Smart Single Phase Power Factor Improver Equipment For Domestic User

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This is to certify that "**Arslan Ghaffar 1327-2019**", "**Bilal Hussain 1197-2019**" & "**RazaUllah 1004-2019**" have successfully completed the final project **Smart Single Phase Power factor Improver Equipement for Domestic User**, at the **Hamdard University**, to fulfill the partial requirement of the degree **Bachelor of Electrical Engineering.**

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Smart Single Phase Power Factor Improver Equipment For Domestic User

Sustainable Development Goals

(Please tick the relevant SDG(s) linked with FYDP)

SDG No	Description of SDG	SDG No	Description of SDG
SDG 1	No Poverty	SDG 9 ✦	Industry, Innovation, and Infrastructure
SDG 2	Zero Hunger	SDG 10	Reduced Inequalities
SDG 3	Good Health and Well Being	SDG 11 ✦	Sustainable Cities and Communities
SDG 4	Quality Education	SDG 12 ✦	Responsible Consumption and Production
SDG 5	Gender Equality	SDG 13 ✦	Climate Change
SDG 6	Clean Water and Sanitation	SDG 14	Life Below Water
SDG 7 ✦	Affordable and Clean Energy	SDG 15	Life on Land
SDG 8	Decent Work and Economic Growth	SDG 16	Peace, Justice and Strong Institutions
		SDG 17 ✦	Partnerships for the Goals

ABSTRACT

In the realm of contemporary energy optimization, the project "Smart Single Phase Power Factor Improver Equipment For Domestic Users" addresses the pressing need for efficient power consumption in residential settings. With escalating energy demands and environmental concerns, power factor enhancement becomes pivotal. This project proposes an innovative solution by integrating advanced control algorithms and real-time monitoring, redefining power factor management. The equipment dynamically adapts to load variations, optimizing power factor in real time and curbing wastage.

Its user-centric design offers an intuitive interface, bridging homeowners and their energy consumption goals. Users access real-time power factor data and equipment adjustments, fostering a sense of energy ownership. Safety measures are paramount, ensuring seamless integration into homes.

In essence, the project merges technology and practicality, revolutionizing energy efficiency. By harmonizing innovation with domestic energy needs, it tackles power factor inefficiency and empowers households to actively shape a sustainable energy future. In a landscape where energy conservation is imperative, this project empowers households to become pioneers in a greener and responsible energy era.

UNDERTAKING

I certify that the project Smart **Single Phase Power Factor Improver Equipement for Domestic User** is our own work. The work has not, in whole or in part, been presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledged/ referred.

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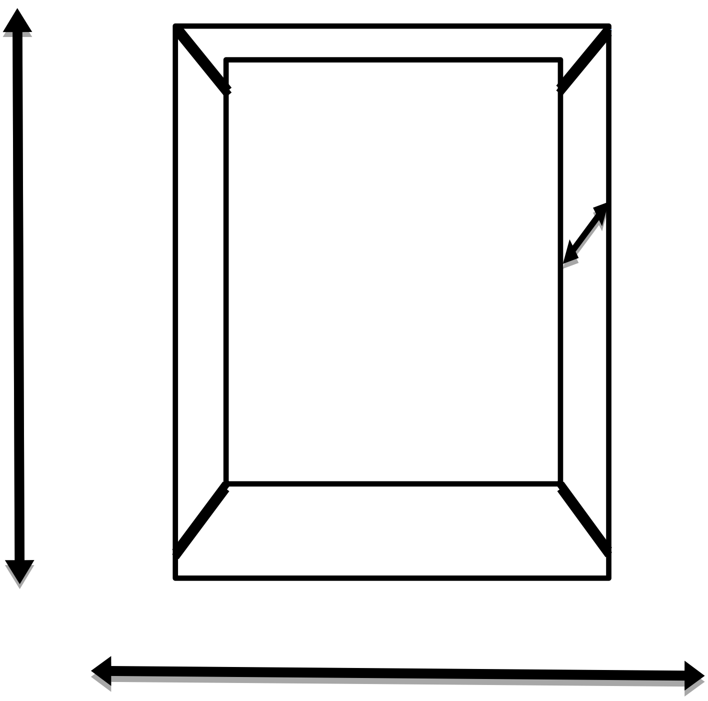
1. Trainer Dimension

Length.. 15 inches
Height..18 inches
Width.. 10 inches



- **Dimension**

Length…..15 inches
Width…..10 inches
Height..18 inches

- **Material**

  - SMC (Sheet Molding Compound)

- **Features**

  - Compact design for space-saving wall mounting
  - Sturdy and durable SMC material construction
  - Suitable for electrical distribution and protection applications
  - Easy installation and wiring
  - Designed to accommodate various electrical components
  - Front access panel for convenient maintenance

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ABBREVIATIONS

S.no	Acronym	Definitions
1.	CB	Circuit Breaker
2.	NO	Normally Open
3.	NC	Normally Close
4.	APFC	Automatic Power Factor Correction
5.	LV	Low Voltage
6.	MV	Medium Voltage
7.	HV	High Voltage
8.	CT	Current Transformer
9.	DB	Distribution Box
10.	DC	Direct current
11.	RYB	Red Yellow Blue
12.	AC	Alternating Current
13.	SLD	Single Line Diagram
14.	MCB	Miniature Circuit Breaker
15.	SP	Single Pole
16.	DP	Double Pole
17.	TP	Triple Pole
18.	FP	Four Pole
19.	PF	Power Factor

CHAPTER 1

INTRODUCTION

Chapter Overview

In this chapter we will discuss the details background of the project and try to understand that why we need this project and how important this project is for the university and what problems this project will going to solve and what we aim while designing and making this project. Also the whole report summary will be discussed under the heading of organization of thesis.

1.1 Background

Electricity is an critical a part of contemporary existence, and domestic users depend upon a stable and efficient electric supply for their daily sports. However, the quality of electrical energy can vary, impacting the performance of household home equipment and the general efficiency of the electrical distribution device. One essential element of energy fine is strength component.

Power component is a degree of how efficiently electric strength is transformed into beneficial work. It represents the ratio of actual power (in watts) to apparent strength (in volt-amperes) in an electrical circuit. A electricity aspect of one (or a hundred%) indicates that each one the power is getting used correctly, at the same time as a lower energy component signifies wasted energy and expanded energy charges.

In many home households, energy aspect troubles are prevalent because of the sizeable use of inductive hundreds like automobiles, fridges, and air conditioners. These loads draw reactive strength, leading to a lagging electricity thing. A low power issue can bring about extended strength bills, decreased equipment lifespan, and inefficient energy distribution.

To address these troubles, a Smart Single-Phase Power Factor Improver Equipment has been evolved for domestic customers. This system targets to decorate power satisfactory and optimize the power thing in residential settings. Similar to the demanding situations faced inside the transmission and distribution networks, home strength factor problems can lead to gadget harm and higher electricity consumption.

1.1.1 Key Objectives of the Project:

Power Factor Correction: The primary goal of this challenge is to expand a tool that actively corrects the power element of the electrical supply in home settings. By monitoring the electricity element in real-time, the system will automatically regulate the power issue to close to team spirit [1] by using adding or subtracting reactive power as needed.

Energy Efficiency: Improving the electricity component in households will cause decreased energy consumption, decrease strength payments, and a greater sustainable power footprint. The assignment aims to make contributions to electricity conservation and fee financial savings for home customers.

Smart Monitoring and Control: The Smart Single-Phase Power Factor Improver Equipment could be prepared with advanced tracking and manage capabilities. Users can access real-time energy aspect facts via a person-pleasant interface, letting them song improvements and optimize their power utilization.

Safety and Reliability: Ensuring the safety and reliability of the gadget is paramount. The device will include shielding features to prevent overcorrection or capacity electric problems. It will also be designed for long-term reliability to serve domestic customers successfully.

User-Friendly Design: The device may be designed with home users in mind, with a truthful set up system and intuitive controls. It will seamlessly combine into present electrical setups.

By addressing energy element issues at the domestic stage, this undertaking aims to beautify the satisfactory of energy deliver for households, lessen power waste, and make contributions to a extra sustainable and efficient electric distribution machine. This Smart Single-Phase Power Factor Improver Equipment will empower home users to take manipulate in their electricity factor and, in flip, their energy charges and environmental impact.

1.2 Motivation

The motivation at the back of the improvement of the Smart Single-Phase Power Factor Improver Equipment for Domestic Users is pushed with the aid of the vital to enhance electricity efficiency, reduce strength costs, and reduce the environmental effect of residential strength intake. By enhancing the power factor in domestic settings, we goal to empower house owners to conserve energy, lower their software bills, and expand the lifespan of their home equipment. This venture also aligns with the broader goals of lowering strain on electrical grids, promoting sustainable strength practices, and fostering innovation that positively affects the ordinary lives of hundreds of thousands of families. Ultimately, our motivation is rooted inside the notion that knowledgeable customers, ready with accessible and efficient solutions, can play a pivotal function in creating a greater energy-green and environmentally responsible destiny.

1.3 Problem Statement

The propose of this project fulfilling the following objectives:

1. The massive use of inductive loads in families, which includes cars and appliances, results in a frequent difficulty of low energy aspect. This consequences in inefficient power usage, extended electricity payments, and environmental impact.
2. Currently, there's a lack of on hand and consumer-pleasant solutions for house owners to cope with electricity element problems of their houses. This challenge targets to fill this gap with the aid of growing a Smart Single-Phase Power Factor Improver Equipment tailored for home users, permitting them to optimize energy component and enhance electricity efficiency.
3. Low energy component not best affects strength efficiency but additionally contributes to multiplied strength consumption and greenhouse gasoline emissions, aligning with the growing want for sustainable electricity practices. This assignment aims to address those inefficiencies and environmental issues in residential electricity consumption.

1.4 Aim

1 Design, broaden, and set up a Smart Single-Phase Power Factor Improver Equipment for domestic users.

2 Empower homeowners to optimize their energy element.

3 Enhance energy efficiency in residential strength consumption.

4 Reduce electricity prices for families.

5 Promote sustainable and environmentally responsible electricity utilization in home settings.

1.5 Objective

1. Design and Develop: Create a user-pleasant Smart Single-Phase Power Factor Improver Equipment tailored for clean integration into domestic electrical setups.

2. Power Factor Optimization: Enable house owners to actively reveal and enhance their power aspect, thereby reducing reactive electricity intake.

3. Real-Time Monitoring: Implement superior monitoring features to offer users with actual-time electricity component data and utilization insights thru an intuitive interface.

4. Cost Savings: Help home users reduce their electricity payments through casting off wasteful strength consumption related to low power factors.

5. Appliance Protection: Extend the lifespan of family appliances via supplying them with cleaner and more green electrical energy.

