DEVELOPING A LOW-COST SCADA SYSTEM FOR INDUSTRIAL APPLICATION

An Undergraduate CAPSTONE Project
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Faculty of Engineering
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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

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APPROVAL

The CAPSTONE Project titled **DEVELOPING A LOW-COST SCADA SYSTEM FOR INDUSTRIAL APPLICATION** 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 the respective programs mentioned below on **June 2021** by the following students and has been accepted as satisfactory.

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ABSTRACT

In this project, a low-cost industrial SCADA system has been presented which has been developed for small and medium-sized enterprises (SMEs). Bangladesh is a developing country and there are many SMEs in the country contributing to the country's economy. Commercial SCADA systems, which are available in the market, are costly to set up and maintain for smaller companies. Also, the controlling and data acquisition interface of the loads through software has to be developed which is also costly. As a result, keeping the cost-cut of the small companies in mind, those SCADA systems can't be used in general. So a low-cost SCADA system prototype has been designed for SMEs. In this project, two microcontrollers have been used for faster data acquisition and better performance for the logic switching of loads by minimizing the switching delay. For the designing purpose, the circuit has been divided into two parts. The first part was designing two rooms with priority-based loads and controlling them via Arduino Mega 2560 and relay modules. The second part was to get data from loads of the two rooms using Arduino Uno and an Ethernet shield connected to the Wi-Fi router. The data acquisition of the loads was done using current sensors and uploading the data to the Blynk app for live observation using an Ethernet shield connected to the router through a LAN cable. These two parts have been connected to complete the whole circuit of this project. Available commercial SCADA system uses PLC microcontroller and RTUs for faster data streams to provide remote indication and control of system parameters which is developed for bigger industries. As a result, the software interface for data acquisition and control is alone very costly to develop. But in this project, a free software, the Blynk app is used for data acquisition and controlling of the loads for different rooms. This app is connected to the internet server through Wi-Fi which is responsible for all the interaction between the smartphone or laptop and hardware. This app is free of cost and available for free download in Play Store but a certain amount of money is needed to unlock more features of the app. But for this project to properly function, there were no extra features needed. As a result, free software has been which results in cost-cut for SMEs for monitoring loads of the whole designed prototype system of this project. And the hardware that has been used in this project such as relay modules, current sensors which are available in local markets and cheaper. The installment and maintenance of this project are also cheap and easy which results in cost-cut as compared to commercially available SCADA systems. This book illustrated how this prototype system works and gave an elaborate concept about this project based on SCADA.

Chapter 1

INTRODUCTION

1.1. Overture

SCADA undergoes for Supervisory Control and Data Acquisition. This SCADA system refers to the mixture of telemetry and data acquisition. The industrial procedure is observed and controlled by the SCADA System that is installed entirely at the plant. SCADA is an integration of software and hardware components that simplify supervision and control of commercial or any methods easily and more conveniently. The system to be observed and controlled embroils the important time operation and data logging, process stirring, and supervisory control access. SCADA encloses the collecting of the knowledge via an RTU (remote terminal unit), transferring it back to the central site, completing any necessary exploration and control then showing that information on the variety of operator's screens or displays. SCADA system can collect data from sensors and instruments situated to distant sides. SCADA sends data to interior space for the controller monitoring process. The SCADA unit simplifies the survey and control of all the pant process easily and more conveniently. In the present situation, the SCADA system has been used more widely and its scope is flourishing day by day, but thanks to the upper costs, the smaller and medium scale industries are within the reflection of using SCADA system in the monitoring of their plant processes. The proficient accession to scale back the value of the SCADA system is using the low-cost software development tools and spreading the scope of software customization as per the need of the plant to be placed.

1.2. Significance of the Project / Research Work

The significance of this project is to develop a SCADA system that costs less than the available one. This system is mainly focused on SMEs (Small and medium-sized enterprises). By using this SCADA system monitoring and the controlling process can be done for SMEs. In industry, an all-time constant electricity supply is very important also there is a need of making the electricity use more efficient at a low price and maintenance like if it's needed to turn off or on a certain load at a certain time or situation it can be done using this SCADA system. In this way, the load distribution can be maintained in the order that the owner wanted or the situation needs. Also, the electrical component is more secure than before. If we use the SCADA system in the conventional method it will cost too much and our one is the simplest way where there is no day-to-day maintenance cost.

1.2.1. Related Research Works

Several works have been conducted related to this one in the world. A conference was held in 2020 among the IEEE International Students and the conference sector was Electrical, Electronics, and Computer Science. Two students from the Department of Electrical and Electronics Engineering, one from Computer Science and Engineering, Kathmandu University, Nepal, and the other student from the Faculty of Electrical engineering in Wroclaw University of Science and Technology, Poland, published a research paper called “Performance Analysis of New SCADA Interface Developed in C# Environment”. In this paper mainly investigated the SCADA software performance which was developed in the C# environment and also compares it with the commercial SCADA software in the perspectives of cost-effectiveness, performance, and easy customization. In 2006, four students from the Department of Electrical and Computer Engineering, University of Virginia, Charlottesville, USA, publish a research paper about Security issues in SCADA networks”. They discussed the general architecture of SCADA networks, security threats issues, Ongoing work in several SCADA security areas like improving access control, firewalls and intrusion detection systems, protocol analyses of SCADA, management system, device, and operating system security.[1]

1.3. Engineering Problem Statement

Bangladesh is a developing country. There are so many small and medium industries in our country. The economy of this country is also dependent on SMEs. Commercial SCADA system which are available in the market are both costly to set-up and maintain. Available commercial SCADA system uses PLC microcontroller and RTUs for faster data streams to provide remote indication and control of system parameters which is developed for bigger industries. Also, IEDs are installed on the distribution feeders of a system with some communicating to the substation RTU while others communicated directly to the network operations center. As a result, the software interface for data acquisition and controlling is alone very costly to develop. As a result, those SCADA systems can’t be used by the SMEs. So, we need to develop a SCADA system which will be cost-effective and easier to maintain properly. [2]

For developing this SCADA system, theory and simulation-based proper understanding of electrical and electronics parts are necessary. As this project is related to the priority-based switching of loads, so the priorities must be set properly for switching the loads on and off. For that reason, Arduino coding part is also needed to be developed to set the logic sequence properly. Many important concepts of engineering are used for developing the project. Also, for completing the project, complex engineering method has to be applied as per requirement.

1.4. Objective of this Work

The main goal of this project is to design and implement a cost-effective SCADA system. No need for an extra man power to monitor and control all the electrical components. Everything is showed on a display of a smartphone or a laptop. Also need to develop the schematic diagram of the SCADA system. In the microcontroller/Arduino/ raspberry pi, all the programs will be fixed and the whole system will run successfully.

1.4.1. Primary objectives

- ❖ To develop appropriate logic for a SCADA system for industrial application.
- ❖ To implement the hardware for SCADA system by using cheaper micro controllers.
- ❖ To implement the software interface for online supervision and control.

1.4.2. Secondary Objectives

- ❖ To perform a literature survey on existing industrial SCADA systems.
- ❖ To analyze the developing cost of different commercial SCADA systems

1.5. Comparison with Traditional Method

- ➢ Instead of PLC microcontroller, Arduino is used which is cost effective
- ➢ Free software is for live data acquisition and controlling.
- ➢ This software can also be used in mobile phone.
- ➢ Use a central server, so it can be controlled from anywhere with internet connection.

1.6. Innovation / Scope of the Project

Instead of depending on manpower to monitor and control the industrial organizations, SCADA came out in the early 1970s. In the 80s and 90s SCADA was continuing in a progress process with the Local Area Network (LAN) technology, PC-based HMI software. The modern SCADA system has allowed us to access any real-time data from anywhere in the world. The modern SCADA system has high reliability, sustainability, efficiency, productivity, and even high security of the data. However, available commercial SCADA systems are costly and hard to maintain. In our project, an innovative SCADA system is used which allows accessing the real-time data and also mainline controlling through a smartphone or a laptop. Massive manpower is not needed to maintain this SCADA system and also only one person can observe and control the system very easily. Arduino is used as a PLU device that takes the output from the system and gives the real-time data to the central pc with SCADA software by a wired network connected by LAN cable through the Wi-Fi router to the pc.[2]

1.7. Impact of Project on Society

The project will bear a great impact on the industrial zone of our country. This project will assure a pollution-free industrial environment and will not bear any negative impact on the social environment. This project will ensure supervisory control and live data acquisition for the respected companies. A survey also has been taken based on the solutions of the currently available systems problems and what people think about the proposed solution of this project. Also, SMEs of Bangladesh can be benefited from this project which leads to a positive view of the economy of a society. The main point of this survey is to understand people's thoughts and views about our project's idea and the purpose.

1.7.1. Survey data representation

A question about knowing the existence of SCADA system. As shown in figure 1.1, 68.5% of people responded yes and rest of them have not heard about it.

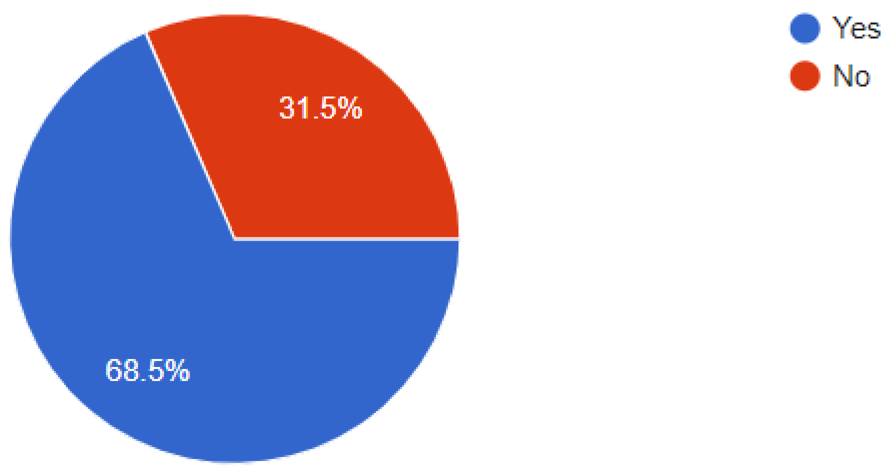


Figure 1.1: Survey result of hearing about SCADA system

Figure 1.2 shows most people think a system should be built to monitor and control loads, 24.1% say maybe and 11.1% say no.

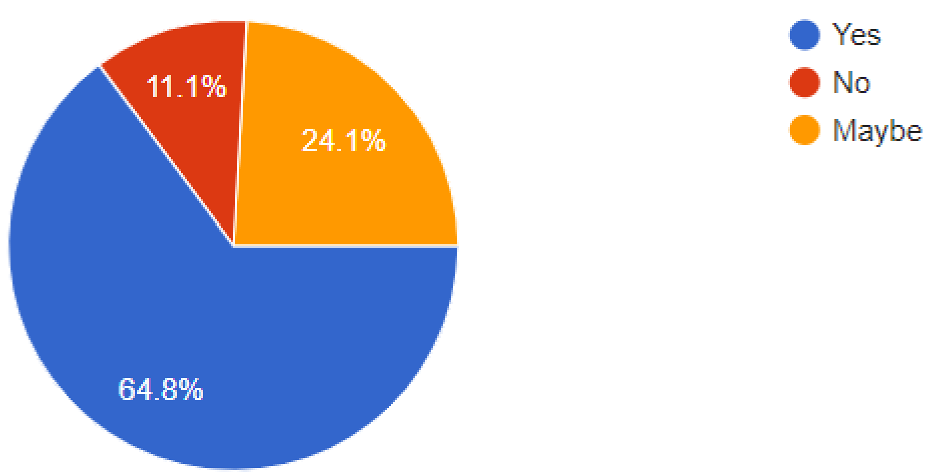


Figure 1.2: Survey result of thinking about a system should be built to monitor and control loads

Very few percentages of people are negative about the load controlling feature but 74.1% people think it is possible and others 19% are not sure.

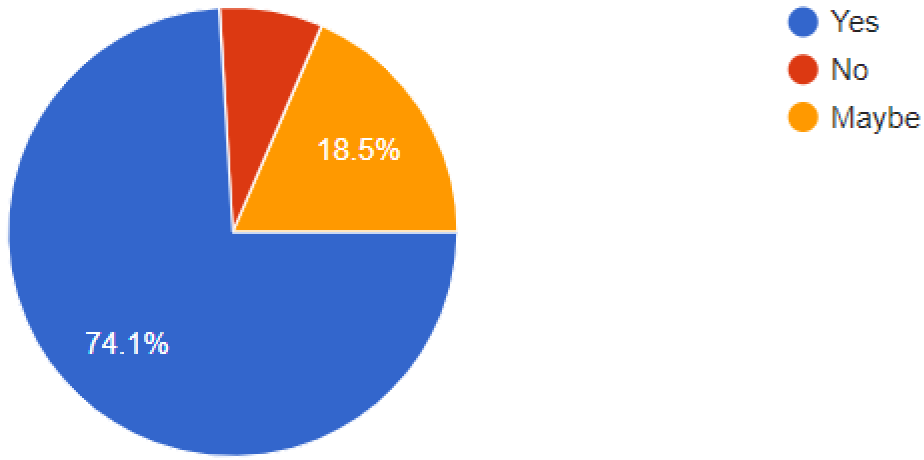


Figure 1.3: People's thought about the load controlling feature.

Almost everyone predicts this project will be helpful for the power industry.

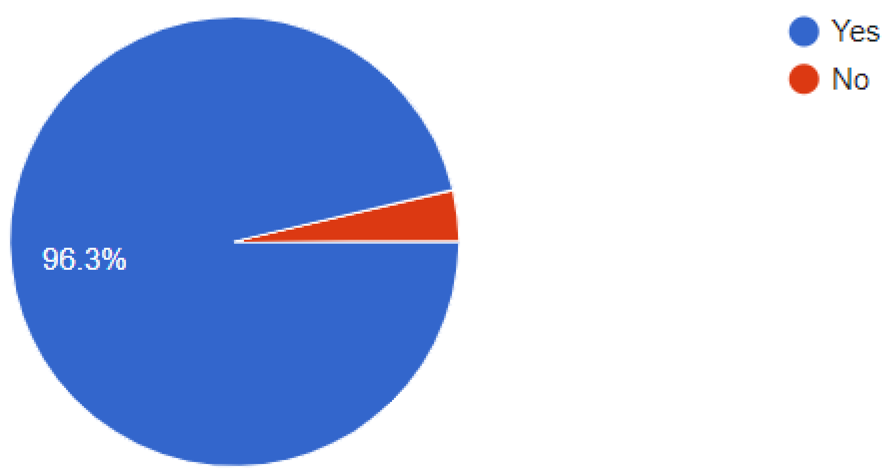


Figure 1.4: Question about the project whether it is helpful for the power industry or not.

When the respondents were asked whether this kind of project will be helpful or not, most of their responds are positive. As shown in fig 1.5, 88.9% of people believe that live monitoring of current and power will be helpful for the industry and 11.1% say maybe.

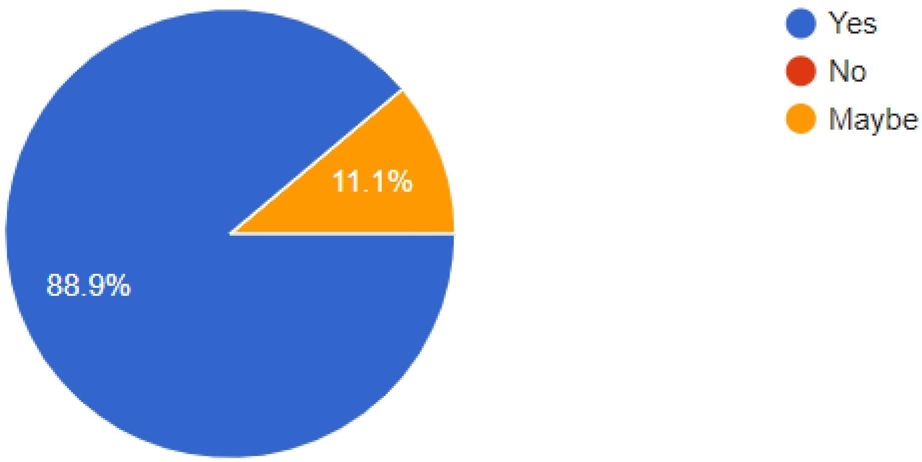


Figure 1.5: Survey about live monitoring of current and power

Almost 85% of people think that commercially available systems for power saving and load analysis are quite expensive and sophisticated.

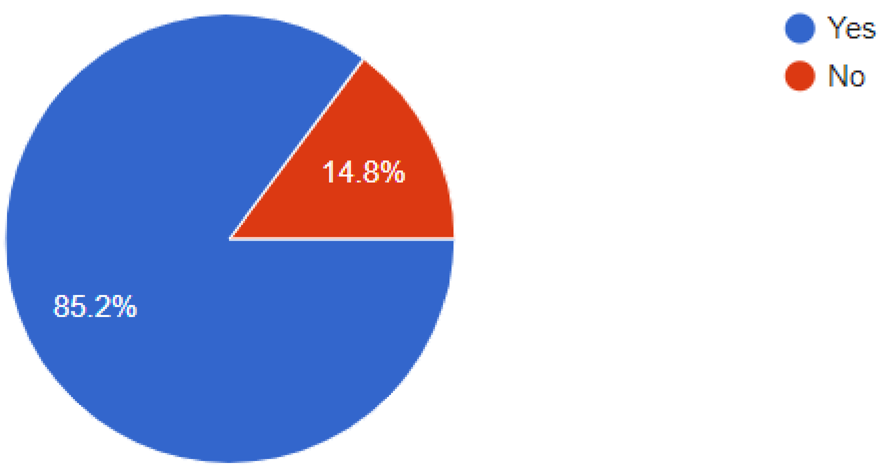


Figure 1.6: Survey about commercially available systems for power saving and load analysis.

In figure 1.7, 85.2% say this project should be generalized and cost-effective.

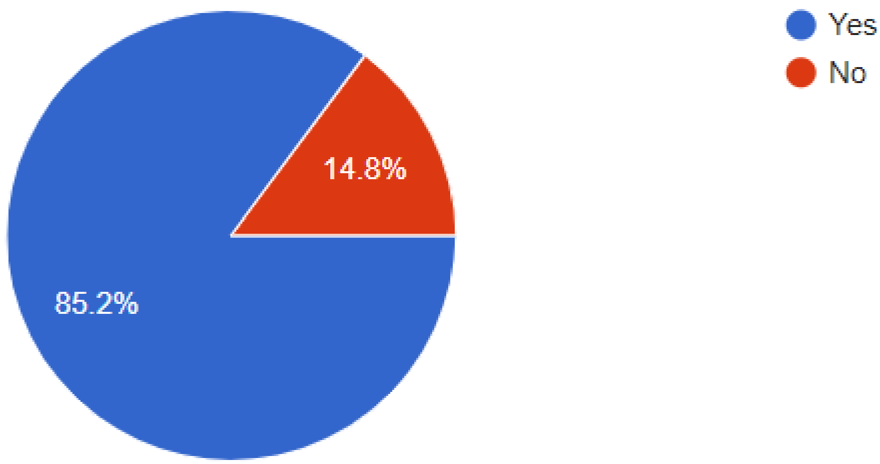


Figure 1.7: People’s thought about the generalization and cost-effectiveness

Most people think this kind of low-cost system is environment friendly, few people say maybe and the rest of the people says no.

