Arduino Based Power System Protection

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Declaration

It is hereby declared that

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

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ABSTRACT

As the distribution of electricity networks has become more sophisticated, power system automation has become a requirement for every utility company like distribution substation, underground substation, switchyard, customer substation, and system station. The power system's efficiency highly depends on its inbuilt power types of equipment. It is vital to understand what kind of faults has occurred to improve the quality of the power station. Furthermore, suppose a power system's safety, monitoring, and control are insufficient. In that case, a critical monitoring system must be created to detect, monitor, and classify existing electrical power system problems.

The purpose of this project is to design and construct a system capable of collecting remote electrical characteristics such as voltage, current, and frequency and relaying them in real time to the power station. The concept of the online monitoring system incorporates a Global System for Mobile Communication (GSM), an Arduino MEGA single-chip microcontroller, and other sensors. The system's analog to digital converter (ADC) records the above characteristics at the distribution power system site. This project also uses a relay to protect the electrical wiring. This relay is engaged when the electrical parameters surpass predefined limitations. This system is capable of updating electrical parameters in real-time regularly. This system can be programmed to send alarms when the relay trips or when the voltage, current, or frequency exceeds predefined thresholds.

When our prototype is powered on, all of the sensors begin monitoring voltage, current, frequency, and temperature, transmitting real-time data to the server and displaying it on display. It compares all current values to specified values, generates a fault alarm, and refreshes the display if any values exceed or fall below the predefined values. If the problem continues

for the predetermined time, the relay isolates the leads from the rest of the system. As is customary, the loads are reconnected to the rest of the system via relays while the comparison is being completed.

Dedication:

This thesis is dedicated to those electric linemen who lost their lives in the line of duty while serving us silently to ensure the uninterrupted power supply.

May their soul rest in peace, and may God grant their family the strength to endure this great pain. We will never forget their kindness. We express our sincerest sympathy to them and their family. Their loss saddens us and our others.

Acknowledgement

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List of Acronyms

AC	Alternate Current
ADC	Analog to Digital Converter
AMI	Advance Metering Infrastructure
CPU	Central Processing Unit
BPL	Bangladesh Premier League
DC	Direct Current
GPS	Global Positioning System
GSM	Global System for Mobile Communications
IED	Intelligent Electronic Device
IEEE	Institute of Electrical and Electronics
IoMT	Internet of Medical Things
IoT	Internet of Things
IP	Internet Protocol
LAN	Local Area Network
LCD	Liquid Crystal Display
Li-Fi	Light Fidelity
LPWAN	Low Power Wide Area Network
LTE	Long Term Evolution

NFC	Near Field Communication
PLC	Power Line Communication
PWM	Pulse Width Modulation
RAM	Random Access Memory
RBM	Risk Based Management
RCM	Reliability Centered Maintenance
RFID	Radio Frequency Identification
RPMA	Random Phase Multiple Access
RMS	Root Means Square
SIM	Subscribers Identity Module
SMS	Short Message Service
SoC	System on Chip
SOE	System on Events
SPDT	Single Pole Double Throw
TBM	Time Based Maintenance
UID	Unique Identification
VSAT	Very Small Aperture Terminal
Wi-Fi	Wireless Fidelity
WSN	Wireless Sensor Network

Chapter 1

Introduction

1.1 Introduction

Substations are pieces of electrical equipment that transmit power directly to low voltage customers in power systems, and their performance is critical to the overall operation of the distribution network. Electrical substations have a long life if they are operated under their rated conditions. However, when they are overloaded, their life is significantly reduced, causing sudden failure and supply interruption for many users, jeopardizing system reliability. The primary reasons for distribution transformer failure are overloading and insufficient transformer cooling [1][2]. Electrical power systems are incredibly nonlinear, complex, and massive networks. These electric power networks are interconnected to provide cost savings, increased reliability, and operational efficiencies. They are a crucial component of national and global infrastructure, and their failure has significant economic and national security ramifications, both direct and indirect. Generators, wires, transformers, loads, switches, and compensators are part of a power system. On the other hand, modern power systems are typically configured with widely spread power sources and loads. Today, power outages and blackouts continue to occur due to a lack of automated analysis and the utility's insufficient view of the grid. By aggregating data from the grid's several subsystems, WSN will give the utility the required view. A sensor node will select whether to provide information or to send it with a short delay. With the complexity of the distribution network increasing, substation automation has become a prerequisite for all utility businesses seeking to maximize efficiency and improve the quality of electricity distribution.

1.2 A Brief Overview of the Project

The goal of this project is to collect and broadcast real-time electrical metrics over the network. It can also operate an SPDT relays to protect the electrical circuits when the readings get too high. This relay can be used to turn off the main power supply [3]. It can also be programmed to read and control remote electrical characteristics. The project uses an Arduino MEGA microcontroller. The system is capable of handling multiple sensors. The code is stored in its internal memory.

1.3 The Project's Necessity

With the distribution network becoming more complicated, power system automation has become a must for any utility company seeking to maximize efficiency and improve the quality of energy distribution. Today, power outages and blackouts continue to occur due to a lack of automated analysis and a utility's insufficient view of the grid. By aggregating data from the grid's several subsystems, WSN will give the utility the required view. A sensor node will select whether to provide information or to send it with a short delay. The distance between the generators and the load may be hundreds of miles, resulting in a tremendous amount of power exchange over vast distances due to low-quality electric power. Issues with power quality were not regularly observed throughout the early stages of development. The alarm has been triggered due to increased customer demand for electricity, which has increased the quality of power delivered to the user [4]. Significant energy is wasted during general ability transportation, resulting in a degradation of the power received at the substation. To increase the power quality with the tolerance solution, it is necessary to determine the type of restriction that occurred. Additionally, if a power system's safety, monitoring, and control are poor, the system may become unstable. As a result, an autonomous detection, monitoring, and classification system for existing electrical line constraints are required [5].

1.4 The Project’s Salient Objective

To increase the dependability and compatibility of the system

One of our project's critical goals is to increase the dependability of the electricity delivered by quickly detecting and isolating faults and maintaining a constant voltage, current and frequency level, resulting in a project that is exceptionally dependable and compatible.

Monitoring in real-time

As the distribution network has become more complicated, power system automation has become a must for every utility firm looking to improve efficiency and service quality. Our project's principal objective is to ensure real-time monitoring.

Observer parameter remote sensing

Although this project is intended for all power system protection equipment, we focused on protection frequently placed in remote places. We hope to achieve remote sensing of all observable characteristics through this study.

Maintaining Supply Continuity

We wish to keep track of the real-time parameters in order to ensure supply continuity.

To save money on labor.

One of the critical goals of our project is to minimize labor costs to some level, making the facility more cost-effective.

1.5 The Project’s Benefits

Monitoring in real-time

This was a significant factor in our decision to pursue this project in the first place. Due to a lack of infrastructure for acquiring real-time data, most modern facilities lack this capability;

instead, they rely on annual data acquired regularly. As a result, determining the actual health of the machine we monitor can be challenging at times; what obstacles were overcome due to this initiative. We can now monitor the machine's real-time data from this place, regardless of the situation.

Remote Access

This is one of the project's critical benefits. The server receives all of the WSN's real-time data, enabling remote access. This eliminates the need to inspect the data in the control room physically.

Regular Data Collection

Today, most power plants have work people responsible for data collection manually scribble down all of the data in the control room, then return and update the data on the sheets, which takes considerable time. All of this, however, is possible in a matter of seconds with our project. All real-time data acquired will be saved to external memory regularly. Although our prototype does not feature external memory, we have shown how to use the microcontroller's memory.

Data without errors

As previously noted, data in power plants are primarily collected manually, making them prone to inaccuracies. Additionally, we do not obtain all of the data collection implies some delay, i.e., the values of all the machines are not instantaneous, which is not a big deal if the facility is small, but consider a scenario in which a single person is required to take hundreds of values and the delay is significant. We eliminated all manual data collecting, ensuring that the data was error-free.

Personalized Fault Notifications

Through the implementation of this project, we will receive individualized messages when there are irregularities, such as when electrical parameters surpass predefined limitations. We have included relays that act on and physically isolate the disrupted machines.

Reduced Dangers

There is much high-voltage equipment in larger switchyards, which are potentially dangerous to workers. As a result of a project's ability to remotely observe and collect all essential data, hazards are reduced.

Budget-friendly

We no longer need to send people to every location to collect data after implementer our project; this decrease in manual labor reduces labor costs to some extent. Because the seasons and transducers utilized do not require routine maintenance, the cost of care is reduced. As a result, the total labor cost is decreased.

1.6 Thesis Organization

The thesis is divided into five chapters, with an introduction as the first. Each chapter is distinct from the others and delves deeply into the subject at hand, as well as the necessary theory to comprehend it.

Chapter 2 covers the thesis's organization and theoretical framework. This chapter will examine who has already worked on this subject and how our work varies and advances from theirs. Additionally, it covers the fundamental theory necessary to comprehend the intelligent devices and systems being used and how they are integrated into our project. It explored the properties of IoT, IED, and wireless sensor network (WSN) devices. Additionally, it encompasses the necessary theoretical components of our research. It discusses all of the theories that aided in the development of this project, and it incorporates all of the theories necessary for each component.

Chapter 3 explains our project's process, including all relevant block diagrams, flow diagrams, and circuit diagrams.

Chapter 4 provides all updates on the project's implementation, including all information on hardware and software implementation and results and comments.

Chapter 5 includes a final statement of our work and covers any future scope linked to the project.

Chapter 2

Literature Review and Theoretical Background

2.1 Literature Review

The goal of this project is to collect electrical parameters like voltage from a distance. Use the GSM modem/telephone to send these current, frequency, and power numbers via the GSM network. The user can send an SMS command to obtain information about the remote electrical parameters. The system can also be set up to provide electrical parameters in real-time via SMS regularly (based on time settings). So, if you want to receive an SMS every time the relay trips or if the voltage or current reaches a certain threshold, you can set up the system that way [6].

As the complexity of distribution networks grows, substation automation has become a requirement for all utility providers. When the power system is not adequately protected, monitored, or controlled, it is challenging to improve the quality of the electricity it provides. In this way, automatic detection, monitoring, and classification is needed for electrical lines. This project aims to collect remote electrical characteristics like the voltage, current, and frequency and communicate them in real-time across the network as a function of the power plant's temperature. The project also aimed to activate relays to safeguard electrical circuits. This was another goal. This relay is actuated whenever an electrical parameter exceeds a predetermined value. This system can update electrical parameters in real-time in the background (based on time settings). When the relay trips or when the voltage or current exceeds a preset limit, the system can be set to emit an alert. For the proposed project, this is a proof-of-concept that utilizes a microcontroller. The Arduino Uno was utilized for demonstration reasons. Communication between the controller and the numerous sensors is seamless, thanks to the controller. At this point, all sensors are collecting data and sending it to a server in real-time as the prototype is powered on. Real-time values are displayed on the screen and are compared to preset values. If the real-time value exceeds the preset value, a relay and buzzer fault alarm is activated, and the display is updated. The relay isolates the load from the rest of the system if a fault occurs during the predetermined interval. In the meantime, the comparison process proceeds as usual; if the problem is fixed, the relay reconnects the load to the rest of the system [7].

This project aims to develop a secure and reliable mobile platform for monitoring and recording various critical parameters of a transformer such as its load current and oil level. The system would use a single-chip microcontroller and a GSM modem.

The transformer distribution is executed using an analog to digital converter (ADC). The acquired parameters are then recorded in system memory. If an anomaly or emergency occurs, the distribution sends an SMS to a mobile phone to inform the user about the issue [8].

This article is about the prevention of single-phase distribution transformer faults. There are many factors in the distribution transformer, but some factors are essential to protect the distribution transformer. This work uses temperature sensors, ultrasonic sensors, voltage sensors, and current sensors to measure readings. These sensors must detect specific parameters in the transformer. The system is entirely based on an embedded system via GSM. The information is sent through a specific substation. In some unreachable places, it is challenging to measure parameters. This system is beneficial for measuring and controlling single-phase distribution transformers. This system is beneficial for the electrical panel. We can design and implement single-phase distribution transformers in a mini prototype model. The large capacity of three-phase distribution transformers can be realized in future models. The data of each distribution transformer is collected through the system to identify and eliminate faults. The open-source Arduino platform can be used to integrate all sensors [9].

2.2 Theoretical Background

2.2.1 Substation

Power generation, transmission, and distribution Substations are part of the overall power generation, transmission, and distribution systems. Maintaining the reliability of the power supply and maintaining the quality of the power transfer system is vital to the function of this device. An important function, such as converting voltage from high to the opposite, is done by this device. Because power is transmitted between the power plant and the consumer at varying voltage levels, it can flow through multiple substations.

2.2.1.1 Classification of Electrical Substation

Typification of Electrical Substations:

- Step-up substation (Primary)
- The primary grid substation
- Step-down substation (Distribution)
- Substation for transformers
- Substations
- Converting the substation
- High voltage substation
- Extra high voltage substation
- Ultra-high voltage substation
- Indoor substation
- Outdoor substation
- Pole-mounted substation
- Foundation-mounted substation

2.2.2 Generic Terms Classification

2.2.2.1 Step-up Substation:

The electrical grid's buck substation is located at the junction where the grid changes from alternating current (AC) to direct current (DC). Distribution and sub-transmission lines are derived from the connections between other parts of the grid. The transmit voltage can be changed from the decompression substation to a sub-transmission voltage. After using the sub-transmission voltage line as the source for the substation, the line can be used as the return for the substation.

2.2.2.2 Underground Substation:

Also, the distribution substation is situated underground, close to the final consumer. The sub-transmission voltage is altered to a lower level for end-user use in distribution substation transformers. As the free-surface area in the city center can be used for other purposes, like shopping malls and parks, underground placement of the substation reduces the required area. While improving upon existing substations, underground substations are smaller and occupy less space above the ground [10].

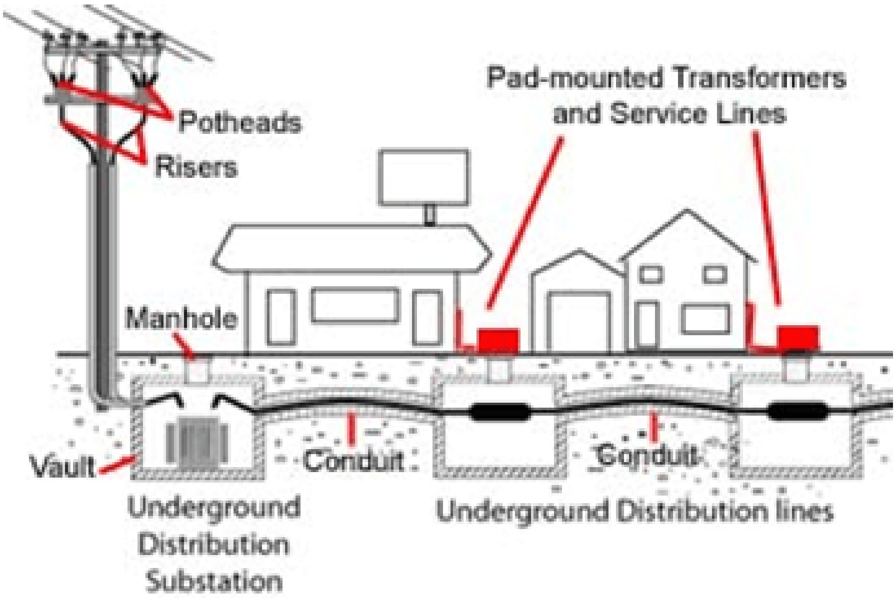

Figure 2.1: Underground Substation [11]

2.2.2.3 Components of an Electrical Substation:

Buses and bus systems use specific designs for different subsystems. To this end, the application's design varies based on the location of the power station, such as indoor substations, power plant substations, power transmission substations, and other locations. It is a sizeable outdoor converter, a small outdoor substation, a switching substation, etc. A collection substation is also required for large-scale power generation systems. Several hydroelectric and thermal power plants are connected to form a single power transmission unit that distributes power to different areas. These electrical components are part of the substation's overall operation.

2.2.2.4 Instrument Transformer:

A static device such as a digital multimeter can measure lower currents and voltages, and they are used to reduce high currents and voltages for safe and practical use. AC-protected relays use transformers that support voltage and current as well as operate in AC circuits.

2.2.2.5 Current Transformer:

To transfer a large amount of current to a lower value, a transformer is needed. The AC appliance controls and indicators are in the same way used with these devices.

2.2.2.6 Potential Transformer:

As current transformers, the transformers' characteristics are similar, but they are used for different purposes.