6. Environmental Impact: Contribute to a greener surroundings by way of decreasing normal power intake and greenhouse fuel emissions associated with inefficient electricity factors in residential settings.

7. Grid Resilience: Alleviate strain on local electric grids, main to improved grid reliability and decreasing the need for high-priced infrastructure upgrades.

8. User Empowerment: Educate and empower homeowners to make knowledgeable decisions about their electricity utilization, fostering a culture of strength performance and sustainability.

1.6 Where will it be installed?

The project will be installed in the power system lab in Hamdard University. The Smart Single-Phase Power Factor Improver Equipment can be seamlessly integrated into our lab centers. This project is meticulously tailor-made to suit the lab's requirements. Our aim is to create a gadget capable of rapidly detecting and rectifying power issue troubles in unmarried-phase electric setups. The user-pleasant show interface guarantees that the device's operation and strength element optimization may be without difficulty comprehended by way of all people the use of the lab. This installation represents a widespread leap forward in improving our lab's capabilities for research, experimentation, and training inside the discipline of energy factor improvement and energy performance.

1.7 Organization of Thesis

This thesis document is structured to offer a complete evaluate of the improvement and implementation of the Smart Single-Phase Power Factor Improver Equipment for home customers. The report includes several chapters, starting with an advent that outlines the assignment's dreams, objectives, and the set up place within the power system lab at Hamdard University. The subsequent bankruptcy conducts an intensive literature evaluate, exploring current research on electricity issue optimization and power efficiency in residential settings. The method chapter offers particular insights into the gadget's layout and development, supported by visual aids like block diagrams and flowcharts. We then describe the practical implementation of the gadget inside the lab and gift findings on strength aspect improvements within the results phase. A complete dialogue follows, addressing demanding situations confronted and evaluating results with preliminary objectives. The conclusions and recommendations segment summarizes the project's advantages, recognizes limitations, and shows destiny upgrades, even as the appendix includes undertaking codes and technical info. This dependent technique ensures a coherent presentation of the Smart Single-Phase Power Factor Improver Equipment undertaking, facilitating a holistic knowledge of its improvement and impact in home settings.

CHAPTER 2

LITERATURE REVIEW

Chapter Overview

In this chapter, we embark on a adventure via current research and knowledge associated with our project's central topics. We discover the standards of strength component correction, home energy efficiency, and clever power control systems. Our goal is to provide a comprehensive information of the context in which our undertaking operates and to spotlight key insights from preceding research and enterprise practices. We also address demanding situations and barriers even as glimpsing into future developments and improvements inside the field. By delving into this literature evaluation, we lay the muse for the subsequent chapters wherein we introduce and examine our project's unique components and findings.

2.1 INTRODUCTION

In a world wherein power efficiency and sustainability are paramount, the optimization of electricity consumption is a popular challenge. This project embarks on a journey to discover modern solutions designed to beautify electricity efficiency for domestic users. The quest for stepped forward energy usage transcends industries, touching the lives of people and households in their homes.

This introduction units the stage for a comprehensive exam of numerous strategies and technology geared toward empowering families to make smarter power choices. As we navigate via this exploration, we will delve into the world of power issue correction, clever home equipment, and modern electricity management structures.

Our objective is to shed light on how those improvements can revolutionize the way we eat and manipulate electricity in our houses. By synthesizing current know-how and insights, we intention to offer a foundation for homeowners to make informed choices, lessen power waste, decrease software bills, and make a contribution to a more sustainable future.

Through this task, we invite you to embark on a adventure in the direction of a more power-efficient and green household, in which technology and clever practices integrate to create a greener and more value-powerful dwelling surroundings.

2.2 POWER FACTOR

Consider the power factor (PF) of an alternating current (AC) power system to be a means of measuring "how much actual power gets to your devices compared to the amount of current flowing through the system."[2] The circuit's real power is what it can truly supply over time. Consider the current and voltage in the circuit to be the primary actors in how power operates. The projected power may not always match the actual power due to factors such as how the load stores energy, changes in the power supply, or distortions induced by certain equipment. This discrepancy is similar to what happens when what you expect does not occur, as depicted in Figure 2.1.

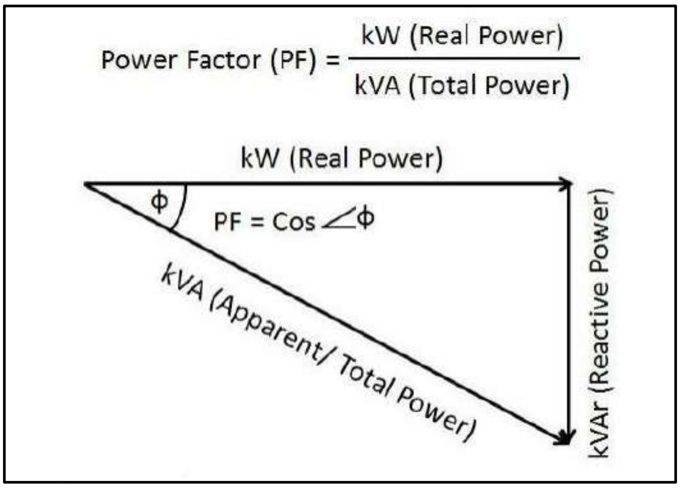


Figure 2.1: Schematic Diagram for Power Factor [2]

The most environmentally friendly way to load a supply system is by using loads with energy factors of 1.0, while loads with strength factors of 0.5 result in significantly reduced supply system losses. A poor power factor can be attributed to a high phase difference between voltage and current at the load terminals, a high level of harmonic content, or a distorted or discontinuous current waveform. Typically, inductive loads such as induction motors, power transformers, lighting fixture ballasts, welders, or induction furnaces are responsible for the poor phase angle of load currents.Improving a poor power factor caused by a distorted modern waveform often necessitates substantial changes in system layout or costly harmonic filters. On the other hand, addressing a low energy factor due to inductive loads can be achieved by implementing energy factor correction. To ensure effective gadget operation, energy efficiency should be maintained close to 1.0. When an industrial customer's energy factor falls below a certain threshold, usually in the range of 0.9 to 0.95, utilities often impose additional charges

2.2.1 The Causes of a Low Power Factor

1. **Inductive Loads from Appliances:** Many family appliances, together with air conditioners, fridges, and washing machines, utilize induction motors that may draw huge reactive strength, leading to a low strength element. Your clever power component improver can help optimize the strength factor of these appliances.

2. **Imbalanced Loads in Homes:** Uneven distribution of electrical loads throughout exclusive phases in residential electrical systems can reason strength aspect disparities. Your gadget should probably deal with imbalances and improve strength element.

3. **Inefficient Lighting Systems:** Traditional incandescent and fluorescent lighting fixtures structures, normally utilized in houses, are less energy component-green. Your venture ought to discover ways to enhance electricity thing whilst the use of these lighting technology.

4. **Non-Linear Loads from Electronics:** The proliferation of non-linear digital devices like computer systems, TVs, and chargers can introduce harmonics and have an effect on energy factor in residential settings. Your clever gadget can also have functions to mitigate those outcomes.

5. **Underutilization of Appliances:** In families, home equipment are regularly operated below their complete potential or left in standby mode, ensuing in inefficient power element operation. Your task ought to inspect methods to optimize electricity component even for the duration of low-load durations.

2.3 POWER FACTOR CORRECTION

In order to mitigate the negative impacts of electric loads that result in a power factor (PF) of less than 1, power factor correction (PFC) is a strategy. To increase the stability and effectiveness of the transmission network, power factor correction may be used by an electrical power transmission utility.

Individual power consumers could also install rectification to lower the price imposed on them by their provider of electricity.In order to rectify the capacitive Power Factor in circuits using induction motors, decreasing the current's inductive component to cut down on supply losses. Capacitors "Static Power Factor Correction" refers to the connections made at each starter and the control of each starter.

Resistive constituent of motor are:

- Load Current
- Loss Current

Inductive constituent of motor are:

- Leakage reactance
- Magnetizing Current

2.3.1 Static Power Factor Correction

Static Power Factor Correction involves using constant capacitors in electrical structures to counteract the lagging reactive power introduced via inductive hundreds, which includes motors and transformers. By strategically setting capacitors, this technique generates leading reactive strength, which offsets the lagging factor, thereby enhancing the energy factor and making electrical systems extra strength-green. The blessings include reduced electricity losses, value savings, and stronger gadget performance. These systems may be controlled routinely or manually, depending on actual-time necessities. Static energy component correction is a extensively adopted practice for optimizing electricity factor and selling green electrical power utilization.

2.4 STRATEGIES FOR POWER FACTOR CORRECTION

Improving power factors necessitates the use of various strategies based on the kind of load - whether constant or changing over time [3]. There are several methods for adjusting the power factor to improve the efficiency of electrical systems. Establishing capacitor banks is one of these approaches. These banks produce reactive power, which compensates for the delay induced by equipment such as motors. Special motors known as synchronous condensers are used in bigger industrial settings. When pumped with excess electricity, these motors produce a lot of reactive power. Then there are Active Power Factor Correction (APFC) systems, which employ devices to monitor and change power factors in real time in order to keep them near to the optimum value of Unity (1). All of these strategies work well together to improve the efficiency of electrical systems, reduce losses, and lower energy expenditures. It's a wise approach towards conducting cost-effective and sustainable electricity operations.

2.5 DEVICES FOR CORRECTING POWER FACTORS

Power factor improving devices are quite significant. They contribute by delivering the extra reactive power that a system need to optimise its power factor and maintain a stable voltage profile. The shunt capacitor is the most common device used for this purpose in many sectors. It's frequently utilised and performs an excellent job of increasing power factors.

2.5.1 Static Capacitors

Shunt capacitors are very important in industrial networks. They jump in to give the extra reactive power that balances out the erratic current taken by certain equipment. Using these capacitor banks has several advantages: they lessen the burden on the power supply, enhance the power factor, and help keep the total voltage steady. It's fascinating that these capacitor banks only influence objects locally and don't interact with things in distant places. They are classified into three types: those that can be switched on and off, those that are fixed, and those that are a combination of both. You may also switch them manually or automatically. People prefer these capacitor banks because they are dependable and simple to set up, and straightforward to get up and running [4].

Figure 2.2: Static Capacitor [4]

2.5.2 Synchronous Condensers

In the past, we'd utilise a synchronous motor, also known as a synchronous condenser, as a compensating device with preset settings. It balanced things out by altering the field excitation to a specified amount. But here's the thing: maintaining and creating this gadget with its mechanical pieces is a bit of a pain. That is why many prefer capacitors to synchronous condensers. Capacitors provide more flexibility than synchronous condensers' set compensation level, acting similarly to fixed capacitor banks [4].