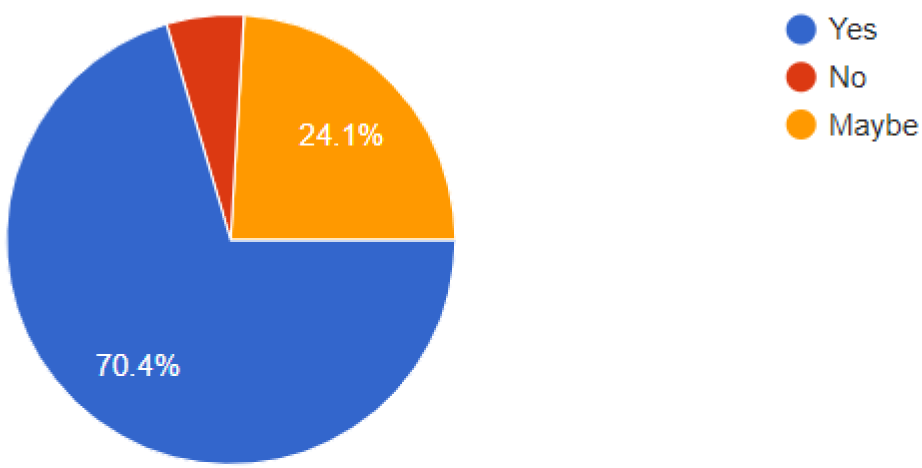


Figure 1.8: People’s thought about the environmental friendliness of the project

Figure 1.9 shows, 94.4 % of peoples thought this project will bear a positive impact on our industry.

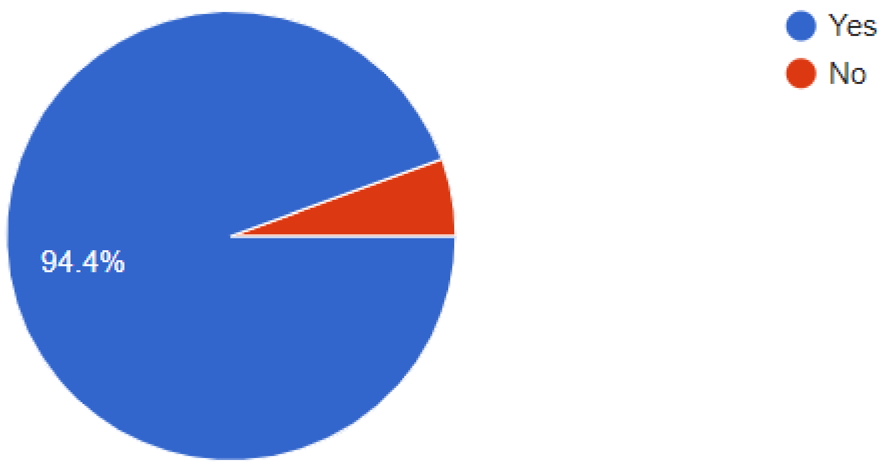


Figure 1.9: People’s thought about the positive impact of industry

A question was asked about the customer’s perspective whether they will use this kind of system for power saving and load analysis or not. Only 11.1% of people were negative about this.

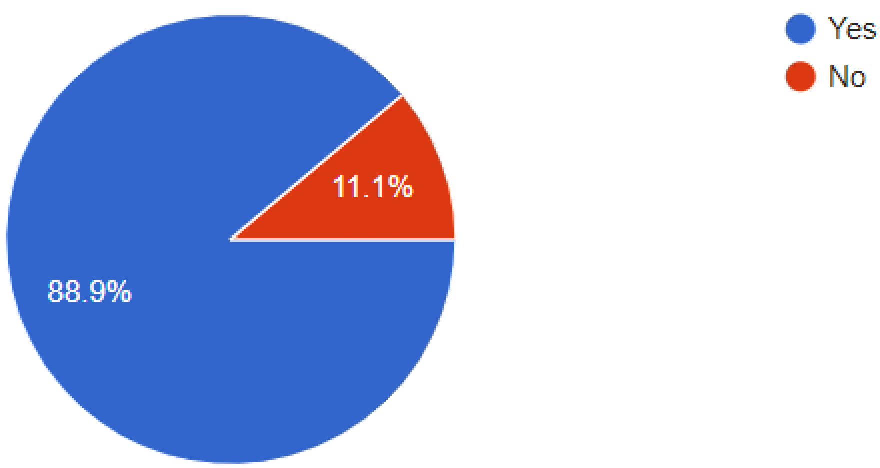


Figure 1.10: Customers thought about this kind of power-saving and load analysis system

The below figure 1.11 shows the people’s opinion on the future of this project whether it holds strong position in future or not. There are 5 options given which are in ascending order from 1 to 5 where 64.8% of people are strongly positive about this project to hold a strong position in the future. Total 54 responses have been collected.

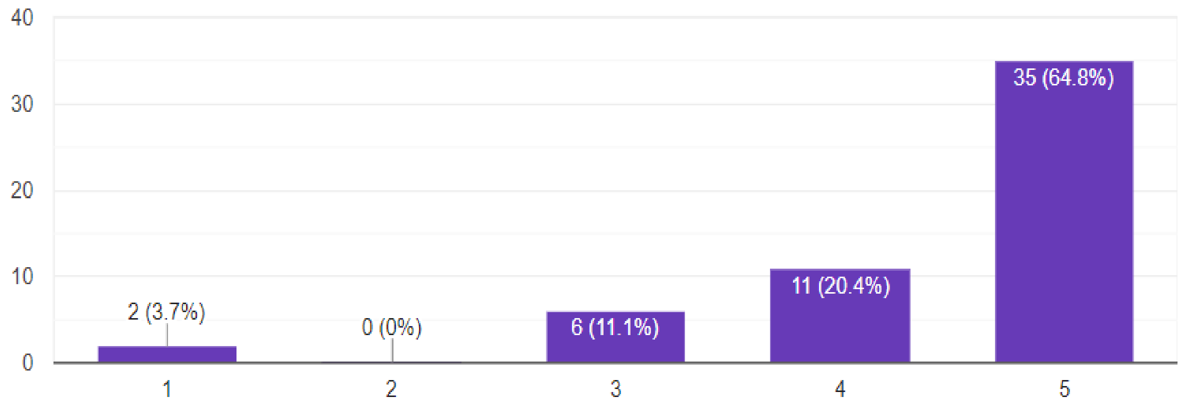


Figure 1.11: People opinion on the future of this project

1.8. Organization of Book Chapters

The organization of remaining parts of this book is as follows:

Chapter-2: Literature Review with in-depth investigation

In this chapter, historical background of SCADA system and earlier research works has been analyzed properly. Related research works have been analyzed thoroughly for betterment of this project. Critical specialist engineering knowledge and state of art technology have been described.

Chapter-3: Project Management

S.W.O.T. analysis, Project schedule management, cost analysis, P.E.S.T. analysis, individual accountabilities, multidisciplinary components management and project lifecycle have been described in this chapter of the book.\

Chapter-4: Methodology and Modeling

The methods that have been used to develop this project such as flowchart, block diagram used for modeling purpose, required software that has been used etc are described in this part of the book.

Chapter-5: Implementation of Project

In this part of the book, the simulation process of the whole circuitry and full prototype setup have been described thoroughly. Required software for simulation, full circuit in simulation, designed prototype and full setup also have been shown.

Chapter-6: Results Analysis & Critical Design Review

In this part of the book, expected result outcomes have been analyzed properly. Simulated results have been described properly, also the logic sequence of loads for each of the rooms have been described thoroughly in tabular format and software observations have been revised to meet the expected values.

Chapter-7: Conclusion

The summarized findings have been discussed in this chapter. The novelty of the work, project finance, project sustainability and future scopes, recommendations on future developments, limitations of the work ethical concerns have been described also.

Chapter 2

LITERATURE REVIEW WITH IN-DEPTH INVESTIGATION

2.1. Introduction

Electrical systems are groups of electrical components to carry out some operation. Such as, within the context of an extended building area, an electrical system is a network of conductors and equipment that are deployed to carry, distribute and convert electrical power safely from the delivery point or generation to the various loads consuming electrical energy around that area. At the Substations protective devices are employed to allow system to be isolated the system failures so that faults may not be able to bring down the entire system. Sometimes a human operator can't supervise the status of various electrical equipment operating in the substation of an area without an automated system. That's why we wanted to develop a low-cost SCADA system that can monitor the equipment by maximizing the efficiency of the power and load distribution system providing features like real-time operation view, data trending, and logging, protecting the equipment by maintaining desired voltages, currents, and power factors, generating safety alarms, etc.

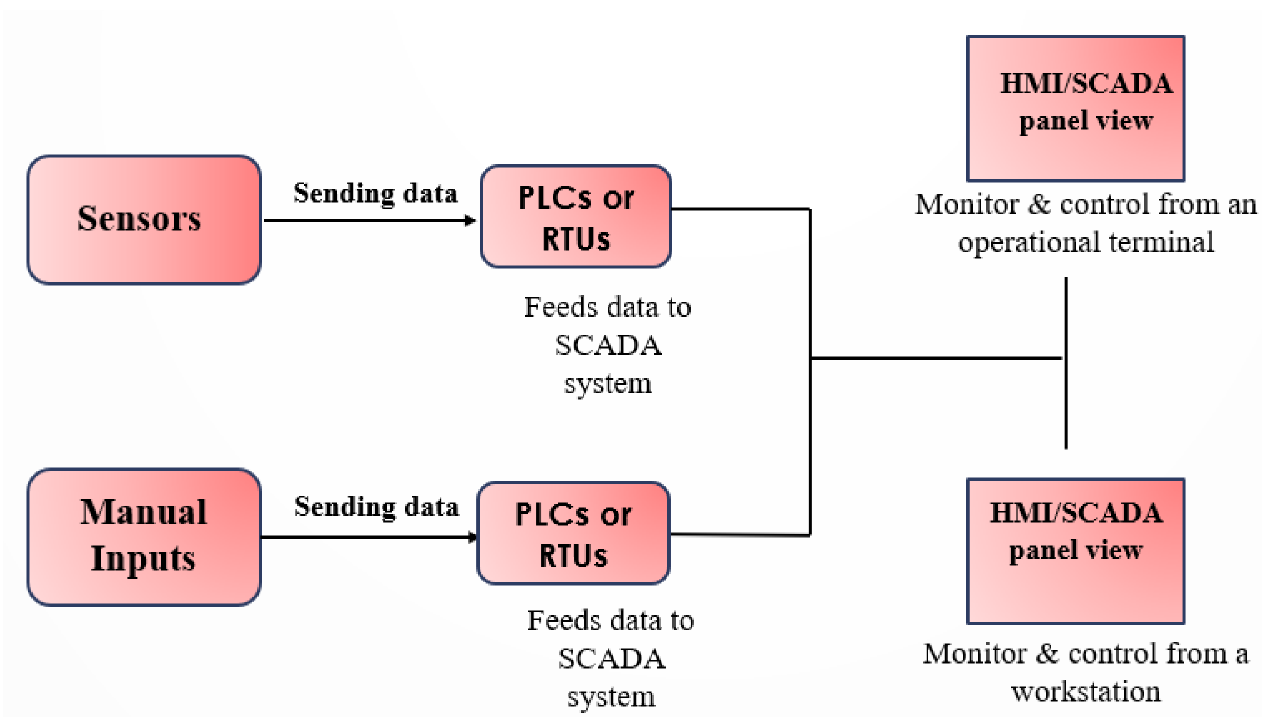


Figure 2.1: Basic SCADA diagram

The above figure 2.1 shows the diagram of a basic SCADA system. Basically, the existing SCADA system in our country follow this way to design their own SCADA system.

2.2. Historical Background

The electrical power system as we see it nowadays began developing in the first phase of the 20^{th} century. As the demand for electric power grew, so people felt the need to find ways to improve the reliability of the power system. Substations became common where power lines came together or where voltages were transformed. As the demands for reliable electric power became greater and as human labor became a more significant part of the cost for providing electric power, technologies are known as supervisory control and data acquisition (SCADA) was designed to allow remote monitoring and even controlling some key parameters of the system. SCADA systems began to reduce and even eliminate the need for a human operator at substations.

Early SCADA systems provided remote indication and control of substation parameters using technology which is borrowed from automatic telephone switching systems. In 1932, "remote-control" products were advertised by Automatic Electric and it was based on its successful line of "Strowger" telephone switching apparatus. Another example (used in the late 1960s) was an early Westinghouse REDAC system that used telephone-type electromechanical relay equipment at both ends of a conventional twisted-pair telephone circuit [4]. When SCADA systems were developing, a second technology, known as remote teleprinting, or "Teletype"-was coming of age, and by the 1960s had gone through several generations of development. The invention of a second device, the "modem" (Modulator/Demodulator), was allowed to send digital information over wire pairs that had been designed to carry the electronic equivalent of human voice communication. Also, in the late 1960s and early 1970s, the use of small computers, such as minicomputers were began exploring, mainly for substations to provide advanced functionality, proper monitoring of load, and increase communication capability [5]. But at that time, usage of computers in electric substations met with industry resistance because of distinguishing problems and real reliability issues. In the 1980s, microprocessors began to apply equipment with a communication ports such as protective relays, meters, various controllers, and other devices. Early SCADA communication protocols were usually state-owned and were also often kept secret from the industry. A trend beginning in the mid-1980s has caused to minimize the number of state-owned communication practices and to drive field practices toward open, standards-based specifications.

2.2.1. Remote Terminal Units (RTUs)

As digital electronics were introduced in electrical systems, it became possible to use faster data streams to provide remote indication and control of system parameters. As a result, a Remote terminal unit (RTU) was developed which could provide remote indication and control of both discrete events and analog voltage and current quantities. The introduction of the microprocessor with the Intel 4004 in 1971 has created a new door for increasing sophistication in RTU design that is continuing today [6]. Traditional point-oriented RTUs could be built in a fraction of the physical size required by previous discrete designs because of their reported discrete events and analog quantities. By using microprocessors, the hardware complexity of the RTU is reduced, but the interface wiring remained unchanged or even increased because of the use of external milliamp transducers instead of internal analog to digital converters [7]. As a result of introducing microprocessors, the capabilities of RTUs increased such as timekeeping, more complex and powerful protocols, individual point numbering, local logging and time tagging of events, higher communication speeds, multiple communication ports, etc.

2.2.2. Intelligent Electronic Devices (IEDs)

By the late 1970s and early 1980s, integrated microprocessor-based devices were introduced, and these came to be known as intelligent electronic devices, or IEDs. IEDs quickly became the preferred interface between the power system and the RTU of many updated substations. Because of these devices the magnitude and complexity of the control and instrumentation wiring are greatly reduced. In the 1990s, utilities began installing IEDs on their distribution feeders with some communicating to the substation RTU while others communicated directly to the network operations center.[8]

2.3. Earlier Research

Substations are an essential unit for maintaining electrical load control and power supply in low voltage, medium voltage, and high voltage electrical distribution sites. For the smooth functioning of substations and related equipment, most servicing companies use SCADA systems for automatic monitoring and control. In mid-1970, the term SCADA was emerged to describe automated control and data acquisition. In the 80s and 90s, SCADA was designed for LAN (Local Area Network) technologies and PC-based HMI (Human Machine Interface) software which gave merchants control to optimize data transfer [9]. Then In the 90s and early 2000s, an open system architecture and communications protocols were adopted by SCADA that were not merchant-specific and also allowed other merchants to communicate with each other, eliminating the limitations of older SCADA systems, and allowed companies to connect more devices to the network by taking the advantage of Ethernet communications technologies. From the late 90s to the early 2000s, as a part of a technological boom personal computing and IT technologies were lifted to another level of development [10]. Modern SCADA software is introduced with SQL and web-based applications which improves the security, efficiency, dependability, and performance of SCADA systems. Now the modern SCADA designer applications have RAD (rapid application development) facilities that allow users to style applications easily. Almost all digital control systems use SCADA with Remote Terminal Unit (RTU) to supervise the metering devices for incoming and outgoing feeders. Besides RTUs PLC (Programmable Logic Control) techniques are used in the SCADA system to control and monitor the system inside substations.

2.4. Related Research/Published Works

In which circumstances it is possible to develop efficient low- cost-solutions in a small manufacturing company and the impact the introduction of information technology has on developing managerial capabilities of industrial processes is analyzed in the paper. It follows an exploratory single-case study research design. From direct observations, documents such as production orders and log sheets, and semi-structured interviews data was collected. An implemented low-cost-solution for supporting an SME in its first two steps of the digitization process was presented from the data. The tool which is used is adaptable and transferable to similar manufacturing companies suggesting that the start of the digitalization process can be heavily simplified. [11]

To develop practical and affordable applications that will optimize the bottling process of a SME beverage plant by combining its existing production resources to basic principles of the current trend of automation, Industry 4.0 (I40) was the main contribution of this study. This research shows how the small beverage industry can achieve higher production rate, better delivery time and easy access of plant information through production forecast using different solutions such as linear regression, predictive maintenance using speed vibration sensor and decentralization of production monitoring via cloud applications. To program the optimized process with very few additional resources such as the existing plant Siemens S7-1200 programmable logic controller (PLC) and ZENON supervisory control and data acquisition (SCADA) system were used. By use I40 in their production processes with available means and limited cost this study opened doors for automation in SMEs. [12]

In this paper, the design and implementation of a low-cost, open-source program SCADA using the Thinger IO server platform as MTU and ESP32 Thing micro-controller as RTU is introduced. It shows how SCADA structures have evolved over the years from monolithic (stand-alone) with distributed construction and network construction to the latest Internet of Things (IoT) architecture. The SCADA program proposed for this project is based on the Internet for SCADA Building Materials that include web resources and standard (traditional) strict control and monitoring SCADA. It contains analog Current and Voltage Sensors, a low-power ESP32 Thing micro-controller, Raspberry Pi micro-controller, and local Wi-Fi Router. In its implementation, current and electronic sensors receive the desired data from the process plant, the sub-ESP32 controller detects, processes and sends sensor data obtained via the Wi-Fi network to the Thinger.IO platform for the IoT data storage server, real-time monitoring and remote control. The Thinger.IO server is hosted locally by the Raspberry Pi micro-controller, while the Wi-Fi network that creates the SCADA communication channel is created using a Wi-Fi Router. To test the proposed SCADA system solution, Hardware is designed to be used to remotely monitor Photovoltaic (PV) power, current, power, and power consumption of 260 W, 12 V Solar PV System. Other Human Machine Interfaces (HMIs) have been created in Thinger.IO Server where operators can remotely monitor data in the cloud, and initiate administrative tasks if the data received is not within range, using both a computer connected to the network and Thinger.IO Mobile Apps introduced on paper.[13]

SCADA systems (managed control and data acquisition) are currently being used in many systems, such as home automation, greenhouse automation, and hybrid power systems. SCADA trading systems are very expensive to set up and maintain; therefore, those are not used for small renewable energy systems. This paper shows the use of Reliance SCADA and Arduino Uno in a small photovoltaic (PV) power system to monitor current PV, voltage, and battery, and efficiency. The built-in system uses inexpensive sensors, the Arduino Uno microcontroller, and the free Reliance SCADA software. The Arduino Uno microcontroller collects data from sensors and communicates with a computer via a USB cable. Uno is designed to transfer data from Reliance SCADA to PC. In addition, the Modbus library is uploaded to Arduino to allow communication between Arduino and our SCADA program through the MODBUS RTU protocol. The test results show that SCADA works in real time and can be used effectively to monitor the solar energy system. [14]

Nowadays, quick and uninterrupted access to information is important because of its impact on our personal and professional lives. Even in the industry, any factory manager would like to get real-time information on the operation of machinery using various industrial monitoring tools. In this regard, a complete example of an industrial monitoring tool is the Supervisory Control and Data Acquisition (SCADA) system that monitors and manages a network of Programmable Logical Controllers (PLCs). However, the SCADA system has its challenges as it is designed to operate only on closed networks. Therefore, real-time data of operating equipment is only available within the factory premises. To solve this challenge, Industrial Internet of Things (IIoT) is being used. Under the IIoT umbrella, various features, improvements, and benefits of IoT can be used to improve industrial systems. However, the SCADA system is traditionally expensive, and the PLCs used cannot connect to the Internet. For this reason, PLCs can be monitored or monitored remotely. In this paper, an IIoT low-cost SCADA system is proposed to connect any PLC-supported device to a remote cloud server. The entire proposed system is implemented and tested in a web-based framework. The proposed web-based framework leads to better use of connected devices. [15]

2.5. Critical Engineering Specialist Knowledge

For solving the project, different section of engineering knowledge was required. This includes the different kinds of hardware knowledge, SCADA system, setting of priority for different load, power distribution, coding, knowledge, and use of different kinds of software based on wireless remote controlling. In the industries, different types of loads are used, which has different types of power consumption rating. And maintaining this rating effectively while also saving the overuse of electricity is quite tough. If a system that can handle the loads as per requirement and maintain the desire power flow while saving the excess use of electricity, also at a low cost will be very useful to a company like SMEs.

