connection between the terminals. It provides a simple and reliable means of controlling the flow of electrical current is a circuit with its ergonomic design and durability. A one channel relay module is an electric device that is designed to control the flow of electrical current in a circuit by switching the connection on or off. It contains a single relay that is controlled by a microcontroller. The main purpose of a one channel relay module is to provides a simple and efficient way of controlling the operation of devices that require high-levels of electrical power. All the connections lead to the WROOM. It is an open-source development board. The purpose of the

WROOM is to provide a low-cost IoT system that can be accessed from further. Its analog and digital inputs and outputs helps to integrate the connection of the AC voltage, AC current, smoke sensor, relay to the loads of the commercial, industrial and residential buildings. The AC current and AC voltage sensor module reads the value of current and voltage that is used in the households, officials and commercial properties in real-time and send this information back to Arduino. The core controller is integrated with various sensors such as AC current sensor AC voltage sensor, MQ2 smoke sensor. The sensor leads are placed in the Loads. The sensor values will be processed by Arduino Uno, the core controller reads the value and it will be uploaded on the cloud by WROOM. The values will be monitored continuously by checking whether the sensor value is greater than threshold or not. If the sensor value is greater than threshold, then it will be tripped automatically. When the load demand becomes normal all the loads come back to connection. The sensor values checked again and again by maintaining a minimum delay.

4.2. Required Tools and Components

Required Software Tools and/or Hardware components are:

- ESP 32-WROOM Development Board,
- Arduino Uno ATmega 328P,
- MQ2 smoke sensor,
- AC voltage sensor module,
- AC current sensor module,
- One channel relay module,
- rocker switch,
- DC power supply,
- Regulator,
- LCD display.

AC VOLTAGE SENSOR

An AC voltage sensor is installed at input side of the power source to measure the voltage differences of two ends and monitor the amount of voltage that has passed through conductors. The output of the AC voltage sensor is typically a voltage signal that is proportional to the AC voltage being measured. When there is a use of power in commercial, industrial or residential areas there is a constant unit of voltage which is 220V. The red wire or the positive wire is connected to the wire carrying the AC voltage and the black wire or the negative wire is connected to the Ground. We monitor the output voltage by connecting the AC voltage sensor if there is a fluctuation in voltage parameters. The voltage outputs are shown through LCD display and the IoT system that is integrated with the system that requires an Arduino microcontroller board for processing.

Figure 4.1: AC Voltage Sensor Hard ware Image

AC CURRENT SENSOR

An AC current sensor module is a device that is used to measure the current flowing through an AC circuit. It is a non-invasive current transformer that is used to measure the flow of the current across the electric conductor. The current sensor module is connected in series with the load. As we have used 25 W incandescent lights, the AC sensor is connected with the lights in series and one sensor is used in the input side of the circuit to measure the input current. The output values are then sent to the microcontroller that stores the information for future analysis and that can be also accessed anytime from a cloud system from anywhere.

Figure 4.2: AC Current Sensor Hard ware Image

SMOKE SENSOR

A smoke sensor is a type of gas sensor module that is widely used to detect smoke in the surroundings. It detects the presence of different propane, methane, butane and other gases in the air. It operates on the principles of gas conductivity. The resistance of the sensor changes with the concentration of the gas in the air. We have used an MQ2 sensor in our work. It detects gas, smoke, or any LPGs. The sensor has an heating element and when it gets heated, a metal oxide semiconductor material gets oxidized and reduces the conductivity of the sensor. The MQ2 sensor is in small size and that makes an advantage in case of integration it the circuit. It has four pins and they are power pin Ground pin and two output pins. It operates between -20 to 50 Degree Celsius and a relative humidity of 95%.

Figure 4.3: MQ2 Gas Sensor Hardware Image

ONE CHANNEL RELAY MODULE

A relay is defined as an electric switch; used to control high voltage electrical circuits by means of a low-power signal Its interface can be controlled directly by the microcontroller. In our work, we have used a one channel relay module. This relay module is used at every load side for automatic switching purpose. For safety reasons, this module is isolated from the high voltage side, and it also prevents ground loops when connected to a microcontroller. When there is an overload or any electrical or fire hazard, the microcontroller sends signal to the relay and it disconnects the circuit to reduce the loss of device from both power or load side.

Figure 4.4: One Channel Relay Module Hard ware Image

ARDUINO

Arduino is an open-source electronics creation platform based on free, flexible, and easy-to-use hardware and software for creators and developers. With this platform, the developer community can create many different types of single-board microcomputers for different uses. A microcontroller is an integrated circuit that can store instructions written in a programming language that can be used in the Arduino IDE environment. You can use these instructions to create a program that interacts with the circuitry on your board. Arduino, on the other hand, provides a development environment (IDE) that implements the Arduino programming language, tools for transferring firmware to a microcontroller, and software that includes a bootloader that runs on the board. The main characteristics of software and programming languages are their simplicity and ease of use. Arduino promises to be an easy way to create interactive projects for everyone.

Figure 4.5: Arduino Uno Hard ware Image

WROOM

A low-cost System-on-a-Chip (SoC) called the ESP8266 serves as the foundation of the WROOM, an open-source ecosystem for developing both software and hardware. The ESP8266, created and produced by Express if Systems, includes all of the necessary components of a computer, including a CPU, RAM, networking (Wi-Fi), and even a contemporary operating system and SDK. This makes it an ideal choice for all types Internet of Things (IoT) projects. However, using the ESP8266 as a chip is challenging. For the simplest operations, like turning it on or sending a keystroke to the "computer" on the chip, solder wires with the proper analog voltage to its pins or use it with various pieces of equipment. The controller must also program it with low-level machine instructions that the chip hardware can understand. Using the ESP8266 as an embedded controller chip in mass-produced devices is not problematic at this degree of integration. It is a significant burden for hackers, amateurs, or students who wish to test it out in their own IoT projects.

Figure 4.6: WROOM Hardware Image

LCD DISPLAY

The idea behind LCD screens is that liquid crystal molecules have a tendency to rise up when an electric current is applied to them. This causes the angle of light passing through the glass molecule to be polarized and also causes the angle of the top polarizing filter to change. As a result, some light is allowed to pass through the polarizer through a specific area of the LCD screen. At the top of the device, an indium-tin-oxide electrode plane is preserved, and a polarizing glass with a polarizing film is also added at the bottom. The following piece of glass has another polarizing film on top and a rectangular electrode at the bottom. In the absence of a source, light that enters the LCD's front will be reflected by the mirror and bounced back. The liquid crystal separates between the common flat electrode and the rectangular electrode when the electrode is connected to the battery by its current.

Figure 4.7: LCD Display Hardware Image

DC SUPPLY:

We have used a 5V 10A DC supply that provides a constant DC voltage of 5V and a maximum current of 10A to run the components we have integrated in our work. It maintains a constant low voltage even under varying input voltage. It generally consists of a transformer that steps down the input voltage, a rectifier that converts AC input to DC output and a voltage regular circuit that maintains a constant DC output.

Figure 4.8: DC supply Hardware Image

4.3. Implemented Models

The work consists of two parts, the first one is hardware & second one is software. The hardware part has sensors which help to measure the real time values, another one is Arduino Uno converts the analog values to digital and LCD shows the displays output from sensors, The connection between hardware and software Arduino Uno and for data transfer used WROOM is an open-source platform based on ESP8266 which can connect objects and let data transfer using the Wi-Fi protocol. The parameters are checked by one by one and updated in the cloud server as well as the values are displayed in the LCD display.