Key factors to take into account when contemplating any installation include:

1. The equipment's reliability for the intended purpose.
2. Expected lifespan of the equipment.
3. Initial capital cost of the installation.
4. The ongoing maintenance costs.
5. Operational running expenses.
6. The required space and the ease of installation.

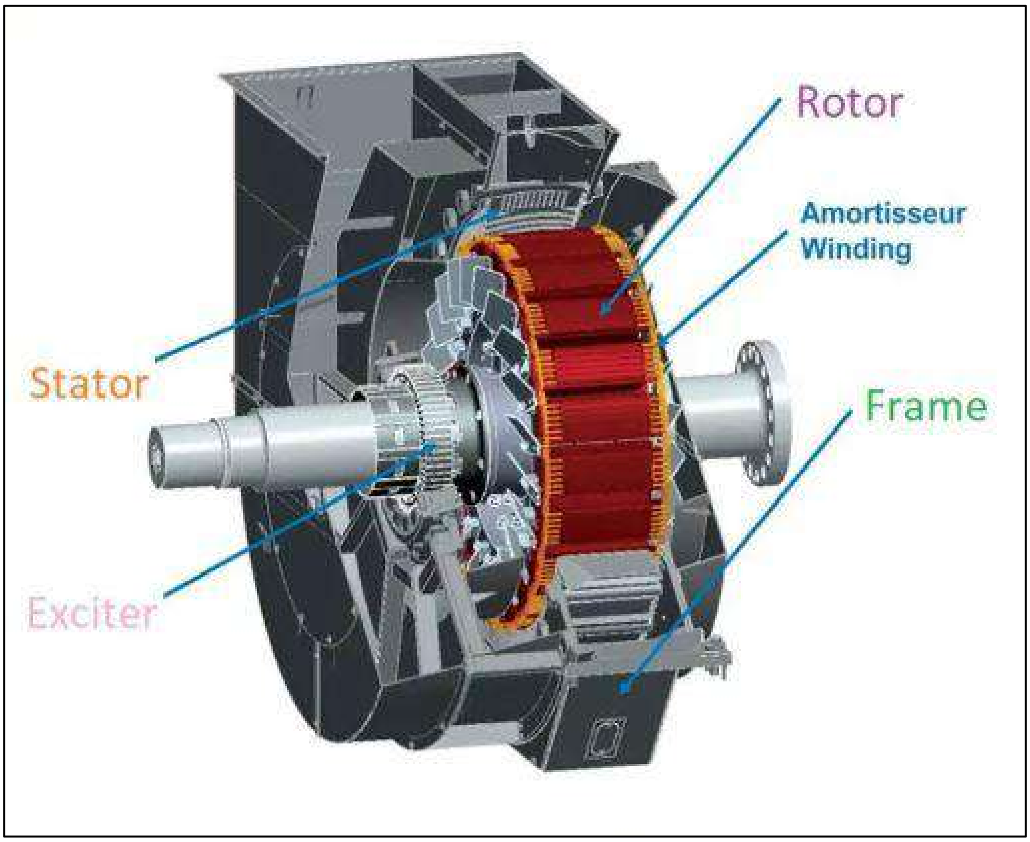


Figure 2.3:Synchronous Condenser [4]

2.5.3 Phase Advancer

A phase advancer is an electrical device used to raise the voltage of an induction motor. It accomplishes this by causing a regulated change in the current flowing through the motor windings. Changing the timing of the current relative to the voltage waveform increases motor efficiency and reduces reactive power usage.

As such, when an induction motor operates with a negative power factor, it can draw excessive reactive power from the grid and put a strain on the power system This not only increases energy costs but puts a burden power distribution grid as well. The phase initiators are strategically used to address these issues. They are especially valuable in situations where other methods of power factor correction such as capacitors or synchronous condensers are not possible or very effective.

By optimizing the power factor of induction motors, phase initiators contribute to the efficiency of both industrial and commercial power systems, reducing energy costs and increasing the reliability of power distribution networks [4].

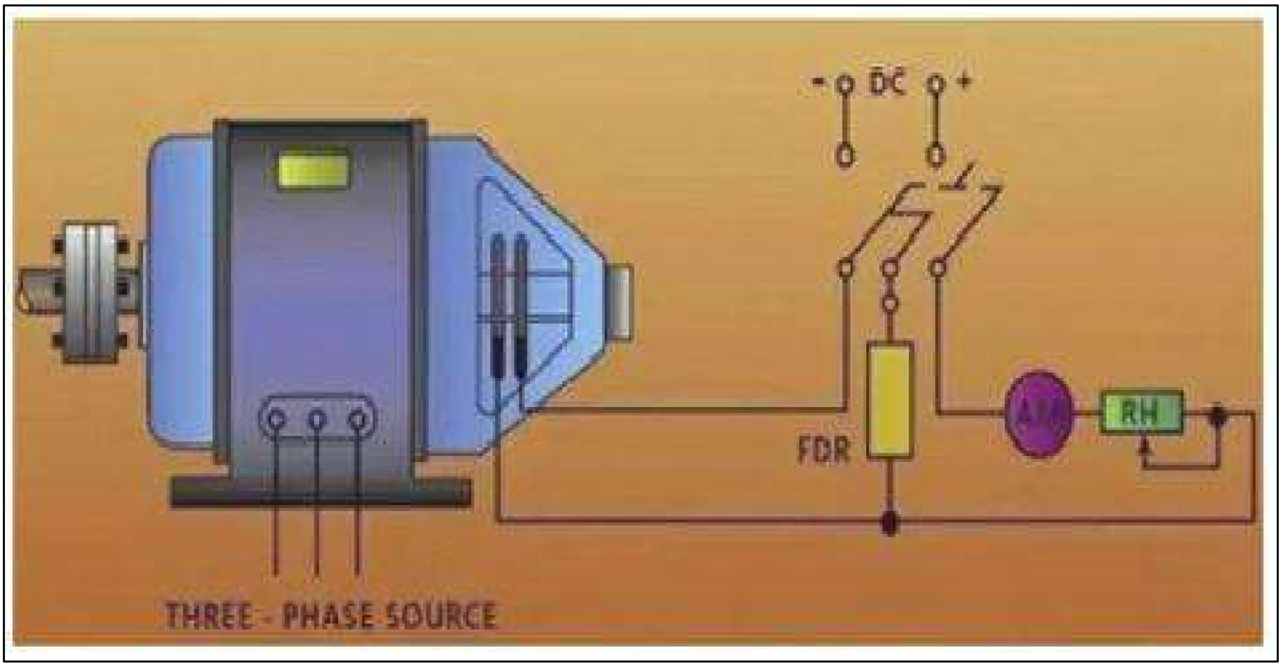


Figure 2.4: Phase Advancer [4]

2.6 LOCATION OF THE CORRECTING DEVICE

To get the most out of power factor correction, it's critical to put these power factor compensators in the proper places. These compensators perform best in three places in the power system: first, on the distribution side of the main substation transformer; second, on each individual motor or machine that works on a motor; and third, at the load centres [5].

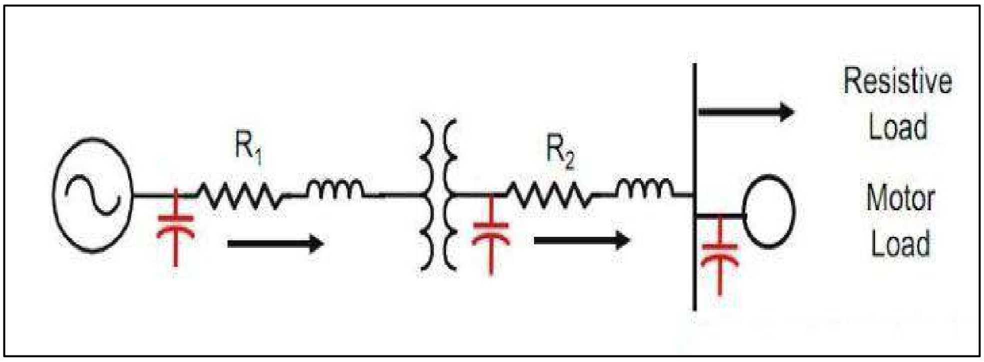


Figure 2.5: Different Capacitor Locations [5]

The location of these compensators might be near the load, next to the transformer, or on the utility side. It is critical to select the correct location while considering how it would effect the system's voltage control, as illustrated in Figure 2.2.

2.7 THE ADVANTAGES OF POWER FACTOR CORRECTION

The following advantages may result from raising a facility's power factor [6]:

1. Power factor surcharges promote increased efficiency
2. reduced demand charges reduce costs.
3. Enhanced Capabilities for Carrying More Load on Existing Circuits
4. Increased Voltage
5. Reduced Power-System Losses

When capacitors minimise losses, they only reduce losses caused by KVAR current. Because they are tied to the squared current, which decreases as the power factor improves, these losses decrease in response to the square of the power factor. Though capacitors incur some losses, they are extremely minor—about one-third of one percent of the KVAR value.

2.8 ENVIRONMENTAL IMPACT OF THE PROJECT

In an era of growing environmental consciousness and the urgent need for sustainable energy solutions, the development of a smart single-phase power factor improvement equipment for domestic users emerges as a beacon of eco-friendliness. Leveraging a capacitor bank expertly controlled by an Arduino microcontroller, this effort addresses power factor cleaning in a way that not only bears on individual homes but in line with global efforts to reduce energy waste and reduce our carbon footprint Commentary- It is also a promising step towards a responsible future.

1. Promoting Energy Efficiency and Conservation

Developing a smart single phase power factor improver equipment for domestic users through the utilization of a capacitor bank controlled by Arduino is not only a technological advancement; it's a considerable step toward promoting a nature-friendly and sustainable technique to strength consumption.

2. Reducing Energy Wastage

One of the maximum great aspects of this mission's nature-friendliness lies in its inherent capacity to lessen strength wastage. Household electrical structures regularly be afflicted by bad power thing due to the presence of inductive hundreds like cars and transformers.

3. Efficient Power Factor Correction

By enforcing this clever electricity factor correction machine, we efficaciously reduce the reactive power call for from the grid. This interprets right into a decrease load on strength era facilities, reduced transmission losses, and an standard lower in electricity consumption. Consequently, fewer natural sources are required for electricity manufacturing, and carbon emissions related to power era are curtailed.

4. Eco-Friendly Use of Capacitors

Furthermore, the mission's use of capacitors for strength component correction underscores its environmentally aware method. Capacitors, in contrast to a few different energy element correction strategies, do no longer devour additional power themselves.