2.2.2.7 Busbars:

The importance of busbars in a substation cannot be overstated: They serve as the current conductors that lead to several connection points. A bus bar is an electrical junction where the two current paths have the same function: output and input. Bus types can be grouped into three varieties: double bus, single bus, and ring bus. This is called a simple bus bar.

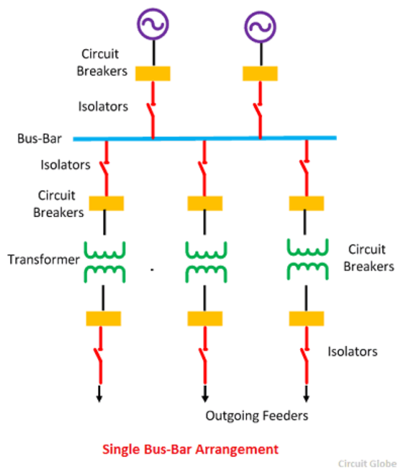

Figure 2.2: Single Busbar Arrangement [19]

2.2.2.8 Lightning Arrester:

Lightning arresters can do both to protect the substation equipment from high voltages and restrict the amplitude and duration of current flow. It is connected to the track because of this on to the following line. Therefore, it is linked to the substation's equipment. The wire is wrapped around the insulators and conductors to help protect the insulation and electrical components from damage during a current surge.

2.2.2.9 Circuit Breaker:

Circuit breakers are switches used to fix a problem within the electrical system. The tripped command would be severed from the circuit breaker if the system's relay failed, causing any circuit damage.

2.2.2.10 Relay:

A relay is a dedicated part of a substation's equipment used to guard against any unforeseen circumstances. Defect relays are essentially error-detecting detectors that can locate them, determine their position, and then transmit an interrupted message to the point of specific circuit wiring for commands that have been tripped.

2.2.2.11 Capacitor Bank:

A capacitor bank is a type of electrical device that consists of many identical capacitors. They are used to protect various circuits in a wide range of applications.

2.2.2.12 Battery Bank:

The emergency light relay systems and automatic control circuits for critical substation components, such as power source relay systems and circuit breakers, all run on batteries.

2.2.2.13 Wave Trapper:

The high-frequency trap input line has one of the substation components placed on it called the wave hunter. We are isolating low-frequency voltage and current sources by blocking the entrance of high-frequency currents and voltages.

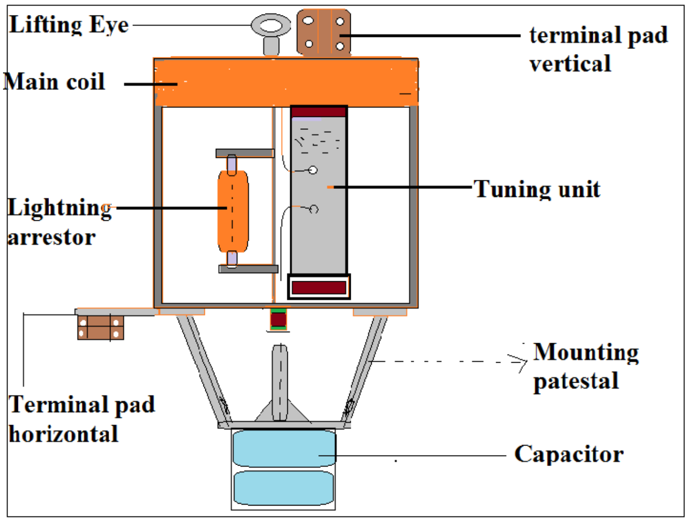

Figure 2.3: Wave Trap sectional view design [20]

2.2.3 Substation Maintenance:

Maintaining the power system is essential to ensure proper system operation. As a result, significant public and financial resources are required for utilities. While liberalization and privatization of the electricity market made the electricity market more competitive, that process also had some drawbacks. Additionally, the current infrastructure is challenged and on the verge of failure. You must emphasize cutting costs, increasing profits, and enhancing reliability in your management strategies. The survey results showed that the current maintenance procedures mainly consist of correcting and preventing issues (time basis). The electron is a good choice when assets that are abundant, non-essential, and simple to replace are needed. This latter option is the most used these days. It involves examining the asset's condition according to the schedule defined by the manufacturer's specifications and the utility's own experience. In the end, time-based maintenance means that a company regularly spends more money on purchasing new assets but neglects to care for its older assets. To increase maintenance efficiency, time-based preventive maintenance (TBM) is gradually replaced by state-based maintenance (CBM). An enterprise CBM strategy can minimize costs related to maintenance and maintenance activities while also helping to improve the overall quality and continuity of the power supply to optimize asset utilization: preventive maintenance and later reliability (RCM). Preventive maintenance benefits the overall power system by enhancing the utilization and maintenance of its assets because it can have parameters for measurement and operational equipment. To predict failures or accidents in the distribution network, this information is necessary. Maintenance with RCM has the advantages of a lower total cost, considering the asset's critiques and importance and condition. Focus on two critical assets of the substation. A rapid increase in power transformer, shock, and breaker accidents is substantial regarding technical and economic factors.

2.2.4 System of Monitoring:

Monitoring utilities' overall performance and efficiency are essential for shifting from a corrective maintenance approach to preventative maintenance. CBM implementation is the first step on the path towards that strategy. One approach to surveillance is to collect critical data about the asset of interest. The acquired data can be studied and identify the asset's condition. This can be of significant assistance in establishing maintenance schedules and preventing breakdowns. There are so many different options to consider that monitoring substations get complicated. Often, an asset is both online (continuous) and offline (discontinuous), or a combination of both. However, it may be continuous (online) and discontinuous (offline), or both depending on the asset. It is also necessary to acquire appropriate sensors and data and the necessary software to process the data. As well, substations utilize assets from various vendors, operating systems, and communication protocols in common. The monitoring system can be configured with three levels, such as

Level 1: Obtaining data from each asset by utilizing the proper sensors.

Level 2: At the substation, data storage and processing are carried out.

Level 3: Bringing together information from various sources.

The term "appliance monitoring system" refers to a collection of hardware and software components used to keep tabs on domestic appliances like electric heaters and air conditioners. Transmission and distribution substations utilize substation monitoring systems that gather real-time data from the devices inside the substation. If you have installed the substation monitoring system's data monitors, you can see when equipment fails, when equipment trips, and when damage occurs. With this information, you will be able to take immediate action to correct any problems. The substation monitoring system helps to safeguard and operate substation equipment.

2.2.5 GSM (Global System for Mobile Communications) Technology:

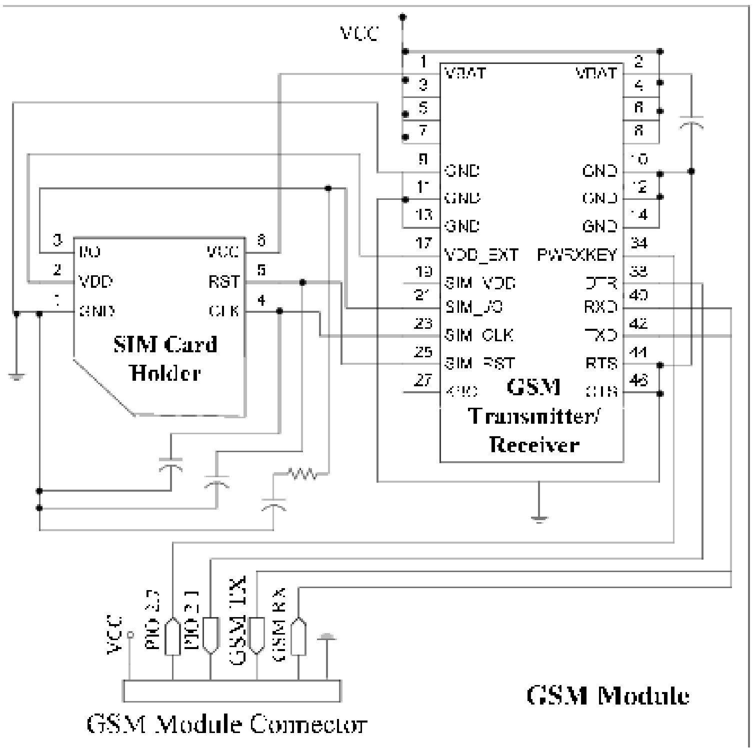

Figure 2.4: Circuit diagram of the GSM Module [12]

GSM is a digital cellular system that is used around the world. Finland (as part of Europe) is where it all began. Today, however, it has indeed spread across the globe. 80% of the global market for mobile phone technologies uses GSM technology. The number of people who have a GSM phone is approaching 3 billion. Because people used it to talk to their friends and relatives, GSM technology became widespread. GSM (Global System for Mobile Communication) is used thanks to the SIM (subscribers identity module). 2G technology is the GSM global system for mobile communication. Because GSM has multiple frequency ranges (the Global System for Mobile Communication), the 2G frequency range is the most used. GSM offers a moderate level of security. It enables encrypted communication between the serving base station and the end-user. The various cryptographic modules used in GSM technology are present in each phone.

2.2.6 Arduino:

Arduino is an open-source electronics platform or board, and the programming tools needed to program it are collectively referred to as Arduino. If you are an artist, designer, hobbyist, or just interested in creating interactive objects or environments, the Arduino is built for you. A completed Arduino board is available for purchase, or the hardware design is released under an open-source license, and so it can be made by hand. Users can also upgrade and publish their versions of the boards [13].

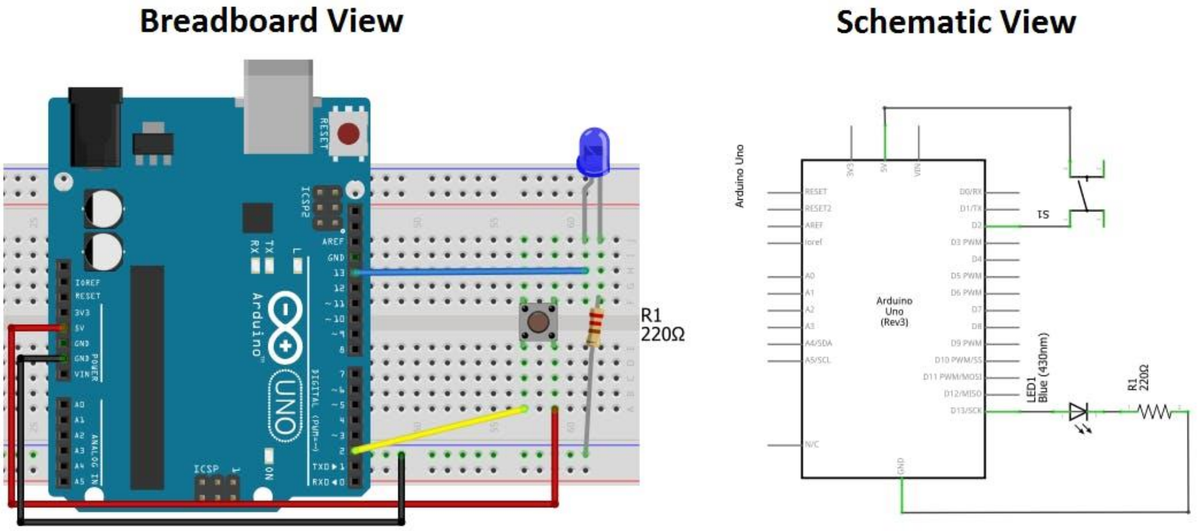

Figure 2.5: Arduino

2.2.7 Embedded System Hardware:

This hardware is typically built into a microprocessor or microcontroller-based system. Integrated circuits are typically the heart of a system's design. They perform real-time processing in both cases [14].

A microcontroller is a type of component that's housed inside a system. It provides a wide range of peripherals and CPUs. They are commonly used to implement complex tasks and to provide low-power options.

Microcontrollers are typically used in various industries such as vehicles, robotics, and medical devices [15].

2.2.8 Embedded System Software:

Industrial microcontrollers typically use software that is integrated with the hardware. This software is simpler to program and uses less memory than a standard enterprise desktop computer. In particular, if you need a real-time operating environment, embedded systems can use operating systems or language platforms customized for your embedded application. A near-real-time method is acceptable with higher chip capabilities such as those present in SoCs, which allow designers to make systems run at a fast enough rate with modest changes in reaction time. After that, other choices must be made. Deprecated Linux is routinely provided as a result of such circumstances. Windows Embedded (formerly Windows Embedded) and Windows IoT (previously Windows Embedded) have been optimized for embedded systems. Programs and operating systems are typically stored on flash memory or rewritable flash on embedded devices [16].

2.2.9 Delineation of the Internet of Things:

2.2.9.1 Introduction:

Using the Internet of Things (IoT), unique identities (UIDs) can be created, and data can be transmitted across networks without the requirement for human-to-human or human-to-computer interaction. Yes, that is correct. Real-time analytics, machine learning, consumer goods, and embedded technology have all come together to create the Internet of Things.

Traditional domains such as embedded system automation (including building and home automation) have contributed to implementing the Internet of Things.

2.2.9.2 Scope of Application:

The diverse range of IoT device applications is frequently divided into industrial, consumer, and commercial sectors.

2.2.9.3 Industrial Application:

Industrial IoT devices, alternatively referred to as Industrial Internet of Things (IoT) devices, collect and analyze data from connected equipment.

Figure 2.6: Applications of IoT

Energy management:

Several energy companies have started implementing energy management solutions that combine internet connectivity and utility billing. These devices allow the users to centrally manage their energy consumption and provide features such as remote control.

The Smart Grid is a platform that utilities use to improve the efficiency and reliability of their electricity distribution. It uses big data to analyze and improve the efficiency of its operations.

Manufacturing:

The Internet of Things can enable the seamless integration of various industrial equipment through various communication and networking capabilities.

Applications in Infrastructure:

An important use of the Internet of Things is the monitoring and control of urban and rural infrastructure that is sustainable. The Internet of Things (IoT) architecture allows for the monitoring of any event. The Internet of Things (IoT) has the potential to reduce construction costs, cut lead times, and boost productivity in processes that document the quality of the day's work. You can save money by using real-time data analytics to make better judgments.

2.2.9.4 Application for End-Users:

Consumer-facing IoT devices such as connected cars, home automation, wearable technology, connected health, and consumer electronics with remote monitoring capabilities are being developed rapidly.

Smart Home:

IoT devices are a subset of the broader concept of home automation, including lighting, heating, air conditioning, media, and security systems. Long-term benefits may include energy savings associated with an automatic lighting and electronic device shutdown. Intelligent and automated homes can be built on platforms or hubs that control smart devices and appliances. It comes with its own set of applications and native applications.

Assistance for the elderly:

One critical application of smart homes is to assist people with disabilities and the elderly. Utilization of these home system assistance technologies is proportional to the owner's inherent impairment. Voice control aids users with limited vision and mobility, and the Alert system can communicate directly with a deaf or hard-of-hearing user wearing a cochlear implant.

2.2.9.5 Organizational Application:

Medical and health care services:

Medical and health care services:

It is possible to collect and analyze medical and health-related research and monitoring data using IoT (IoT). The Internet of Medical Things (IoMT), sometimes known as "Smart Healthcare," is a digital health system that integrates medical resources and services. Connect your Internet of Things (IoT) gadget to your home network to enable remote monitoring and emergency alerting. Fitbits and fitness trackers, and more complex devices that can monitor specialized implants, such as wristbands, are examples of the capabilities of these devices.

Transport:

It is possible to integrate communication, control, and information processing between different modes of transportation by using the Internet of Things in transportation. Intelligent traffic management, intelligent parking, electronic tolling, logistics and fleet management, fleet management, safety, and load assistance are all made possible by the dynamic interactions between various transportation system components. The use of sensors to monitor the quality of air, water, and soil to aid in environmental protection is every day in IoT environmental monitoring applications. Tracking wildlife and ecosystems may be one of these applications.

2.2.10 Internet of Things Enabling Technologies:

The Internet of Things is made possible by a wide range of technologies. The network that connects IoT-enabled devices is crucial in this scenario. Some wireless and wired technologies may be able to play this role.

2.2.10.1 Addressability

Due to their integration with the Internet, devices now use IP addresses as unique identifiers. Because IPv4 addresses are limited, objects on the Internet of Things must scale to the enormous address space required by the next-generation Internet protocol, IPv6.

2.2.10.2 Wireless Short Range

Light-Fidelity is a Wi-Fi expansion that makes use of visible light to increase transmission bandwidth (Li-Fi).

With near-field communication (NFC), devices as close as four centimeters apart can communicate with one another by using protocols that are named as such.

Radiofrequency identification (RFID) utilizes electromagnetic fields to read data from tags attached to objects.