4.3.1. Simulation Model

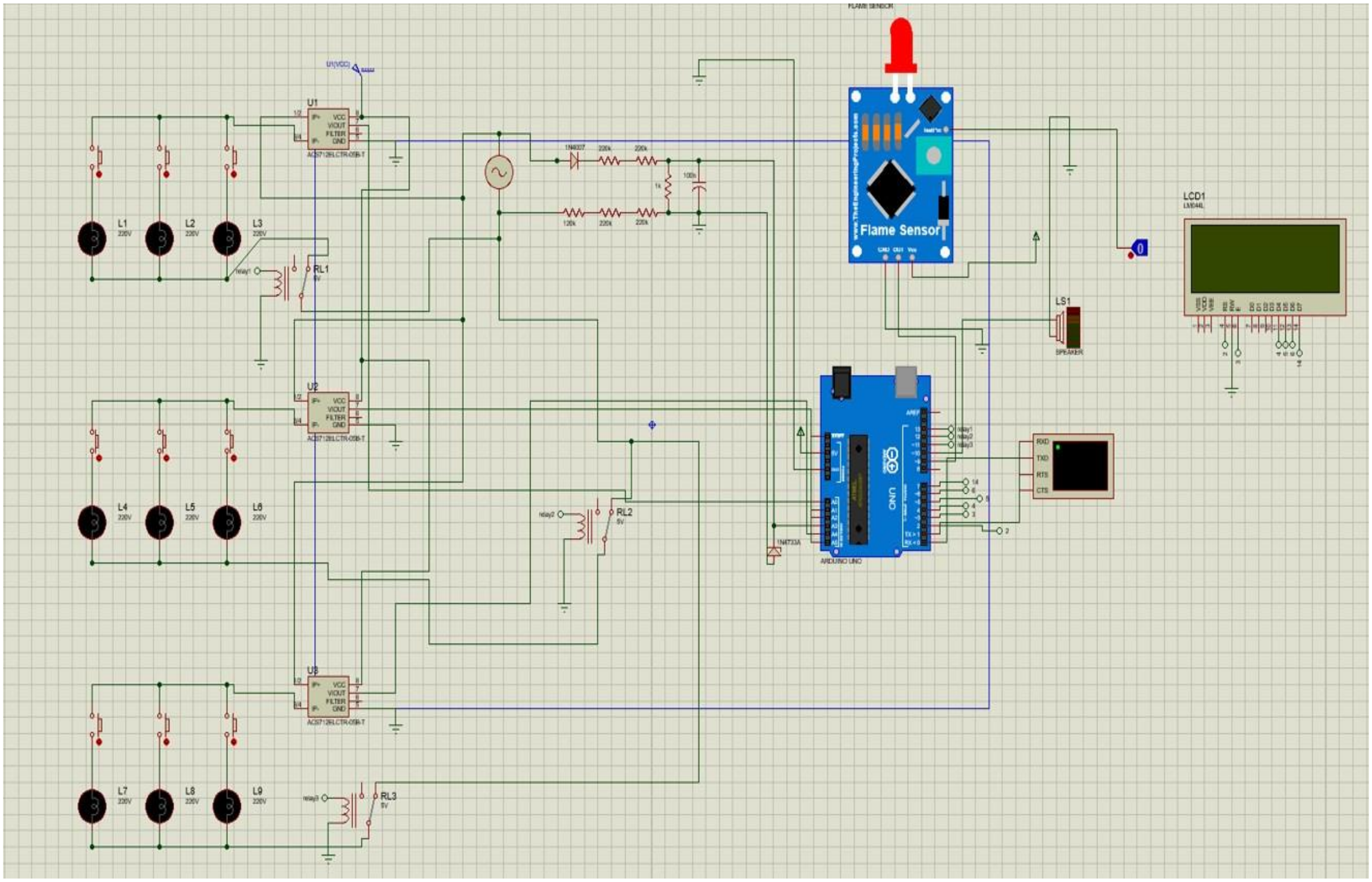


Figure 4.9: Simulation Model of the Project

Table 4.1: Individual Sensors Model Name

ITEM	MODEL
Arduino Uno	ATmega 328P
WROOM	ESP32
AC Voltage Sensor	ZMPT101B
AC Current Sensor	ACS712
Smoke Sensor	MQ2
LCD Display	20X4
Relay Module	0501RLYM10
DC supply	MIS 00524

With the advances in IoT technology, the power monitoring system in sub-stations and different industrial and commercial buildings are becoming smarter with reduced power consumption and ease of operation. The core controller is integrated with various sensors such as Voltage Sensor, Current Sensor, Smoke Sensor. The sensor leads are placed within the MDB or SDB to be tested. The sensor values will be processed by Arduino Uno and the core controller reads the value and it will be uploaded on the cloud. The values will be monitored continuously by checking the sensor value. If the sensor value is greater than threshold, then it will be communicated to the concerned end user for further action.

4.3.2. Hardware Model

At first the overall connection has been completed. All the sensors and LCD monitor connected to the Arduino Uno. Then the WROOM is connected with the Arduino for transferring data from Arduino Uno to the IoT based Cloud.

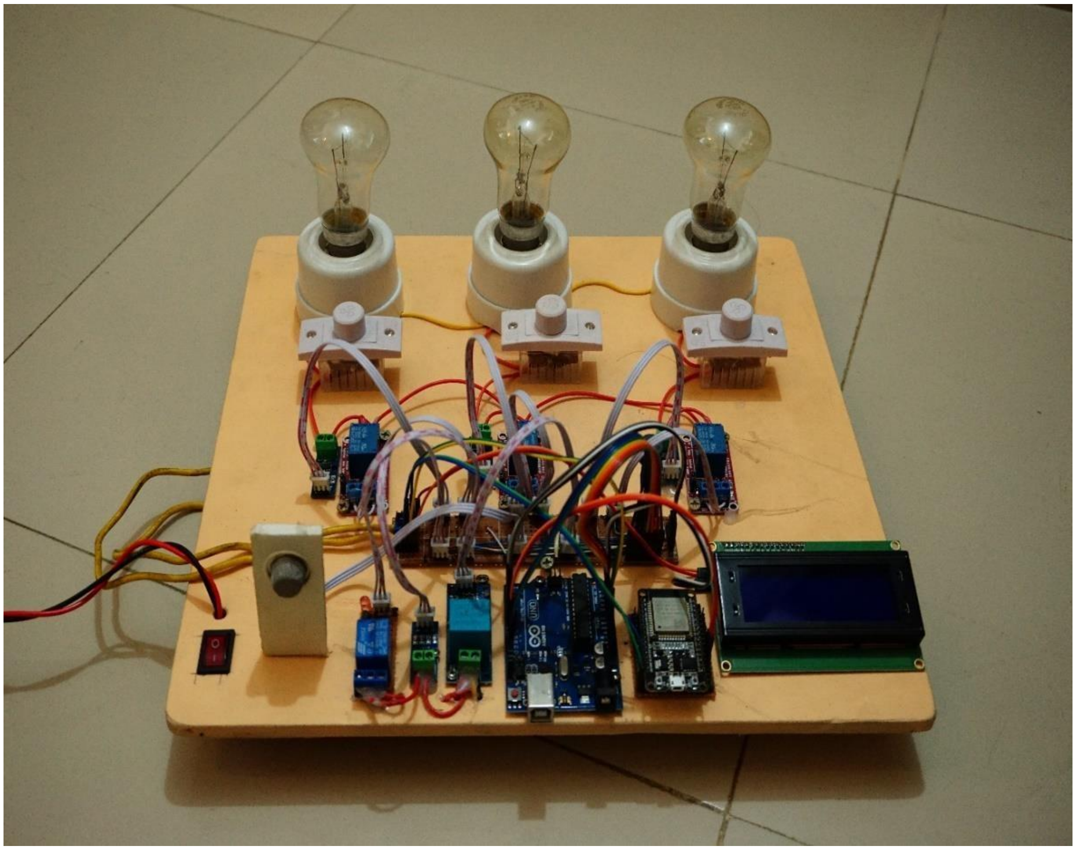


Figure 4.10: Hardware Implementation

The developed method is a IoT-Based Power Monitoring System that is used to measure current, voltage, power, power factor, reactive power, gas. The parameters like current, voltage, power, power factors are measured using sensors and are processed by Arduino Uno micro controller.

4.4. Engineering Solution in accordance with professional practices

We presented a comprehensive smart IoT based power monitoring and management system of distribution sub-station solution that aims at tackling the heterogeneity of protocols and standards. Power sector is now in the highlight of Bangladesh Government and it has developed a lot since last decade. The development in power production sector needs more comprehensive power monitoring system. An IoT-based power monitoring system is a better solution. In this work, a comprehensive review of different methods of power plant and sub-stations monitoring and an efficient IoT based method for power plant monitoring has been discussed. Although there have been many excellent power plant and substations monitoring systems, still the research area remains challenging. This work presents a review of the recent works carried out by the researchers in order to make power monitoring systems smart, low powered and highly efficient such that monitoring will be continuous and alerts/notifications will be sent to the concerned authorities for further processing. The developed model in this work is cost effective and simple to use. As an engineer, the suggestion is to use latest sensors for detecting various other parameters, use wireless communication standards for better communication and IoT to make a better system for power monitoring and the energy resources can be made safe by immediate response.

4.5. Summary

In our project, we connected the current and voltage sensor to a Load prototype. It measures current and voltage continuously and calculates current, voltage, power, power factor. There is a smoke sensor to detect gas if any fire accident or any hazards. There is three area based on priority less, more and most. When there is too much demand then the production of energy, the less priority area is in load shedding. If the situation continues than the area with more priority is in load shedding. The area with most priority is never in load shedding. This situation keeps continuing in a loop until the load demand is in a suitable condition.

Chapter 5

RESULTS ANALYSIS & CRITICAL DESIGN REVIEW

5.1. Introduction

A detailed analysis is a fundamental part of any project. Every stage of the project implementation and research activity is regulated to ensure the accuracy of this project. This chapter discusses the critical design review as well as the analysis of the results.

5.2. Results Analysis

This section presents the results of specific observations after the project's implementation, both in simulation and in hardware.

5.2.1. Simulated Results

Simulation with Proteus Software:

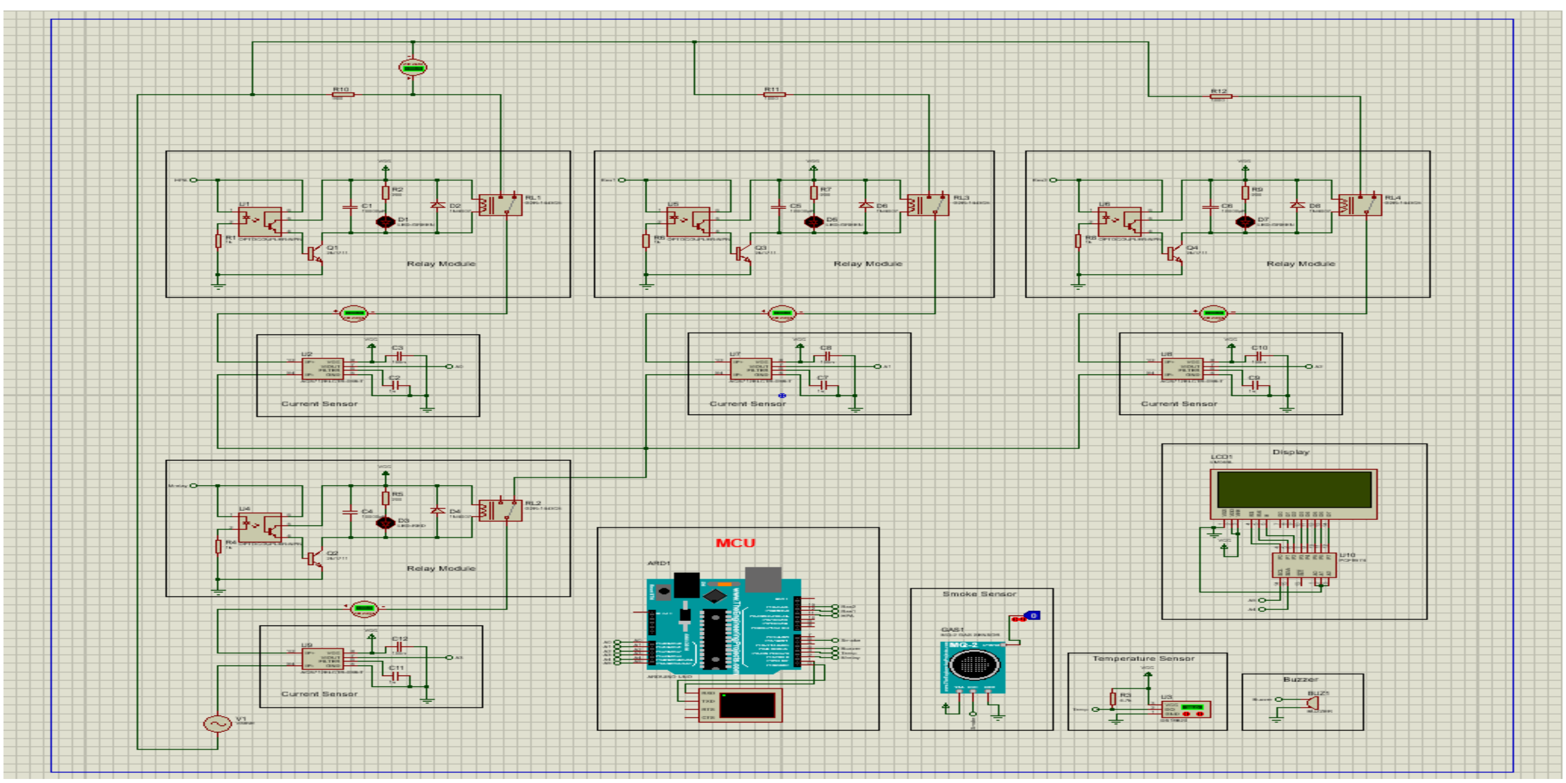


Figure 5.1: Proteus Simulation

Output:

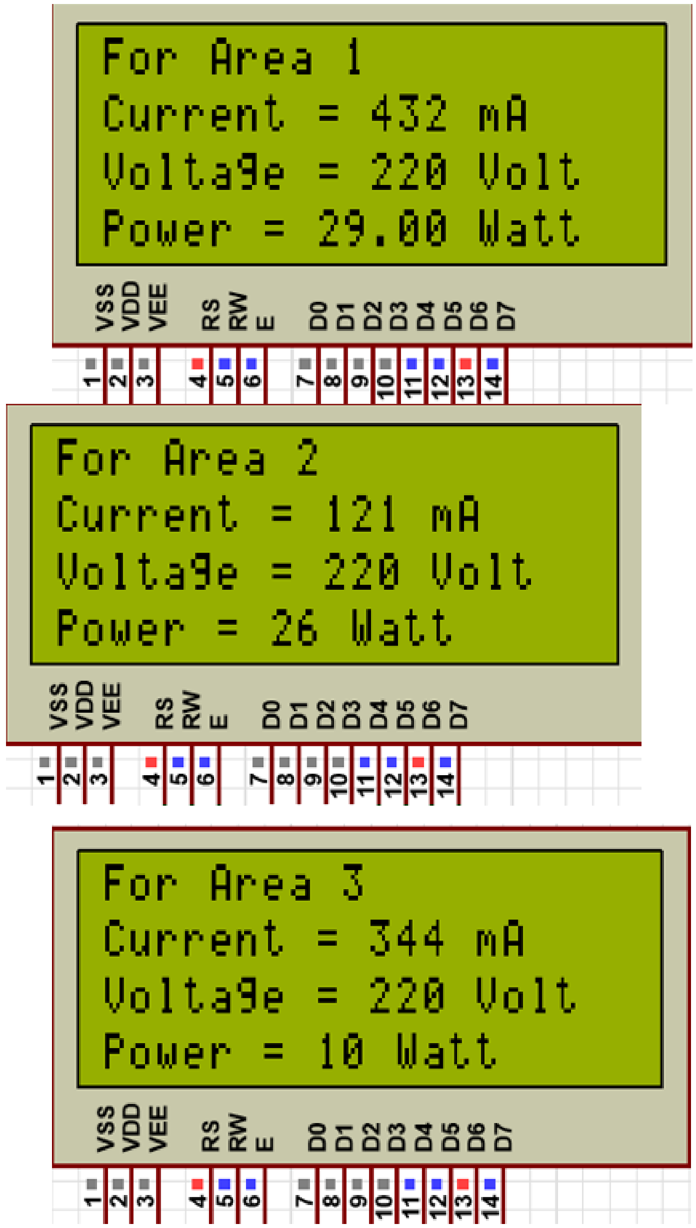


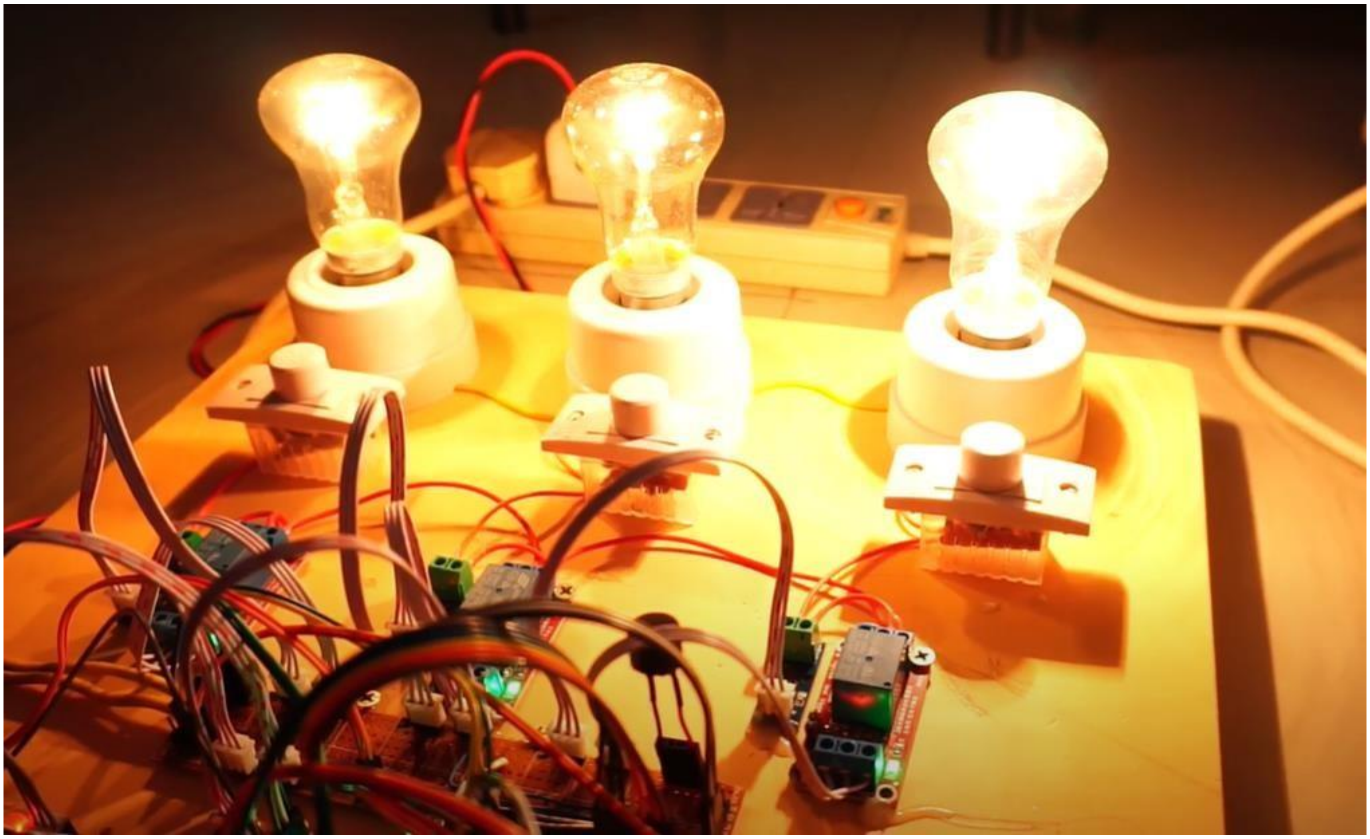
Figure 5.2: Current and Power Measurement

In Figure 5.2, we run the simulation then we find 29.00W of power for Area-1, 26.00W of power for Area-2 and 10.00W of power for Area-3. Here our total load capacity is 75.00W where we set the maximum power for Area-1 is 30.00W, 25.00W for Area-2 and 20.00W for Area-3 according to their demand. But we see here that Area-2 has exceeded its maximum power so even though their demand is high we have to do load shedding here as per our capacity which occurs through automation system.

5.2.2. Hardware Results

- **Case-1: When all areas are active (Area-1: Hospital, Area-2: Residential, Area-3: Industrial)**

  We have set 55 watts load capacity and load shedding will occur when the load demand of three areas exceeds this value but here it can be seen that the load demand of three areas is 53.05 watts which less than our load capacity so the three areas are running as per their demand.