The SCADA system is a database system which process, monitor and gather real-time data. In the SCADA system, manual input can be given to PLU (programmable logic unit) or RTU (Remote terminal unit). And that information can be seen and required steps can be taken as per given orders on the computer using SCADA software.

In the Arduino different types of coding will be needed according to the conditions. The current measurement of multiple loads using multiple current sensors can be read by doing the proper coding. And the power flow rating, priority settings of the loads or maintaining the loads in a certain order have to be done by coding. All those conditions need to implement in the code and that has to be marched in one code with proper instructions and delays to perfectly work it out. To implement this code the basic of python language or C++ coding or Arduino codding needed such as how the loops, variable works, how to declare the variable, what they are the major function of coding, the library for each and different equipment that are used to instruct with the code and mainly how to march all the code in such a way that it works successfully and so on. The basic function for using the Arduino is digital write (), pin mode (), analog read (). The variable can be declared by using a float, int., char. and so on. A piece of clear knowledge about the Arduino and the different types of equipment is also needed.

This project will help us to observe continuous current flow by using the current sensor which will be connected to the Arduino and that measured value of the current, that value of current will be sent to PC using Wi-Fi module and SCADA system will show will all the data and also priority will be set for each load and the system will turn on or off the load as per required or the situation based on the given priority at the code portion and also the load data will be sent to the computer.

2.6. State of the art technology

In the project of SCADA system designing, best available components were used. SCADA system is widely used in the power system, but the conventional way of the system causes a lot of money and SMEs can't effort those. In our project current sensor is used which can measure the current flow and power consumption of the load system and also able to maintain the constant flow of current at a certain rate and also will maintain the load as per priority setting. The Arduino is used as a PLU which will receive data from the current sensors of each load and send the data through a wireless system (Wi-Fi) to a PC with SCADA software. The real-time data can be stored in the system and can continuously see the live data as well. According to the priority of the load, the loads will be maintained. As it is targeted at SMEs, the system is designed to make sure the value for the money. At low cost best possible components were used in the project. This type of system is very easy to install and doesn't need any kind of maintenance until any component gets perish.

2.7. Summary

In the industries, an uninterrupted power supply is needed for maximum production. But due to different reasons, different kinds of faults occur in the distribution system network. This can be solved by using the SCADA system. SCADA system is widely used for monitoring and creating data. In our project, real-time data of the load distribution was observed to maintain to flow the constant flow of constant power to the load easily. This is a low-cost system that is made for SMEs. This project makes the maintenance of the load easier and more efficient as a priority order can be set here. This leads to the saving of electricity and extra cost that may bring maximum benefit for the company. Also, this SCADA system is highly suitable for the small and medium companies of Bangladesh. With this SCADA system, live data acquisition and controlling of the loads can be done easily.

Chapter 3

PROJECT MANAGEMENT

3.1. Introduction

Nowadays our lives are unpreventable by technology. The development of new technologies improves work and makes the world better alongside helping to save lives. In reality, technology has played a very important role in how we live in the world today and how we communicate with everything around us. It just made our lives easy. The recent development of SCADA is a technology that is a system of software and hardware that allows industries to control industrial processes locally or at remote locations, monitoring, gathering, and processing real-time data much like IoT. This project is aimed to reduce the cost of SCADA systems and make them more attainable for SMEs. This project work has been developed in both simulation and hardware implementation. Some parts of this project were designed at simulation using proteus then the full project was implemented on hardware as all the design was not possible to do in simulations. All the results of the simulations and Hardware implementation were observed.

Every project needs to be done under proper management. To complete a project successfully in time, one needs proper and specific planning, an effective schedule, and enough researches. In this chapter, some management procedures like S.W.O.T analysis, PEST analysis are discussed. S.W.O.T analysis will portray the strengths, weaknesses, opportunities, and threats of our project. And PEST analysis will portray the possible political, economic, social, and technological impact of our project. This analysis will key up a suitable payoff for this project and also the possible external and internal factors that can affect our project can be shown.

3.2. S.W.O.T. Analysis of the Project

SWOT analysis is a framework used to evaluate the strengths, weaknesses, opportunities, and threats of a project to develop strategic planning. SWOT helps to analyze the internal and external factors, current and future potential of a project. [16] It works best when realistic data points are provided rather than prescribed messaging. For S.W.O.T analysis the interior study shows the critical point in specifying the source of competitive benefit and the exterior recognizes market opportunities and threats. For our project, this analysis is used as an internal study which can be based on surveys but we did it using the knowledge available on the internet.

Strength: The following strengths of this project are given below:

- Designed to work for small and middle-size industries and enterprises to maintain their load distribution and to avoid any kind of overload situation.
- It can work with IoT
- Priorities can be set as per requirement.
- It can reduce manpower in industries because this system can manage the whole load system automatically by itself. So if an overload situation there is no one there will no problem, because it will automatically shut down the load.
- Cost-efficient because the mechanical structure is quite simple rather than another SCADA system available in the market.
- Available and comparatively cheap parts were used to design the system, so overall it will be easy to install at a low cost and with less hassle.
- Maintains is very easy. No extra knowledge is needed to maintain this system.

Weakness: The following weakness of this project are given below:

- At the time of setting the priority, it may difficult to reconstructing the different parts of the coding.
- One may need some knowledge about the Blynk software to catch up with the working procedure of the system.
- It cannot be figure out that whether it will work for a very large load distribution system or not as Arduinos are used. So, the Arduinos may not be able to handle the mass information or data of the load distribution system.

Opportunities: Every scientific project has some future opportunities which indicate what development can be made in the oncoming time. The future opportunities of this project are given below:

- This project can be simulated on a large scale and also can be implemented in hardware on a large scale.
- Advance research can be done for the hardware implementation to perform more strictly and cost-effectively.
- More security for the system can be achieved by further research.
- A full self-designed SCADA system can be designed.

Threats: This project has several opportunities as well as it has also some particular threats which are given below:

- The economic advantages may not attract the SMEs at the beginning.
- This proposed system may cause an unemployment problem.
- As a wi-fi connection is used, it may vulnerable.
- If the main ac supply of the system gets short-circuited, the system may collapse and may be needed to reconstruct the hardware part.

3.3. Schedule Management

Schedule management is the whole process of organizing project tasks in a systematic way with the distribution of works, equipment and maintaining time table. There are several objectives of schedule management which include efficient utilization of project members, equipment and facilities and minimization of time. A schedule was planned and followed for completing all tasks of the project in due time, which has been shown in figure 3.1. For each task, there was a time limit set, and the tasks were tried to be completed within that. With proper schedule management, the development and documentation of the project were done.

Project Schedule (Gantt Chart) Group-01

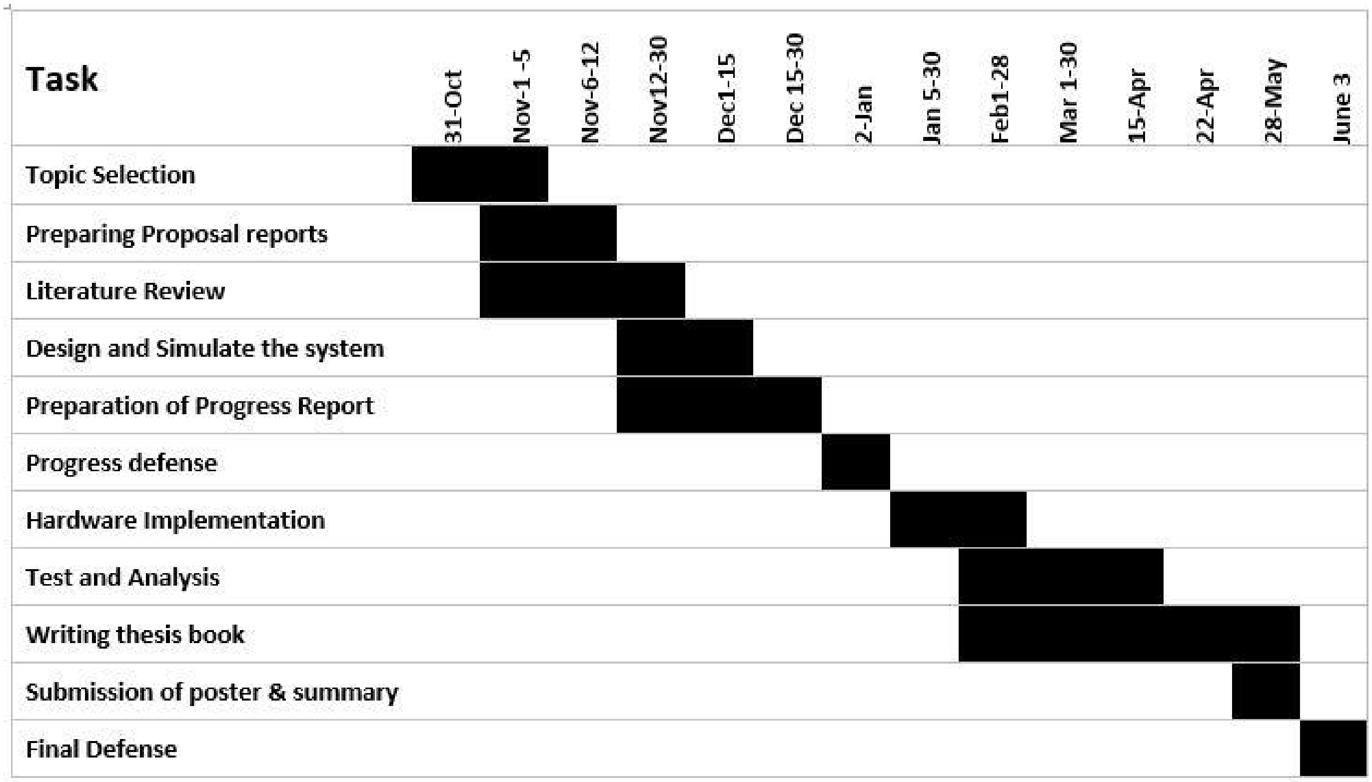


Figure 3.1: Gantt Chart

3.4. Cost Analysis

Based on our forecasted estimation of total project cost and final implementation cost as appeared in table 3.1 a standard deviation is determined dependent on the equation demonstrated as follows:

$$\sigma = \sqrt{\frac{1}{N} \sum_{i=1}^{N} [Xi - \mu]^2}$$

…………………….……………….3.1

Where N is the population size and **μ** is the population mean.

Table 3.1: Cost Analysis of Project with standard deviation

Name of Components	Quantity		Estimated Cost	
		Cost per Unit (In BDT)	Total Estimated Cost	Total Final Cost (In BDT)
Ethernet W100- 1000	1	230	210	230
Arduino Uno	1	499	400	499
2 channel Relay	1	210	210	210
4 Channel Relay	2	580	1000	1160
Current Sensor	2	219	400	438
Stranded copper wire	12 gauge	18	216	216
Arduino Mega	1	978	950	978
Energy Bulb	2	150	300	300
Dim Bulb	5	18	90	90
Bulb Socket	7	30	210	210
Switch Board with Socket Outlet	1	300	280	300
Bread Board	1	80	80	80
Jumper Wire		70	70	70
USB 3.0 Hub with Adaptor	1	600	550	600
Total			**4966/- BDT**	**5381/- BDT**
Standard Deviation			**284.1334**	**318.6869**

So, the standard deviation is 17.2768 which is acceptable. Here, almost four hundred fifteen (BDT) difference between estimated cost value and final cost value. There are few reasons for that. At first, our project was developed in simulation because of the COVID-19 pandemic. At that time it was difficult to gather all the hardware components. Then when the new normal situation started, manage to gather our hardware components. Most of the components was ordered in the online shop so it was needed to add the delivery cost for those components. In March 2020 a virus named COVID-19 infected most of the country and it became a global pandemic. For this virus whole world economy was greatly affected and unstable. So, for that reason, some component price was increased or decreased.

3.5. P.E.S.T. Analysis

In this chapter, P.E.S.T analysis will discuss. PEST Analysis includes political, economic, social, and technological analysis which shows the threats and opportunities of a project. It is a management method that we can use to assess major external factors that influence our project operation to become more competitive in the market [17]. This PEST analysis will be useful for any institution that needs to measure the current and future markets of our project.

Political: Small and medium-sized enterprises (SMEs) are playing an increasingly important role as an engine for economic growth in Bangladesh. SMEs provide low-cost employment opportunities and render flexibility to the economy. Many of the SMEs are engaged in export activities suggesting that they are internationally competitive. Considering the importance of the SME sector in the economy of Bangladesh and understanding the constraints under which such enterprises operate, it is evident that policies to support the development and growth of SMEs are necessary. Chapter 5 of the National Industrial Policy of 2016 concentrates on the development of micro, small, and medium enterprises and cottage industries. Special initiatives by the government are in place to eliminate the still existing barriers to SME development. Major commitments include the provision of collateral-free, single-digit SME loans; refinancing of SMEs; cluster-based SME development. Also, The Sustainable Development Goals adopted by UNDP are a landmark step. Where all the state leaders of the world have come together and decided that by 2030, the planet will be protected and all people will enjoy peace and prosperity. In the continuation of which Bangladesh is determined to follow these goals. "Industry, Innovation and Infrastructure" is the 9^{th} goal of the Sustainable Development Goals. The government of Bangladesh has highly invested in infrastructure and innovation which are crucial drivers of the country’s economic growth and development. The Government is encouraging everyone to build resilient infrastructure, promoting inclusive and sustainable industrialization and fostering innovations.

Figure 3.2. Sustainable Development Goals. [18]

Economic: This proposed project is economically stable. As all the electronic parts are within an affordable price range it will make a positive impact on each economic factor. The components are also available in online and local markets. The technology we are using is not expensive. Even the Blynk app that we are using is a free resource but requires a certain amount of money for extra features. Using this system for maintaining the load and remaining safe from unwanted load faults can save a lot of money.

Social: This system reduces manpower. As a result, fewer industrial hazards will occur because of human errors and less accidental deaths or body paralysis due to electrical shocks will happen. Also, it will help the SME owners to lower their operating and maintenance costs of their load system. It will also save a lot of money and time.

Technological: There are several similar types of systems in the market. Our project represents the low-cost technological impacts that may attract the companies. Technology has always been the best way to research. In the future, this system can be upgraded with the flow of new technology.

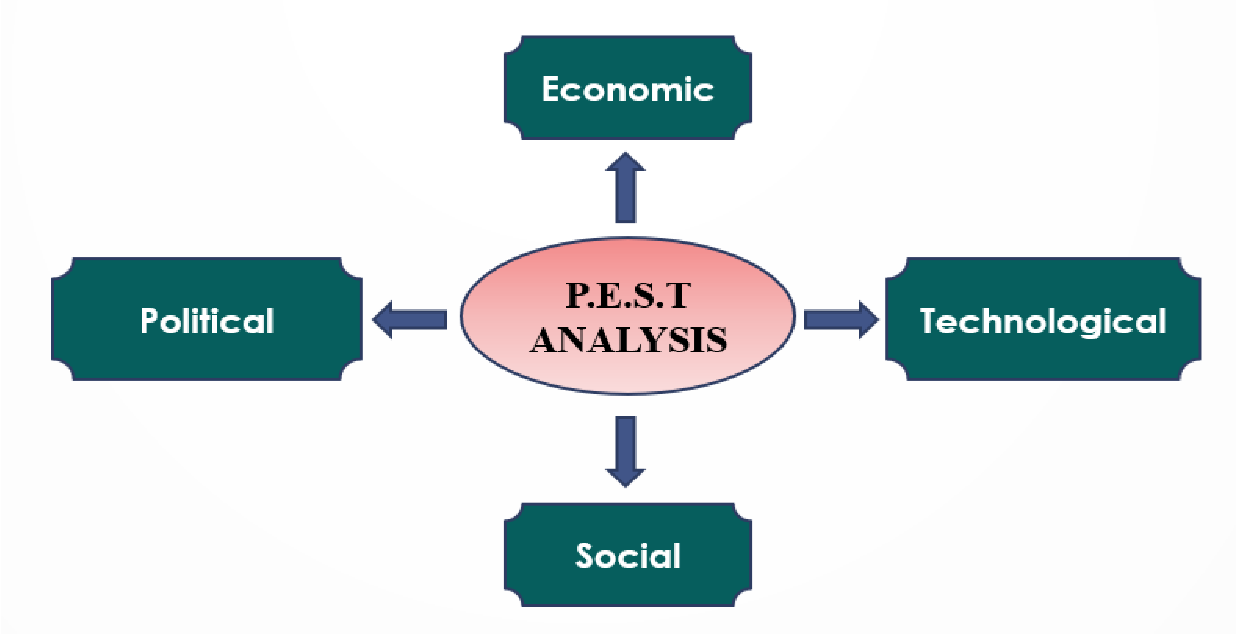


Figure 3.3: Factors of P.E.S.T Analysis

3.6. Individual Accountabilities

The works associated with this project, including necessary documentation, were done by the group members under the supervision of the project supervisor. All the four members of the group worked together as a team, and for the overall project, all of them were responsible. However, for working advantage and to utilize the unique skills, tasks were distributed among the members. Table 3.2, table 3.3, table 3.4 and table 3.5 shows the listed accountabilities of the members. With proper collaboration between each other and using the interpersonal skills, the members worked together from beginning to the end of the project that significantly contributed to the successful completion of the project.