5. Energy Awareness and Efficiency

In addition to its direct electricity-saving blessings, the project promotes a subculture of strength recognition and efficiency amongst home users. By integrating an Arduino-based totally manage device, users advantage real-time visibility into their energy intake patterns and strength aspect improvement.

6. Open-Source Collaboration

Moreover, the use of Arduino as a control mechanism adds an additional layer of efficiency. Arduino's open-source nature encourages innovation and the sharing of thoughts within the global network.

7. Scalability for a Greener Future

Finally, the project's scalability is a noteworthy function that contributes to its eco-friendliness. Its applicability in domestic settings makes it reachable to a huge spectrum of users.

8. A Greener and More Environmentally Responsible Future

In conclusion, the development of a smart single-phase power factor improvement system using a capacitor bank controlled by Arduino represents a remarkable stride towards a nature-friendly and sustainable approach to energy management. Its capability to lessen electricity wastage, foster power recognition, inspire innovation, and scale its impact makes it a pivotal participant in the journey closer to a greener and extra environmentally accountable future. By championing the reason of strength performance, this venture now not simplest blessings individual households but additionally contributes to the renovation of our treasured natural sources and the well-being of our planet.

2.9 PREVIOUS RESEARCH WORK OVERVIEW

There hasn't been much study on how having a low power factor impacts our houses or what we can do to improve it—there's a huge void there.

Waqas Ali, Haroon Farooq, Mohsin Jamil, Ata ur Rehman, Rana Taimoor, Monib Ahmad (2018)

There are numbers of domestic loads which are inductive in modern electrical distribution system like refrigerators, washing machines, air conditioners, water dispenser, fans, water pumps and dryers. Such inductive loads are responsible for the low power factor and inefficient power system. Low power factor causes the more current drawn from the circuit for doing the same amount of work. There are other methods to improve power factor but the most suitable one for domestic load is using capacitor bank[7].

P. Saxena, L. Gidwani and A. K. Sharma (2019)

There are three most popular techniques for improving power factor named as Active, Passive and Active-Passive technique. Firstly, the problem with these techniques is that these are based on buck converter. Hence required AC-DC and then DC-AC conversion which makes the system more complex and expensive. Secondly, there are power losses involved in conversion[8].

Rodríguez, Alejandro & Muñoz, Francisco (2022)

The goal is to make the process of PFC more efficient and inexpensive. The proposed solution will not include any type of conversion. The major component of the purposed solution will be a Capacitor Bank, AT Mega Microcontroller and Arduino Or Raspberry pi for the IoT aspect. The smart control and screening will be included for user friendly experience and result will be cosΘ 0.99.[9]

Shahid and Anwar (2013)

Proposing a electricity aspect development circuit design based on a PIC (Programmable Interface Controller) chip, this solution aims to acquire heightened efficiency and price-effectiveness by means of minimizing aspect rely. The method entails assessing the weight's power factor, then employing an set of rules to perceive and set off switching capacitors as necessary. This capacitive reimbursement method effectively mitigates immoderate reactive components, therefore elevating the strength issue to the desired level [10].

Haque and Sharma (2014)

Conducted changed into a comprehensive simulation and analysis research focused on electricity thing correction specifically tailor-made for metal halide excessive-depth discharge lamps. The have a look at brought an innovative approach, incorporating a changed increase converter ready with energetic devices, complemented by a PI controller for manipulate loop stabilization. The layout prioritized minimizing voltage and present day ripple across the capacitor and inductor, aiming for the lowest possible ripple values. Additionally, the objective turned into to facilitate the absorption of sinusoidal input modern-day to curtail total harmonic distortion (THD) inside the enter present day even as retaining precise output voltage law [11].

R. Abd Allah (2014)

For automated electrical issue rectification, a cutting-edge technology known as the Alienation technique is offered. This approach analyses power factor, active and reactive powers in real time to determine the required capacitor banks. It provides a viable solution by applying alienation coefficients from phase voltage and current inputs. Its use was made possible by ATP and MATLAB programmes [12].

CHAPTER 3

DESIGN & METHODOLOGY

Chapter Overview

In this chapter, the general layout of the research and the strategies used for statistics series are explained in detail. It consists of three foremost elements. The first element offers a highlight about the dissertation layout. The Second part discusses approximately qualitative and quantitative information collection techniques. The ultimate component illustrates the overall studies framework. The cause of this segment is to suggest how the research changed into conducted throughout the examine periods.

3.1 INTRODUCTION

Let me show you to our incredible Automatic Power Factor Correction technology! It's a clever solution that employs an embedded system using an Arduino Nano microcontroller. This ingenious device examines the voltage and current data, calculating time differences to determine how the phases fluctuate, and then calculating the power factor. It constantly monitors this component, altering things as needed by adding capacitors from a bank. A user-friendly screen makes it simple to check the power factor and phase lag. A mobile app allows you to keep an eye on everything and make adjustments in real time. It's like having entire control in the palm of your hand, making it very simple to handle your electrical system and keep everything working Smoothly!

3.2 BLOCK DIAGRAM

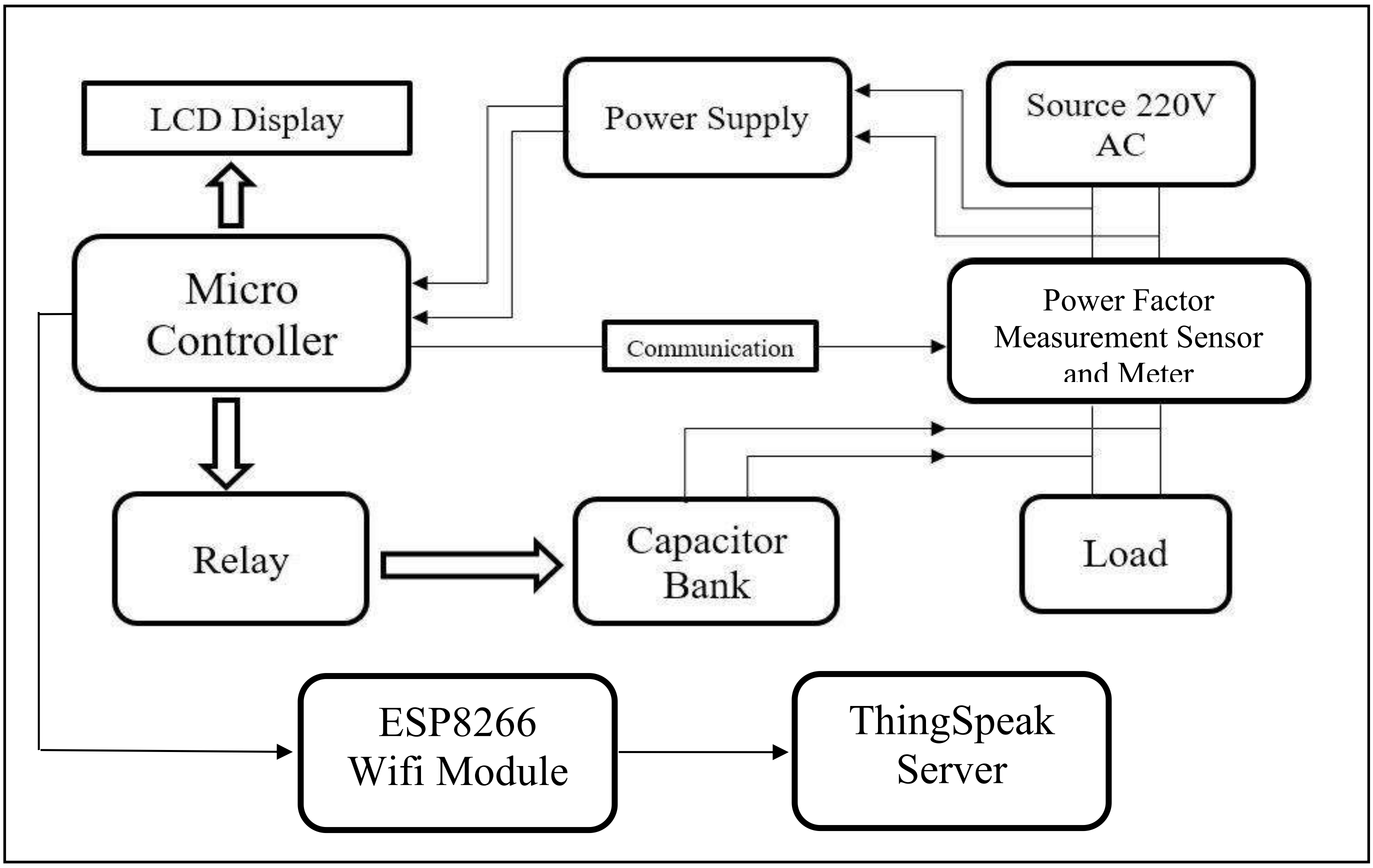


Figure 3.1: Block Diagram of Correction Equipment

3.3 ALGORITHM

Step-1: To begin, enter the voltage and current values..