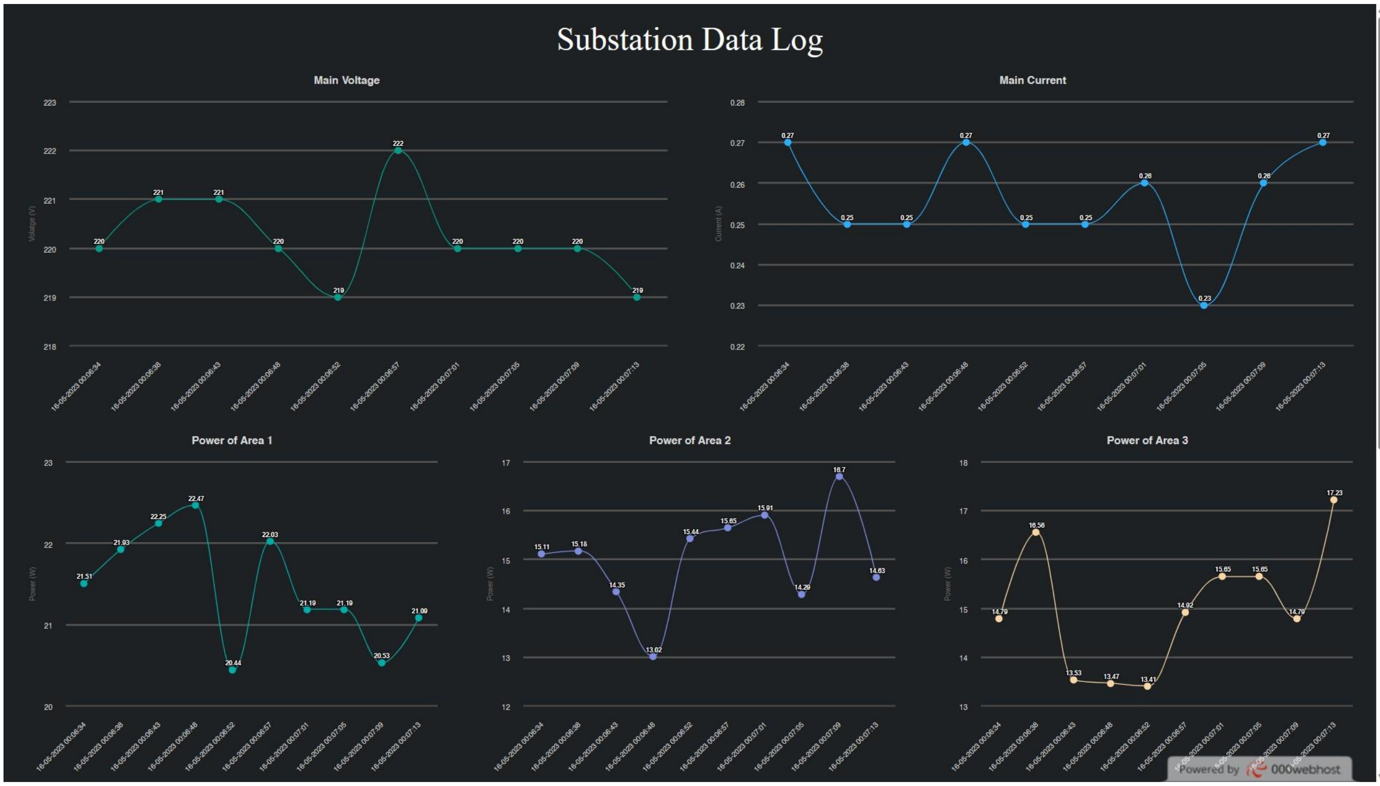
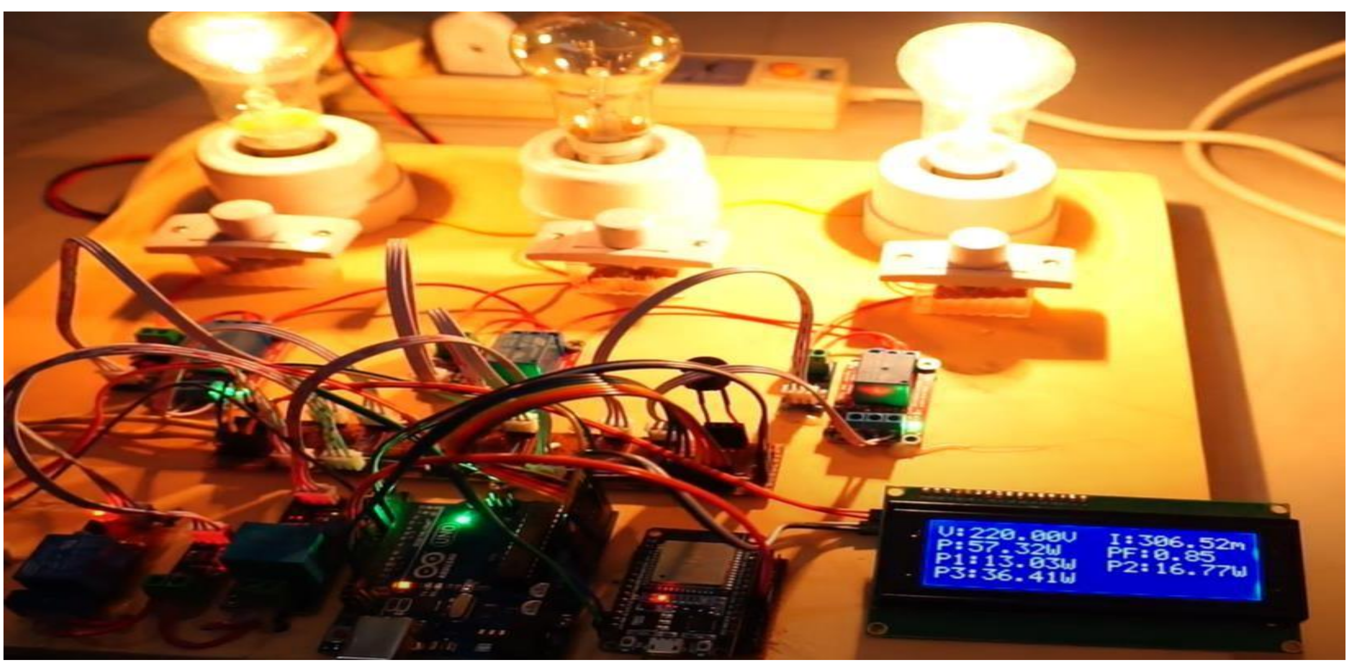


Figure 5.3: Voltage, Current, Power & PF value of Area-1,2,3

- **Case-2: Power Cut at Area-2 (Residential Area)**

  At this stage it is seen that the load demand is 57.32W in three areas has exceeded our load capacity of 55.00W, so the least critical area will now have automatic load shedding and the remaining two areas will continue to operate in normal condition.



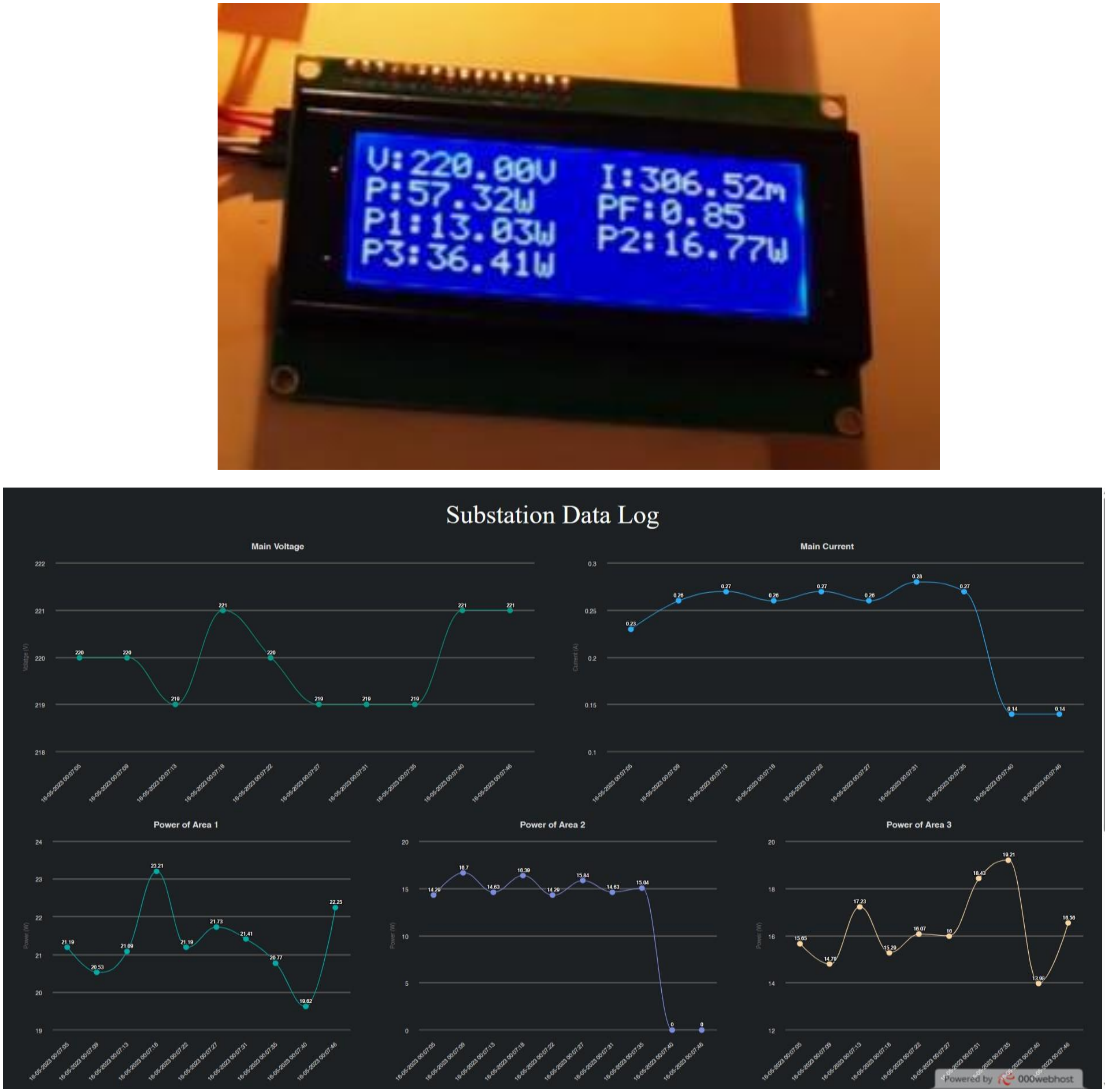


Figure 5.4: Load Shedding at Area-2

- **Case-3: Sequential Load Shedding (Area-3: Industrial)**

  Now again load shedding will occur as our load demand exceeds load capacity but as earlier, we have already done load shedding in area-2, this time load shedding will occur in area-3 as there should not be continuous load shedding in any area at almost same time.