- **Accountabilities of Member 1**

Table 3.2: Table of the accountabilities of member 1

Name	Assigned Responsibilities	Status
Nahid, Parvez	Analyzing project feasibility and maintaining project finance.	Completed
	Analyzing the designed circuit of the project	Completed
	Doing the wirings of the prototype	Completed
	Chapter 1, 4 & 7 writing of the project book	Completed

- **Accountabilities of Member 2**

Table 3.3: Table of the accountabilities of member 2

Name	Assigned Responsibilities	Status
Sazid, Mir Mohibullah	Conducting necessary surveys for the project	Completed
	Analyzing the simulated circuit, setting the logic for prototype functioning & creating a flowchart	Completed
	Doing Arduino coding	Completed
	Chapter 6 & 7 writing of the project book	Completed

- **Accountabilities of Member 3**

Table 3.4: Table of the accountabilities of member 3

Name	Assigned Responsibilities	Status
Shakib, Mohammed Ashraful Alam	Choosing project components	Completed
	Modeling & Designing the circuit	Completed
	Simulation circuit implement using Proteus 8.9	Completed
	Prototype designing, doing wiring connections, and testing the prototype	Completed
	Chapter 2 & 5 writing of the project book	Completed

- **Accountabilities of Member 4**

Table 3.5: Table of the accountabilities of member 4

Name	Assigned Responsibilities	Status
Billah, Mokabbera	Doing the project Research	Completed
	Analyzing the surveys	Completed
	Doing Arduino coding	Completed
	Chapter 1, 2 & 3 writing of the project book	Completed

3.7. Multidisciplinary Components Management

A lot of studies, research, basic hardware knowledge, basic software using capability, proper knowledge of Microsoft Word, and the proper way of writing a book and summary needed to complete a project successfully. Also, knowledge about Gantt chart, flow chart, block diagrams or conduct a survey, simulation, modeling, designing, are required.

First of all, a lot of old research works, reading of old related papers are needed to get the new ideas for the project. Tons of old research-related information is needed to be gathered to write the book and the summary. Research capability can be increased by reading several conference papers, journals, thesis papers, research papers, and topic-related work papers.

The titled project was written on Microsoft word for which increased our writing capabilities. The writing manner and properly preparing paragraph was developed.

While doing this project we learned about communication, teamwork, deadlines, planning, plotting, goals, cost analysis, and so on. Also, the capability of using different kinds of software was increased. This project also helped us to improve our ability of critical thinking and capability of coding using different software and also improved the knowledge of designing and simulation in different software. Simulation on Proteus needs to be learned, or any other software. How to simulate the model and find the result was learned, analyze it on Proteus. How to match the coding with the design and make the design more compatible with coding was learned.

Every part and component of the project was learned. After doing the simulation part which is possible in simulation, the whole project was done in hardware, so need to acknowledge the specification of every component and their working procedure, their model, their ratings, and also learned how to do wiring successfully, the practical designing knowledge of a circuit was also gathered.

3.8. Project Lifecycle

This chapter discussed the lifetime of this project. Nowadays no project has a fixed lifetime. So, also our project doesn't have a fixed lifetime. Because this system can be improved by further research. The simulation and also the hardware portion can be connected to advanced technologies as everything is going updated every other day. We cherished designing a system that can handle multiple loads, with multiple priorities at the same time. We can make this project more discriminative protection way. Also, the own SCADA software can be created to control and maintain the whole system. We used an ethernet w100-1000 that has around a 5-7 years life span depending on their usage and without any external damage and can transfer data fast. All the components we used in this project are very convincing and economical.

3.9. Summary

This chapter was based on the complete project management from the beginning which included strategic planning, time scheduling, cost analysis of the project, analysis of economic, political, technical, and environmental factors, accountabilities of each member of the group, maintaining multidisciplinary components, and studying the lifecycle of the project. Schedule management was about the distribution of tasks in terms of time, It helps to maintain the timetable to ensure the best utilization of resources as well as finishing all tasks in time. The strategic analysis provided an overview of the project's internal details and future potential in terms of social, economic and technical factors. Cost analysis helps to keep track of the expenses of the project. Distribution of accountabilities refers to the proper utilization of expertise. After all, this chapter covers the project management and costs analysis part of this project.

Chapter 4

METHODOLOGY AND MODELING

4.1. Introduction

This chapter contains a description of the methodology along with the modeling of the project. In the beginning, the methodology was explained with the flow chart. After explaining the methodology of the project with the flowchart, the basic idea of the project was mentioned and block diagrams were also showed. The prototype of this project was made. The orientation of the components inside the prototype was also shown. The way this project was made, it becomes more helpful to observe and control the whole scenario. For modeling, this proposed system was provided an idea of the circuit difficulties of the architecture.

4.2. Software Requirements

To complete this project simulation, Proteus 8.9 software was used. The circuitry was placed in this software to determine the value of current and power. Blynk app was also used to measuring the current and power and this app also able to control the room load's on and off activities. The Flow chart was done in Lucid chart and the block diagram of this project was done in Microsoft PowerPoint.

4.2.1. Proteus 8.9 software

Simulation is a very essential tool to comprehend how the device will act in a real-life scenario. In every project, it is a good idea to simulate the design for verification then apply it in the practical field. This proteus is free software and we can use it offline. For various design purposes, this software can be used. Schematic design, flowchart design, PCB layout, 3D view of PCB layout can be done in this software. By using this proteus software Arduino can also simulate to follow few necessary steps.

4.2.2. Blynk app

It is free to download. This app allows us to prepare interesting interfaces for our projects where anyone puts different types of widgets. It has also a server that is responsible for all the interaction between the smartphone and hardware. This app also can be installed on pc. But one important thing is this app requires an internet connection. In this app, we can arrange few features like buttons, sliders, graphs, and other widgets onto the screen.

4.2.3. Lucid chart

It is a free version as well as it's a paid version. To work in this software internet connection is required. No need to download this software. Users need to internet connection and do their activities. With this software, it is very easy to prepare and publish diagrams, flowchart which looks professional.

4.3. Methodology

The method of this project was described by flowchart. From this flowchart, anyone can understand the process of our project and what is our desired goal. Our main theme was load priority when the load was on or off. Because of this coding part was set up in Arduino where priority was also mentioned. According to priority, load works automatically and also doing the controlling job. In the prototype of our project room 1 has 4 loads, if switch 1 is on load 1 is on and if switch 1 is off the load 1 is off and this process is also the same for load 2. When switch 3 is on load 3 is also on but checking the load no.1,2,5,6 and when it is off load 3 is also off. For switch 4 few loads also need to check the process.

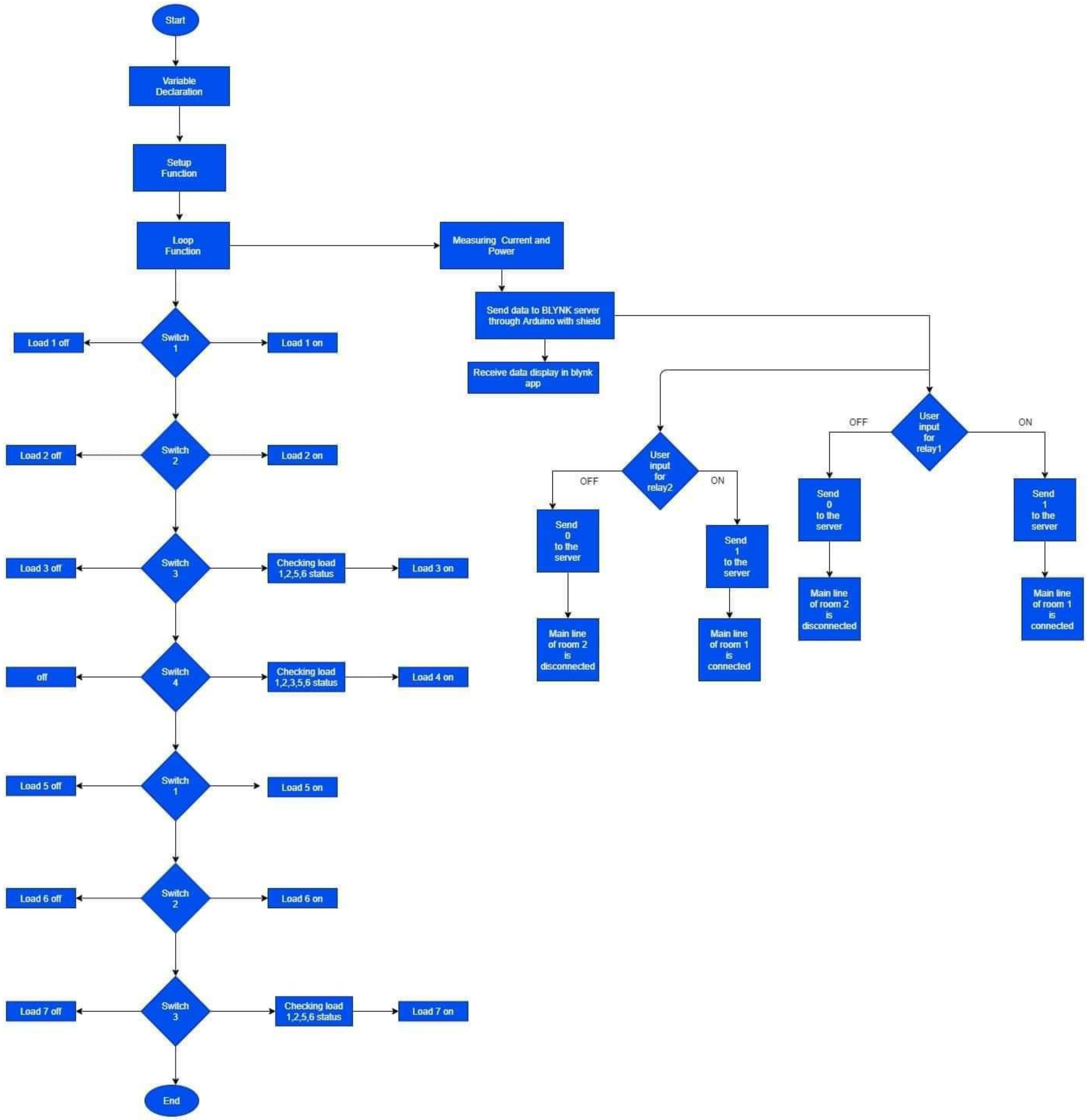


Figure 4.1: Flowchart of SCADA System

In room 2, 3 loads were used. If the switch 1 is on load 5 is on and if switch 1 is off the load 5 is off. For load 6 the process as same as load 5. If anyone want to turn on switch 3 then load 7 is on and also check the load 1,2,5,6 status.

The value of current and power was also showed in Blynk app. The data was sent into Blynk app through Arduino ethernet shield. Here the main line of both rooms can be controlled from Blynk app according to the user inputs. If the user presses ON, the app will send 1 to the server and from the server Arduino will take the data and connected the line for room 1 via relay. If the user sends OFF opposite will happen. The same thing will also happen for room 2 main line connection as well.

4.4. Modeling

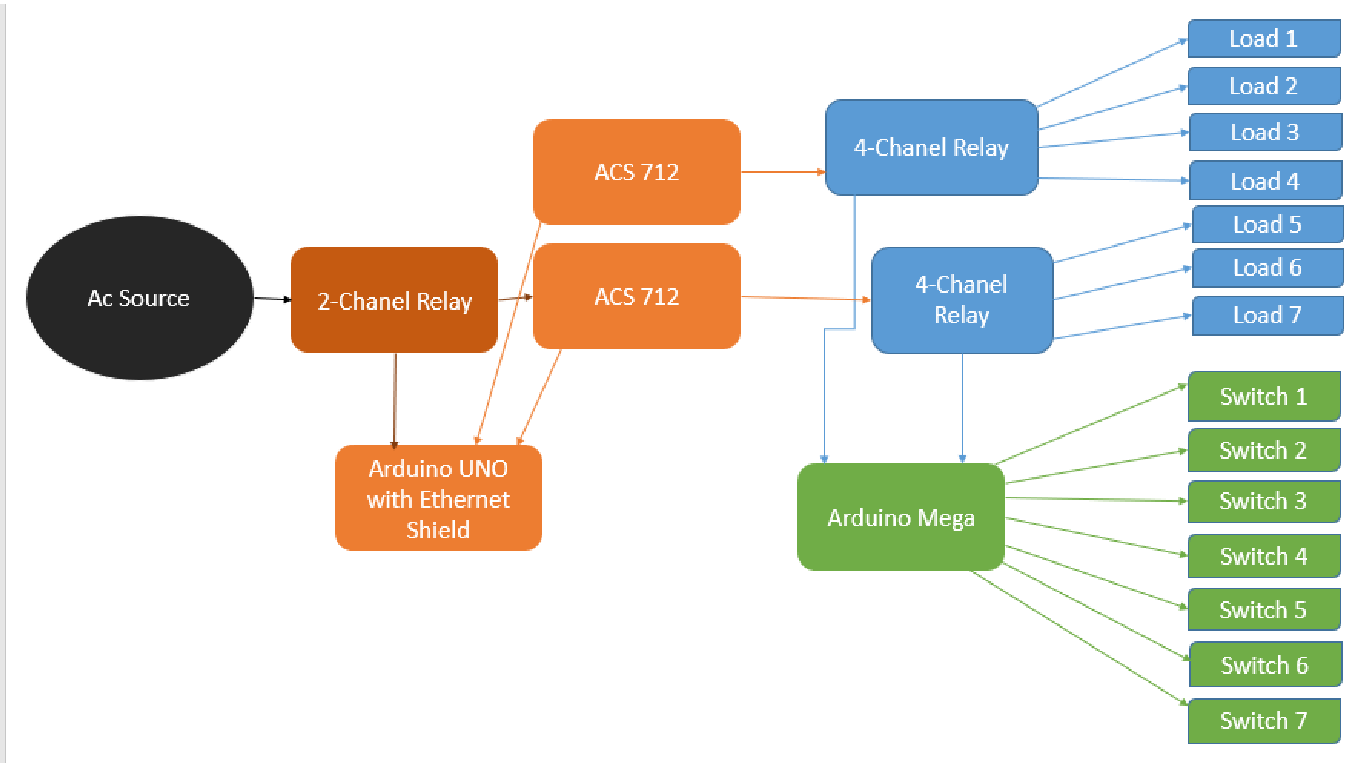


Figure 4.2: Block diagram of SCADA System

This block diagram explains the main working principle of the project. A 2-channel relay was connected from the AC source. The purpose of using relay was to operate switch electrically. Two ACS 712 current sensor was coming from 2-channel relay. Current sensor measures the current value and two current Sensor was used for two room. Two 4-channel Relay was connected from two current sensor. Each relay used for each room. 4-channel relay and switch boxes connected with Arduino mega. Arduino mega can receive the data as well as send information. To reduce delay of the system Arduino ethernet shield was directly connected with the Wi-fi router. According to the priority switch was on and off and load was also on and off.

4.5. Summary

The methodology of this project was properly explained in this chapter. The project was done in a proper process and following the systematic steps. Some software were also needed for completing this project. According to the way of doing the project, a flowchart was also required and the flowchart was also analyzed accurately. Modeling of the project was also done with the block diagram. The block diagram showed the architecture of the project. The purpose of using every piece of equipment was also described in this chapter.

Chapter 5

PROJECT IMPLEMENTATION

5.1. Introduction

For the project implementation, first, the main theme of the SCADA system had to be understood. After that, a block diagram based on the understandings was designed, and had to design the system by selecting the required components. Based on the design, the simulation of the system was done. But while doing the simulation, a conclusion was made that the live data acquisition in the system was not possible in the simulation. So the decision was taken to start implementing the project. The overall prototype was divided into two parts. In the first part, Arduino Mega was used as the main microcontroller and selected to design two rooms for our prototype. In-room 1, there were four loads and in room 2, there were three loads. In each room, load-wise priority was set for controlling. In the second part, Arduino Uno was used along with Arduino Ethernet shield for a direct internet connection to the Wi-Fi router which gave faster data acquisition from the current sensors and also for mainline controlling for each room. Only one microcontroller could have been used but there was a handful time of delays in logic function which lessened the proper functioning of the whole system.

5.2. Software Requirements for Simulation

The development of simulation models does not require mathematical and programming expertise but it does require a good understanding of the considered system. Simulation often offers safe implementation of the system, optimization without hampering the proper function of the system, and observing the proper results. As a result, the simulated system can be inspected and queried while in action and the results can be compared with our expected values. The results of the modeling and simulation, therefore, give confidence and clarity for engineers.

Keeping that in mind, we have used Proteus 8.9 professional for the simulation of the project. This software was chosen because it offers a complete PCB design package with support for schematic and logical drawing features as well as provides a variety of modules and components for schematic capturing and analog simulation. As for the simulation for this project, schematic capture was used. The complete two rooms with loads were set up in the simulation and the priority controlling of the loads was tested in Proteus with proper current rating values from the current sensors shown in the virtual terminal of Arduino Mega 2560.