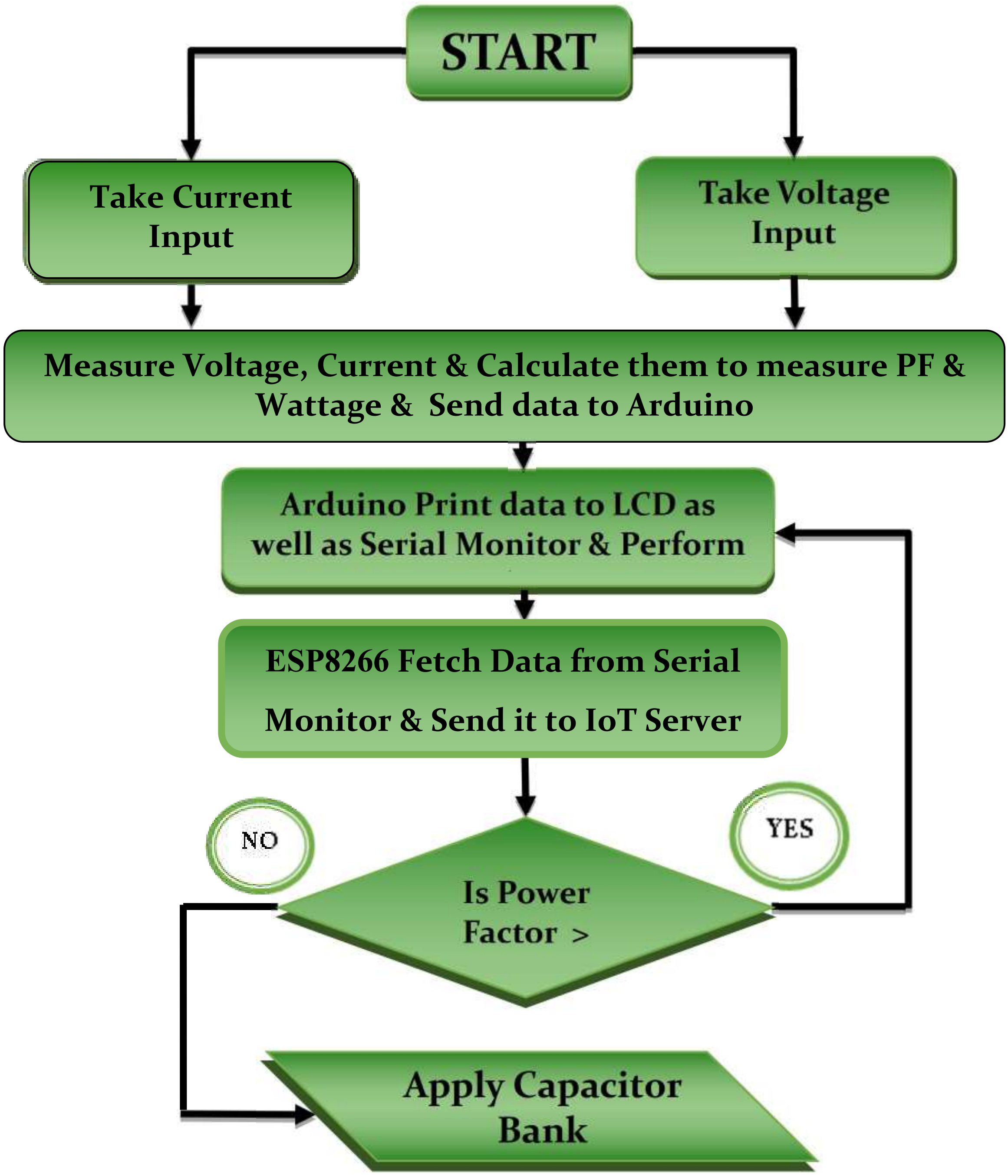
Step-2: Determine the power factor by using the phase lag.

Step-3: Examine the amount of reactive power required in relation to the target power factor.

Step-4: Depending on how much power they supply, turn on or off the appropriate capacitors from the bank.

Step-5: If the power factor does not match what you desire, return to step 1 and start over.

3.4 FLOWCHART



3.5 MEASUREMENT

The essential parameters for measurement include power factor and energy consumption. In addition to these, monitoring the load effectively will benefit from measurements of voltage level, current flow, and active power. To fulfill all these measurement needs, the chosen instrumentation is the Smart Socket [13].

3.5.1 Smart Socket

This smart socket is very amazing! It has all of these very sophisticated microcomputer chips and a unique Energy Metering IC, as well as a very precise current sensor and a display panel. It's ideal for keeping track of how much energy your appliances, such as the air conditioner, refrigerator, or microwave, consume. Whether at home, in a flat, workplace or lab, this gadget provides you the ability to simply regulate your energy use.

Figure 3.2: Smart Socket [13]

3.6 DESIGN OF DIFFERENT LOADS

To ensure that the correcting mechanism functions properly, we devised three distinct sorts of loads. These loads behave similarly to those found in a real power system, simulating how energy is utilised, the type of load it provides, and even power factor.

3.6.1 Design of Resistive(R) Load

To design a pure resistive load, a light bulb or incandescent lamp of 100W can be used. The circuit connection is shown below.

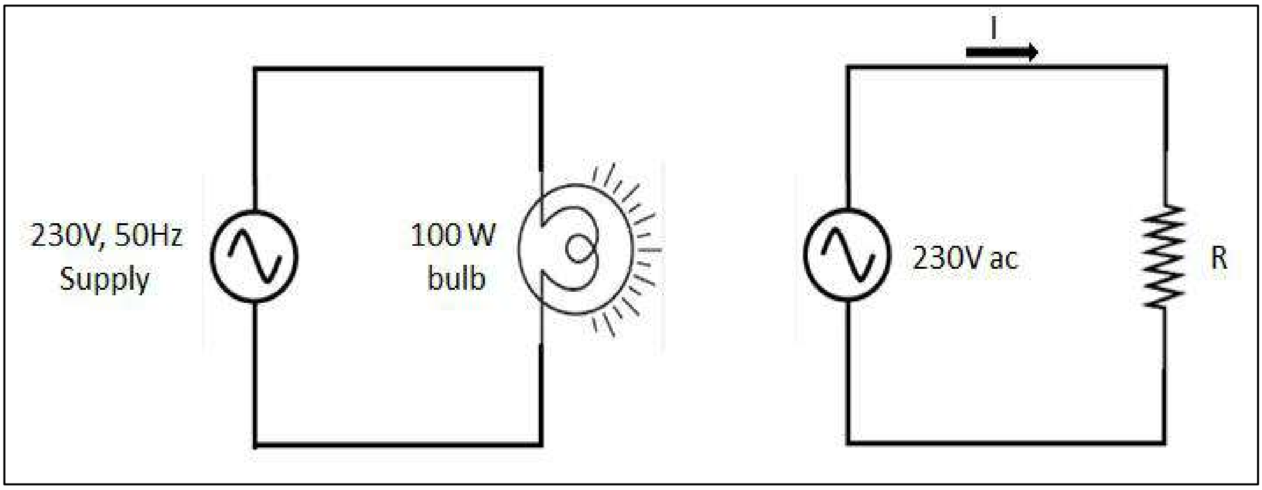


Figure 3.3: Connection Diagram & Circuit Diagram for Pure R Load

The resistor R represents the resistance value of the bulb filament.

Here V=230V, R=550KΩ

According to Ohms Law,

Current, I = V/R = 230/550 = 0.41 mA

3.6.2 Design of Series R-L Load

A fluorescent tube with a choke can be used to simulate an inductive load. When you connect the choke and the bulb in series, they operate as a combined R-L load. This configuration is shown below. Keep in mind that the voltage across the bulb may be somewhat lower than the supply voltage due to the voltage drop across the choke.

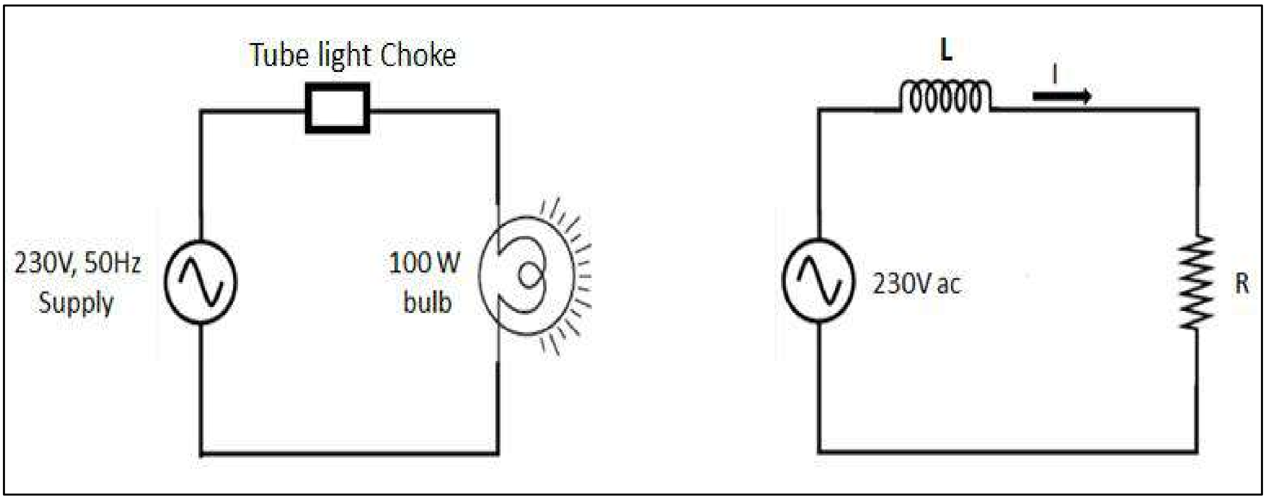


Figure 3.4: Connection Diagram & Circuit Diagram for Series R-L Load

The impedance of the circuit will be, Z= R+jXL

Current, I = V/Z

3.6.3 Design of Pure L load

The choke and the bulb when connected in parallel will behave as a Pure L load. The bulb will get the same voltage as the supply. The circuit connection is shown below.

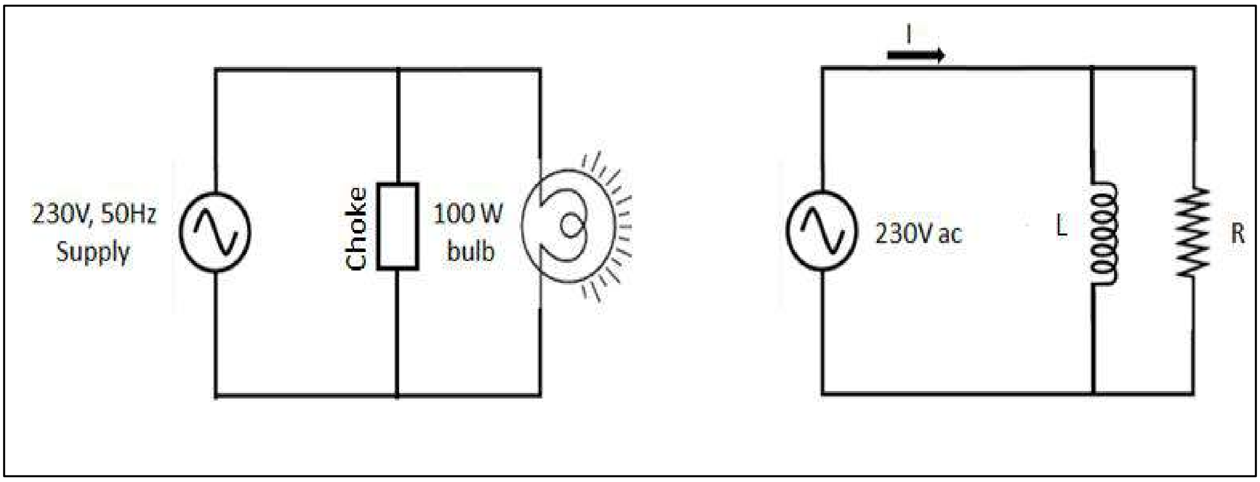


Figure 3.5: Connection Diagram & Circuit Diagram for Pure L load

The impedance of the circuit will be, Z= R+ jXL / R x jXL

Current, I = V/Z

CHAPTER 4

DESIGN & IMPLEMENTATION

Chapter Overview

This chapter presents a comprehensive exploration of the project, supplying an in-intensity investigate the numerous components utilized and the intricacies of their integration. This chapter goes beyond theory to provide practical insights, providing specified schematic diagrams of the project setup. It meticulously outlines the selection and configuration of components, allowing readers to understand the assignment's technical intricacies and apprehend the way it correctly enhances power factor in real-world packages.