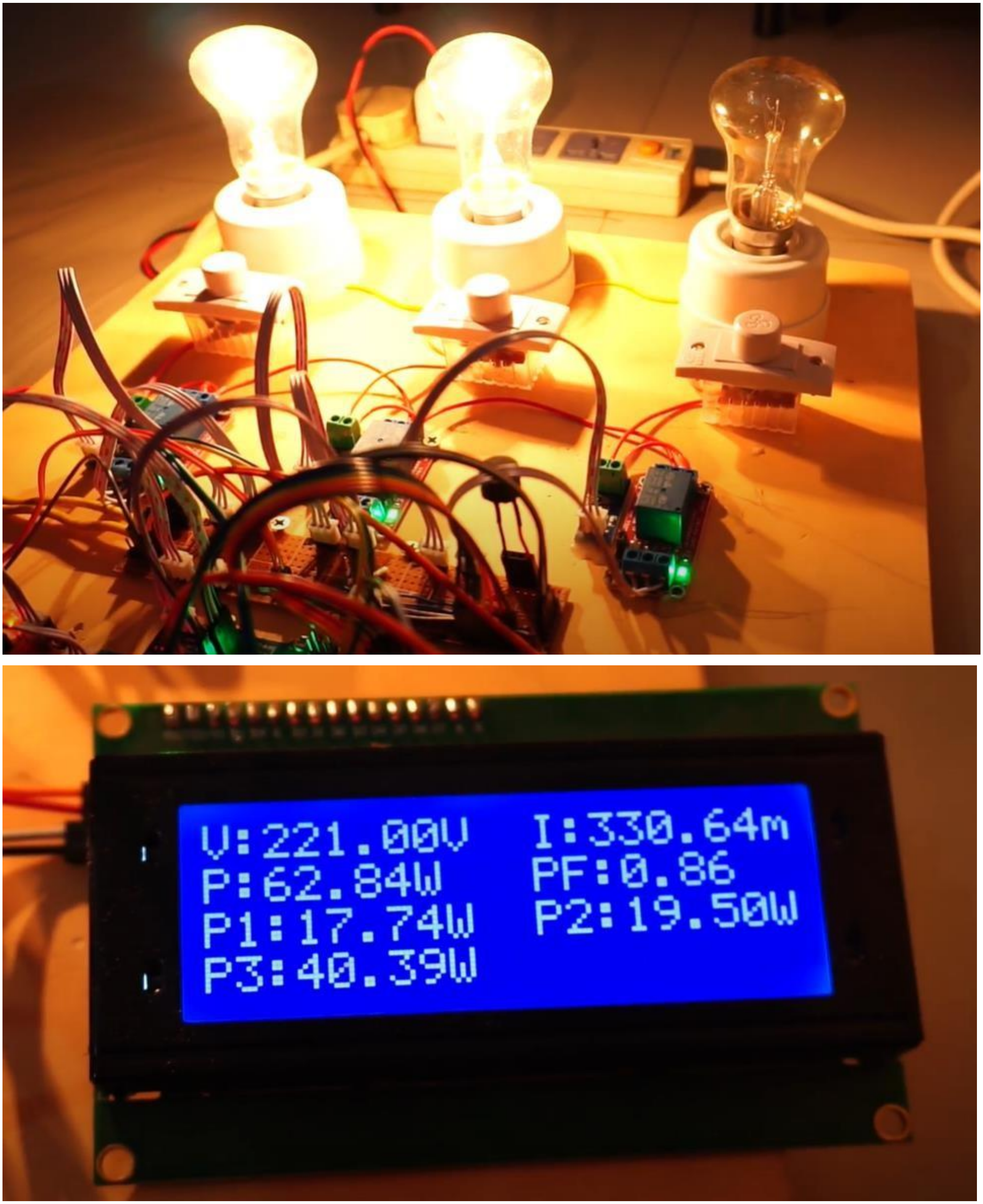
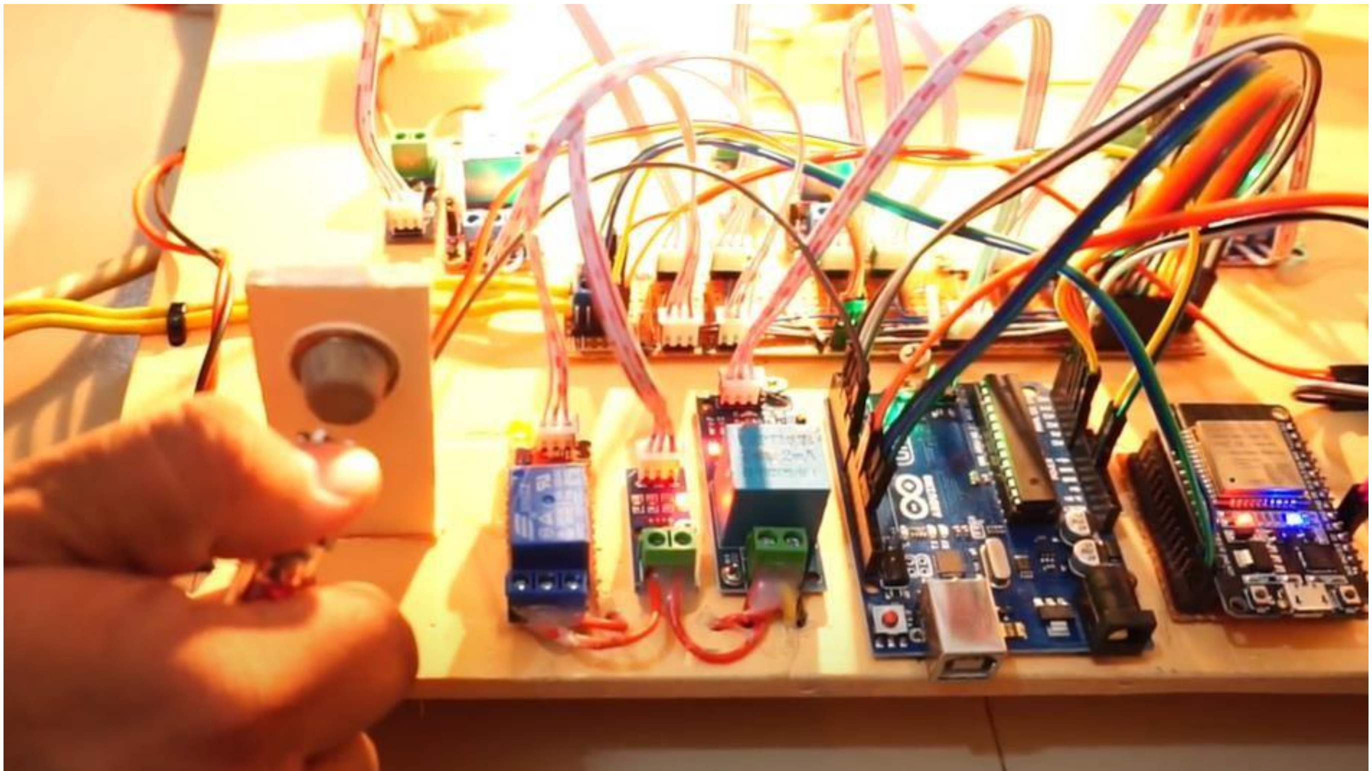


Figure 5.5: Load Shedding at Area-3

- **Case-4: Emergency Shutdown (All areas are closed)**

  Here the system can detect fire which automatically close the entire substation to avoid any accidents. For that reason, we don't get any value from LCD display.