5.2.1. Circuit Implementation

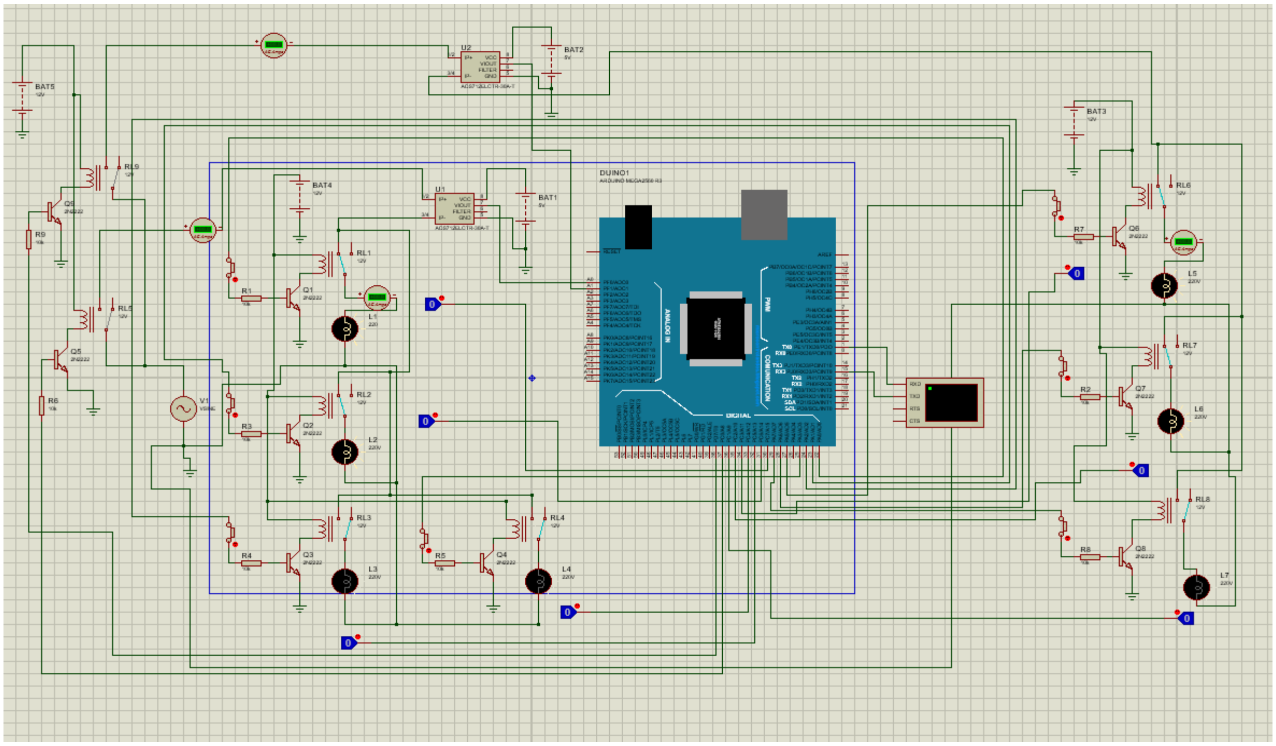


Figure 5.1: Main Circuit Diagram

The simulation circuit shown in Fig. 5.1 was done for two rooms using Arduino Mega 2560. Only one ac source has been used to power the loads in the two rooms. The loads are connected to the relays and loads are connected in parallel with each other for each room. One ACS712-30A current sensor has been connected in series with the main line for each of the rooms. Before the ACS712-30A current sensor, one relay has been connected with the main line of each of the rooms for line controlling. Toggle switch for each of the loads has been connected with the Arduino for priority-based controlling of the loads. Virtual terminal is used to observe the output current values from the current sensors. The below Table 5.1 shows the pin configuration of the simulated circuit shown above-

Table 5.1: Pin configuration for Figure. 5.1

Name	Pin no. of Arduino Mega 2560
Current sensor for room 1	A0
Current sensor for room 2	A1
Relay of main line for room 1	37
Relay of main line for room 2	38
Room 1- Load 1 (L1)	22
Toggle switch for L1	30
Room 1- Load 2 (L2)	23
Toggle switch for L2	31
Room 1- Load 3 (L3)	24
Toggle switch for L3	32
Room 1- Load 4 (L4)	25
Toggle switch for L4	33
Room 2- Load 5 (L5)	27
Toggle switch for L5	34
Room 2- Load 6 (L6)	28
Toggle switch for L6	35
Room 1- Load 7 (L7)	29
Toggle switch for L7	36
Virtual terminal RXD pin	1
Virtual terminal TXD pin	15

5.3. Components

- Arduino Mega 2560 R3
- Arduino Uno R3
- Arduino Ethernet Shield W5100
- Current Sensor ACS712- 30A
- 4 Channel 5V Relay Board Module
- 2 Channel 5V Relay Board Module

- Breadboard
- Jumper wires
- Lightbulb sockets
- 180-240V, 50/60 Hz Energy bulbs
- LED bulbs
- 2 Pin Plug with wires
- 12 Gauge stranded copper wire
- Bell push switch with socket outlets
- 4 port USB 3.0 Hub

5.4. Hardware Implementation (Prototype)

Hardware implementation often takes longer to create and that can make it more expensive. But with the help of proper simulation, it is easy to build up a prototype. But in this prototype, some changes had been made comparing to the simulation. For hardware implementation, the prototype was divided into two parts for proper functioning of the system and also for faster data acquisition.

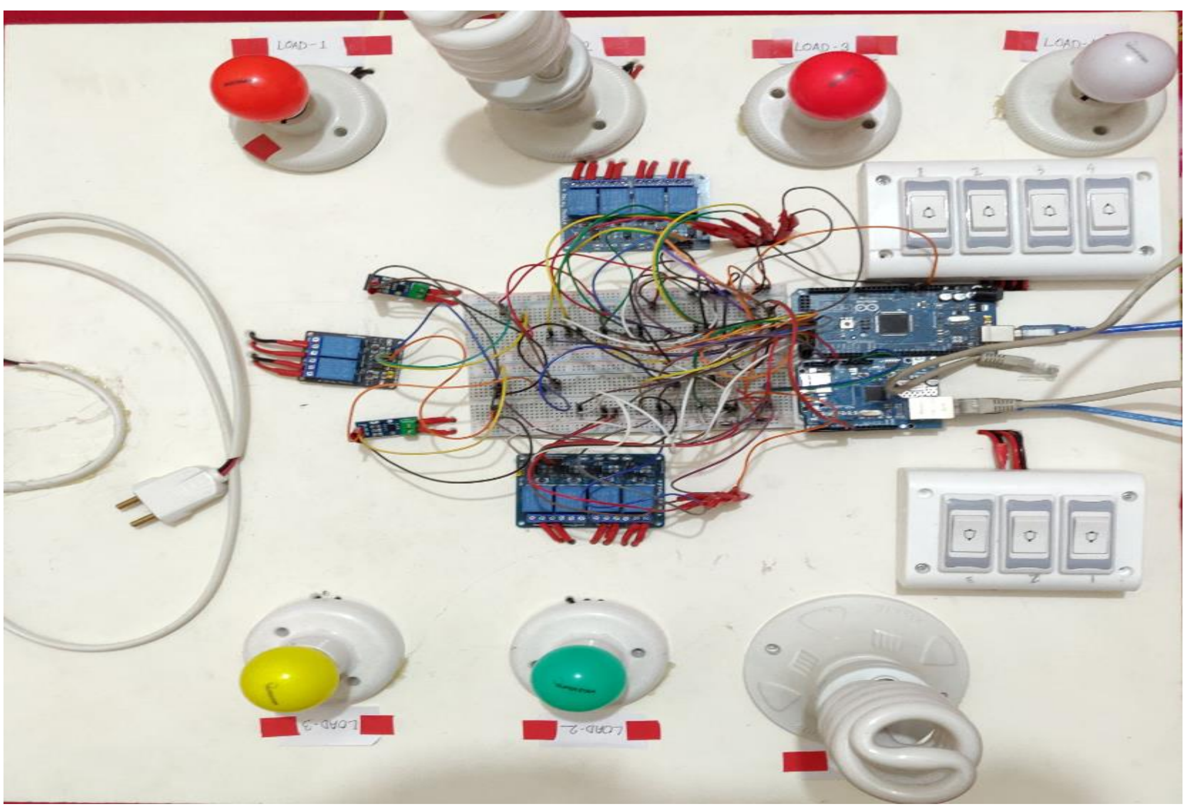


Figure 5.2: Prototype design

The above Fig. 5.10 shows the prototype design of the project. The loads have been used are energy bulbs and led bulbs. Different single-phase loads can be used but energy bulbs are used as loads for their low cost and availability. The loads will get power from the single-phase ac power socket by the two-pin plug. The switch box has been placed, connecting them to the Arduino for the users for the priority controlling of the loads. The connections in the breadboard are made carefully for proper functioning of the whole system.

5.4.1. Full Prototype Setup

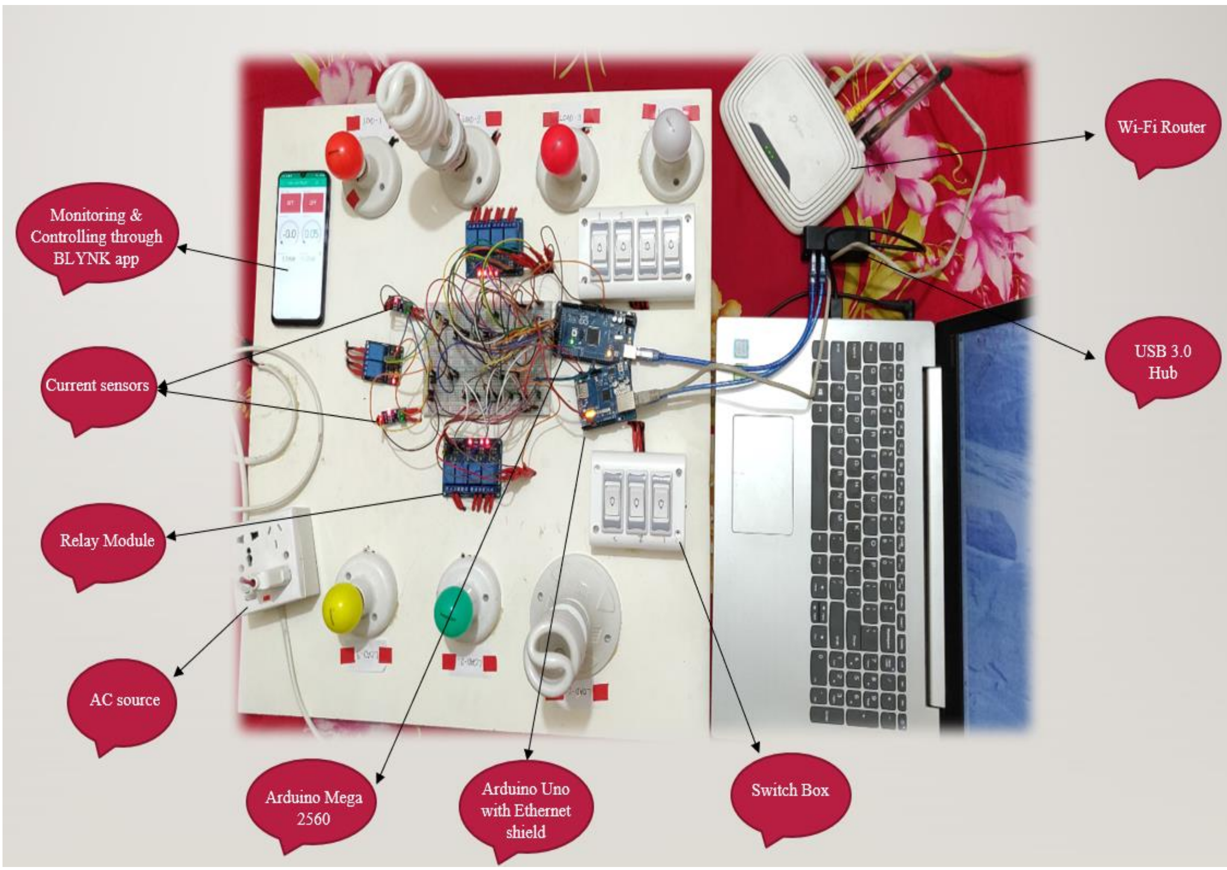


Figure 5.3: Prototype Setup

The above Fig. 5.3 shows the full setup of the prototype of the project. The full setup includes Arduino Ethernet shield directly connecting to the Wi-Fi router for connecting it to the Blynk app in the smartphone. Also, Arduino Mega and Arduino Uno with the Ethernet shield are both connected to a USB 3.0 hub connecting to the laptop for providing DC operating source to the Arduinos. A single-phase ac power socket has been provided from the house wirings to provide power to the loads through the 2-pin plug. Precautions were taken while connecting to ac single phase line as there was no earthing done to the circuit or to the relay modules. As a result, there might be some minor electrical shock when the relay modules are touched.

5.5. Summary

In this chapter, the simulated circuit, as well as the prototype design of the project, was provided. In the simulation, the main microcontroller which has been used was Arduino Mega 2560. The necessary components such as the relay circuit have been built in the simulation as well as other components block were taken from the simulation library. At first, the loads for different rooms along with relay circuits have been designed and connected in parallel with each other, and toggle switches have been provided for each of the loads. Current sensors and mainline relay circuits also have been connected. The current ratings for each of the rooms are observed in the virtual terminal from the Arduino. All the pin configurations in the Arduino and the circuit diagram are explained properly. As for the prototype design, in part 1, the loads for each of the roams are connected using 12-gauge stranded copper wire and connected to the Arduino Mega 2560. 4 channel relay modules have been connected with the loads. In part 2, the current sensors and 2 channel relay modules are connected to the Arduino Uno with Ethernet shield W5100 which is connected to the Wi-Fi router with LAN cable. The smartphone has been connected to the server to observe the live current and wattage value and also the mainline controlling of each of the rooms.

Chapter 6

RESULTS ANALYSIS & CRITICAL DESIGN REVIEW

6.1. Introduction

In the design of a low-cost SCADA system, both the simulation and hardware were simulated or implemented. After running the simulation and implemented the prototype, the most satisfactory outcomes were there, which have been examined in the results analysis part. All the result was analyzed by showing the simulation result as well as the implemented result pictures. In this chapter, an elaborate discussion of the whole project will be propounded with simulation and hardware results, and analytical observation of those results will also be represented here.

6.2. Results Analysis

Here the overall system has been explained part by part showing the result of each section. The findings were demonstrated and evaluated with necessary theoretical logic and explanations.

6.2.1. Power Consumption

In the project, the prototype was designed, and all the loads are demo loads. In this power consumption calculation, only the primary system power consumption is shown:

Table 6.1- Total power consumption.

Component	Quantity	Power	Total power
Arduino Uno	1	5V*1A	5W
Arduino Mega 2560	1	7V*800mA	5.6W
4 channel relay	2	2*5V*20mA	0.2W
2 channel relay	1	5V*15mA	0.075W
ACS 712	2	2*5V*13mA	0.13W
Ethernet Sheild W100	1	5V*500mA	2.5W

Total			13.505W

Total Daily Load (8Hours per day) = $(\frac{13.505}{1000})$*8

= 0.108 kWh

Without considering any system load, 0.108kWH is needed to run the system from a DC source.

6.2.2. Simulation

At first, the project simulation was done in proteus 8.9 to make sure all the codes are working perfectly or not. Later on, the hardware was implemented. As live data acquisition and controlling is not possible in proteus, only codes of the current sensor, relay, switches value were observed from the simulation.

Here, the highest priority load will be connected. If the consumer wants to connect all the loads, only the higher priority load will be connected, and the lower priority load will automatically be disconnected. As soon as the consumer disconnected the higher priority load, the lower priority load will get connected.

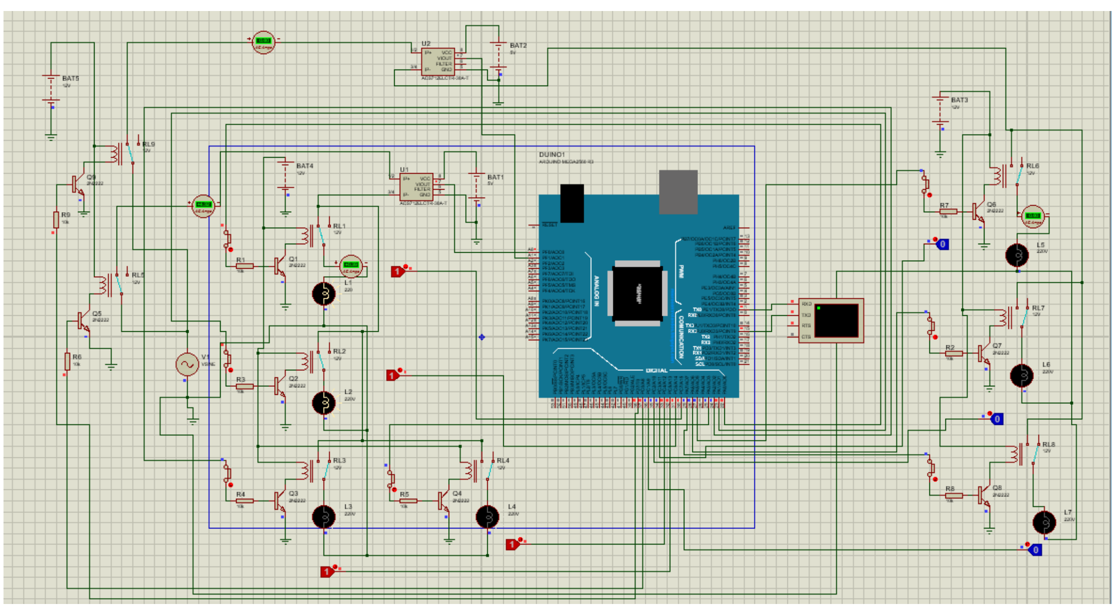


Figure 6.1: Priority control of room one.

Here in the 6.1 simulation diagram, only room one highest priority loads are running. Even if the switches turn on the lower priority loads, they won't turn on. But as soon as higher priority loads are disconnected, the lower priority loads will turn on automatically. And when the higher priority is turn on, lower priority loads will get disconnected automatically.

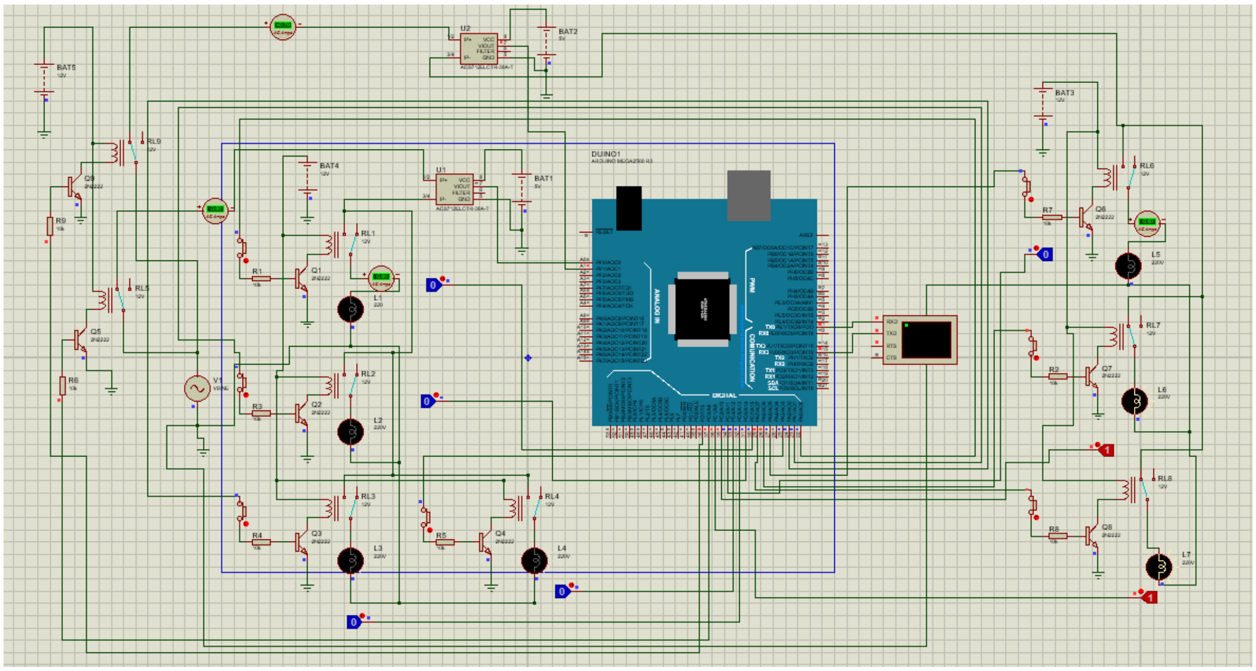


Figure 6.2: Priority control of room two.