4.1 INTRODUCTION

This chapter delves into the design specifics of each section of the power factor correction equipment. It discusses how each item operates inside these divisions and how they're set up to get the task done. The chapter concludes by presenting the ultimate circuit diagram that was used as a reference for assembling the equipment. We were especially cautious during the fabrication process to avoid any unintentional short-circuits or overlapping routes.

4.2 CURRENT TRANSFORMER

In an electrical circuit, current transformers (CTs) have the primary function of measuring electric currents. These CTs, often used alongside voltage transformers (VTs), collectively fall under the category of instrument transformers. When the current in a circuit exceeds levels that can be directly applied to measuring instruments, the current transformer steps down the current to a precisely proportionate lower value. This lower value can then be conveniently connected to measuring and recording devices. Furthermore, the current transformer serves as a critical isolating barrier between measuring instruments and potentially high voltages present in the monitored circuit. Current transformers are extensively applied in various uses, including metering and protective relays, particularly within the electrical power industry.

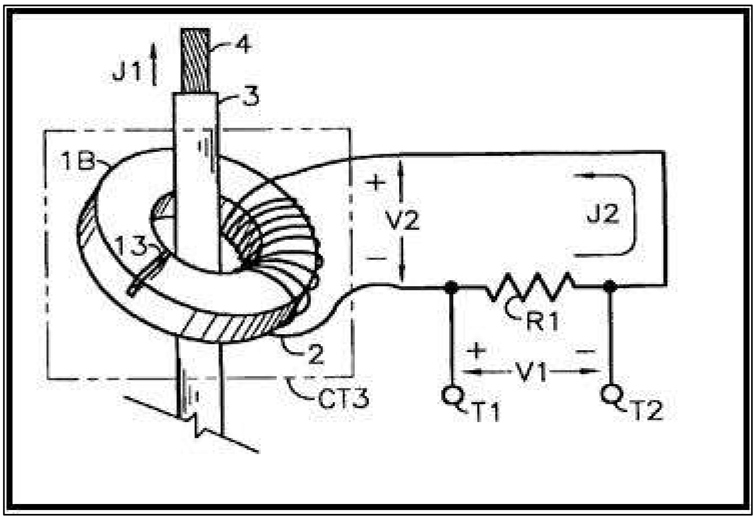


Figure 4.1: Schematic of a Current Transformer [14]

4.3 POWER SUPPLY FOR CIRCUIT

The embedded device circuit operates with specific DC voltage requirements, specifically 12 volts and 5 volts. To meet those voltage desires, the preliminary step entails the conversion of the 230-volt AC deliver into usable DC energy. This venture is accomplished using a electricity adapter, which correctly transforms the excessive-voltage AC input right into a strong 12-volt DC output. Subsequently, for components stressful a five-volt power deliver, a DC-to-DC buck converter like the LM2596 ADJ comes into play. This flexible converter guarantees a reliable and controlled five-volt DC output, correctly assembly the awesome voltage requirements of the embedded device's various components.

The synergy of those energy conversion additives is instrumental in making sure the clean and dependable operation of the embedded device.

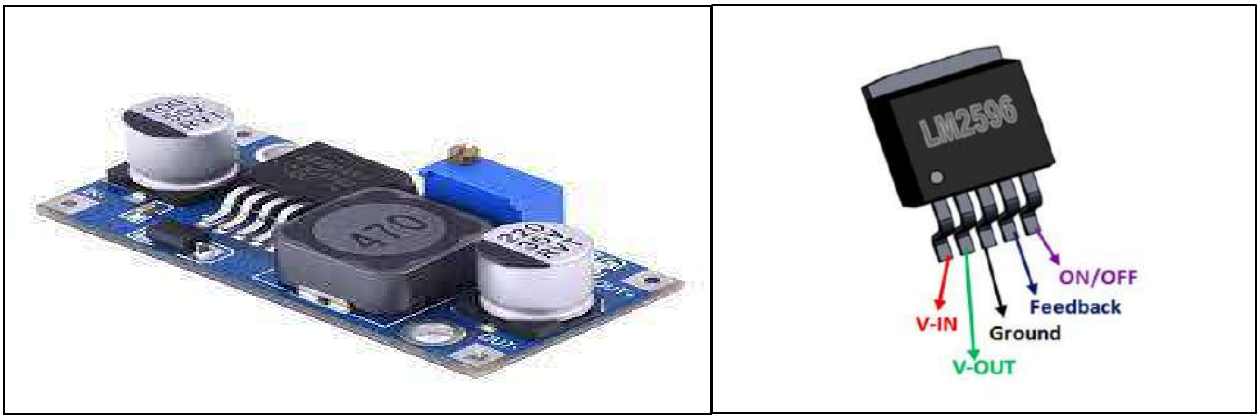


Figure 4.2: LM2596 ADJ DC-DC Buck Converter & its Pin-out [15]

4.4 DISPLAY UNIT

In this device configuration, the microcontroller serves as a sort of intermediary between the outside world and how we connect with it via various gadgets. One essential component it links to is the LCD display, which displays information. LCD displays come in a variety of sizes, including 16x2 (16 characters on 2 lines) and 20x4 (20 characters on 4 lines). We're utilising a 16x2 model called the JHD 162A for this project. This display graphically shows the power factor and phase lag between voltage and current, allowing us to observe these quantities in milliseconds.

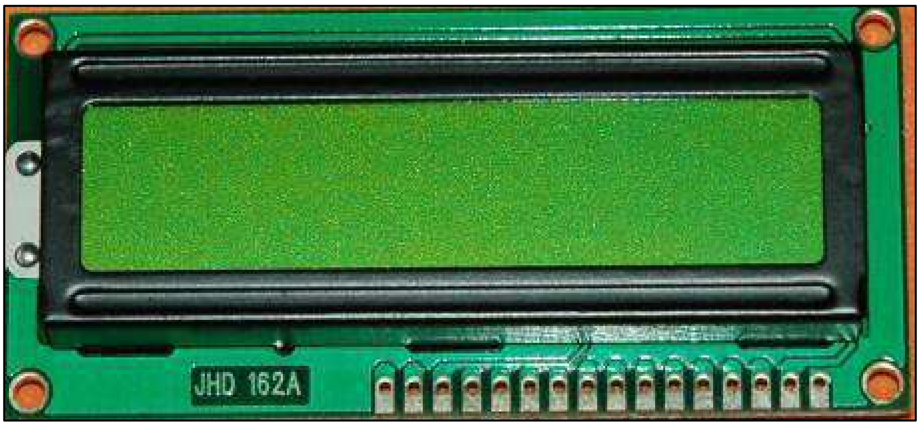


Figure 4.3: A 16x2 LCD Display [16]

4.4.1 LCD Connections

You'll need three control lines and four or eight I/O lines for the data bus when connecting to the microcontroller. You have the option of using a 4-bit or an 8-bit data bus mode. If you pick the 4-bit option, you will require a total of seven lines (three for control and four for data). However, if you use an 8-bit data bus, you'll want a total of eleven lines (three control lines and eight data lines).

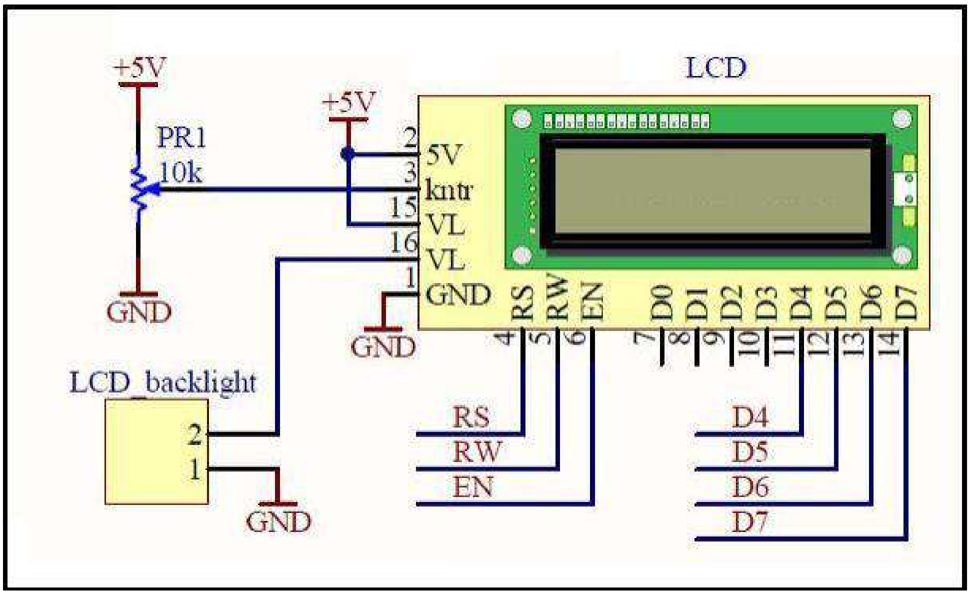


Figure 4.4: Pin Description and Connection Diagram of 16x2 LCD in 4-bit Mode [16]

4.5 MICRCONTROLLER

The core of each embedded system is a microcontroller, serving as the valuable unit liable for all logical processing responsibilities. It gets enter, executes application instructions, and generates processed output. Additionally, it boasts on-chip memory to briefly save variables during ongoing processing. In this machine, we hire the ATmega328P, an 8-bit microcontroller, to meet these essential features.

The Arduino Nano is a compact and flexible microcontroller board that has received mammoth popularity in the global of electronics and embedded structures. It is ready with the ATmega328P microcontroller, offering 32KB of flash memory for program garage and 2KB of SRAM for facts garage. With its small form issue, the Nano provides 22 trendy-motive I/O pins, making it suitable for a wide range of projects.

It helps a clock pace of up to sixteen MHz and features handy onboard capabilities like a voltage regulator and USB interface for programming and communique. Arduino Nano's flexibility, ease of use, and compatibility with a wealth of libraries and shields make it an excellent desire for each novices and experienced developers in the maker and electronics groups. Whether you're running on robotics, IoT projects, or easy DIY creations, the Arduino Nano empowers you to carry your ideas to lifestyles with efficiency and creativity.