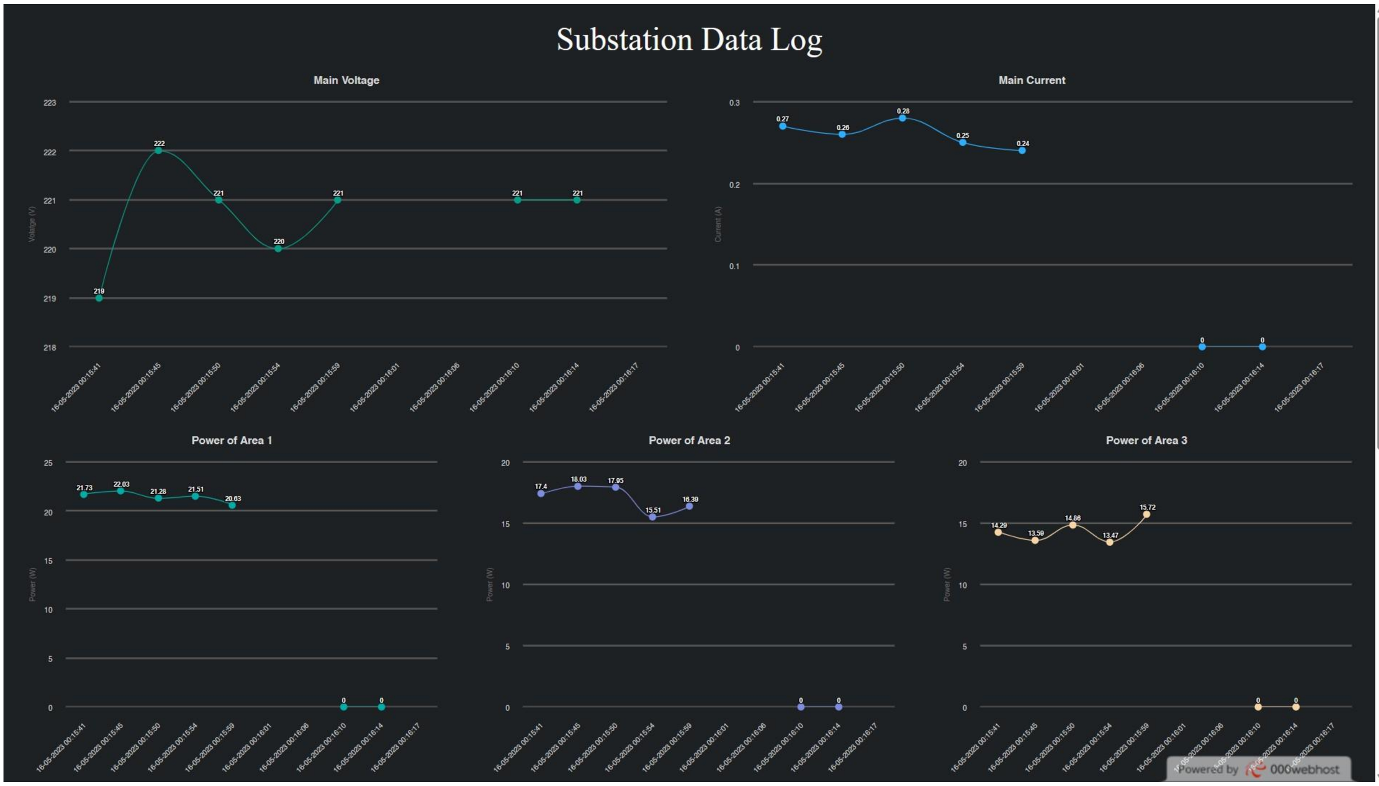


Figure 5.6: Shutdown for Fire

- **Case-5: Power recovery after emergency shutdown (fire extinguished)**

  The system closed the substation completely after fire detection and then restarts the entire system after solving the problem. This way the system can return to normal condition after solving any problem which will ensure the safety of our substation.

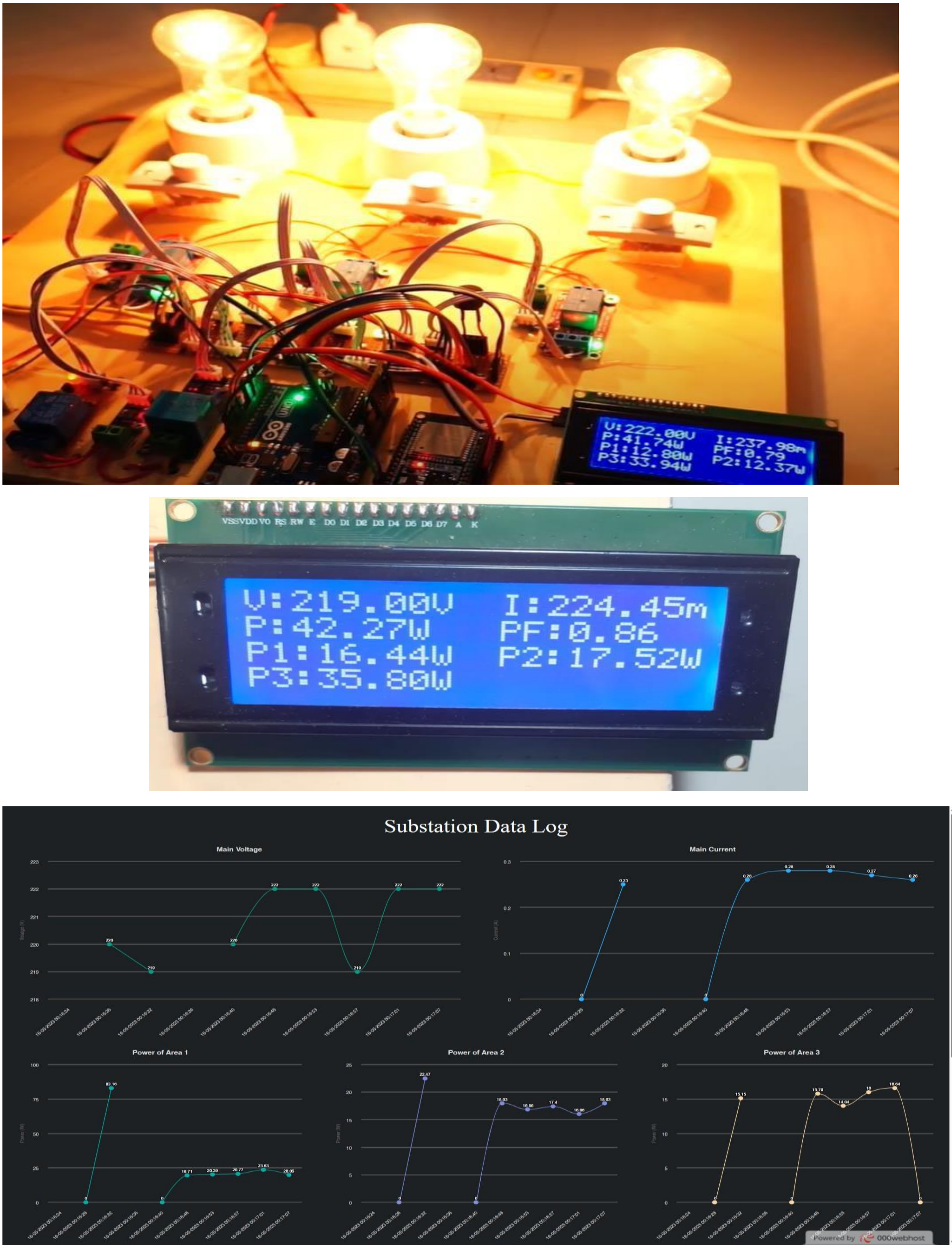


Figure 5.7: Power Recovery

5.3. Comparison of Results

In this project, there are some differences between simulation and hardware results. In simulation, the main microcontroller is the Arduino UNO. For hardware prototypes, we used two microcontrollers, such as the Arduino UNO and the ESP32-WROOM. From the different papers and journals, we know that most of the substation are controlled manually. In our project, we implemented this system through an automation system. For hardware implementation, we just did a small prototype. In the simulation we got the values of power factor, supply voltage and total load current for the three areas but we do not get desired output after a certain time. Through the hardware results, the changes that occurred in the whole system in each situation were perfectly visible. The results we got after the simulation were fluctuating a lot which made it a bit difficult to reach our target from them but when we were working on the hardware then two microcontrollers were used and we were getting the results of each condition here in graph form every second. As a result, it became much easier to understand its changes and get more accurate value for that we could complete our main objective.

5.4. Summary

A prototype design was created for power station emulation and implementation. The results are shown graphically, the channel fields are created by our own developed website for monitoring our design measurements of power factor, voltage and single-phase current load. This website collects, plot graphs and saves these live data. There are three areas in our project based on different types of priority. When load demand increases more than available energy, automatically load shedding happens to the lesser priority areas. If it is sensed that there is a fire, this system will close the power station immediately and the fire alarm will be activated. If there is no sensitivity to the presence of the fire, it will proceed to collect station data. Thus, the station performance can be monitored and the best decision made depending on the station performance, in the event of a fire or any emergency. Also, the system implements automatic power factor correction which can be used to increases efficiency and the capability of the power system. The results of the system are displayed in many ways to assure that the system parameters will be monitored by more than one person because of safety and protection reasons. The uniqueness of this system is the display of results on desktop and mobile phones simultaneously.

Chapter 6

CONCLUSION

6.1. Summary of Findings

At this moment, it is possible to say that the project aims of creating and implementing IoT-Based Smart Power Monitoring and Management System of a Distribution Sub-stations has been totally completed. This wireless IoT-Based project is now a technologically advanced which will inform about the production of energy and the load supplied to the consumers. When designing and carrying out this project, we made sure to use a method that was both economical and efficient. The integration of AC voltage and current sensors allowed for the real-time monitoring of voltage, current, power, and power factor values within the distribution substation. This enabled operators to have an accurate and up-to-date understanding of the power parameters, facilitating effective decision-making and control. The inclusion of a fire sensor in the system provided an additional layer of safety. The sensor could detect the presence of fire, allowing for prompt response and preventive measures to mitigate potential hazards. The ESP32 Wi-Fi module facilitated the transmission of processed data to an online cloud system. This cloud system provided a centralized platform for storing and accessing real-time data from anywhere. The ability to visualize the data in the cloud system allowed for better analysis, monitoring, and reporting. The system incorporated load-shedding functionality to address load demand exceeding the available energy capacity. By prioritizing different areas based on their importance, the system automatically implemented load shedding in lower-priority areas. This dynamic load management helped prevent power overloads and improved the stability of the distribution network. The cloud-based system provided remote access and control capabilities. Authorized personnel could monitor and manage the distribution substation from anywhere, enhancing operational flexibility and efficiency. The modular nature of the system, with its integration of Arduino and ESP32, allowed for scalability and future expansion. Additional sensors, devices, and functionalities could be easily integrated into the existing system, accommodating evolving needs and technological advancements. These findings highlight the effectiveness of the system in improving the monitoring, management, and reliability of the distribution substation.