Here in figure 6.2, the lower priority loads are connected as the switch's higher priority loads are disconnected. On the left side of the simulation, it was considered room two. In-room two, three loads are connected. If the higher priority loads get connected, the lower priority loads will automatically get disconnected according to priority. When the switch turns off the higher priority loads, the lower priority loads get connected automatically. That's how the system will operate.

There is also a room-wise priority where the loads' connection will operate according to the priority. Only the highest priority of both rooms will be connected in the room priority, and others will be disconnected even the switches are on.

In figure 6.2.2.3, the highest priority loads are running through all the switches are turned on. All this priority was designed using the AND gate, OR gate, and priority encoder logic in the coding. This truth table will be discussed in the implementation section.

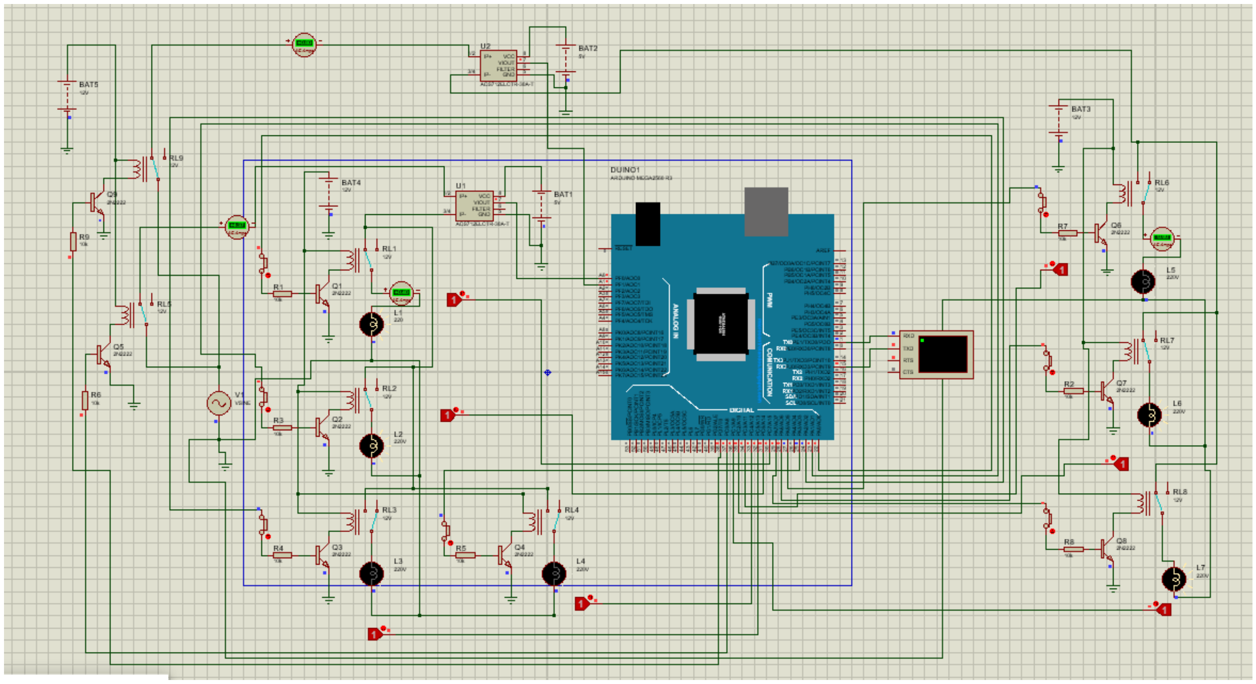
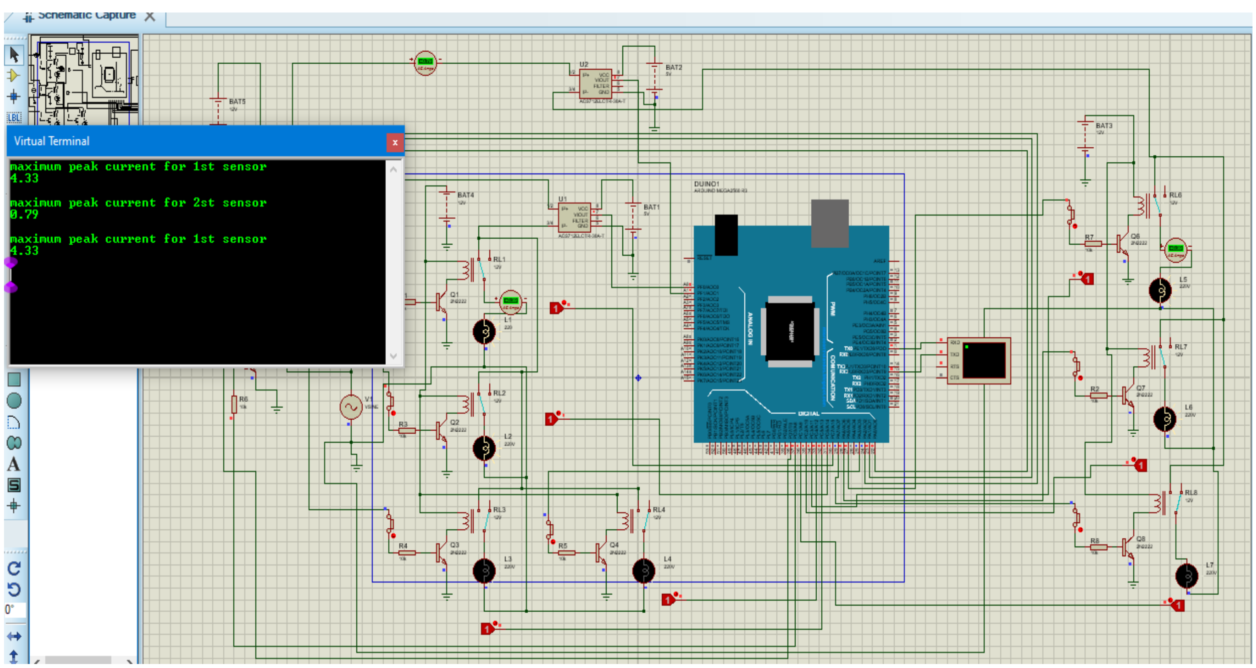
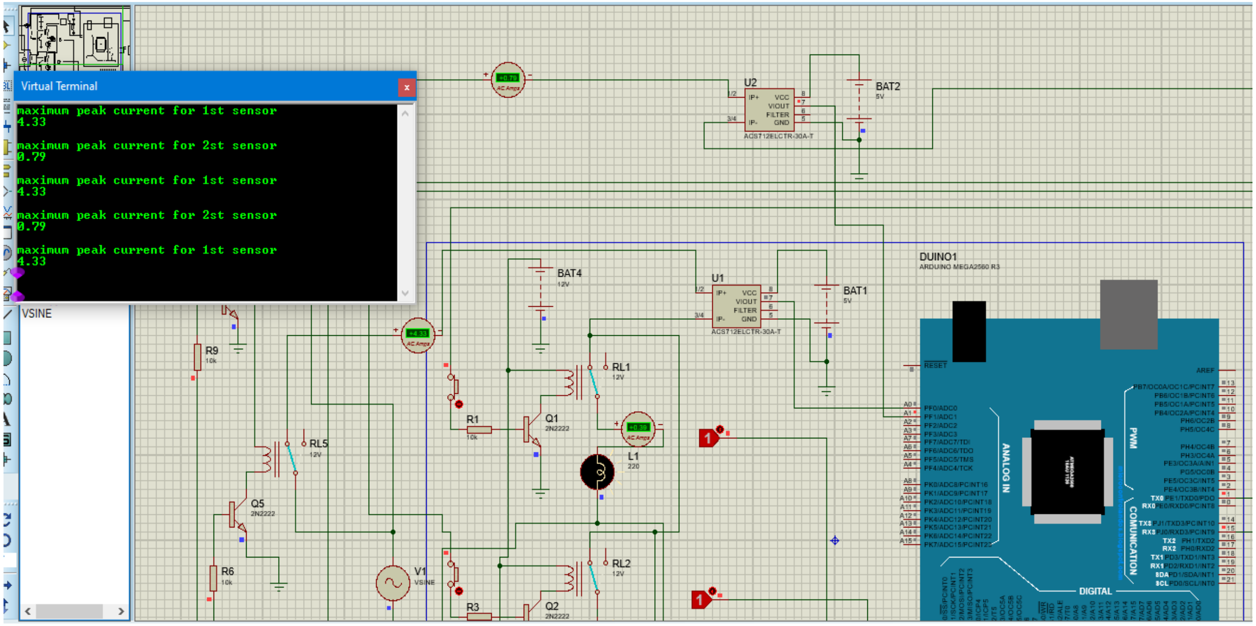


Figure 6.3: Priority control of two rooms.

Here the lower priority loads will be turned on only if both rooms' higher priority loads are turned off. It will get automatically turned off if the higher priority loads get the switches on. In the simulation figure 6.3, that's why only the higher priority loads are turned on through all the switches are turned on.



(i)



(ii)

Figure 6.4: (i)Measured current value of two rooms. (ii)Zoomed view of the current sensor reading

In figure 6.4, the current live value was measured from the sensors. The current sensor's current value and the ammeter's current value are almost equal to each other, which can be seen clearly in the zoomed figure. The high priority loads are also running, and the reason is already explained in the previous simulations.

6.2.3. Implementation

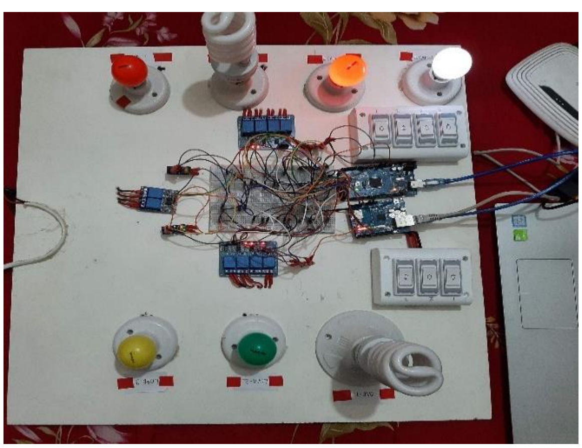
In the implementation, live data acquisition and control were made by the Blynk app. All the connection was given according to the simulation. Due to the system's delay and offline activity, Arduino with an ethernet shield was used.

In the first room priority, switches are inputs, and load connections are outputs. The following table shows how the outcome will work in the responses of inputs.

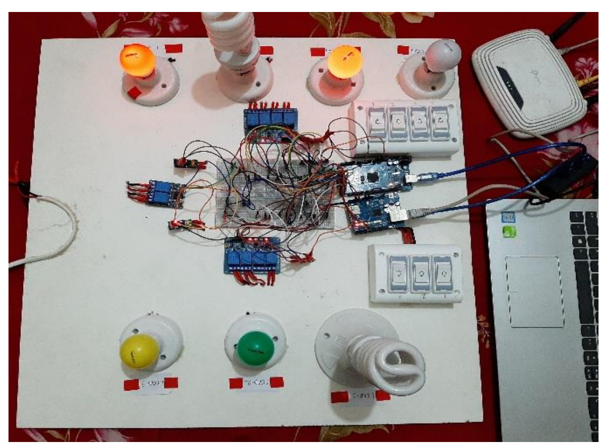
Table 6.2- Output response from input according to inputs.

I_1	I_2	I_3	I_4	O_1	O_2	O_3	O_4
0	0	0	1	0	0	0	1
0	0	1	0	0	0	1	0
0	0	1	1	0	0	1	1
0	1	0	0	0	1	0	0
0	1	0	1	0	1	0	1
0	1	1	0	0	1	1	0
0	1	1	1	0	1	1	0
1	0	0	0	1	0	0	0
1	0	0	1	1	0	0	1
1	0	1	0	1	0	1	0
1	0	1	1	1	0	1	0
1	1	0	0	1	1	0	0
1	1	0	1	1	1	0	0
1	1	1	0	1	1	0	0
1	1	1	1	1	1	0	0

Here "1" means high, so the switches or loads will be "ON" and "0" represents low, so the switches or loads will be "OFF". The 6.2 table shows how the higher priority loads automatically get connected, and lower priority loads are getting disconnected.



(i)



(ii)

(iii)

Figure 6.5: Priority-based load controlling of room one.

In figure 6.5, the load connection according to the priority is shown in the implemented circuits. The input and outputs are the same as the table shown in table 6.2. Here only three conditions are shown. When switch 1,2,3,4 is ON, loads 1,2 are connected in figure (iii). Switch 1,3,4 is ON but loads 1 & 3 are connected in figure(ii). And in the figure(i), switch 3,4 are ON and loads 3,4 is connected. In-room two, three loads will be connected or disconnected according to the priority. The following table will show how the output response according to the change in inputs.

Table 6.3- Output response from input according to inputs

I_1	I_2	I_3	O_1	O_2	O_3
0	0	1	0	0	1
0	1	0	0	1	0
0	1	1	0	1	1
1	0	0	1	0	0
1	0	1	1	0	1
1	1	0	1	1	0
1	1	1	1	1	0

In the room-two load, 1 and 2 have the highest priority. Load 3 has the lower priority so that it won't turn on unit either load 1 or 2 is turned off. This priority can be changed according to the consumers' demand. In this prototype, priority was set in the numerical serial as all loads are almost the same in the prototype. But in the real-time scenario, consumers' can set the priority according to their need to save power.

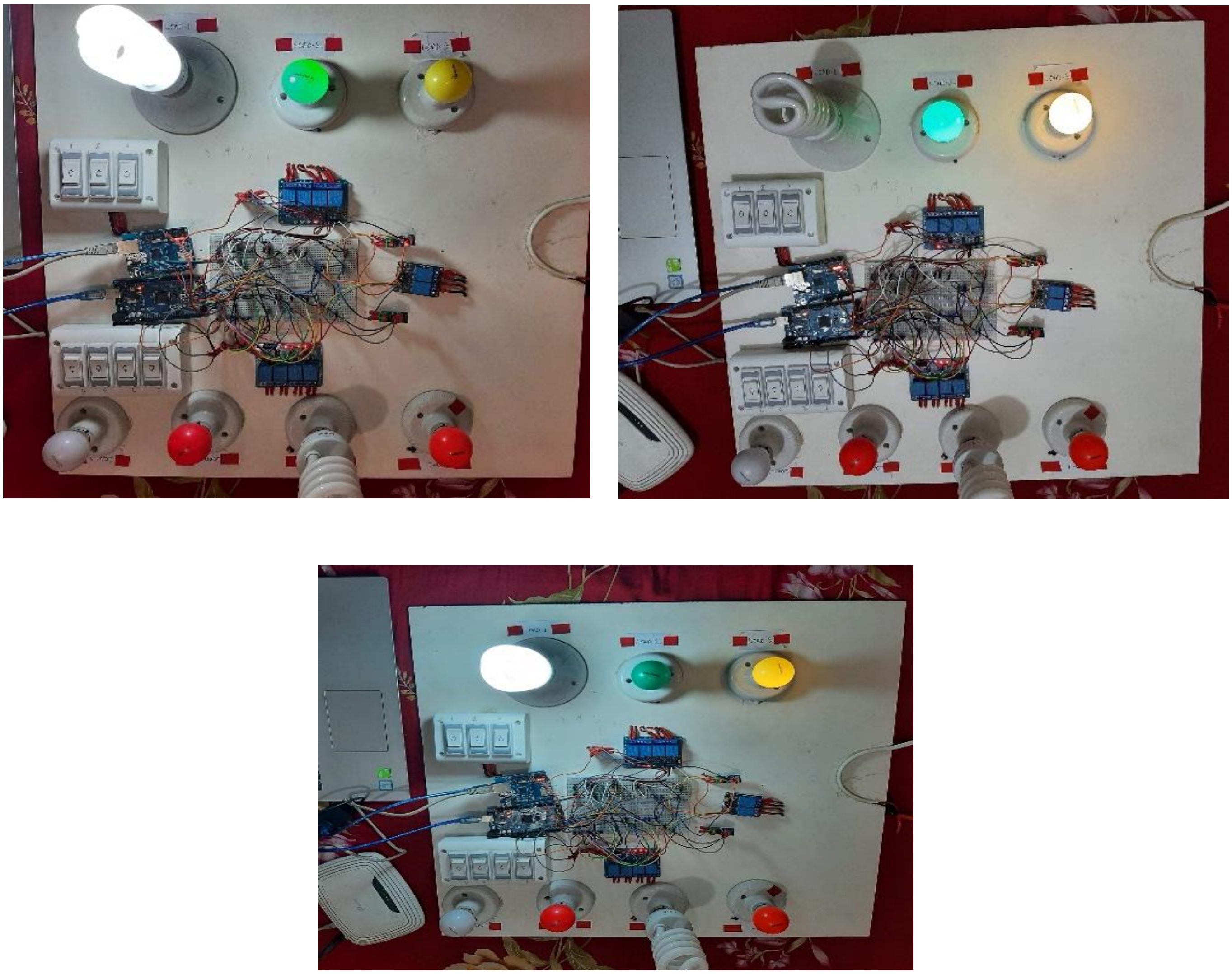


Figure 6.6: Priority-based load controlling of room two

In the room priority, the high priority loads will operate. If all the high priority loads are switched off, then only the low priority loads will operate. The following table shows how it responds according to the change in inputs.

Table 6.4- Output response from input according to inputs

I_1	I_2	I_3	I_4	I_5	I_6	I_7	O_1	O_2	O_3	O_4	O_5	O_6	O_7
0	0	0	0	0	0	1	0	0	0	0	0	0	1
0	0	0	0	0	1	0	0	0	0	0	0	1	0
0	0	0	0	0	1	1	0	0	0	0	0	1	1
0	0	0	0	1	0	0	0	0	0	0	1	0	0
0	0	0	0	1	0	1	0	0	0	0	1	0	1
0	0	0	0	1	1	0	0	0	0	0	1	1	0
0	0	0	0	1	1	1	0	0	0	0	1	1	0
0	0	0	1	0	0	0	0	0	0	1	0	0	0
0	0	0	1	0	0	1	0	0	0	1	0	0	1
0	0	0	1	0	1	0	0	0	0	1	0	1	0
0	0	0	1	0	1	1	0	0	0	1	0	1	0
0	0	0	1	1	0	0	0	0	0	1	1	0	0
0	0	0	1	1	0	1	0	0	0	1	1	0	0
0	0	0	1	1	1	0	0	0	0	1	1	0	0
0	0	0	1	1	1	1	0	0	0	1	1	0	0
0	0	1	0	0	0	0	0	0	1	0	0	0	0
0	0	1	0	0	0	1	0	0	1	0	0	0	1
0	0	1	0	0	1	0	0	0	1	0	0	1	0
0	0	1	0	0	1	1	0	0	1	0	0	1	1
0	0	1	0	1	0	0	0	0	1	0	1	0	0
0	0	1	0	1	0	1	0	0	1	0	1	0	1
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0	0	1	1	1	0	0	0	0	1	1	1	0	0
0	0	1	1	1	0	1	0	0	1	1	1	0	0

0	0	1	1	1	1	0	0	0	1	1	1	0	0
0	0	1	1	1	1	1	0	0	1	1	1	0	0
1	0	1	1	1	0	0	1	0	0	1	1	0	0
1	1	0	1	1	0	0	1	1	0	1	1	0	0
1	1	1	1	1	1	1	1	1	0	1	1	0	0

The above 6.4 table shows how the room wise priority works. I4, I5, I6, and I7 are considered room one loads where I4 & I5 have the highest priority. I1, I2, I3 are loads of room two, and I1 & I2 have the higher priority. Whenever both rooms highest priority loads are connected other lower priority loads will get disconnected so that only the highest priority loads can run.