Wi-Fi uses the IEEE 802.11 standard for local area networking to link devices via a common access point or directly amongst them (LAN).

IEEE 802.15.4 ZigBee-based personal area networking communication protocols provide low power consumption, low data rate, low cost, and high throughput.

There are several applications for Z-Wave in the home automation and security industries.

2.2.10.3 Mid-Range Wireless

LTE-Advanced for Wireless Mid-Range — A high-speed transmission mobile network communication specification. Enlarging coverage while also boosting data throughput and minimizing latency are all benefits of the new technology. Many IoT devices, particularly mobile ones, have high communication requirements and need to be connected. 5G wireless networks can meet those requirements and link many IoT devices.

2.2.10.4 Wireless Long-Range

Long-range Wireless Available LPWAN technologies and protocols include the following: Lora Wan, Sigfox, NBIoT, Weightless, and RPMA are all wireless technologies. VSAT (A tiny aperture terminal) is a satellite communication technology that utilizes a small plate antenna to transmit narrowband and wideband data.

2.2.10.5 Wired Ethernet

Ethernet is a general-purpose networking standard that makes use of hubs and switches, as well as twisted-pair and fiber optic cables.

Transmission of both electricity and data over electrical wiring is known as power-line communication (PLC). IoT devices are networked according to the Home Plug and G.hn specifications, which both utilize PLCs.

2.2.11 An overview of IED

2.2.11.1 Introduction

When we talk about "intelligent electronics," we are talking about electrical equipment like transformers and capacitor banks with microprocessor-based controls installed. The IED can collect data from sensors and power equipment and deliver control commands such as circuit breaker trips to detect voltage, current, or frequency irregularities. Circuit breakers, capacitor banks, and voltage regulators are all examples of IEDs. Digital protection relays use microprocessors primarily for protection, control, and other related applications. One common aspect of an IED is its 512-level defenses, 58 control functions for individual devices, auto-closing, self-monitoring, and communication capabilities. The names of electronic gadgets that are clever were correctly chosen as a result. The IEC61850 standard for substation automation has been used to construct specific contemporary IEDs, allowing for compatibility and enhanced communication capabilities [17].

2.2.11.2 Phasor Estimation and Protection Function

Microprocessor-based relays are superseded by relay IEDs because they provide security. Measurements are more precise, and less equipment is used in IEDs.

It is possible to remove the auxiliary CTs when replacing a transformer differential relay because the new relay includes a CT mismatch correction feature. In a modern IED relay, the original primary transformer currents can be analyzed. There is no need to employ an external device to fix CT mismatch, rush, or saturation problems, provided the proper methodology and numerical comparison techniques are used.

2.2.11.3 Braker Control and Programmable Logic

A modern relay IED eliminates the need for external programmable logic controllers (PLCs), as the IED can manage the protection functions' logical inputs and outputs directly through the IED's flip flops AND/OR gates.

2.2.11.4 Metering and Power Quality Analysis

Power utilities soon embraced the IEDs' metering capabilities, and the non-revenue metering function built into the IEDs resulted in significant cost reductions. For revenue metering, the typical current measurement may not be accurate enough for the significant CTs and VTs being used for protection. Measurement of voltage and current RMS values and natural and reactive power are standard metering functions. Measuring now covers commissioning and testing values, lowering commissioning and testing times greatly on-site. The measured values are voltage and current phase shifts' positive, harmful, and zero-order components, as well as the standard root, mean square (RMS) values. Commissioning can be sped up by quickly calculating the values for phase mismatch, differential, and restraints.

2.2.11.5 Self-monitoring and monitoring of External circuit

IEDs can also monitor the interface and the external circuit in addition to the internal circuit. Performing interface monitoring requires looking at the devices' output, which is easily verifiable. Relay currents should be three times as large as any neutral current, for example. One of the present analog channels may be faulty if there is any variance. False tripping can be avoided with the relay. An instrument transformer failure can be detected by inspecting the circuit breaker coil for interruptions in the trip-close path.

2.2.11.6 Fault diagnosis and Event reporting

Relay IEDs have obviated the need for digital fault records, as IEDs can record waveforms during faults, whereas electromechanical relays could not. Reporting events is simple with a relay IED that eliminates the need for a sequence of events (SOE) recorder. The relay IED stores data in non-volatile memory and logs jamming event reports such as pickups, trips, and automatic reclosing for general event logs such as configuration changes. They are separately stored and managed. The IED generates timestamps for all events, which requires a battery backup for GPS synchronization and a real-time clock. If the time tags are specified correctly, the events can be reported in the order they occurred, eliminating the need for a separate sequence in the control room. As a result, the value can be stored in the IED for later retrieval, even during a power failure, facilitating fault diagnosis following a failure.

2.2.12 Wireless Sensor Network

2.2.12.1 Introduction

A wireless sensor network (WSN) is a collection of spatially distributed sensors to monitor and record the physical conditions of the environment and aggregate the acquired data in a centralized place. WSN takes data on various environmental factors, including temperature, sound, pollution, humidity, and wind speed. It is similar to wireless ad hoc networks in that it relies on wireless connectivity and spontaneous network development to facilitate the wireless transmission of sensor data. It is a spatially distributed autonomous sensor network that monitors physical or environmental factors such as current and voltage and temperature, sound, and pressure via a wireless sensor network.

2.2.12.2 WSN overview

The WSN comprises sensor-connected "button" nodes ranging from a few to hundreds of thousands in number (or sometimes some). An electronic communication circuit with sensors and a radio tower tool is all the sensor network button components. There is also some inbuilt power harvesting. This sensor network's buttons are made up of multiple different parts. This is because of the constraints on sensor node size/cost/computing speed/communications bandwidth. WSN topologies can be as simple as a star network or as complicated as a multi-hop wireless mesh network, to put it simply. Between network hops, you can use either routing or flooding as a propagation method.

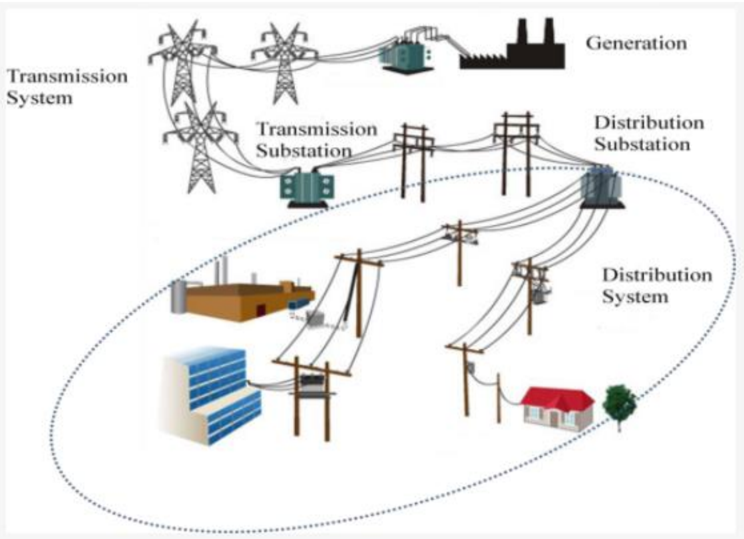

Figure 2.7: An example of Power Grid [18]

Chapter 3

Methodology and Experimental Setup

3.1 Methodology

3.1.1 What do we want to do?

As day by day, the power demand increases, the transmission system becomes more and more complex. Even after extensive development in the power sector has been made compared to the last decade, some key aspects remain under the supervision of human consciousness, and automation has not touched those features yet. The reliability of any power system also includes the protection of all the components if any parameter of the entire process crosses the safety range. These values are usually under constant human supervision and thus prone to mistakes that might lead to deadly consequences. There are hundreds of variables in a power system that needs to be constantly under monitoring. However, we here focus on key ones, such as voltage, current, frequency, and temperature. A simple prototype of a power subsystem is made. Sensors collect data constantly, which includes voltage, current, frequency, and temperature. These parameters are going to be monitored by a micro-controller. Suppose they reach a specific value that exceeds the safety line. In that case, the relays will shut down, connected directly in serial connection with the load, thus saving the consumer load from any damage. At the same time, it will send a notification to the human supervisor about the situation through GSM technology.

3.1.2 Block diagram of the Prototype

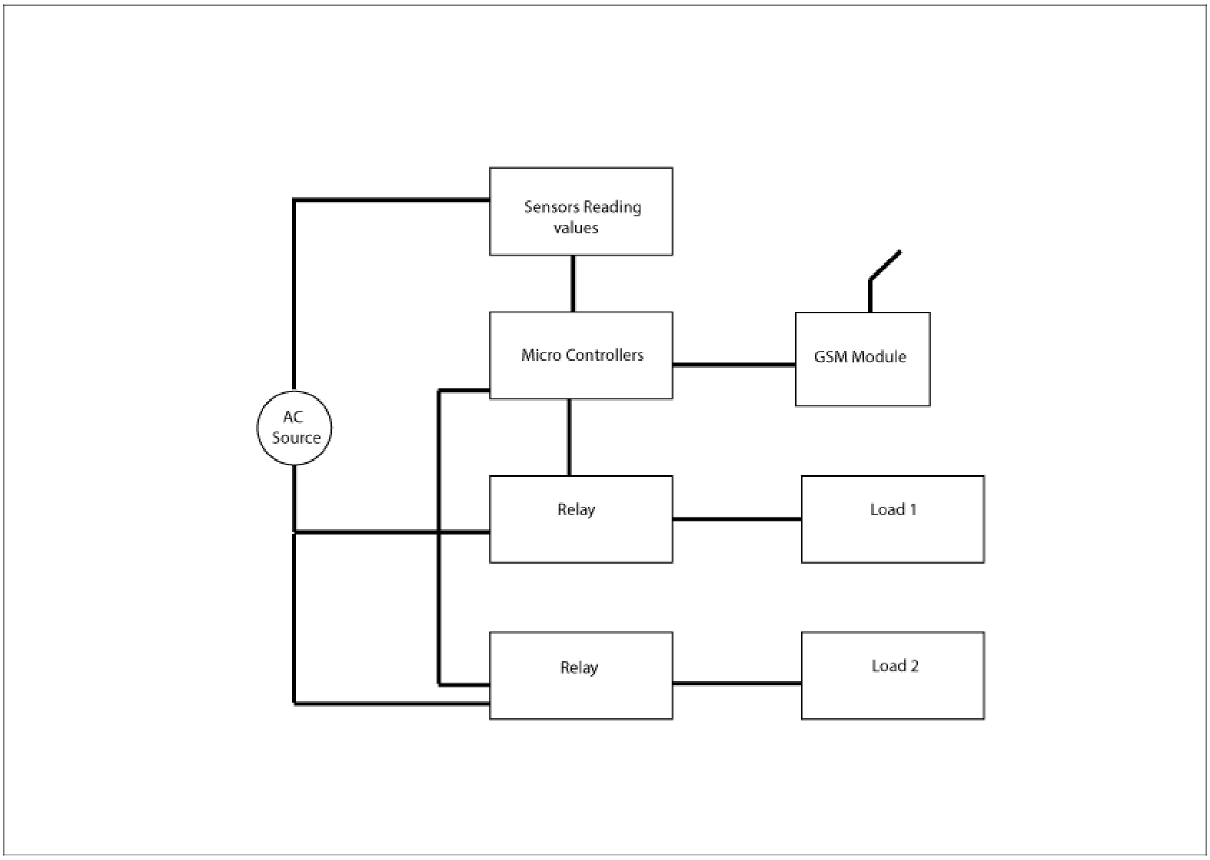

Figure 3.1: Block Diagram of the Prototype

3.1.3 Principle of the Operation

The prototype includes two light bulbs as load. Both are in serial connection with a relay that receives input from the microcontroller to turn OFF/ON. The voltage, current, frequency, and temperature sensors collect data from the main power supply and send the values to the microcontroller. It compares these variables with the safety parameters coded into the microcontroller before the deployed system.

Initially, the power supply was a 230V AC power supply. It is converted to a 12V DC power supply using a 230/12 AC transformer and a bridge rectifier. This is used to power the sensors used in the whole project. However, they all take the reading of the 230V AC power source. Both the voltage and frequency have been measured using a ZMPT101B sensor. The current has been measured using an ACS712 and the temperature using an LM35 Temperature Sensor.

Some of these values are then displayed on a 16*2 LCD, and they can also be customized according to the needs. The safety requirements have been coded into the microcontroller, which shuts down the load if any safety parameters have been violated.

In addition to the disconnection, another notification has been sent to the user through the GSM module to acknowledge the situation and, if need be, take further actions to ensure safety.

3.1.4 Project Specifications

The critical aspects of this illustration are:

Instant notification: The user is notified as soon as the safety is violated to ensure further safety and necessary precautions

Constant monitoring: The sensors collect data continuously and compare variables to each loop so that no time is spared if something goes wrong.

Individual load controlling: Each load is controlled separately. If disconnecting one load is enough to maintain safety, then it can be done.

Data collected over time: Data can be collected over a certain period and plotted to know the system's overall performance.

Easy Maintenance: Sensor failure or adding any maintenance work can be done quickly without much hassle.

3.1.5 Components Required:

1. Arduino Mega
2. ACS712 Current Sensor
3. ZMPT101B Voltage Sensor
4. LM35 Temperature sensor
5. 16*2 Display
6. 230V/12V Transformer

7. Piezo Buzzer
8. Electrolytic Capacitor 470uF
9. Potentiometer
10. Two-channel relay
11. Resistors (330,110k, 33k)
12. Bulb (30W)
13. Male to Female Cable
14. Female to Female Cable
15. 3M cable of 2A
16. Bread Board
17. 12v Power supply unit
18. Wire Stripper
19. Soldering Iron
20. Soldering Rail
21. GSM Module

3.1.6 Components Cost Estimation:

Components	Quantity	Price (BDT)
1. Arduino Mega	1	1050
2. ACS712 Current Sensor	1	220
3. ZMPT101B Voltage Sensor	1	130
4. LM35 Temperature sensor	1	75
5. 16*2 Display	1	170
6. 230V/12V Transformer	1	200
7. Piezo Buzzer	1	25
8. Electrolytic Capacitor 470uF	1	200
9. Potentiometer	1	75
10. Two channel rarely	1	180
11. Resistors (330,110k, 33k)	Combination	100
12. Bulb (30W)	2	350
13. Male to Female Cable	1 set	25
14. Female to Female Cable	1 set	25
15. 3M cable of 2A	1	200

16. Bread Board	1	70
17. 12v Power supply unit	1	150
18. Wire Stripper	1	300
19. Soldering Iron	1	200
20. Soldering Rail	1	150
21. GSM Module	1	1500

3.1.7 Main Microcontroller Unit

3.1.7.1 Arduino Mega

The Mega 2560 is the main component of the project. It features a 64-bit microcontroller with a built-in reset button and an ICSP header. It is also equipped with 54 digital I/O pins and a 16 MHz crystal oscillator [21].

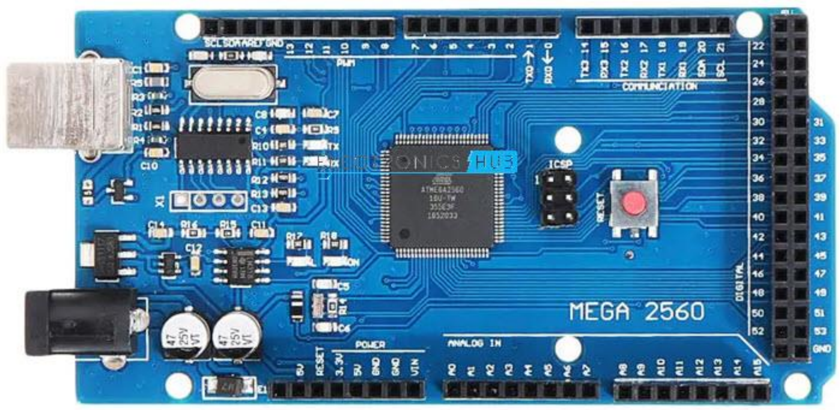

Figure 3.2: Arduino Mega [22]

MCU	ATmega2560
Architecture	AVR
Operating Voltage	5V
Input Voltage	6V – 20V (limit) 7V – 12V (recommended)
Clock Speed	16 MHz
Flash Memory	256 KB (8 KB of this used by bootloader)
SRAM	8 KB
EEPROM	4 KB
Digital IO Pins	54 (of which 15 can produce PWM)
Analog Input Pins	16

Table 3.1: System Description

3.1.7.2 Pin Description

Power Pins

VIN pin is for Supply voltage (7-12V)

GND pin is for Ground

5V Supply is for external hardware device power supply

3.3V Supply is for External low voltage hardware device power supply

Controller Pins

RESET: (Resets input) A reset will be generated if this pin remains low for more than four clock cycles. There is a reset pin on the Arduino Mega that may be used by other devices to re-establish control of the system.