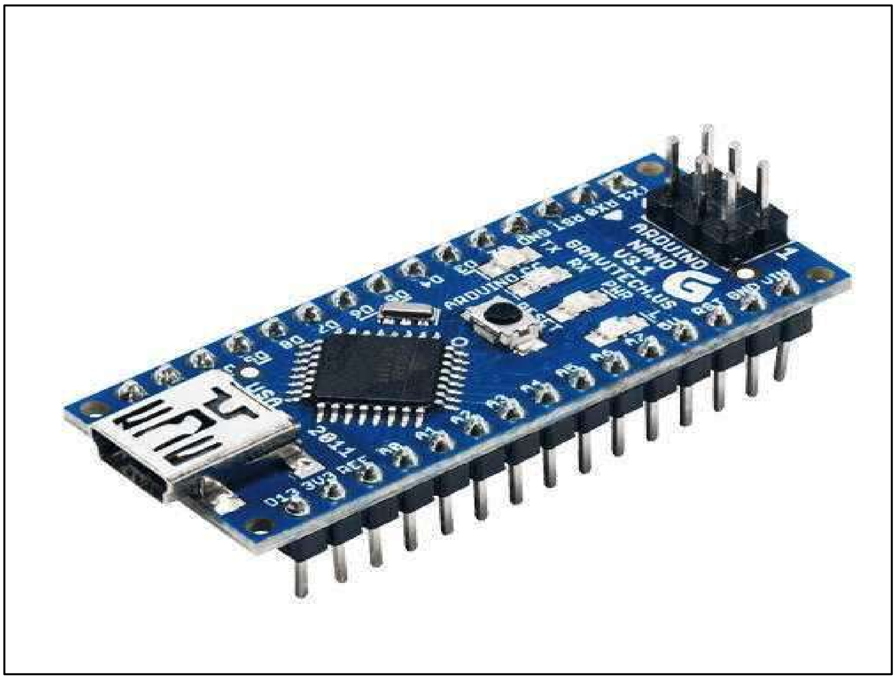


Figure 4.5: Arduino Nano [17]

4.5.1 Key Specifications of MicroController

1. Flash Memory: 32KB for storing the Arduino software.
2. SRAM: 2KB for data storagee.
3. EEPROM: 1KB for non-volatile statistics storage.
4. Clock Speed: It can function at a clock frequency of as much as 16 MHz.
5. I/O Pins: The ATmega328P has a total of 23 preferred-reason I/O pins.
6. Analog Inputs: It has 6 analog enter pins.
7. UART, SPI, I2C: It supports serial communique interfaces like UART (Serial), SPI, and I2C.

The ATmega328P is widely used in diverse Arduino forums, inclusive of the Arduino Nano, because of its versatility and ease of use for hobbyists and developers inside the Arduino surroundings.

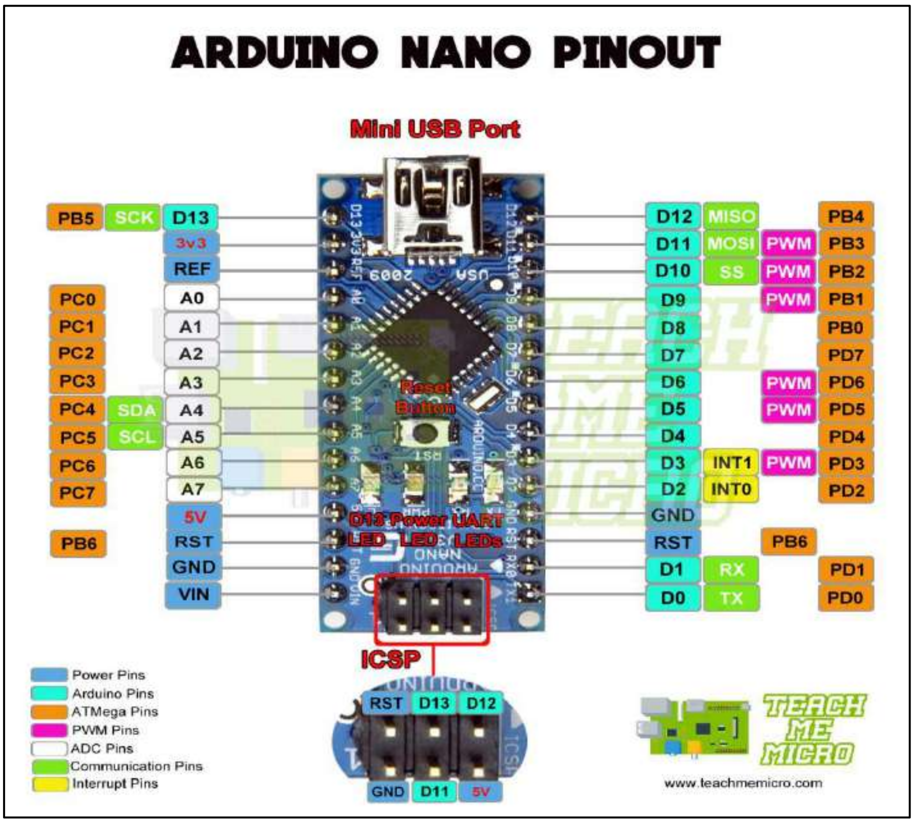


Figure 4.6: Arduino Nano Pin-out [17]

4.6 RELAY UNIT

This device, which includes a relay driver circuit and a set of relays, is an essential component of the project. Its principal duty is to bridge the gap between the microcontroller's low-power output and the high-power circuit in charge of capacitor regulation.

The microcontroller's direct control over the capacitor switching operation is limited in this complex electrical system. As a result, the relay unit plays an important function, acting as a mediator between the microcontroller's low-power control circuitry and the high-power circuit, which is responsible for engaging or disengaging the capacitors.

The relay driver, a critical component of this device, is responsible for producing the signals required to activate or deactivate the relays. These relays, in turn, serve as dependable switches that manage the system's high-power elements. The relay unit enables accurate and responsive control over the capacitor switching process by fulfilling this intermediary role.

In summary, this relay unit serves as an important bridge between the microcontroller's low-power domain and the high-power circuit, allowing for smooth capacitor integration and control. Its function is critical in handling power factor correction successfully, contributing to improved energy efficiency and optimised electrical power utilisation in single-phase systems.

4.6.1 Relay

A relay is a type of electrical switch that is used in circuits. It's really cool since it can open and stop electrical connections in response to electrical impulses. Its primary function is to handle either a low-power signal or circuit or a high-voltage circuit or load.

Figure 4.7: Relay [18]

Relay switch connections are frequently labelled COM, NC, and NO:

- The COM, or Common, is a moveable component of the relay switch.
- When the relay coil is turned off, NC, or Normally Closed, links to COM.
- When the relay coil is triggered, NO connects to COM.

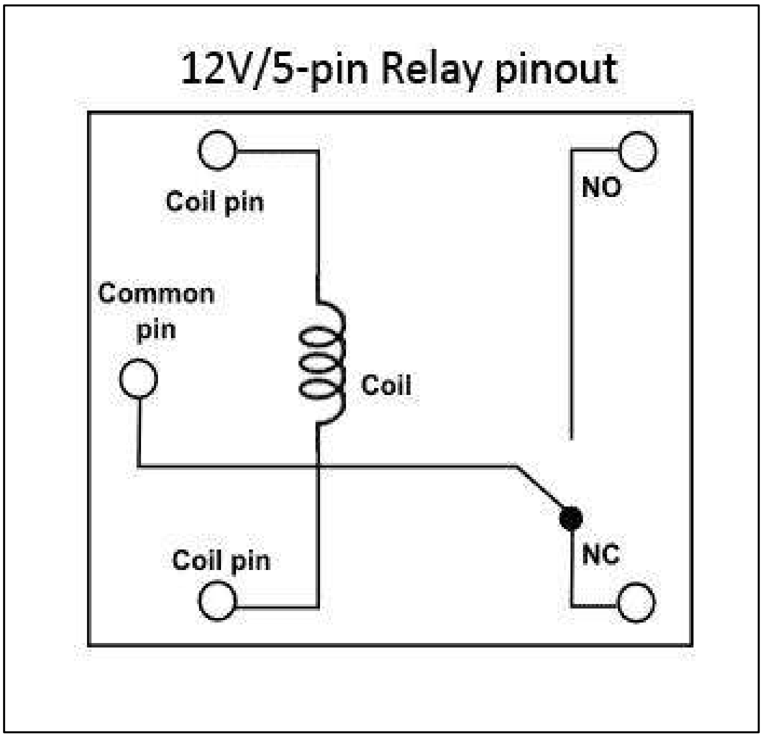


Figure 4.8: Internal Connections of Relay [18]

4.6.2 Relay Module

A relay module serves as a pivotal hyperlink between microcontrollers like Arduino and excessive-electricity electrical components or structures, enabling the safe and green manipulate of devices that operate at voltages and currents past the talents of the microcontroller itself. These modules include important features which include electric isolation, current coping with capability, and built-in safety mechanisms, which include diodes to suppress voltage spikes, ensuring dependable and stable operation. By presenting a truthful interface with categorised terminals for control input, floor, and cargo connections, relay modules facilitate the combination of external equipment, making them imperative tools for an array of packages, from domestic automation to industrial manipulate and robotics initiatives, in which particular and sturdy manipulate of electrical hundreds is paramount.

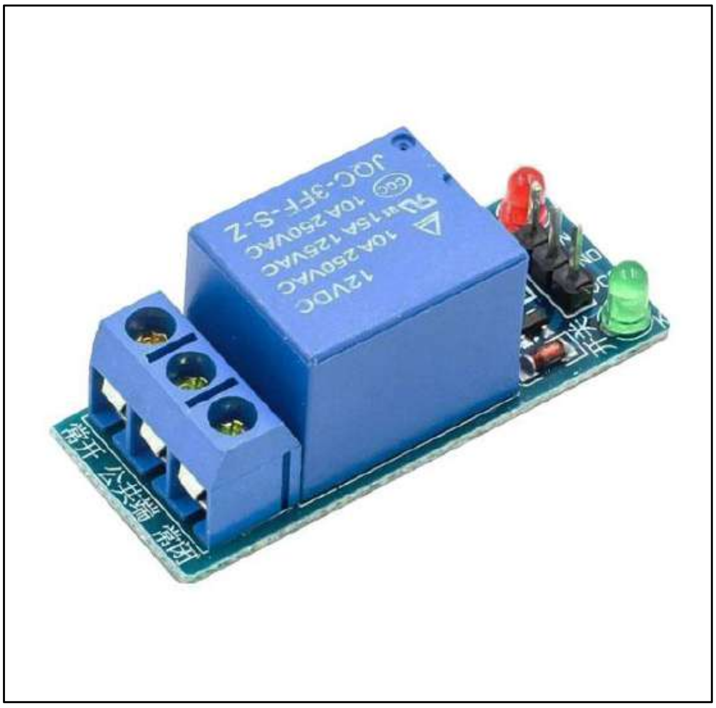


Figure 4.9: Relay Module [18]

4.6.3 Key features of Relay Module:

1. **Relay Switch:** The number one feature is to act as a relay switch, allowing it to control the drift of electrical current in an external circuit.
2. **Voltage Compatibility:** Relay modules can commonly deal with excessive-voltage masses, making them appropriate for a huge range of programs.
3. **Current Handling:** They are designed to handle high-cutting-edge loads, enabling the manipulate of devices that draw large electric cutting-edge.
4. **Electrical Isolation:** Relay modules provide electrical isolation between the control circuit and the load circuit, protective the controlling components from voltage spikes and interference.
5. **Protection Diodes:** Some relay modules include built-in diodes to suppress voltage spikes generated during the switching technique, improving reliability.
6. **Ease of Wiring:** They regularly function absolutely labeled terminals for manage input, ground, and load connections, making them user-friendly and easy to combine into projects.