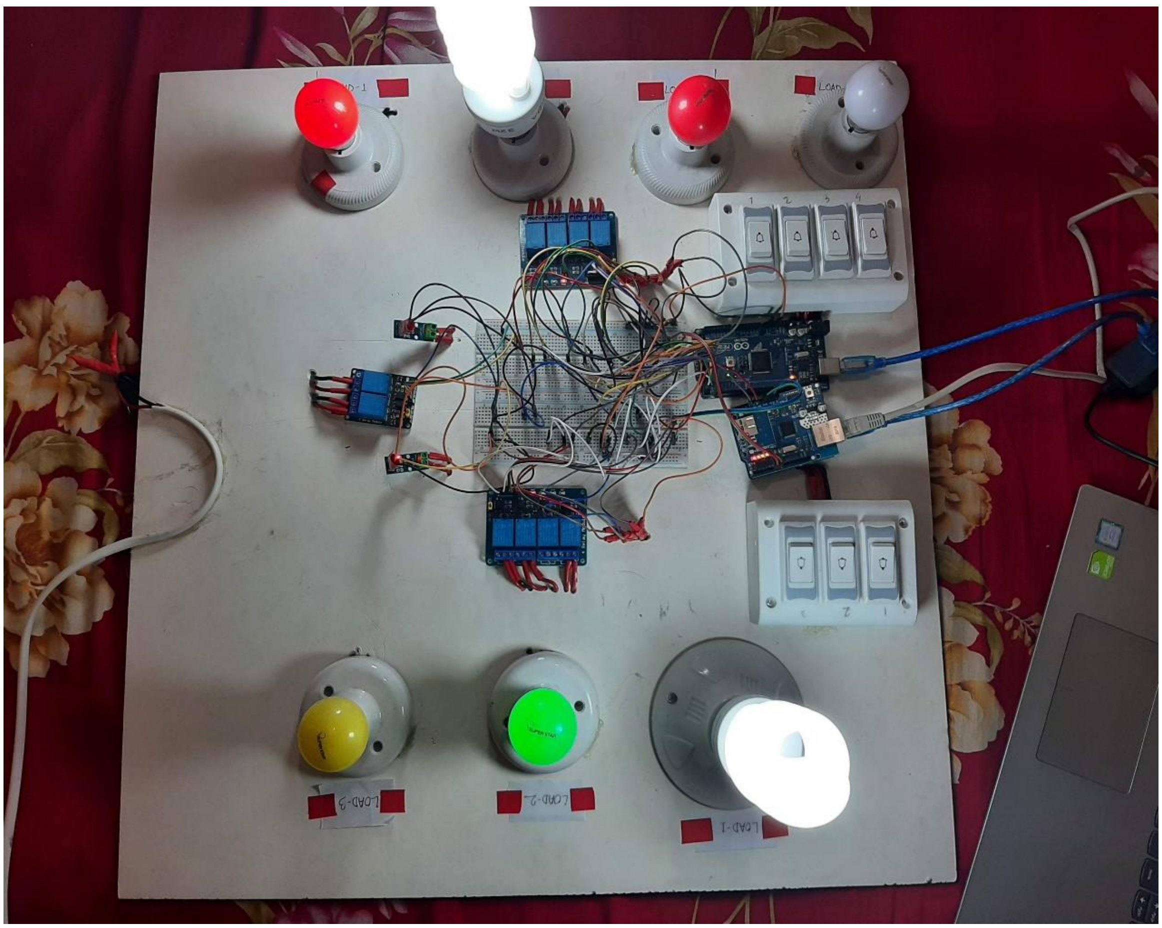

Figure 6.7: Room priority.

There is figure 6.7; the higher priority loads are running through all the switches are connected. The current live value will also be uploading via Arduino ethernet shield to the Blynk server, and from there, power and current live value can be seen, and the mainline of both rooms can be controlled.

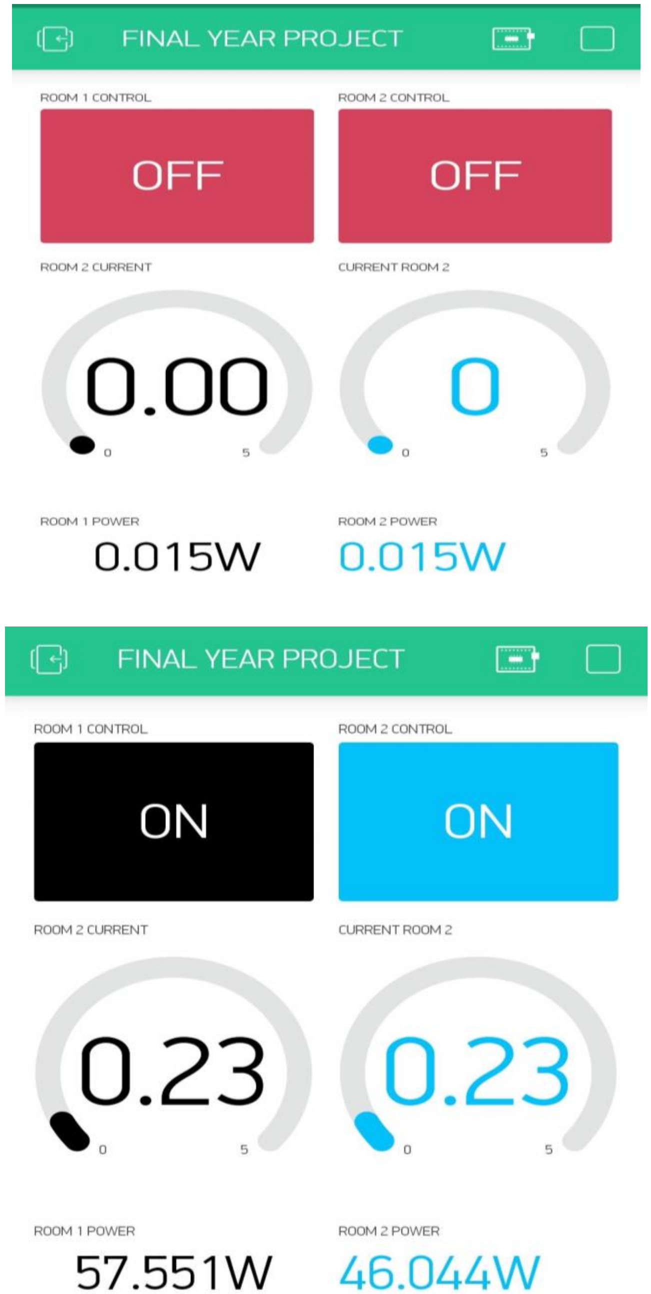

Figure 6.8- Blynk app data acquisition and control

The current and power live value is shown in figure 6.2.3.4 when the mainline off and another value is shown when both rooms higher priority loads were connected. From Blynk app room one and two, all the loads can be disconnected using the control.

6.2.4. Curve analysis

In this section different output of the projects will be analyzed though curve for easier understanding.

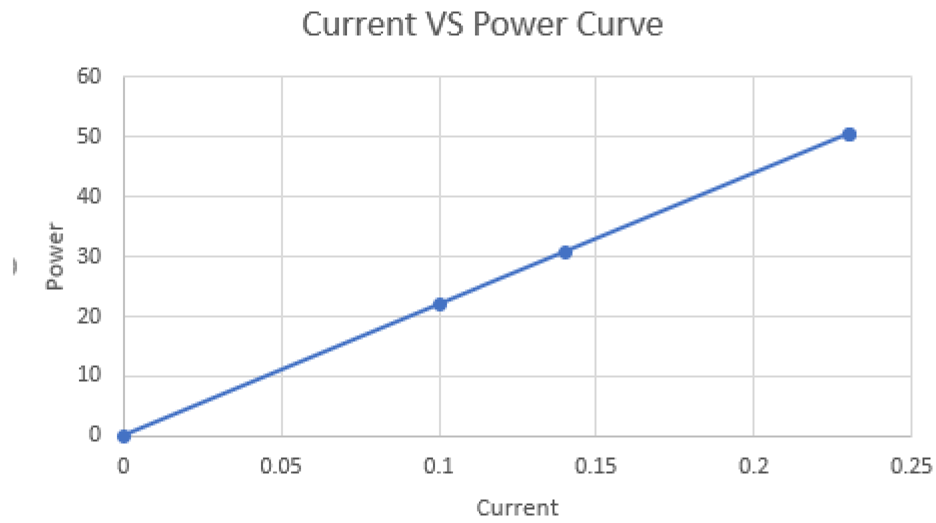

Figure-6.9: Current(A) Vs. power (watt) Curve

In Figure 6.9, how the power change according to the change in current can be observed. From the curve, it can be easily analyzed that the power is directly proportional to the current. As The current increases, the power consumption is also increasing.

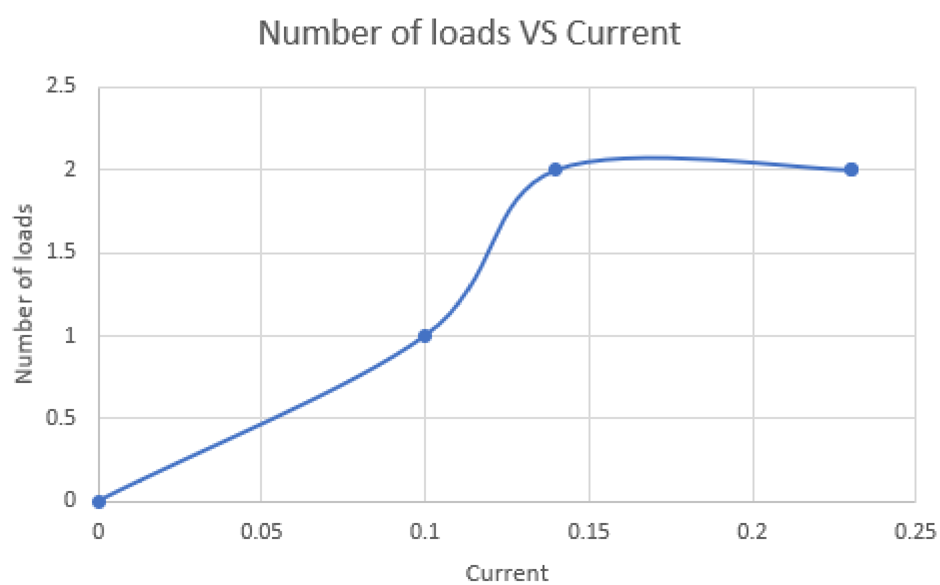

Figure-6.10: Number of loads connected VS Current(A)

In figure 6.10, how numbers of running loads can increase or decreases the current according to the loads rating. In the highest priority running loads (load 1&2) when there is a current consumption of 0.23A. But again, when two loads (load 3&4) are running, there is a current value of 0.14A because lower current rating loads are used. This curve will not be fixed, and it will change according to the current rating of the loads.

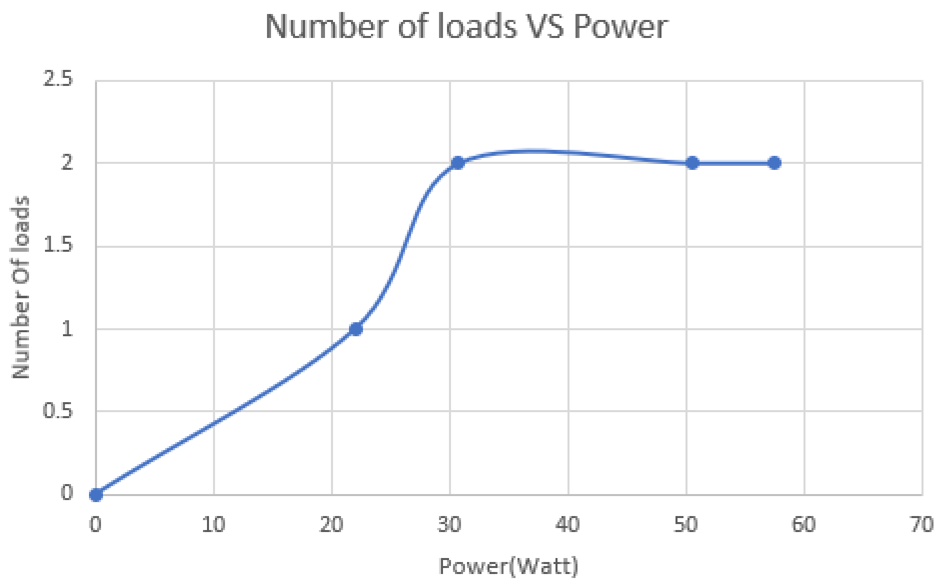

Figure-6.11: Number of loads VS power

Figure 6.11 shows how the number of loads changes the power consumption. It will vary according to the power rating of the loads. This curve will not be fixed, but as in our project prototype, the same kind of loads is used; thus, both rooms will have the same curve.

6.2.5. Delay

In the system, two microcontrollers are used to reduce the delay and workability in the offline scenario. If one Arduino is used, the whole system would be server-based. As a result, 5-7 seconds switching delay was found according to the network speed. All the data acquisition and control were made with Arduino Uno, and an ethernet shield, the priority-based switching, were done in the Arduino mega to reduce the delay. A 300-500ms delay was found with a stopwatch in the priority-based switching, and an 800ms -1s relay was found in the data acquisition and control.

6.3. Summary

This chapter was all about showing and analyzing the results. At first, the power consumption calculation was shown. Then the simulation outcome was analyzed. Later on, with the implementation how the output response to inputs was shown. How the live data acquisition and control was in the server, and the delays were shown. All the things necessary figure of implementation and simulation was correctly displayed. How the switching input is changing according to the priority is shown in the different tables. To justify the current sensor values, an ammeter and current reading were provided in the simulation. Overall, all the calculations, data and images were explained satisfactorily.

Chapter 7

CONCLUSION

7.1. Summary of Findings

Based on our simulation and the prototype of our project, it was clarified that our system was developed successfully. Whatever we want from this system was achieved. All the output of our project was found according to the setup priority. The design of our project was also satisfied with the system. The survey showed a positive vibe. Most of the people were agreed that it was sustainable for the industry and in the future, it will bear a strong position. Because of the set of the priority of our system, no one handles the system whatever they wanted. Only they can do whatever they arranged in the priority system. That means no misuse of electricity as well as we got the best output from every single load. This system is not harmful to the society and environment. The success of the project was noticed whenever we got the exact output whatever we want.

7.2. Project Finance

At initial stage a model of our system was created. Following the model, simulation was done in proteus software and also done with the hardware demonstration. For implemented the prototype cost was required. So, the financial analysis of the project here is about hardware demonstration. Few components were required to demonstrate our system and based on their cost estimation the project cost has been discussed here. In the following table a list of required components and estimated cost has been given. For implementing the project, it would not require any technician or labor cost. The whole demonstration was done by the group member themselves.

Table 7.1: Cost Analysis of Project

Name of Components	Quantity	Estimated Cost	
		Cost per Unit (In BDT)	Total Cost (In BDT)
Ethernet W100- 1000	1	230	230
Arduino Uno	1	499	499
2 channel Relay	1	210	210
4 Channel Relay	2	580	1160
Current Sensor	2	219	438
Stranded copper wire	12 gauge	18	216
Arduino Mega	1	978	978
Energy Bulb	2	150	300
Dim Bulb	5	18	90
Bulb Socket	7	30	210
Switch Board with Socket Outlet	1	300	300
Bread Board	1	80	80
Jumper Wire		70	70
USB 3.0 Hub with Adaptor	1	600	600
Total			5381/- BDT

7.3. Novelty of the work

Almost every project has some newness and absolute features, making that project unique and different from another related project. Exceptional features make a project extraordinary and increase the quality of the project. Our project is about power saving system using priority-based load controlling and monitoring. There are so many available projects for saving power using different methods. But in our project, we have made such a prototype that can save power by only allowing the highest priority loads to run and disconnect automatically any unnecessary loads from running. In the project, two priority is used. At first, the loads-based priority and then room-based priority. We have used different logic of priority encoder, AND gate, OR gate, and so on. All those things did not only in simulation but also in the hardware. Real-time current and power values were also shown in an app. In the app, there was also a controlling option of the loads' in-room-wise priority using a virtual switch. All those things may not be unique, but those things are newly introduced in the power-saving SCADA system.

7.4. Final Impact of This Project

The project will have different impacts on society and also in our country economy. In our country there are so many SMEs industry, the project will have numerous significant effects in this area. Everyone can utilize this system in their very own setup priority system. Because of setting up the priority the whole system run successfully and get the best output of the system. No need to extra manpower to control and monitor the system. This system will not cause any pollution.

7.4.1. Survey on Environmental Impact

In this system there is no chance to emitted any gases. The components were used in this project rarely get damaged by external factors. Even if they get damaged they are easy to repair by changing few IC's. As a result, they don't create any e-west which is harmful for the environment. In the survey similar kinds of response was gotten.

A survey was conducted to know the view of people regarding the project's impact on the environment. Environment friendly based question was asked and 65% of the people said it is environment friendly.

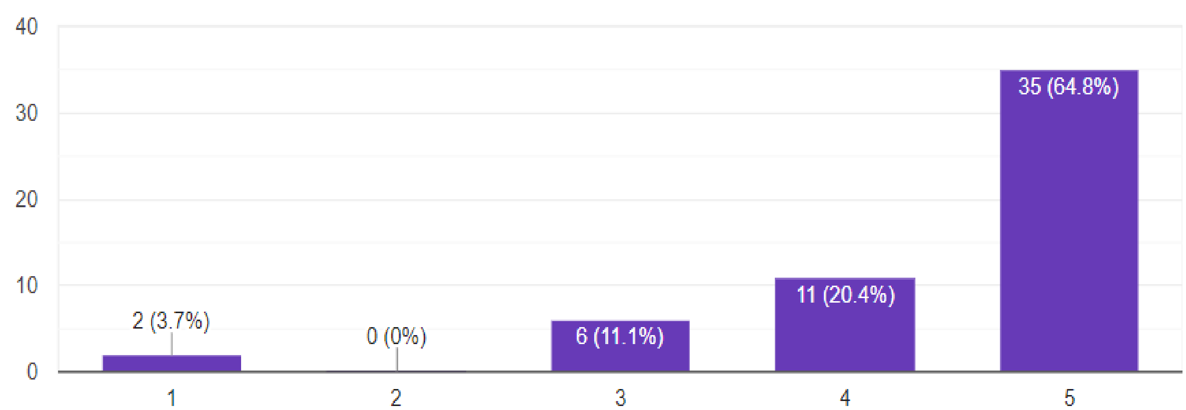

Figure 7.1: People's thought about the environmental friendliness of the project

7.4.2. Project Sustainability and Future Scopes

The sustainability of the project is dependent on some particular factors like environmental indicators, social-economic factors. In today's world, any clean energy concept is highly appreciated as environmental concerns rise among people. There will be no carbon emissions or any gas in our project that is harmful to the environment. The component we used rarely gets damaged in the project and can be repaired easily to reuse those. So it will not create any e-waste. Here we have worked with industrial automation, which is the future for all the industry. It will save power as the user will be using the power according to their priority. In the future, modern technology will upgrade the project and make it more sustainable as the world is moving towards saving energy and making things automatic. Industrial revaluation four mainly focused on automation, and the world is moving to create environmentally friendly, low-cost products. Our project has the advantage on those sides so that it will be a sustainable one.