XTAL1, XTAL2: Two bypass capacitors are linked to the ground, and one is connected to the controller's supply clock crystal (16Mhz).

Aref: As long as we do not need internal 1.1V or 5v references, we may use Adc for analog to digital conversion.

Digital Pins (70)

Digital Pins: These pins can be used for input or output.

Analog Pins: These pins can be used for analog input.

Alternative Pins Function:

SPI Pins: These pins can be used for communication between two or more devices.

I2C Pins: These pins can be used to enable two-wire communication with other devices.

PWM Pins: These pins can be used as PWM output to write PWM values from 0-255.

USART Pins: These pins can be used for serial usart communication with pc or other systems for data sharing and logging.

Pin change Interrupt Pins: These pins can be used for pin change interrupt.

Hardware Interrupt Pins: These pins can be used for interrupt services [23].

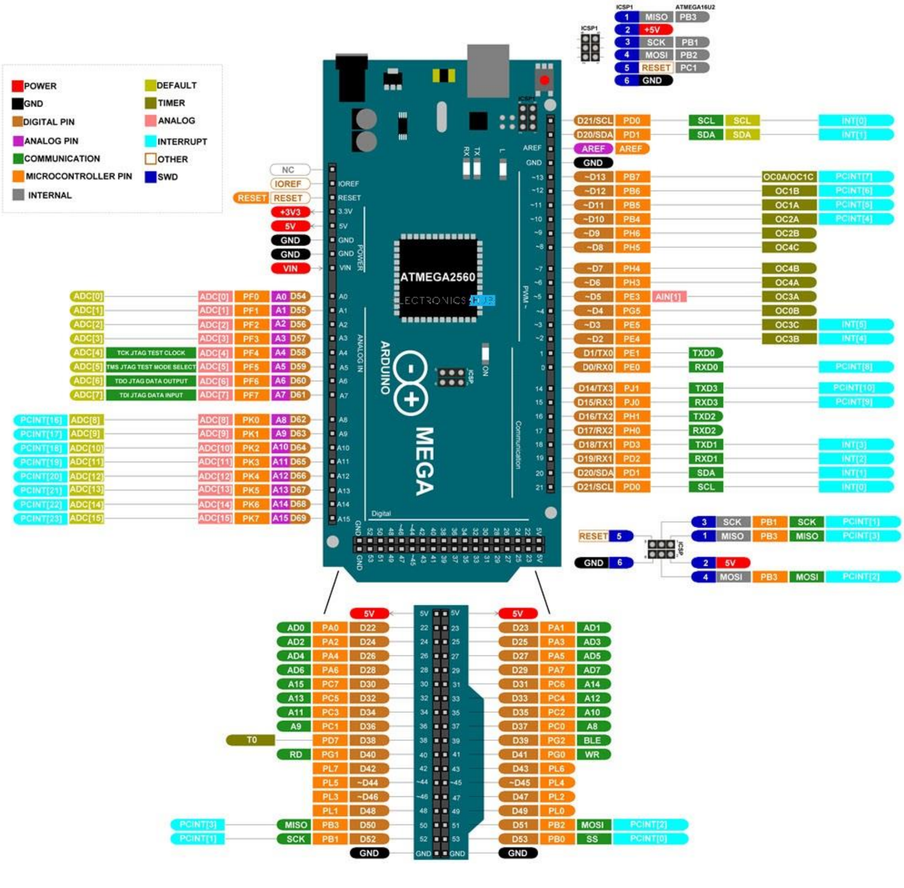

Figure 3.3: Arduino Mega Pin Layout [24]

3.1.8 Power Supply Processing Unit

A Step-down Transformer, a Bridge Rectifier, and a few diodes make up an Electronic Power Supply or Electronic PSU. A single printed circuit board has all of these parts and connections. In the first place, one phase of a 230 volt, 50 cycle per second (cycles per second) single-phase AC supply is converted to a 12 volt, 50 cycles per second alternating current (cycles per second). The rectifier unit converts the AC to a pulsed waveform of 12 voltage direct current (DC), smoothed down using a 470-cycle capacitor before being fed back into the system (cycles per second). The voltage regulator IC7805 received this smooth 12-volt DC to convert it to 5 volts DC.

3.1.9 Transformer

The term Transformer can be defined as a passive electrical device that utilizes electromagnetic induction to transfer electrical energy from one circuit to another. It is most often used to increase the (usually) lower voltage (also called 'step-up') or decrease the (generally) higher voltage (also called 'step-down') levels between circuits. The magnitude of the voltage is inversely related to the pace at which the flux changes. When you use the term transformer, you are referring to alternating current or AC. Thereby the primary winding generates an alternating and varying magnetic flux. Then, we have the secondary coil, which is located near the primary coil. They have linked together because of the alternating current in the primary transfers to the secondary. Faraday's law of electromagnetic induction asserts that as the flux constantly changes, it produces an induced EMF in the secondary coil. To understand the essential workings, consider this: Current will flow if the secondary circuit is closed.

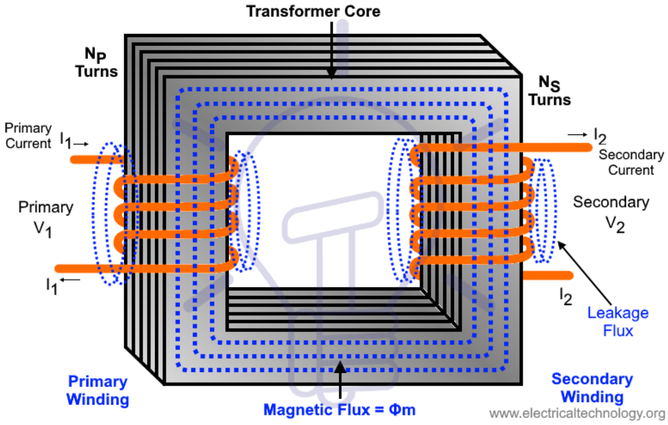

Figure 3.4: Basics of a Transformer [24]

3.1.10 Bridge Rectifier

A bridge rectifier is a type of alternating current (AC) to direct current (DC) converter that converts mains alternating current (AC) to direct current (DC). Bridge rectifiers are frequently used in power supplies to provide the required direct current voltage for electronic components or devices. They can be made using four or more diodes or any other type of controlled solid-state switch. A suitable bridge rectifier is selected based on the load current requirements. When selecting a rectifier power supply for an appropriate electronic circuit application, considerations such as component ratings and specifications, breakdown voltage, temperature ranges, transient current rating, forward current rating, mounting requirements, and other factors are considered [25].

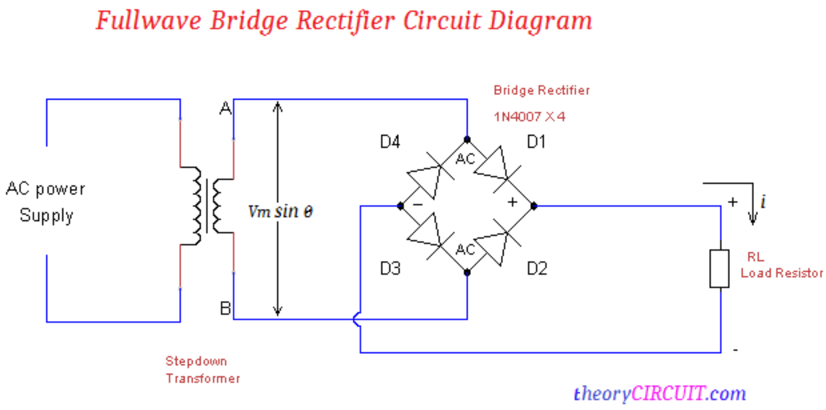

Figure 3.5: Bridge Rectifier [26]

3.1.11 Filter

A filter circuit eliminates the alternating current components or filters them out in a rectifier circuit. A filter circuit is a device that eliminates the rectified output's alternating current components while allowing the rectified output's direct current components to reach the load. A filter circuit is generally composed of an inductor (L) and a capacitor (C), referred to as an LC filter circuit. A capacitor allows only alternating current to pass, while an inductor allows only direct current to pass. As a result, an appropriate L and C network can effectively filter out the alternating current component of the rectified wave.

In combination, a filter circuit is constructed using passive circuit elements, such as inductors, capacitors, and resistors. Their electrical properties determine the filtering action of passive circuit elements. For instance, an inductor allows direct current to flow through it. However, it obstructs AC. On the other hand, a capacitor allows for the passage of alternating current. However, it obstructs the DC. Some of the critical filters are-

1. Series Inductor Filter

2. Shunt Capacitor Filter

3. L-C Filter

4. Pi (π) Filter

Because we have just addressed the Shunt Capacitor Filter thus far, our discussion will be brief. Shunt Capacitor Filter: A capacitor is connected across the load in this filter and charges during the rise of the voltage cycle. This charge is then supplied to the load during the fall of the voltage cycle. This procedure is repeated for each cycle, resulting in a decrease in repellence across the load. It is depicted in the preceding Figure. It is popular due to its low price, compact size, lightweight, and favorable characteristics. Utilized in transistor radio battery eliminators for loads up to 50mA [27].

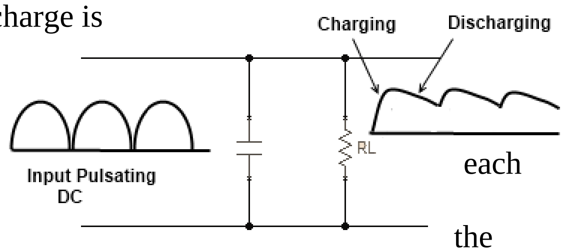

Figure 3.6: Capacitor Filter [27]

3.1.12 Voltage Regulator

A voltage IC regulator ensures that the provided output voltage is always the same. In the 78xx family of voltage regulating ICs, IC numbered 7805 is a voltage regulating IC belonging to the same family. It is a voltage regulator with a known output voltage. The 78xx hexadecimal code represents the IC's fixed output voltage value. A +5V regulated DC power source is required for a 7805 integrated circuit. The input voltage of this voltage regulator may go as high as 35V. If the input voltage is less than or equal to 35V, the IC will output a steady 5V. This is the regulator's operating limit.

Pin No.	Pin	Function	Description
1	INPUT	Input voltage (7V-35V)	In this pin of the IC positive unregulated voltage is given in regulation.
2	GROUND	Ground (0V)	In this pin where the ground is given. This pin is neutral for equally the input and output.
3	OUTPUT	Regulated output; 5V (4.8V-5.2V)	The output of the regulated 5V volt is taken out at this pin of the IC regulator.

Table 3.2: Interpretation of Pins of LM7805

3.2 Experimental Setup

3.2.1 Current Measurement

The ACS712 provides cost-effective and precise current sensing solutions for industrial machines, commercial applications and communications systems. The chosen device package enables the customer to implement the device quickly. Typical applications are for motor control, load detection and management, switched-mode power supplies, and over-current fault protection. The ACS712 module uses the well-known ACS712 integrated circuit to measure current via the Hall Effect principle. The ACS712 module comes with two phoenix terminal connections and mounting screws. These are the terminals that the wire must pass through. On the opposite side, there are three pins. To power, the module connects the V_{cc} to +5V and the ground to the C's ground. Then, using an analog pin on the C, the analog voltage output by the ACS712 module is read.

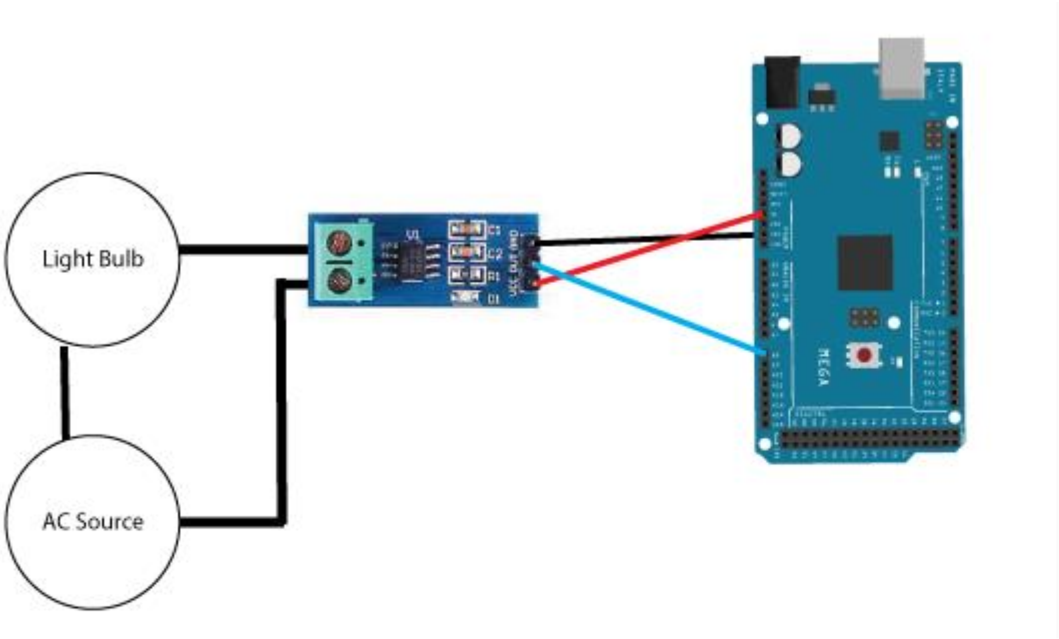

Figure 3.7: Current Measurement Setup (Software)

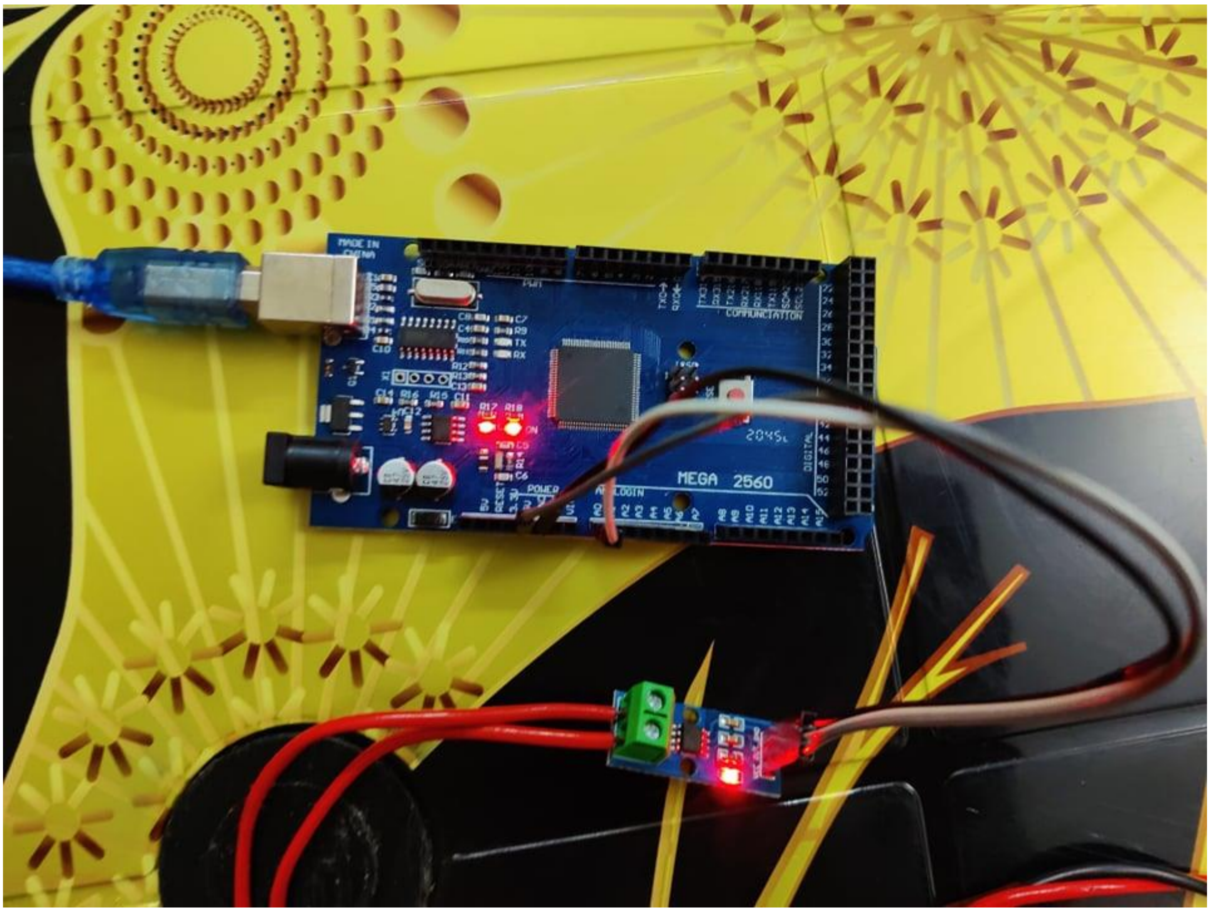

Figure 3.8: Current Measurement Setup (Hardware)

3.2.2 Voltage Measurement

When building our project prototype, we utilized a voltage sensor module such as the ZMPT101B. The ZMPT101B which belongs to a series of high-precision voltage transformers and op-amp current having high accuracy is installed in a single-phase active output voltage mutual inductance module, making it simple to acquire AC power signals up to 250V.