6.2. Novelty of the work

Every project has its own set of distinctive qualities that distinguish it from other projects, as well as make it more productive and lucrative than those other initiatives. This project now has a contemporary appearance and has reached new heights as a result of the additional modifications. The primary objective of this project is to measure the amount of load supplied to a consumer over a specified period, to track load usage, to measures the power, current, voltage, power factor and to igniting and exploding through using different technologies. The production cost of this project is being kept in a minimal limit and the maintenance cost is not so many too. This project is one of a kind which is being distinctive from other for some specific reasons. The wireless IoT middleware can handle multipurpose objectives such as AC current, AC Voltage, Power, Power factor measuring. Along with these, a smart fire detection feature is used to maintain safety. The sensors are controlled by the Arduino Uno microcontroller which is connected to the internet via Wi-Fi. Using the internet, Arduino Uno sends and receives the data or command to/from Cloud for performing the real-time operation. Thus, with these distinctive features this smart IoT-based power monitoring and management system for distribution sub-station becomes completely unique from existing related projects.

6.3. Cultural and Societal Factors and Impacts

IoT-based projects are used to perform dangerous, unsafe, extremely tiring, and scary tasks, and reduce labor and time consumption. Nowadays IoT usage is increasing day by day and many ideas are generated based on it. IoT-based power monitoring and management system expresses important views in modern culture and society. The Internet of Things (IoT) will have a hugely positive impact on people, businesses, and governments. It will help governments to improve the healthcare system and quality of life. The project can have economic impacts by optimizing power distribution. communities can experience cost savings and economic benefits. IoT-based power monitoring and management systems promote energy efficiency and conservation. the project can help reduce overall energy consumption and carbon footprint. This aligns with societal values related to environmental sustainability and can contribute to a cleaner and greener future. The implementation of an IoT-based system can lead to improved infrastructure and reliability of power distribution. By continuously monitoring key parameters in real time, the system can facilitate proactive maintenance and minimize downtime. The implementation of an IoT-based system requires skilled personnel for installation, maintenance, and operation. This can create job opportunities within the community and contribute to local economic development. This project follows government guidelines and also develops design principles, adopting some IoT ideas. Some additional resources are reserved in the future to accommodate any changes in design requirements where possible. Propose professional solutions for projects for society, culture, and the environment.

6.4. Limitations of the Work

Though the IoT-based power monitoring and management system of a distribution sub-stations was successfully constructed and programmed to meet the requirements, and it has few limitations. The performance of the device was put to the test by using a variety of challenges, scenarios, and testing it in a variety of settings. The results showed that the device sensors functioned well but in some case they were giving wrong data. A few limitations of the project have been discussed below.

- In our work we were unable to do short circuit fault analysis.
- The system we have built is only for single phase system. Three-phase system is not developed yet.
- Reactive power was not measured in the system.
- Voltage regulation was not monitored in the system
- Sometimes the sensors get too much heated and does not function.
- The IoT system that we have built is totally online, there is no offline mechanism to store data.

6.5. Future Scopes

By introducing a more effective programming approach that will be able to use the data more efficiently, the main focus of the following development will be on improving the performance of the system and lowering the amount of mistake. However, using higher-grade sensors to lessen the amount of mistake has the potential to greatly increase the usability of this project. Moreover, this platform is open and flexible, It is clear that the load distribution network would greatly benefit from the downsizing and distribution of high-resolution sensors. By combining sensors and adding more features, it is possible to detect overload, line problems. A few limitations of the project have been discussed below.

- It can improve the system that is able to do short circuit fault analysis.
- The system can be developed for three-phase system.
- Adding of reactive power measurement is also a good improvement in the system.
- Voltage regulation monitoring system can be added to the system.

6.6. Social, Economic, Cultural and Environmental Aspects

6.6.1. Sustainability

IoT system has been growing over the last several years and it is being predicted that it’s going to grow even faster in upcoming years. It’s at the center of technological advances in every industry. The system requires integration between electrical devices that will interact with human being without interference of human activity and the automation of the machines that are conventionally human operated. This project follows a handsome amount of Sustainable Development Goals (SDG) of the United Nations. Through this project we ensure the proper distribution of loads, affordable and clean energy, sustainable cities and communities and lastly responsible consumption and production. This project allows to solve many engineering complex problems in a most convenient way. The use of it will help to control the use of distribution sub-stations which will help in different safety issues.

6.6.2. Economic and Cultural Factors

As the population grows rapidly, the demand for industrial automation based on IoT increases rapidly, and industrial plants continue to grow. Considering social, political, economic and environmental benefits will be beneficial in the coming days. Because conventional automation systems cannot be placed in every industry or factory. The requirements of ethics, responsible behavior, and moral behavior in professional activities to the public's safety, health, and welfare to seek, accept, and offer honest criticism of technical work, recognize and correct errors, to be honest and realistic in stating claims or estimates based on available data, and to properly credit the contributions of others.

The IoT based power monitoring and management system of distribution substation prototype is constructed to meet the requirements, and it has since shown precision performance. Engineering concept is significantly used in this IoT monitoring system. because it improves working ability in Substation area. This project simplifies the operations and enhance how workers are the public health and safety in mind. Because if a suggested design or device does not agree to international standards and professional rules, there is a risk that the device or design would hurt public health and safety, and it will be completely unethical. The suggested principal focus is to protect the public's health and safety. And here in this project, it will try that to did not use any kind of chemical or thing that would have had a bad impact on the public's health and safety.

6.7. Conclusion

The IoT-based power monitoring and management system developed for a distribution substation has successfully addressed several key issues in power management and safety. The integration of AC voltage and current sensors, along with a fire sensor, through an Arduino has enabled accurate measurement of voltage, current, power, and power factor values, as well as fire detection capabilities. The data collected from these sensors are processed and transmitted to the ESP32 Wi-Fi module, which connects to a cloud system for storage and real-time data access. The cloud-based online platform provides convenient and remote access to real-time data from anywhere, enhancing operational efficiency and monitoring capabilities. One significant issue addressed by the project is load management. By categorizing the distribution substation into three priority-based areas, the system automatically initiates load shedding in the lesser priority areas when the load demand exceeds the available energy. This dynamic load-shedding feature ensures optimal energy utilization, prevents power overloads, and maintains the stability of the distribution network. the system's integration with the cloud-based platform offers scalability and flexibility for future expansion and technological advancements. The secure storage and accessibility of data in the cloud system contribute to efficient data analysis. the project addresses the issue of safety through the inclusion of a fire sensor. The detection of fire presence enables prompt response and preventive measures, mitigating potential hazards and enhancing overall safety in the distribution substation. Overall, the IoT-based power monitoring and management system provides valuable insights, real-time monitoring, efficient load shedding, enhanced safety measures, and convenient remote access.

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Appendix A

Datasheet of the ICs used

ESP32-WROOM Development Board Specifications:

- Model: WROOM ESP32
- Type: ESP32
- Processor: Tensilica LX6 Dual-Core
- Clock Frequency: 240 MHz
- SRAM: 512 kB
- Memory: 4 MB
- Wireless Standard: 802.11 b/g/n
- Frequency: 2,4 GHz
- BT wireless connection: Classic / LE
- Data Interfaces: UART / I2C / SPI / DAC / ADC
- Operating Voltage: 3,3V (operable via 5V-microUSB)
- Operating Temperature: -40°C - 125°C
- Dimensions: 48 x 26 x 11,5 mm
- Weight: 10 g

Arduino Uno Specifications & Features:

- Microcontroller: ATmega328
- Operating Voltage: 5V
- Input Voltage: 7-12V
- Input Voltage: 6-20V
- Digital I/O Pins: 14 (of which 6 provide PWM output)
- Analog Input Pins: 6
- DC Current per I/O Pin: 40 mA
- DC Current for 3.3V Pin: 50 mA
- Flash Memory: 32 KB of which 0.5 KB used by bootloader
- SRAM: 2 KB
- EEPROM: 1 KB
- Clock Speed: 16 MHz

AC voltage sensor module specifications:

- Output Signal: Analog 0-5V
- Operating Voltage: DC 5V-30V
- Measure within 250V AC
- Rated input current: 2mA
- Size: 49.5 mm x 19.4 mm

AC current sensor module specifications:

- Output Signal: Analog 0-5V
- Operating Voltage: DC -30A to 30A
- Measure within 250V AC
- Rated input current: 66mV
- Size: 31.73mm x 13.25mm x 14mm

Smoke sensor module specifications:

- Operating voltage: 5V DC
- Output signal: analog 5V / digital 5V
- Size: 35mm x 20mm x 10mm
- Weight: 5 gm

20 x 4 LCD Display specifications:

- Display Contents :20 * 4 Characters (5*8 dots)
- Driving Scheme: 1/16Duty; 1/5Bias
- Viewing Direction :6 0' clock
- Driver IC: AIP31066
- Interface: Parallel
- Operating Temperature: 20 C一 + 70 C
- Storage Temperature: 30 C一 + 80 C

1 Channel Relay module specifications:

- Supply voltage – 3.75V to 6V
- Quiescent current: 2mA
- Current when the relay is active: ~70mA
- Relay maximum contact voltage – 250VAC or 30VDC
- Relay maximum current – 10A