7.4.3. Recommendations on Future Developments

In this project, the main concern was to make a priority-based load controlling and monitoring system. We try our best to add as many features as possible. But in the modern era, features has no limitation. There is always the opportunity to add more. Due to the sudden increase of covid-19 during the project, it was impossible to add new features as countrywide communication almost stopped due to the lockdown. As a result, we only added power and current calculation in the blynk app. In future, the following upgrade is possible.

- Add a PT or voltage sensor to measure live voltage from the system.
- Add virtual switch for every load so that it can be controlled remotely from the app.
- A backup system can be added when there is load shedding or power cut for any faulty condition.
- Make an own app for the system to work more conveniently.

7.5. Limitations of the Work

Every developing scientific project has some limitations, and our project is no different in this scheme. Due to the sudden increase in covid-19 and due to lockdown, we couldn't increase the feature as much. Our project has the following limitations.

- In the project, we have used two Arduino due to the delay of the blynk app server, which has increased the cost a little.
- As this is a prototype, we couldn't use any industrial level loads; instead bulb was used as loads.
- Low-current rating components were used; the cost will increase using high current rating components.
- As Wi-Fi base central server connection is used, it may be vulnerable.
- As free software interface, BLYNK app is used, modifications of features is not possible.
- There is no data server. So, the monitored data have to be saved manually.

7.6. Ethical concerns

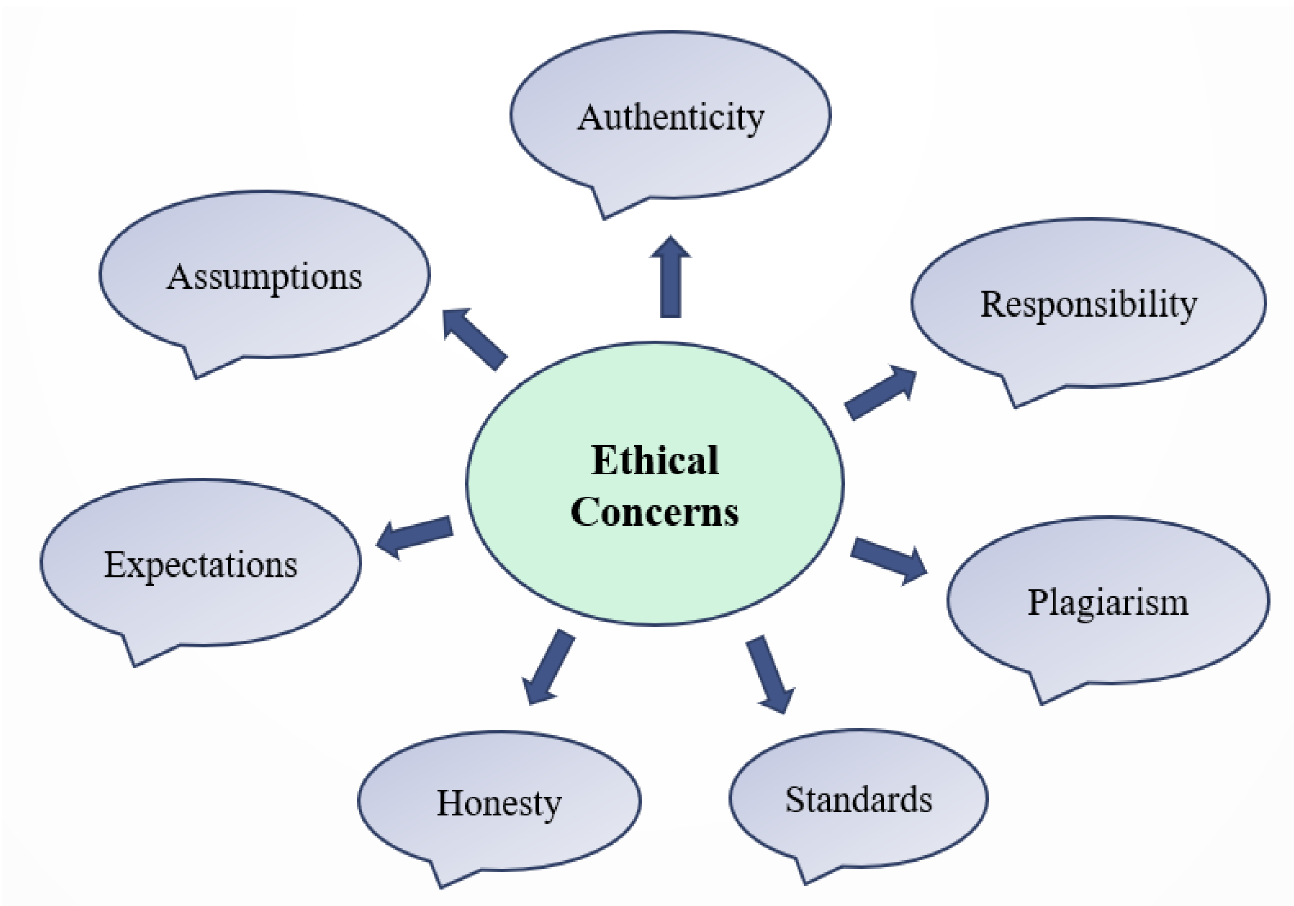

Figure 7.2: Key points of ethical concerns

The above figure 7.4 shows some key points of ethical concerns. Ethical concern in engineering is a necessary quality that helps a man become a better human being and guides a man towards a successful life and. In the project, all the information and data represented have been simulated and collected authentically, and no measurement had been fully on the assumption. In the hardware, all the components are implemented according to the simulation. All the work in the project worked as we were expecting. While working on this project, some difficulties were faced in many different stages, but those problems were solved responsibly and honestly. The research was done as uniquely as possible, with referencing made whenever required. All the work was done keeping in mind the ethical standards. Plagiarism has been kept as low as possible. Nothing illegal has been used during the research, simulation and hardware. All the ethical liabilities were maintained properly.

7.7. Conclusion

The project aims to make a low-cost system for SMEs that will reduce unnecessary power loss for those industries. Here we have at first simulated a system that can do such things in proteus 8.9 professional. The live current was measured in the simulation, and priority-based automatic switching was done according to the consumer's demand. Then the project was implemented to represent the prototype. The Blynk app was used to observe live current and power and control the room priority using virtual switches. The normal switching according to the priority was done using switches and other necessary components. The main microcontroller of the project was Arduino mega. During the project, all ethical concern was highly followed. We tried our best to make the project as novel as possible. This project will help the SMEs by controlling loads automatically according to the priority so that no loads run unnecessarily and increase power consumption. So, this low-cost system can save money for SMEs and increase the production efficiency of running loads according to their priority.

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Appendix A

Survey Questionnaire

1. Did you ever heard about SCADA system?
2. Do you think a system should be build in which we can monitor and control loads?
3. Do you think the system should have a feature which can control loads according to the priority to save power?
4. If this kind of project is built, will it be helpful for power industry?
5. If the system monitor live current and power will it be helpful for the industry?
6. Don't you think commercially available systems for power saving quite expensive and sophisticated?
7. Don't you think this project should be generalized and cost effective?
8. Don't you think this project is environmental friendly?
9. Don't you think this project will bear a positive impact in our industry?
10. As a customer perspective will you use this kind of system to for power saving?
11. Will this project holds a strong position in future?

Appendix B

Datasheet of the ICs used

8.1. Components Description

In our project few basic components were used. The details description of the components are given as follows.

8.1.1. Arduino Mega 2560 R3

Arduino Mega 2560 is a microcontroller board based on the ATmega2560. It contains 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. [19]

Table 8.1: Technical Specifications

Microcontroller	AT-mega 2560
Operating Voltage	5V
Input Voltage (recommended)	7V-12V
Digital I/O pins	54 (of which 15 can be used as PWM outputs)
Analog Input pins	16
DC current per I/O pin	40 mA
DC current used for 3.3V pin	50 mA
Flash Memory	256 KB of which 8 KB is used for bootloader
SRAM	8 KB
EEPROM	4 KB
Clock speed	16MHz
USB host chip	MAX3421E
Length, Width & Weight	101.52 mm, 53.3 mm & 36 g

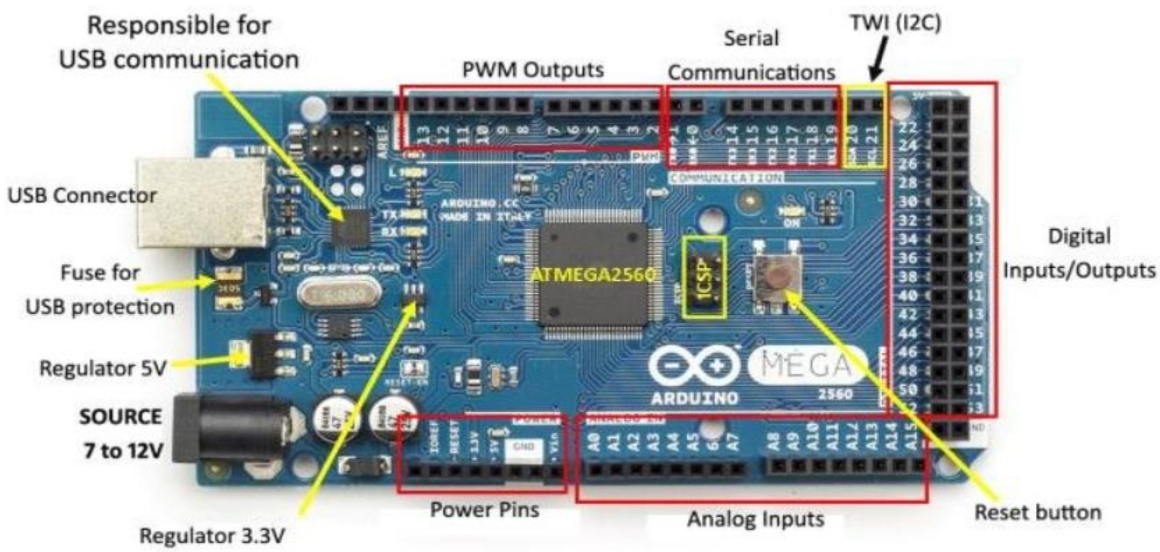

Figure 8.1: Arduino Mega 2560 R3[20]

8.1.2. Arduino Uno R3

Arduino Uno is a microcontroller board based on the ATmega328P (datasheet). It contains 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator (CSTCE16M0V53-R0), a USB connection, a power jack, an ICSP header and a reset button. It also contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.[21]

Table 8.2: Technical Specifications

Microcontroller	AT mega 2560
Operating Voltage	5V
Input Voltage (recommended)	7V-12V
Digital I/O Pins	14 (of which 6 provide PWM outputs)
Analog Input Pins	6
DC Current per I/O Pin	20 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
Length, Width & Weight	68.6 mm, 53.4 mm & 25 g

Figure 8.2: Arduino Uno R3[22]

8.1.3. Arduino Ethernet Shield W5100

The Arduino Ethernet Shield W5100 allows Arduino Uno R3 board to connect to the internet. It is based on the Wiznet W5100 ethernet chip (datasheet). The Wiznet W5100 provides a network (IP) stack capable of both TCP and UDP. It supports up to four simultaneous socket connections. The Ethernet library is used to write sketches which connect to the internet using the shield. The ethernet shield connects to an Arduino board using long wire-wrap headers which extend through the shield. This keeps the pin layout intact and allows another shield to be stacked on top.[23]

Table 8.3: Technical Specifications

Operating Voltage	5V
Ethernet Controller	W5100 with internal 16K buffer
Connection Speed	10/100Mb
Connection	With Arduino on SPI port

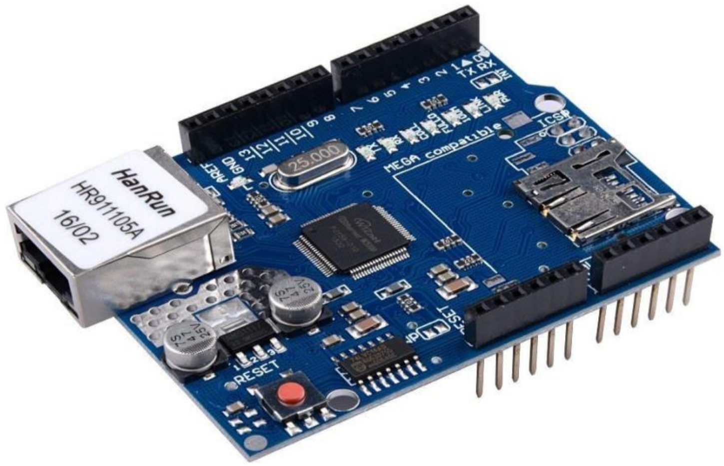

Figure 8.3: Arduino Ethernet Shield WS100[24]

8.1.4. Current Sensor ACS712- 30A

ACS712 current sensor is based on the Hall Effect principle. Current measurement for both AC and DC signals was precisely given by the sensor. Thick copper conductor and signal traces allows for survival of the device up to 5 times overcurrent conditions. The ACS712 outputs an analog voltage output signal that varies linearly with sensed current.[25]

Features:

- Current sensor chip: ACS712ELC- 30A.
- Pin 5V power supply, on board power light.
- This module can measure plus or minus 30A current, Corresponding to analog output 66 mV/A.
- No test current through, the output voltage is VCC/2.
- PCB size: 31(mm) x13(mm).

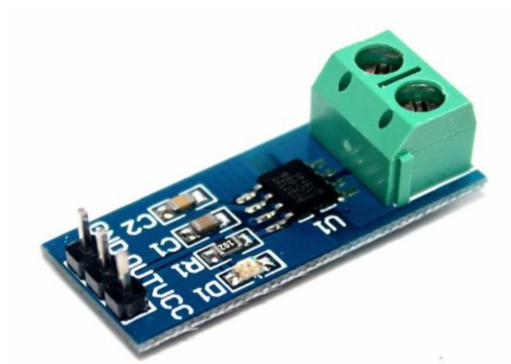

Figure 8.4: ACS712- 30A [26]

8.1.5. 4-Channel Relay Module

This type of relay module is a convenient board which can be used to control high voltage, high current load such as motor, solenoid valves, lamps and AC load. It is designed to interface with microcontroller such as Arduino, PIC etc. The relay terminals (COM, NO and NC) are being brought out with screw terminal. It also comes with a LED to indicate the status of the relay [27].

Features:

- Controllable digital output.
- Compatible with any 5V microcontroller.
- Rated through current: 10A (NO), 5A (NC).
- Control signal: TTL level.
- Max. switching voltage 250VAC/30VDC.
- Max. switching current 10A
- Size: 76mm x 56mm x 17mm

Figure 8.5: 4-channel relay module [28].

8.1.6. 2-Channel Relay Module

The 2-channel relay module is more or less the same as a single-channel relay module, but with some extra features like optical isolation. The 2-channel relay module in this project is used as main line controlling for each of the rooms from the pins of a microcontroller [29].

Table 8.4: 2- Channel Relay Module pinout

Pin Number	Pin Name	Description
1	JD-V_{CC}	Input for isolated power supply for relay coils
2	V_{CC}	Input for directly powering the relay coils
3	GND	Input ground reference
4	GND	Input ground reference
5	IN1	Input to activate the first relay
6	IN2	Input to activate the second relay
7	V_{CC}	V_{CC} to power the optocouplers, coil drivers, and associated circuitry

Specifications-

- Supply voltage – 3.75V to 6V
- Trigger current – 5mA
- Current when relay is active - ~70mA (single), ~140mA (both)
- Relay maximum contact voltage – 250VAC, 30VDC
- Relay maximum current – 10A

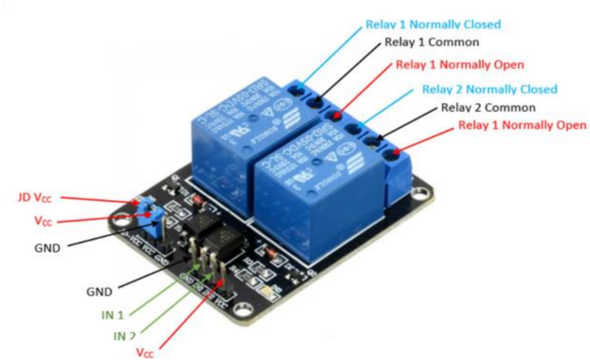

Figure 8.6: 2-Channel Relay module [30].

8.1.7. 12AWG (gauge) stranded copper wire

In the prototype, 12-gauge stranded copper wire has been used to connect all the loads in parallel with each other for each room to the single-phase ac line. The specifications which have been provided here for 12-gauge copper wire are subject to change based on different manufacturer variances [31].

Construction:

Conductors:

Solid, uncoated copper conductors per ASTM-B3

Stranded, uncoated copper conductors per ASTM-B3, ASTM-B787 and ASTM-B8

Insulation:

Color-coded Polyvinyl Chloride (PVC), heat and moisture-resistant, flame-retardant compound per UL-1063 and UL-8

Specifications:

Size: 12 AWG

Number of Strands: 19

Cross Section Area (mm2): 3.31

PVC Insulation Thickness (Conductor): 0.380 mm / 0.015 inches

Nylon Jacket Thickness: 0.100 mm / 0.004 inches

Outside Diameter: 3.23 mm / 0.127 inches

Allowable Ampacity: 20 Amps at 60ºC / 20 Amps at 75ºC / 20 Amps at 90ºC

8.1.8. 4-port USB 3.0 hub

To supply dc voltage to both the Arduinos and also for faster operation, a 4 port USB 3.0 hub has been used to connect with the pc [32].

Features:

- Model: Orico W5PH4-U3-V1-BK-BP
- Plug and play, hot swapping supported
- 4 SuperSpeed USB 3.0 Ports
- Controller - Via-Labs VL812
- Cable Length: 30 CM

Figure 8.7: USB 3.0 hub [33]

8.1.9. Single bell push switches with socket outlets

To toggle on/off the loads as a user, single bell push switches have been used with socket outlets.

Features:

- Switch Size: 1 Module
- Rated Current: 6A
- Color: White
- Switch Operation: Bell Push
- Voltage 240 V

Figure 8.8: Bell push switch [34].

Appendix C

iThenticate Plagiarism Report