The ZMPT101B voltage transformer is used to build the voltage sensor module ZMPT101B. It measures voltage and power with excellent accuracy and consistency and can measure up to 250V AC. The ADC output may be tweaked using the trim potentiometer, which has a large number of turns. The following are the main characteristics of this item:

- High galvanic isolation
- Broad range
- High precision
- Consistency

The voltage transformer ZMPT101B has a high level of accuracy. This small module, about the size of a bouillon cube, allows easy monitoring of mains alternating current voltages up to 1000 volts. With a 1: 1 turn ratio, this current transformer can hold up to 4kV of breakdown voltage. To put it another way, we power it up and then turn it off. The input current is generated with the help of resistor R1, and the output voltage is obtained with the help of a sampling resistor R2.

A ZMPT101B module is needed for AV voltage measurement. The Arduino's 5v supply, GND, and analog pin 0 are connected to the module's Vcc and output, respectively. It is just a matter of connecting everything up, writing that last bit of code, and opening the serial monitor so that we can see the voltage. A voltage of 300 volts may be measured using this gadget.

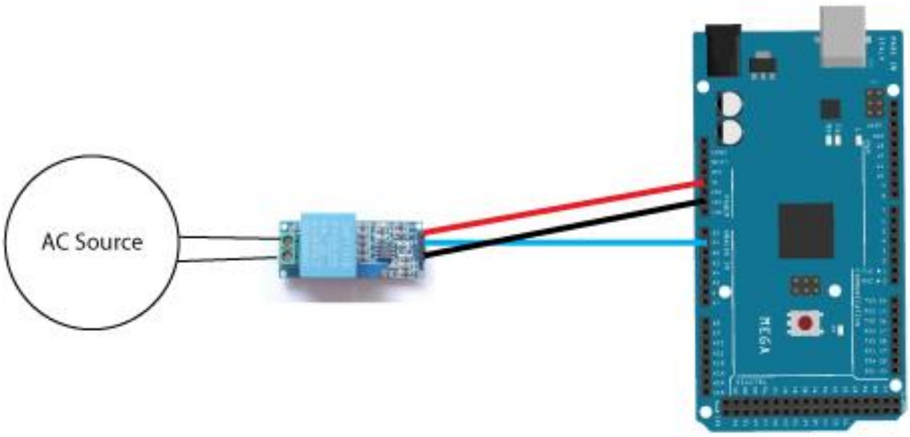

Figure 3.9: Voltage Measurement Setup (Software)

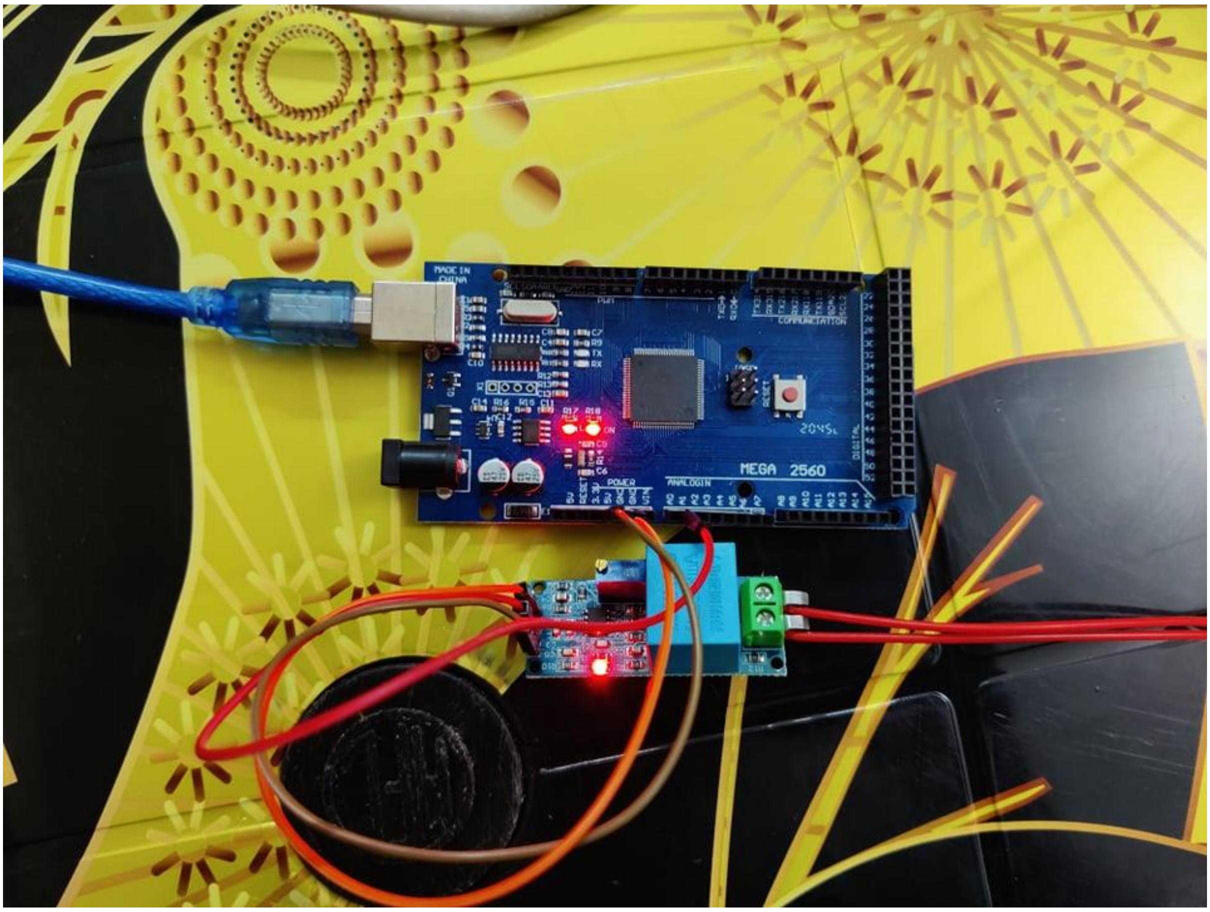

Figure 3.10: Voltage Measurement Setup (Hardware)

3.2.3 Frequency Measurement

The frequency is defined as the number of cycles (full turns) that occur per one second. The Hertz frequency is the primary unit of measurement (Hz). The time required to complete one cycle (turn) is measured in seconds, with the second serving as the primary unit. Frequency equals one-hundredth of a period. The frequency of alternating current (AC) in the home is 50 hertz. The period is 20 milliseconds at a frequency of 50 hertz (hertz). Due to the PC817 optocoupler having a maximum reverse voltage of 6 volts, the diode 1N4007 avoids negative half cycles in this circuit. This resistor (together with a 1N4007 diode) limits how much current may go through the optocoupler LED. The optocoupler is then connected to the alternating current mains (see Figure 1). (IF). Peak forward current is equivalent to 220x2/120k = 2.59 mA (ignoring diode voltages) when using a 120k ohm resistor with a 220V source, while RMS forward current is equal to 2.59/2 = 1.3 mA (half-wave). It is easy to calculate the max forward current using a resistor and a 220V source. The formula goes like this: 220x2/120 (without including diode voltages).

The output is linked as follows when the PC817 optocoupler is attached to the Arduino: The Arduino's GND pin links the emitter, while digital pin two is used to connect the collector. An external interrupt 0 may be connected to this pin if desired. A 10k ohm pull-up resistor links the collector to the Arduino's +5V pin. The optocoupler output decreasing (i.e., moving from high to low) was detected in this project using external interrupt 0. The following shows how to set up this interrupt. In this case,

EIFR |=1; / clear the INT0 flag

attachInterrupt(0, timer1 get, FALLING); // enabled the external interrupt (INT0)

at the time an interrupt occurs, the Arduino is instructed to execute the function timer1 without any more delay () The concept of measuring frequency is straightforward; the Timer1 module measures the time between two consecutive interruptions, which implies we have the duration between two consecutive falling occurrences. As soon as the function timer1 gets () is invoked, the value of Timer1 is stored in a variable named: tmr1. To reset the variable tmr1, the timer1 module has been altered to proliferate by two each microsecond (Prescaler = 8), and attached overflow interrupt has been activated (helps when the signal is removed). Assuming a Prescaler of 8 is used, the input of clock Timer1 module corresponds to Timer1 CLK = 16 MHz / 8 = 2 MHz. With aforementioned setups, the Arduino is capable of measuring frequencies as low as approximately 31Hz.

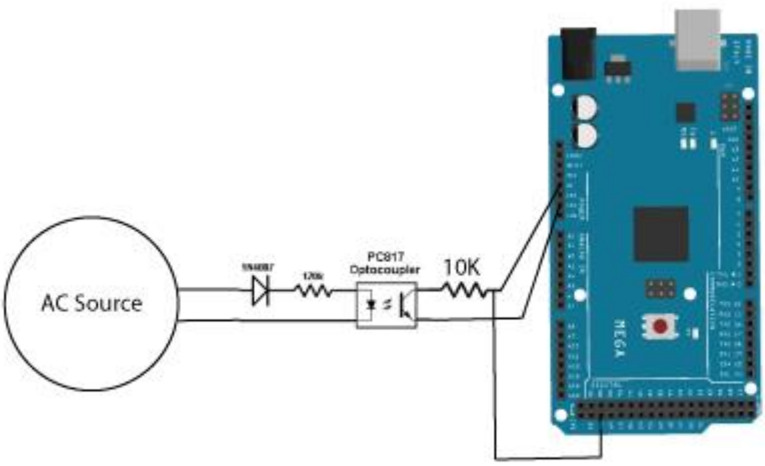

Figure 3.11: Frequency Measurement Setup (Software)

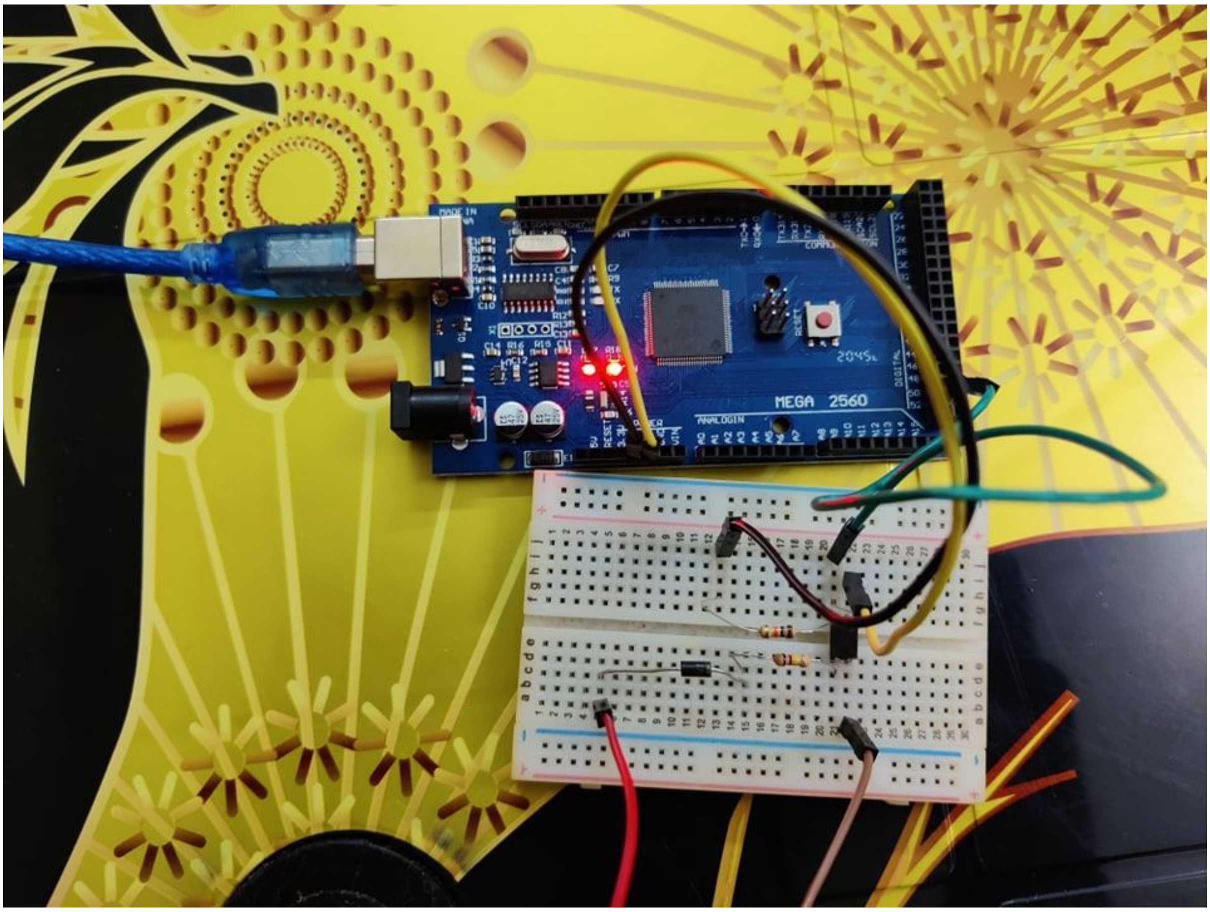

Figure 3.12: Frequency Measurement Setup (Hardware)

3.2.4 Temperature Measurement

The LM35 is a temperature sensor that produces an analog signal proportionate to the temperature at any given time. The output voltage may be interpreted in order to produce a temperature reading expressed in degrees Celsius. Because the lm35 does not require any external calibration, it has an advantage over the thermistor. It is also protected from self-heating, thanks to the covering. Low cost and higher precision are two advantages. The LM35 is capable of measuring temperatures ranging from -55 degrees centigrade to 150 degrees centigrade. In perfect temperature and humidity conditions, the accuracy level is extremely high when the system is run. Also, simple is converting the output voltage to degrees Celsius (or vice versa). When used with an LM35, the input voltage can range from +4 volts to 30 volts. It consumes approximately 60 microamperes of electricity. The LM35 output is connected to Arduino UNO's analog pin A1. The temperature reading is obtained by converting the analog voltage to its digital form and processing it.