Code on Arduino IDE:

```
#include <SoftwareSerial.h>     //library for software UART protocol
#include <ACS712.h>             //library for current sensor
#include <ZMPT101B.h>           //library for voltage sensor
#include <LiquidCrystal_I2C.h>  //library for the display
#include <OneWire.h>
#include <DallasTemperature.h>

#define SENSITIVITY 500.0f
#define UART_RX 10
#define UART_TX 9
#define frequency 50.0f
#define TemperaturePin 3
#define MasterRelayPin 2
#define SmokeSensorPin 6
#define VoltageSensorPin A4
#define BuzzerPin 4
#define RelayPinOne 11 //high priority area
#define RelayPinTwo 12 //residential area 1
#define RelayPinThree 13 //residential area 2
#define MainCurrentPin A3
#define CurrentPinOne A0
#define CurrentPinTwo A1
#define CurrentPinThree A2
#define pi 3.1416

ACS712 CurrentSensor0(ACS712_05B, MainCurrentPin);
ACS712 CurrentSensor1(ACS712_05B, CurrentPinOne);
ACS712 CurrentSensor2(ACS712_05B, CurrentPinTwo);
ACS712 CurrentSensor3(ACS712_05B, CurrentPinThree);

ZMPT101B voltageSensor(VoltageSensorPin, frequency);

LiquidCrystal_I2C lcd(0x3F, 20, 4);

SoftwareSerial uno(UART_RX, UART_TX);

OneWire oneWire(TemperaturePin);

DallasTemperature temp(&oneWire);

//state veriables
int SmokeSensorState = 0;
```

```
//store state variables
int shedcount = 0;
int shedRelay = 13;

//data variables
float i1 = 0.00;
float i2 = 0.00;
float i3 = 0.00;
float im = 0.00;
float volt = 0.00;
float pf = 0.00;
float mem_C = 0.00;
String data;

void setup() {
  Serial.begin(115200);
  uno.begin(115200);

  pinMode(MasterRelayPin, OUTPUT);
  pinMode(SmokeSensorPin, INPUT);
  pinMode(BuzzerPin, OUTPUT);
  pinMode(RelayPinOne, OUTPUT);
  pinMode(RelayPinTwo, OUTPUT);
  pinMode(RelayPinThree, OUTPUT);

  digitalWrite(RelayPinOne, 1);
  digitalWrite(RelayPinTwo, 1);
  digitalWrite(RelayPinThree, 1);

  voltageSensor.setSensitivity(SENSITIVITY);

  tone(BuzzerPin, 2000, 500);

  lcd.init();       // initialization of display
  lcd.backlight();  // enabling of backlight

  temp.begin();
}

void loop() {

  SmokeSensorState = digitalRead(SmokeSensorPin);

  temp.requestTemperatures();
  float C = temp.getTempCByIndex(0);

  if (C != DEVICE_DISCONNECTED_C) {
    mem_C = C;
```

```
}

if ((SmokeSensorState == LOW) && (mem_C < 40)) {
  digitalWrite(MasterRelayPin, LOW);
  noTone(BuzzerPin);
} else {
  lcd.clear();
  lcd.setCursor(0, 1);
  lcd.print("Emergency Shutdown!");
  lcd.setCursor(3, 2);
  lcd.print("Fire Detected");
  digitalWrite(MasterRelayPin, HIGH);
  tone(BuzzerPin, 2000, 5000);
  delay(5000);
}

i1 = CurrentSensor1.getCurrentAC() - 0.15;
i2 = CurrentSensor2.getCurrentAC() - 0.09;
i3 = CurrentSensor3.getCurrentAC() - 0.13;
im = CurrentSensor0.getCurrentAC() - 0.13;

//volt = voltageSensor.getRmsVoltage();
volt = (random(21900, 22200) / 100.00);
//pf = PF();
pf = (random(85, 88) / 100.00);

if (i1 < 0.04) {
  i1 = 0.00;
} else {
  i1 = i1 + 0.01;
}

if (i2 < 0.04) {
  i2 = 0.00;
} else {
  i2 = i2 - 0.03;
}

if (i3 < 0.04) {
  i3 = 0.00;
} else {
  i3 = i3 + 0.02;
}

if (im < 0.04) {
  im = 0.00;
}
```

```
  Serial.print("cmain: ");
  Serial.println(String(im));
  Serial.print("c1: ");
  Serial.println(String(i1));
  Serial.print("c2: ");
  Serial.println(String(i2));
  Serial.print("c3: ");
  Serial.println(String(i3));
  Serial.println();

  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("V:" + String(volt) + "V");
  lcd.setCursor(10, 0);
  lcd.print("I:" + String(im * 1000.00) + "mA");
  lcd.setCursor(0, 1);
  lcd.print("P:" + String(im * volt * pf) + "W");
  lcd.setCursor(10, 1);
  lcd.print("PF:" + String(pf));
  lcd.setCursor(0, 2);
  lcd.print("T:" + String(mem_C) + "C");
  lcd.setCursor(10, 2);
  lcd.print("P1:" + String(i1 * volt * pf) + "W");
  lcd.setCursor(0, 3);
  lcd.print("P2:" + String(i2 * volt * pf) + "W");
  lcd.setCursor(11, 3);
  lcd.print("P3:" + String(i3 * volt * pf) + "W");

  data = "#" + String(volt) + "$" + String(im) + "%" + String(i1) + "&" + String(i2)
         + "*" + String(i3) + "(" + String(i1 * volt) + ")" + String(i2 * volt) + "!" +
String(i3 * volt) + ",";

  uno.println(data);
  Serial.println(data);
  Serial.println("\n\n");

  if ((im * volt * pf) > 55) {
    digitalWrite(shedRelay, LOW);
    shedcount = 0;
  }

  shedcount++;
  if (shedcount > 5) {
    digitalWrite(shedRelay, HIGH);
    shedRelay--;
    if (shedRelay < 12) {
      shedRelay = 13;
    }
```

```
  }

  delay(2000);
}

float PF() {
  float pof = 0, t1 = 0, t2 = 0, dt = 0, theta = 0;
  while (pof == 0) {
    if ((analogRead(VoltageSensorPin) * (5000.0 / 1024.0)) < 2500 &&
(analogRead(MainCurrentPin) * (5000.0 / 1024.0)) < 2500) {
      if ((analogRead(VoltageSensorPin) * (5000.0 / 1024.0)) > 2500) {
        t1 = millis();
        while (true) {
          if ((analogRead(MainCurrentPin) * (5000.0 / 1024.0)) > 2500) {
            t2 = millis();
            dt = abs(t2 - t1);
            theta = (pi / 10) * dt;
            pof = abs(cos(theta));
            break;
          }
        }
      }
    }
  }
  return pof;
}
```

Code for creating Cloud:

```
#include <HardwareSerial.h>
#include <WiFi.h>
#include <WiFiClientSecure.h>
#include <HTTPClient.h>
#include <twilio.hpp>

Twilio *twilio;

const char *ssid = "Anti log";
```

```
const char *password = "@@1212@@";

const char *serverName = "https://psubcapstone.000webhostapp.com/post-data.php";

String apiKeyValue = "psubscapstone123";


static const char *account_sid = "ACb12d0ed80408e9999fcc0706f25735ca";
static const char *auth_token = "3f57ecc0d1f0a33fcb61cf8f72bcdfe6";

static const char *from_number = "+447458156843";

static const char *to_number = "+8801799055296";
static const char *message = "A fire has been detected in the substation. System has
shut down the distribution of power immidietly. Action is needed very fast";

bool FE = 0;

HardwareSerial SerialPort(2);  // using UART2

void blink() {
  digitalWrite(2, 1);
  delay(50);
  digitalWrite(2, 0);
}

void setup() {
  SerialPort.begin(115200, SERIAL_8N1, 16, 17);
  Serial.begin(115200);
  pinMode(2, OUTPUT);
  WiFi.begin(ssid, password);
  Serial.println("Connecting");
  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
  }
  Serial.println("");
  Serial.print("Connected to WiFi network with IP Address: ");
  Serial.println(WiFi.localIP());
}

void loop() {
  String rcv_data = "";
  String V = "";
  String I = "";
  String I1 = "";
  String I2 = "";
  String I3 = "";
```

```
  String P1 = "";
  String P2 = "";
  String P3 = "";
  String debug = "";

  if (SerialPort.available()) {
    rcv_data = SerialPort.readString();
    Serial.println(rcv_data);
    V = rcv_data.substring((rcv_data.indexOf("#") + 1), rcv_data.indexOf("$"));
    I = rcv_data.substring((rcv_data.indexOf("$") + 1), rcv_data.indexOf("%"));
    I1 = rcv_data.substring((rcv_data.indexOf("%") + 1), rcv_data.indexOf("&"));
    I2 = rcv_data.substring((rcv_data.indexOf("&") + 1), rcv_data.indexOf("*"));
    I3 = rcv_data.substring((rcv_data.indexOf("*") + 1), rcv_data.indexOf("("));
    P1 = rcv_data.substring((rcv_data.indexOf("(") + 1), rcv_data.indexOf(")"));
    P2 = rcv_data.substring((rcv_data.indexOf(")") + 1), rcv_data.indexOf("!"));
    P3 = rcv_data.substring((rcv_data.indexOf("!") + 1), rcv_data.indexOf(","));
    debug = V + " " + I + " " + I1 + " " + I2 + " " + I3 + " " + P1 + " " + P2 + " " +
P3;
    Serial.println(debug);
  }

  if (WiFi.status() == WL_CONNECTED) {

    if(FE == 1){
      twilio = new Twilio(account_sid, auth_token);
      String response;
      twilio->send_message(to_number, from_number, message, response);
    }

    WiFiClientSecure* client = new WiFiClientSecure;
    client->setInsecure();
    HTTPClient https;

    https.begin(*client, serverName);

    https.addHeader("Content-Type", "application/x-www-form-urlencoded");

    String httpRequestData = "api_key=" + apiKeyValue + "&tot_v=" + String(V)
                           + "&tot_i=" + String(I) + "&i1=" + String(I1)
                           + "&i2=" + String(I2) + "&i3=" + String(I3)
                           + "&p1=" + String(P1) + "&p2=" + String(P2)
                           + "&p3=" + String(P3) + "&emer=" + String(random(0, 1)) +
"";
    Serial.print("httpRequestData: ");
    Serial.println(httpRequestData);

    int httpResponseCode = https.POST(httpRequestData);
```

```
    if (httpResponseCode > 0) {
      Serial.print("HTTP Response code: ");
      Serial.println(httpResponseCode);
    } else {
      Serial.print("Error code: ");
      Serial.println(httpResponseCode);
    }
    // Free resources
    https.end();
  } else {
    Serial.println("WiFi Disconnected");
  }
  blink();
  delay(1000);
}
```

Appendix B

iThenticate Plagiarism Report

Automated Substation

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