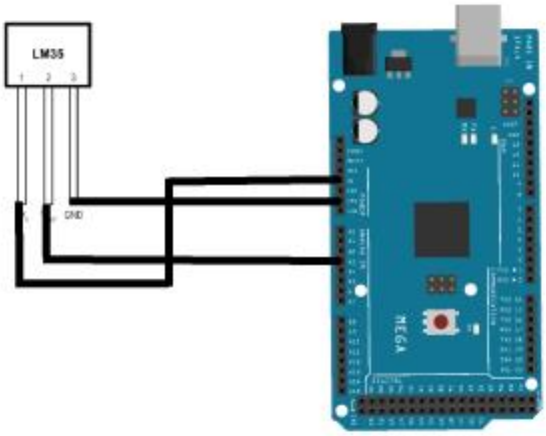

Figure 3.13: Temperature Measurement Setup (Software)

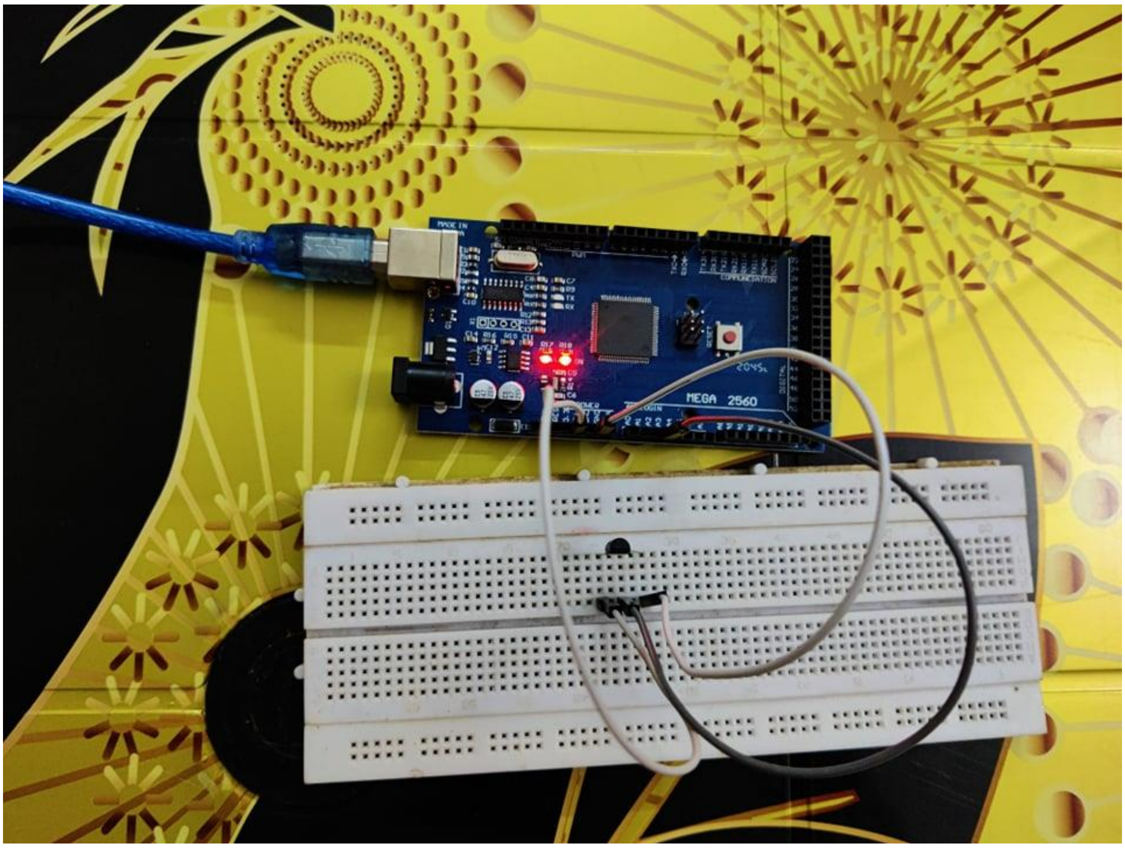

Figure 3.14: Temperature Measurement Setup (Hardware)

3.2.5 Relay Module

A relay is a trip switch operated by an electromagnet in its most basic form. Low voltage is required to activate the magnet; the Arduino provides this. Once triggered by the magnet's low voltage, it will close contact with the high voltage circuit, completing the circuit. The relay module SRD-05VDC-SL-C will be used. We will use Arduino to control it since it runs on 5V and can be controlled by any microcontroller. Three of the five pins on a relay are high-voltage terminals (NC, COM, and NO) that link to the control device. This is standard. The typical (COM) port supplies power to the relay from the computer's main power supply. The NC and NO terminals can only be used if the device is switched on and vice versa. Between the last two pins, a coil serves as an electromagnet (coil1 and coil2). The electromagnet charges and moves the switch's internal contacts when electricity passes through the coil. This is when the normally open (NO) terminal is connected to the standard (COM), and the normally closed (NC) terminal is disabled. A coil's internal contact returns to its original condition when the current is withdrawn. The usually closed (NC) port ties up to the standard (COM), and the ordinarily open (NO) terminal reopens.

A single-pole, a double-throw switch is a technical term for this switch type (SPDT). This prototype demonstration will make use of two-channel relay modules. Modules with one, four, or eight channels are, nevertheless, available. Using your Arduino and this module, you can control two ample power supplies at once. Consisting of two high-current relays, each being rated at up to 10A at 250VAC or 30VDC. Dual LEDs indicate the trigger status of the relay on the relay module. The LED connected with a relay turns on when it is triggered. Optocoupler ICs performs d sound insulation between the relay and the Arduino in these modules, one of their best advantages.

As an AC system is hazardous and may cause damage, you must take the necessary steps to regulate it. As a result, carefully follow the instructions below to prevent any mishaps. To control the AC gadget, we will need some extra electricity. For this reason, use the Arduino's 5V, ground, and pin eight to connect your power supply. Connect a wire from the alternating current supply to the bulb's other end and a wire from the relay's ordinary to the other end of the relay (C). Connect the bulb's opposite end to the normally open (NO) connector.

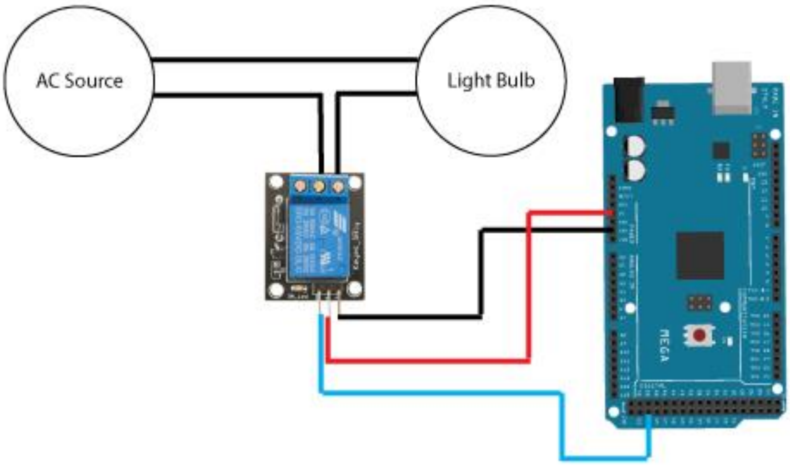

Figure 3.15: Relay Module Setup (Software)

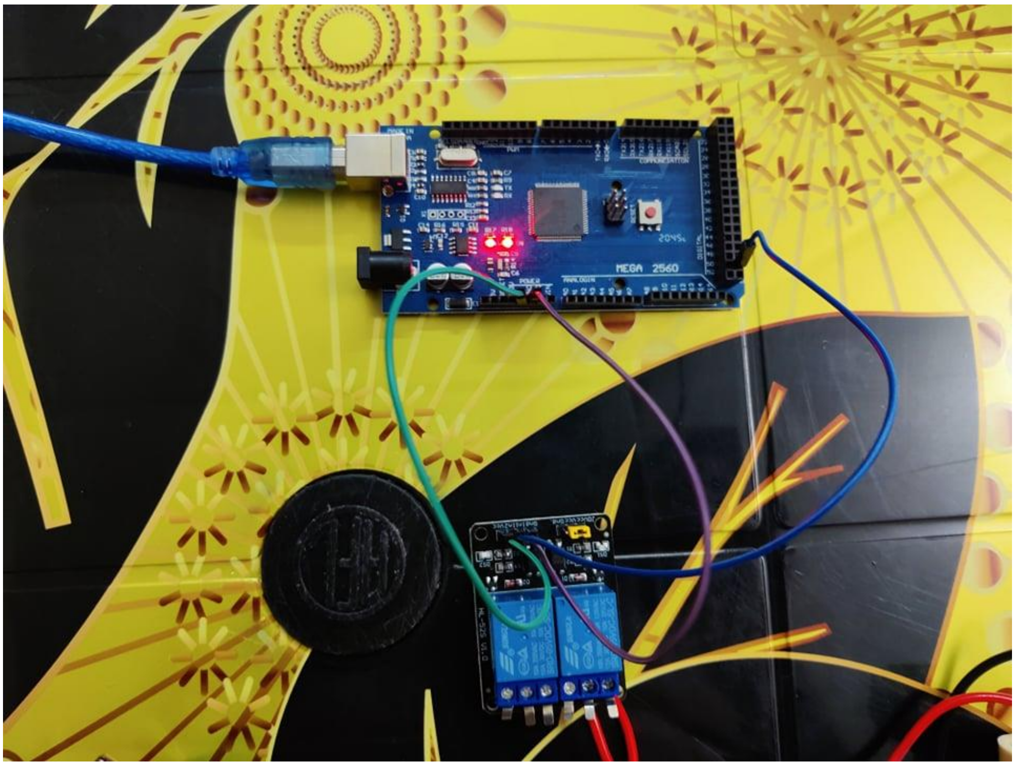

Figure 3.16: Relay Module Setup (Hardware)

3.2.6 GSM Module

GSM is an acronym for Global Technology for Mobile Communications. It is a digital cellular system that is utilized by mobile devices. It is an international mobile communication standard that is commonly utilized for long-distance communication.

Numerous GSM modules are available, including the SIM900, SIM700, SIM800, SIM808, and SIM5320.

The SIM900A module enables users to transmit and receive data via GPRS, send and receive SMS, and make and receive phone calls.

The GSM/GPRS module communicates with the microcontroller or PC terminal through USART. AT commands set up the module in various modes and execute various tasks such as calling and sending data to a website.

For further information about the Sim900A and how to use it, see the Sensors and Modules section's topic Sim900A GSM/GPRS Module.

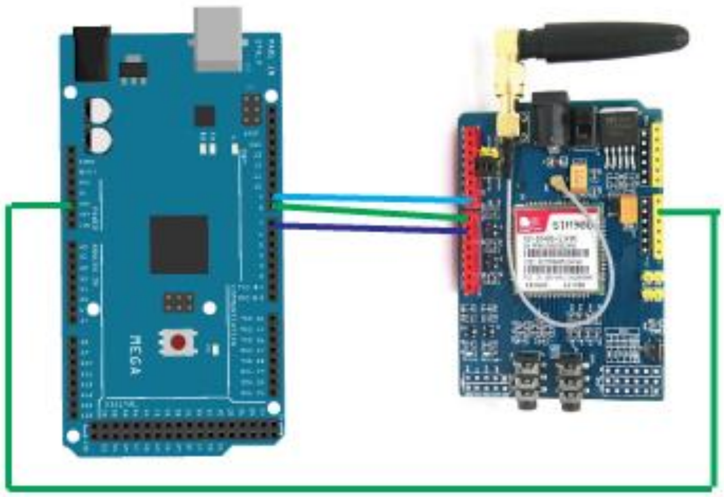

Figure 3.17: GSM Module Setup (Software)

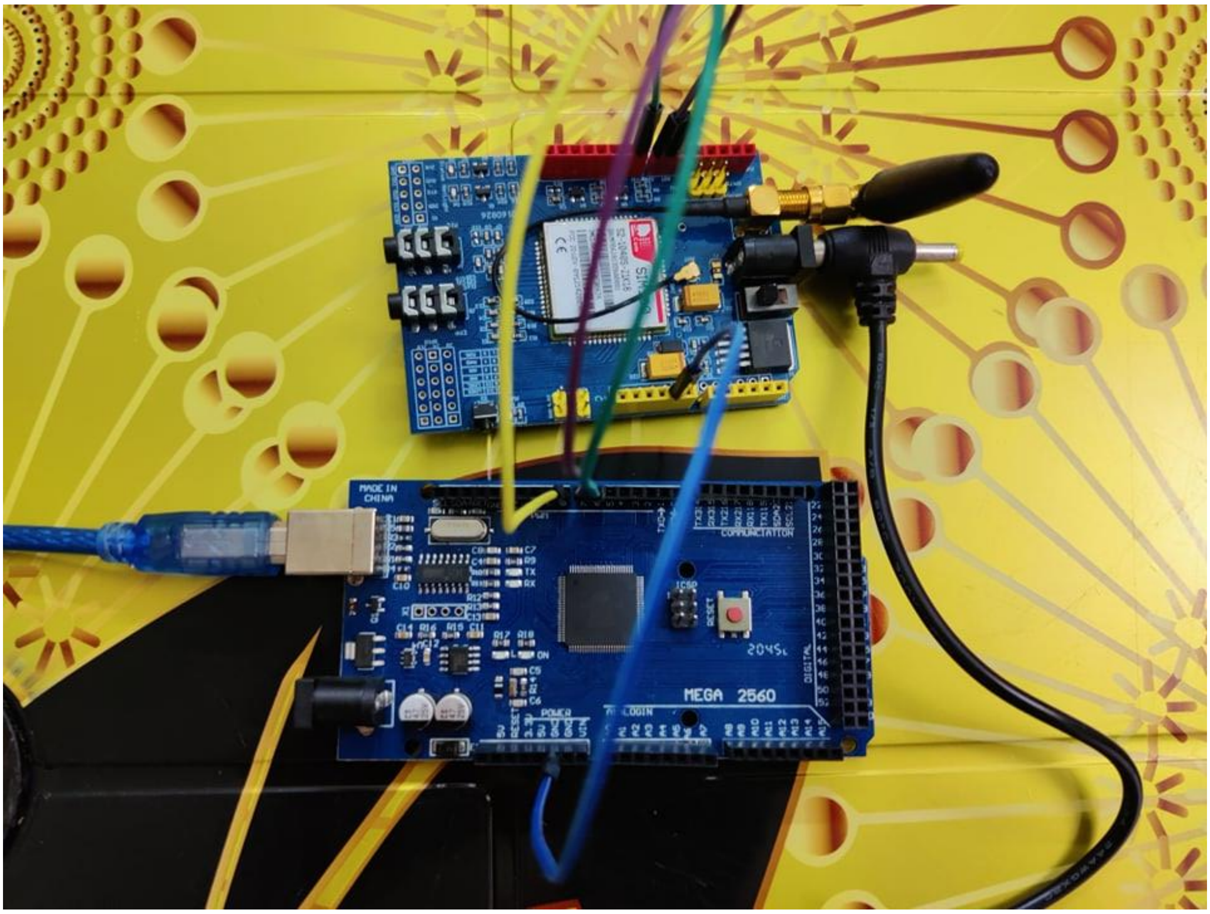

Figure 3.18: GSM Module Setup (Hardware)

3.2.7 Display Unit

A liquid crystal display (LCD) is an electronic display module that employs liquid crystals to generate a visible image. The 162 equates to a 16-character-per-line display in two such lines. Each character is presented in a 577-pixel matrix on this LCD.

A 162 LCD contains two registers, referred to as the data and command register. The RS (register select) primarily applied to switch between registers. Register stationed at zero, it is referred to as the command register. Similarly, when the register is appointed to '1', the register acts as the data register.

The command register's primary role is to store the command instructions sent to the display. Thus, predetermined actions similar to cleaning display, initializing, cursor positioning, as well as the information that needs to be displayed can be controlled here. It may also handle commands.

The data register's primary role is to store the data displayed on the LCD panel. The ASCII value of the character represents the data that will be displayed on the LCD screen. When we send data to the LCD, it is transmitted to the data register, where the process begins. When the register set equals 1, the data register is chosen.

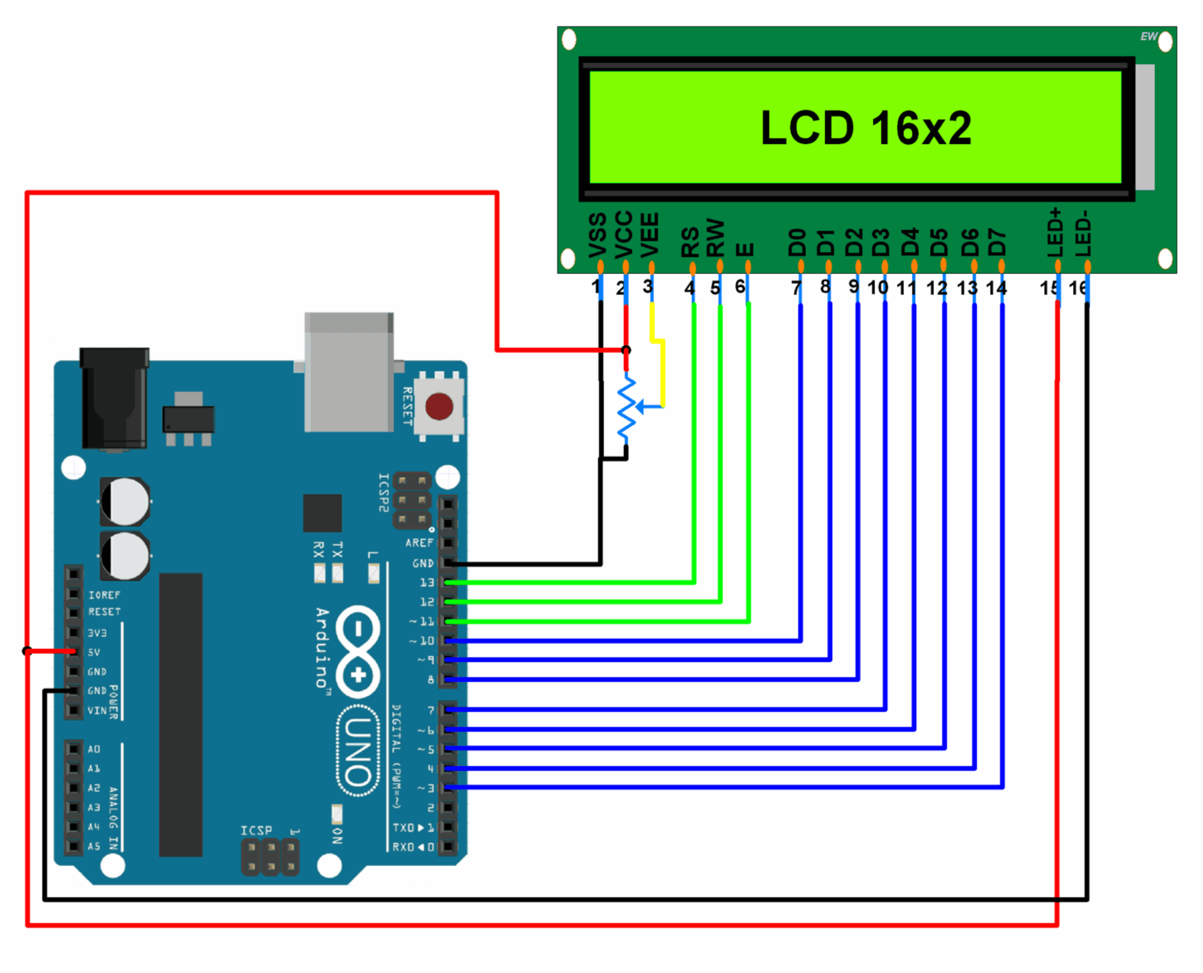

Figure 3.19: LCD Interference Setup (Software)

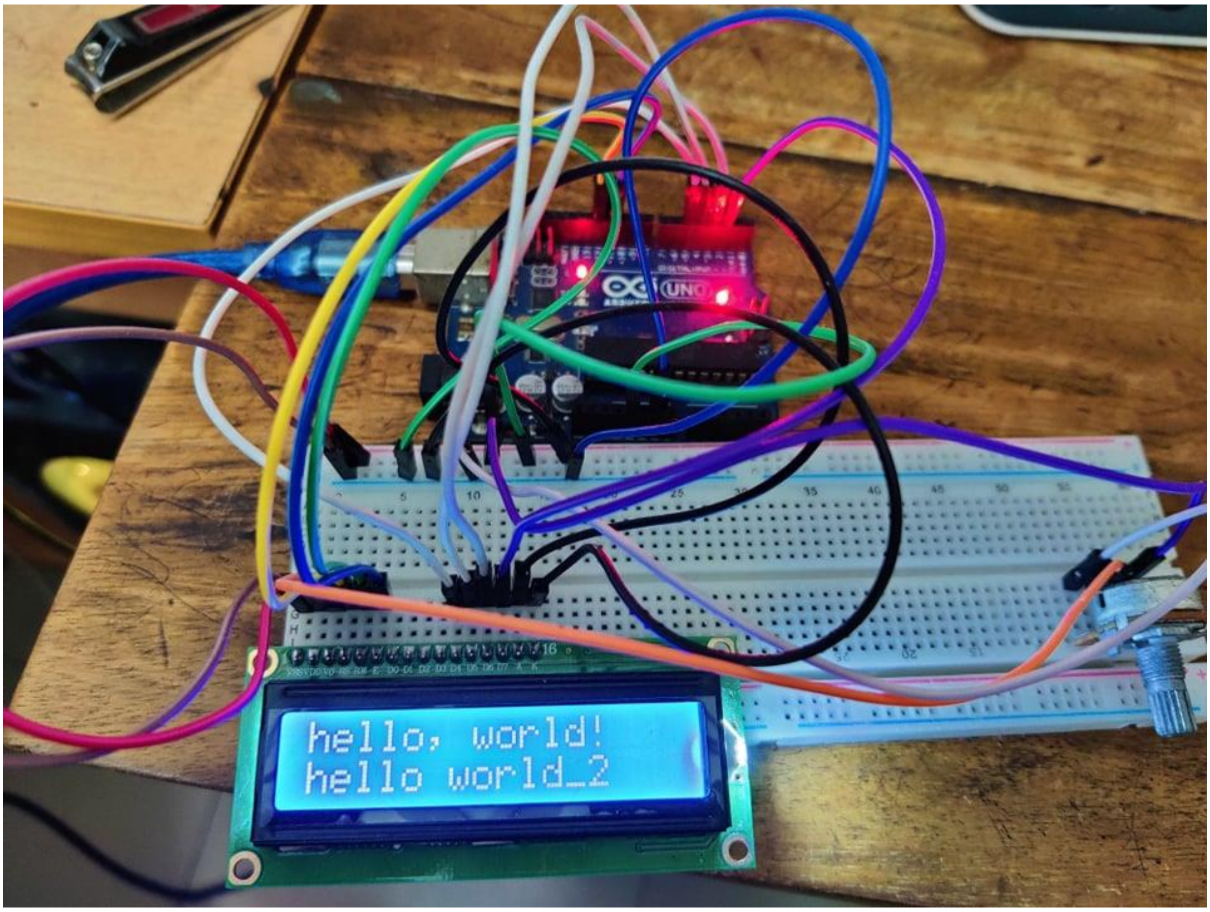

Figure 3.20: LCD Interference Setup (Hardware)

3.2.8 Complete Setup of the Prototype

The Arduino Uno is the central microcontroller in this design. Because of this, it will be the system's beating heart and the point of contact for all other measuring circuits. As an alternative to using a microcontroller, we utilized current, voltage, temperature, and a frequency calculating unit, together with piezo buzzer and a dual-channel relay module, used to illustrate a load. Single supply unit with converter to convert 230 Volts AC to 12 Volts AC was also utilized by us. The 12 Volt AC is subsequently converted to 12 Volt DC pulses using a bridge rectifier device. Using a capacitor for filtering, pulsating DC is converted to ripple free DC. Received 12 Volt DC is passed through 7805-voltage regulator, transforming the 5 Volt regulated DC required by the Arduino Uno and other components. It is necessary to make specific arrangements for buzzers and relays that draw much electricity. For the buzzer, we utilized a Darlington pair of BC 547 transistors driven by a relay driver. We used two BC 547 transistors to power the indicator LEDs, green and red.

When we first turn on our prototype, a welcome message appears on the screen. It starts collecting data in real-time from all of the sensors. This data is then sent to the server and shown on the screen. If any of the real-time values surpass the predefined values, the relay and buzzer sound an alert, and the display is updated. A malfunctioning relay will disconnect the loads if it continues for a specified period. Relays are used to connect loads to the rest of the system while comparison continues as usual. If the issue is addressed, the comparison continues as usual.

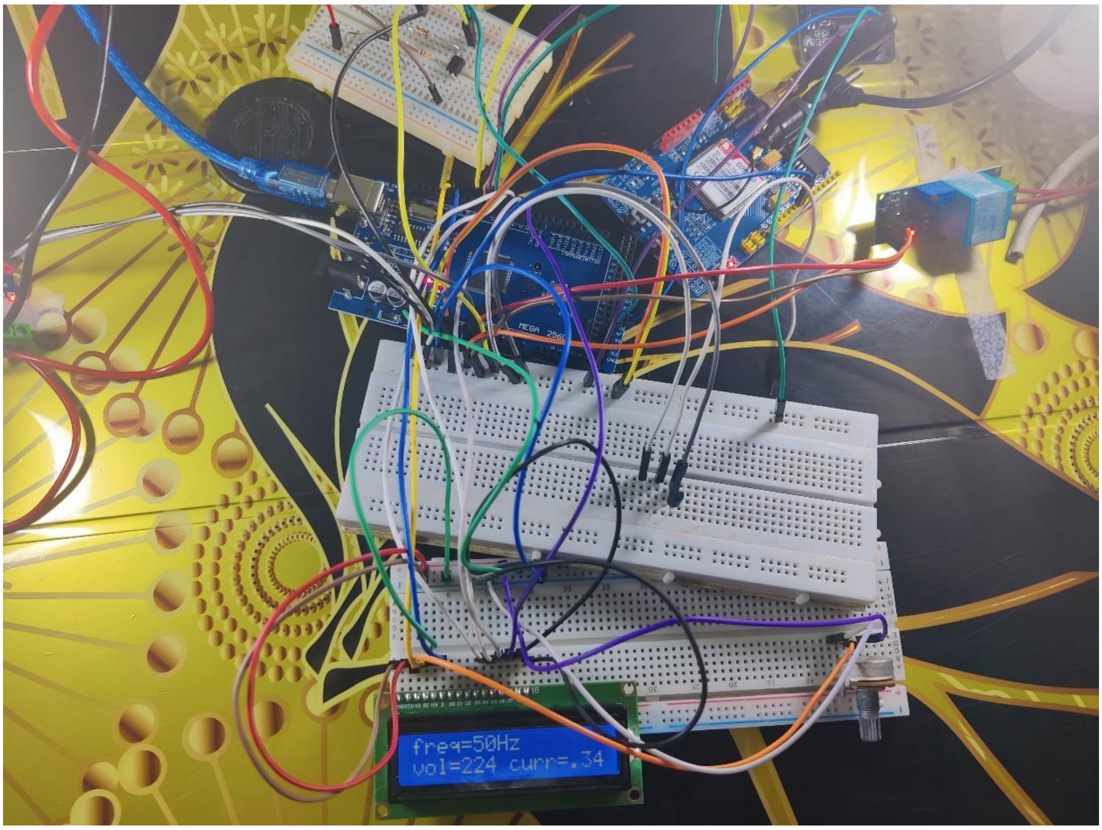

Figure 3.21: Full Setup (Hardware)

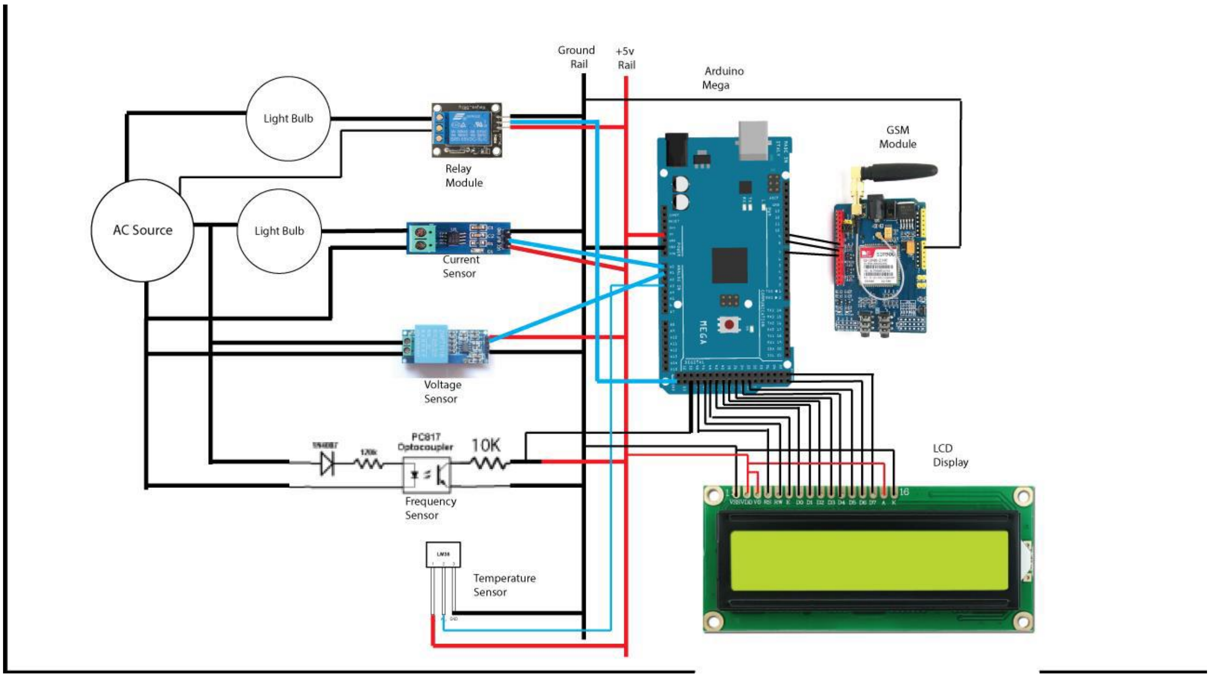

Figure 3.22: Full Setup (Software)

Chapter 4

Result Analysis and Discussion

This chapter will analyze the different parameters' results and discuss their impact on this project.

4.1 Voltage Analysis

In Bangladesh, the standard single-phase voltage is 230V. The power sector is still developing, and we do not get 230V all the time in everywhere. In cities, the voltage more of the time remains more than 230V, and in villages, the voltage remains under 230V. So, in this case, we had taken the under-voltage is 220V and overvoltage is 240V. If the voltage level goes under 220V, the relay shut down the prototype, and also, if it goes over 240V, the same will happen. We had varied the voltage from 220V to 240V to see the accuracy of our prototype value and compared it with the multimeter value. Here, the multimeter value is V_m, and the prototype measuring value is V_r. The accuracy is $\frac{Vr}{Vm} * 100\%$

V_m (in voltage)	V_r (in Voltage)	Accuracy (in %)
221	220	99.547%
222	221	99.549%
223	222	99.551%
224	223	99.553%
225	224	99.555%
226	225	99.557%
227	226	99.559%
228	227	99.561%
229	228	99.563%
230	229	99.565%
231	230	99.567%
232	231	99.568%
233	232	99.570%
234	233	99.572%
235	234	99.574%
236	235	99.576%
237	236	99.578%
238	237	99.579%
239	238	99.581%

240	239	99.583%
241	240	99.585%

Table 4.1: Voltage Analysis

So, we can the accuracy is 99.547% to 99.585% which is good enough to observe.

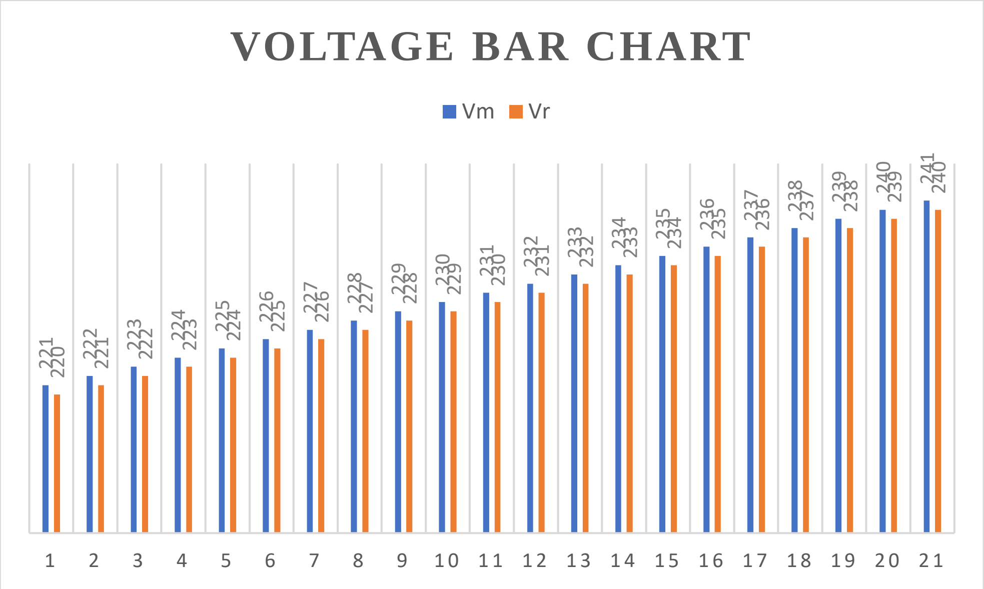

Figure 4.1: Voltage Bar Chart Representation

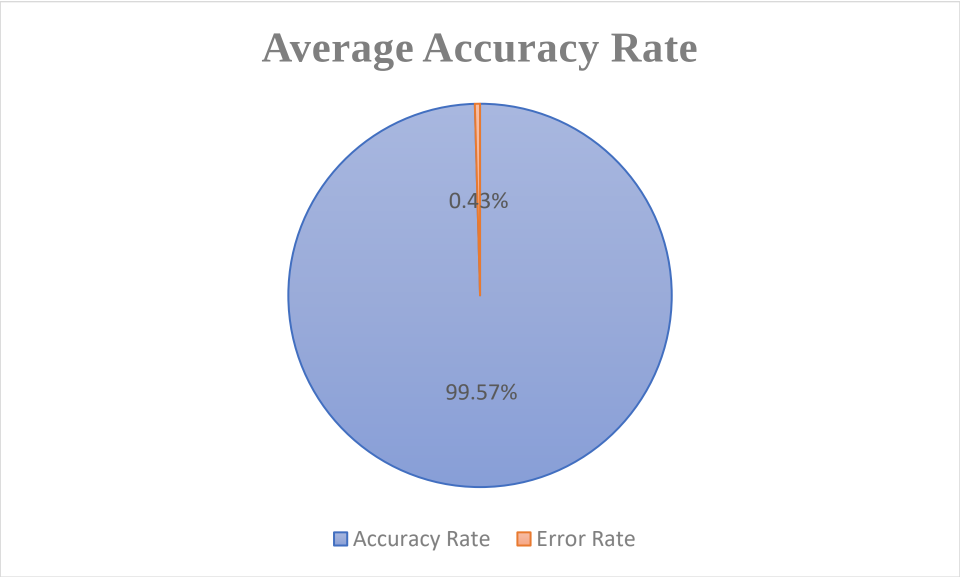

Figure 4.2: Voltage Average Accuracy Rate

4.2 Frequency Analysis

Bangladesh has a single grid frequency of 50 Hz. However, when load changes, the frequency also changes. The frequency is regulated all the time to keep it constant. In our country, the frequency tolerance level is $\pm 2\%$ [28].

So, we had set our projects under frequency is 49 Hz and over frequency is 51 Hz. If the frequency goes under 49 Hz, the relay goes off, and when the frequency exceeds 51 Hz, the relay will also turn off. In other conditions, the power supply will be on. In our project, the frequency level fluctuated from 50.74Hz to 50.80Hz.

F_m	F_r
50	50.74
50	50.75
50	50.76
50	50.77
50	50.78
50	50.79
50	50.80

Table 3.2: Frequency Analysis

4.3 Current Analysis

The amount of current a system draws from the power source depends upon the load that operates actively. Our power outlets usually can deliver up to 2A for 220v. Each device that we use in our home has a specific power rating. For our experiment, we have used bulbs of 60W. When using one light bulb, our reading changes from 0.31-0.37 A. So, we have defined our Under Current as 0.27A, and over current is assumed just the double of it assuming 0.65A. If the current goes below 0.27A, then the relay will be turned off. The same thing will happen for currents over 0.65A as too much current flow will burn the total system for any reason. The comparison between our prototype value (I_r) and the value gained by using a multimeter (I_m) is the series connection given below.

I_m (in Ampere)	I_r (in Ampere)
0.28	0.32
0.30	0.29
0.30	0.31
0.30	0.33
0.30	0.34
0.31	0.30
0.32	0.33
0.32	0.35
0.33	0.31
0.34	0.35

Table 4.3: Current Results

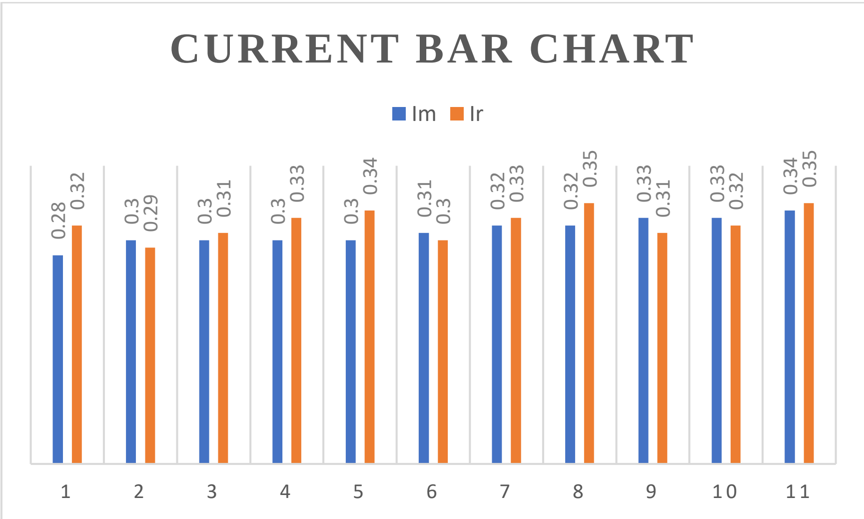

Figure 4.3: Current Bar Chart Representation

4.4 Temperature Analysis

To measure the temperature, we have used an LM35 temperature sensor. It operates on the diode's fundamental principle. As the temperature rises, the voltage across the diode increases, and we can calculate the temperature by coding and modifying the analog value, which varies from 0-1024. The three-terminal voltage sensors are capable of measuring temperatures ranging from -55°C to 150°C. The sensitivity of LM35 is 10mV/°C [29]. To compare and test our prototype's accuracy, we have taken a room temperature sensor found in the market and have calculated our accuracy. The temperature reading received from the market found device is (T_m), and our reading from LM35(T_r) is compared, and the table is shown below:

T_m (in Celsius)	T_r (in Celsius)	Accuracy (in %)
29.5	29.2	98.98%
30	29.2	97.33%
30	29.6	98.38%
31	30.5	98.38%
31	30.6	98.70%
31	30.8	99.35%
31.2	30.2	96.79%
31.2	31	99.36%
31.5	31.2	99.04%

Table 4.4: Temperature Results

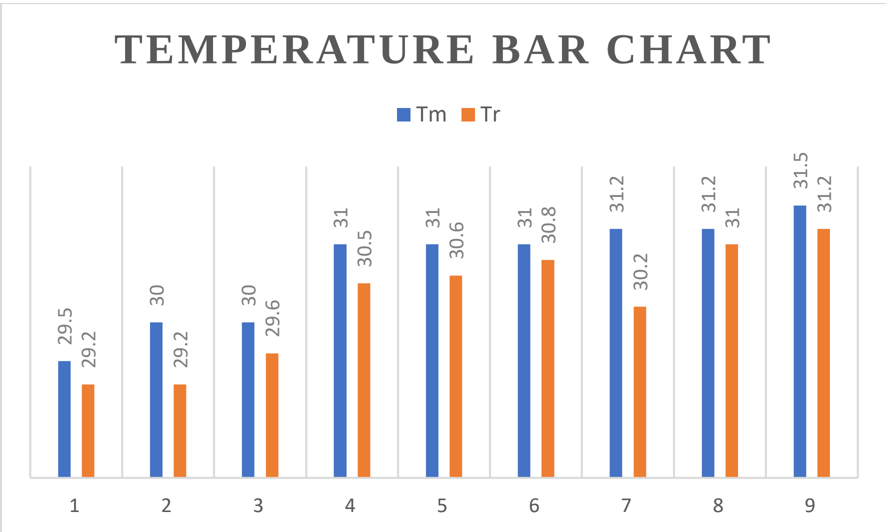

Figure 4.4: Temperature Bar Chart Representation

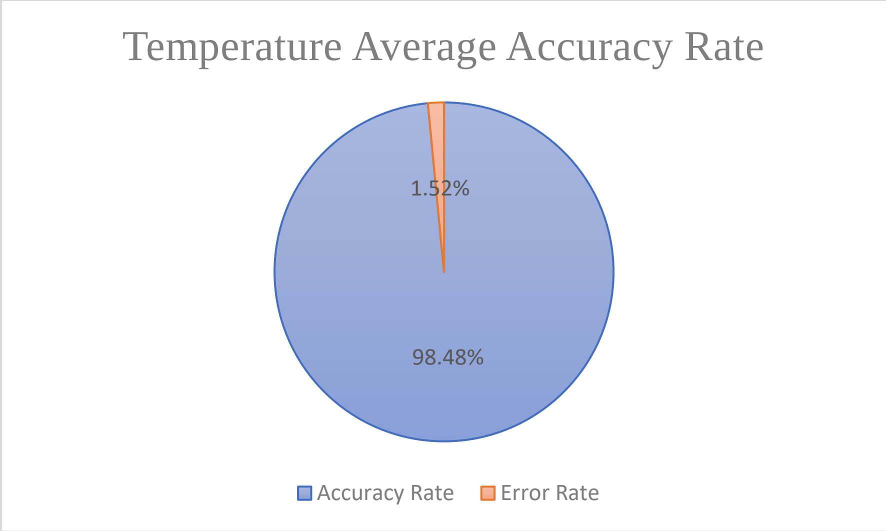

Figure 4.5: Temperature Average Accuracy Rate

4.5 GSM Message Sending

If any of the parameters indicated above exceeds the specified limit, the GSM module will notify the user of a problem with the system. Now, the speed of this system is critical as, if delayed, it can result in significant damage to the whole system. The following table shows how much time it was needed for the SMS to reach the user's phone for six attempts. This has been performed under ideal conditions, such as the weather is stable, not in a confined place, and good GSM network.

Time Delay in receiving(seconds)
4.53
4.55
4.56
4.57
4.59

Table 4.5: Message Sending Time

An example of the received message is given below:

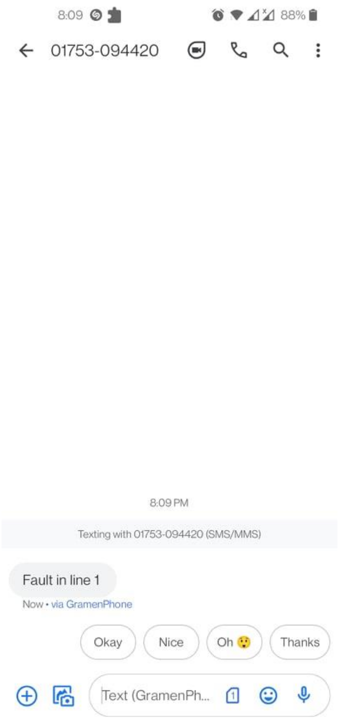

Figure 4.6: GSM Message Sending

Chapter 5

Conclusion

5.1 Conclusion

Monitoring requires collecting essential measurements from the monitored assets. The data collected can be utilized to assess and diagnose the assets' status, which is extremely valuable for scheduling maintenance, managing malfunctions, and maximizing the interval between human and high voltage equipment. Most power system equipment is known to have high voltage and to produce electromagnetic which may damage human health. This suggested system is specifically intended to monitor the status of power system protection used in scattered sites. Many parameters may be measured and regularly monitored. The metrics examined may be prohibitively expensive and difficult to monitor if a person is hired at each location, and data is also prone to inaccuracies when checked manually. The biggest problem is that all power system data are gathered manually on a single sink. All the issues mentioned above may be mitigated to some degree through our suggested approach.

5.2 Future Works

We can send the plant authority personalized SMS to follow the plant and what happens with the GSM module. It also provides a specific SMS format that the microcontroller can utilize to input the required function.

The interface is designed in the manner of a graphical user interface (GUI). On an integrated display, the devices and their parameters can be monitored in a variety of ways. These include, but are not limited to, how often the device was activated, how much time it was running, how much voltage was used to power it, its impedance, whether it was in oil, how warm it is, how well it is cooled down and the rating of power. Operators may see how each device performs with this method in real-time. In addition, if something goes wrong, the operator is immediately advised of which equipment has a problem or failure. It is both possible to prevent blackout events and to ensure a consistent power supply.

The cooling flow and temperature management system includes the temperature sensor module and cooling control system for better flow and temperature maintenance of the cooling system. It can be set to flow quickly and continuously if the temperature of the module or device is beyond a predetermined limit and flows slowly and sporadically if the temperature is within the acceptable range.

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Appendix A.

```
#include <LiquidCrystal.h>

#include <SoftwareSerial.h>

#define ACS_Pin A1

#include <Filters.h>



SoftwareSerial mysim(7,8); // connect gsm modem on this pin

String smstext;



double sensorValue=0;

double sensorValue1=0; //voltage

int crosscount=0;

int climbhill=0;

double VmaxD=0;

double VeffD;

double Veff;




float ACS_Value;

float testFrequency = 50;

float windowLength = 40.0/testFrequency;        // current

float intercept = 0;

float slope = 0.0752;

float Amps_TRMS;
```

```
unsigned long printPeriod = 1000; // in milliseconds
unsigned long previousMillis = 0;// Track time in milliseconds since last reading


int tempPin=2;//defines pin 2 as sensorPin
int temp;//defines variable for LM35


const int rs = 12, en = 11, d4 = 5, d5 = 4, d6 = 3, d7 = 2; //lcd display part
LiquidCrystal lcd(rs, en, d4, d5, d6, d7);



void setup() {
Serial.begin(9600);

TCCR1A = 0;
TCCR1B = 2;
TCNT1  = 0;
TIMSK1 = 1;
EIFR |= 1;
attachInterrupt(0, timer1_get, FALLING);  // enable external interrupt (INT0)



pinMode(tempPin,OUTPUT);//output pin of LM35



pinMode(11, OUTPUT);// connected to S terminal of Relay
```

```
lcd.begin(16, 2);
}




uint16_t tmr1 = 0;
float period, frequency;

void timer1_get() {
  tmr1 = TCNT1;
  TCNT1  = 0;   // reset Timer1
}

ISR(TIMER1_OVF_vect) {  // Timer1 interrupt service routine (ISR)
  tmr1 = 0;
}




void loop() {
sensorValue1=sensorValue;
sensorValue = analogRead(A0);
if (sensorValue>sensorValue1 && sensorValue>511){
  climbhill=1;
  VmaxD=sensorValue;
  }
if (sensorValue<sensorValue1 && climbhill==1){
  climbhill=0;
  VmaxD=sensorValue1;
```

```
  VeffD=VmaxD/sqrt(2);
  Veff=(((VeffD-420.76)/-90.24)*-210.2)+210.2;
  Serial.println(Veff);
  VmaxD=0;
}

Serial.println("the voltage is");
Serial.println(Veff);
```

```
uint16_t value = tmr1;
period = 8.0 * value/16000;
if(value == 0)
    frequency = 0;
  else
    frequency = 16000000.0/(8UL*value);
  Serial.print("the freq is");
  Serial.println(frequency);
```

```
  RunningStatistics inputStats;
  inputStats.setWindowSecs( windowLength );
   ACS_Value = analogRead(ACS_Pin);
```

```
 inputStats.input(ACS_Value);

  if((unsigned long)(millis() - previousMillis) >= printPeriod) {
    previousMillis = millis();

    Amps_TRMS = intercept + slope * inputStats.sigma();

    Serial.println( "Amps: "+String(Amps_TRMS ));
   }

temp = analogRead(tempPin);     //code for LM35
float celsius = (temp/9.31);
float farhanheit = (celsius*9)/5 + 32;//conversion into farhanheit

Serial.print("TEMPRATURE = ");
Serial.print(celsius);
Serial.print("C");
Serial.println();
Serial.print(farhanheit);
Serial.print("F");
Serial.println();
```

```
if(Veff<220 && Veff>240){
  digitalWrite(11,HIGH);
   smstext =  "\nFault in line 1";
      sendSMS(smstext);
      Serial.println(smstext);

}

if(frequency<49 && frequency>51){
  digitalWrite(11,HIGH);
   smstext =  "\nFault in line 1";
      sendSMS(smstext);
      Serial.println(smstext);
}


if(Amps_TRMS<0.27 && Amps_TRMS>.65){
  digitalWrite(11,HIGH);
   smstext =  "\nFault in line 1";
      sendSMS(smstext);
      Serial.println(smstext);
}

lcd.setCursor(0,0);
lcd.print(frequency);
lcd.setCursor(0,1);
lcd.print("vol=");
lcd.print(Veff);
lcd.print("curr=");
```

```
lcd.print(Amps_TRMS);

 delay(5000);

}

void sendSMS(String message)
{
  mysim.print("AT+CMGF=1\r");                    // AT command to send SMS message
  updateSerial();
  delay(1000);

  mysim.println("AT + CMGS = \"+ZZxxxxxxxxxx\"");  // recipient's mobile number, in
international format 'ZZ' is the country code and the rest is of the mobile number
  updateSerial();
  delay(1000);

  mysim.println(message);                        // message to send
  updateSerial();
  delay(1000);

  mysim.println((char)26);                       // End AT command with a ^Z, ASCII code 26
  updateSerial();
  delay(1000);

  mysim.println();
```

```
  delay(100);                              // give module time to send SMS

}

void updateSerial()
{
  delay(500);
  while (Serial.available())
  {
    mysim.write(Serial.read());//Forward what Serial received to Software Serial Port
  }
  while(mysim.available())
  {
    Serial.write(mysim.read());//Forward what Software Serial received to Serial Port
  }
}
```