7. **Indicator LEDs:** Many relay modules consist of indicator LEDs that provide visible remarks on the relay's repute (e.G., whether or not it is energetic or inactive).
8. **Low Power Control:** Relay modules can be caused by low-voltage and low-power manage signals, making them compatible with microcontrollers like Arduino.
9. **Form Factors:** Relay modules are to be had in various form elements, including unmarried-channel and multi-channel variations, to fit special project requirements.
10. **Mounting Options:** Some relay modules offer mounting holes or brackets for stable set up in numerous environments.
11. **Versatility:** They are flexible and may be utilized in a huge variety of packages, from home automation and robotics to industrial manipulate systems.
12. **Reliability:** Relay modules are regarded for their reliability in switching operations, ensuring long-time period performance.

These key functions make relay modules essential components for controlling high electricity electrical hundreds properly and effectively in numerous projects and packages.

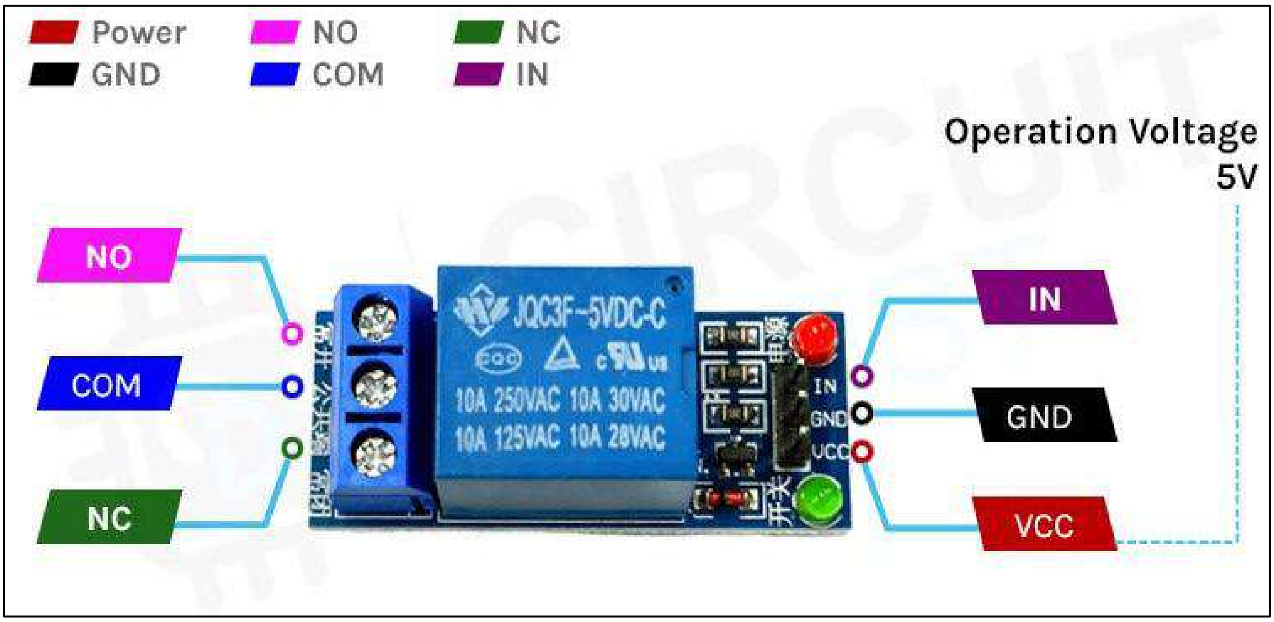


Figure 4.10: Relay Module Pin-out [18]

4.7 CAPACITOR BANK

A single phase power factor correction capacitor bank is a purpose-built combination of power factor correction capacitors carefully designed to improve the efficiency and efficiency of a power system operating in a single phase configuration.

Strategically integrated in the power grid, a capacitor bank works by bringing capacitors in parallel with the load, thus providing reactive power compensation. This compensation action counterbalances reactive power draw by inductive devices, effectively reducing backlog power factor and minimizing energy losses of reduction, electrical system composite- serve as instrumental tools in the quest for improved operational efficiency.

These capacitor banks are especially useful in areas where single-phase power is abundant, such as residential buildings, small businesses, and in some industrial applications if their size and configuration contribute to electricity supply stability and quality, thereby simultaneously prolonging the life of the connected devices In essence, single-phase power factor correction capacitor banks are essential components that enable power systems to operate on at full power while being economical in energy consumption and reducing inefficiencies.

Figure 4.11: Power Factor Correction Capacitor [19]

4.8 DISTRIBUTION BOX

Distribution Box also known as a distribution container, distribution panel, breaker panel, or electrical panel, it is an quintessential a part of an electrical wiring device. It is the important point of distribution and manage of energy in a building or manufacturing unit. Distribution packing containers are commonly found in residential, business and industrial regions, and play an critical role in ensuring the secure and efficient deliver of power to numerous circuits and generators.

Figure 4.12: Distribution Box [20]

4.8.1 Some of the Main Features and Functions of a Distribution Box:

1. **Power output:** Distribution containers obtain electricity from the main deliver line, generally via a circuit breaker or special fuse.
2. **Circuit breakers or fuses:** There is an man or woman circuit breaker or fuse for each branch circuit within the distribution box. These guard the circuits from overload and quick circuits. Circuit breakers may be reset, whilst fuses ought to get replaced if they fail.

3. **Power Distribution:** The distribution field incorporates electricity from the power supply to diverse circuits all through the constructing, inclusive of lighting circuits, mechanical circuits and so forth.
4. **Layout:** Distribution packing containers are frequently ready with surely classified breakers or fuses, making character circuits easy to discover and control.
5. **Safety:** A protection tool is supplied to reduce off strength to unique circuits for preservation with out affecting the whole electric system.
6. **Grounding:** Distribution boxes are placed on the ground so that electric faults are thoroughly routed to the ground, reducing the risk of electric surprise and fire.
7. **Ampere rating:** The circuit breakers in the distribution container have particular ampere scores to make certain that every circuit is protected consistent with the rated load.
8. **Voltage rating:** Distribution boxes are designed to handle a specific voltage rating, such as 120V or 240V, as required by the electrical system.
9. **Access:** They are usually installed in easily accessible areas, such as utility rooms or electrical outlets, to allow for inspection, maintenance and repair.

In summary, a distribution box is an integral part of the electrical system of a building or factory. It organizes and distributes electricity, provides protection against electrical faults, and enhances safety by permitting circuits to be disconnected from carefully designed and maintained distribution boxes is needed to provide reliable and safe electricity to a building.

4.9 ELECTROMAGNETIC CONTACTOR

A tripolar electromagnetic contactor is an vital electric conversion device designed to govern the glide of strength in a better and versatile manner in comparison to its monopolar counterpart because the call indicates, it includes 3 styles of contacts, of which every is related to a selected tree. These poles can manage a couple of electric circuits simultaneously, making them incredibly well applicable for packages that require synchronization and manage of multiple masses or phases in a electricity device.

At its center, a tripolar electromagnetic contactor works at the equal principle as electromagneticism. It has 3 energy traces, one for every tree. When an electric powered present day is carried out to a selected coil, a magnetic subject corresponding to that specific pole is produced. This magnetic subject exerts a mechanical pressure at the corresponding contacts, allowing them to have interaction or disengage exactly.

Figure 4.13: Electromagnetic Contactor [21]

This sophisticated layout permits the tripole contactor to handle more complicated power conditions, along with those found in three-phase energy structures, and three poles of the contactor can deal with distribution, switching and protection of each section so nicely Safe and green circuits need to be used concurrently to ensure operation.

Additionally, the 3-pole electromagnetic contactor offers a high degree of pliability and adaptability. It is regularly hired in scenarios wherein one-of-a-kind circuits or phases should be synchronized or remoted as needed. These contactors are generally included into manage panels, motor starters, and industrial automation systems, in which the coordination of more than one electric components is paramount.

In precis, a 3-pole electromagnetic contactor is a sophisticated electric switching device geared up with 3 units of contacts and coils. Its versatility makes it quintessential in packages related to 3-segment electric structures, permitting the correct manage and coordination of a couple of circuits or loads, ultimately contributing to the efficiency and reliability of complex electrical setups.

4.9.1 Specifications of EMC

Contact Configuration	3NO
Poles	3
HP Rating	30
Switching Power - AC	15 kW
Switching Current - AC	32 A
Switching Voltage - AC	440 V
Switching Voltage - DC	300 V
Coil Voltage - AC	220 V
Protection Rating	IP20
Termination Type	Screw Terminal
Mounting Type	DIN Rail Mount Wall Mount
Series	TeSys

Table 01: Specifications of EMC

4.10 EMERGENCY SWITCH

Emergency Switch is a switch which are used to be stop a Unit at emergency time. Emergency switch plays an important role to control the whole Unit to turn off when emergency occurred. This switch fixe or install in series with control wiring and control the main power to turn off. It has on top RED circle type button which press to turn off on which normally close contact change into normally open contact, This switch is easily available in the market.

Figure 4.14: Emergency Switch [22]

4.11 INDICATION LIGHT

An indication light, also called a trademark mild, is a small, normally coloured, and regularly illuminated light on a device or tool panel that gives facts or indicators the status or condition of that tool or a specific feature. These lights are designed to deliver vital facts quickly and without difficulty to customers with out the want for particular factors.

Figure 4.15: Indication Lights [23]

4.12 ENERGY METER

The PZEM-004T is indeed a popular and versatile virtual multi-characteristic meter renowned for its functionality to degree a extensive variety of electrical parameters in electrical circuits or systems. It is a favored choice in applications spanning power distribution, energy control, and various do-it-yourself (DIY) electronics tasks due to its consumer-pleasant features and reliability.

This compact meter provides the way to monitor and measure essential electric parameters with precision and convenience. Its key features include the ability to measure voltage, current, active power, energy consumption, frequency, and power factor.

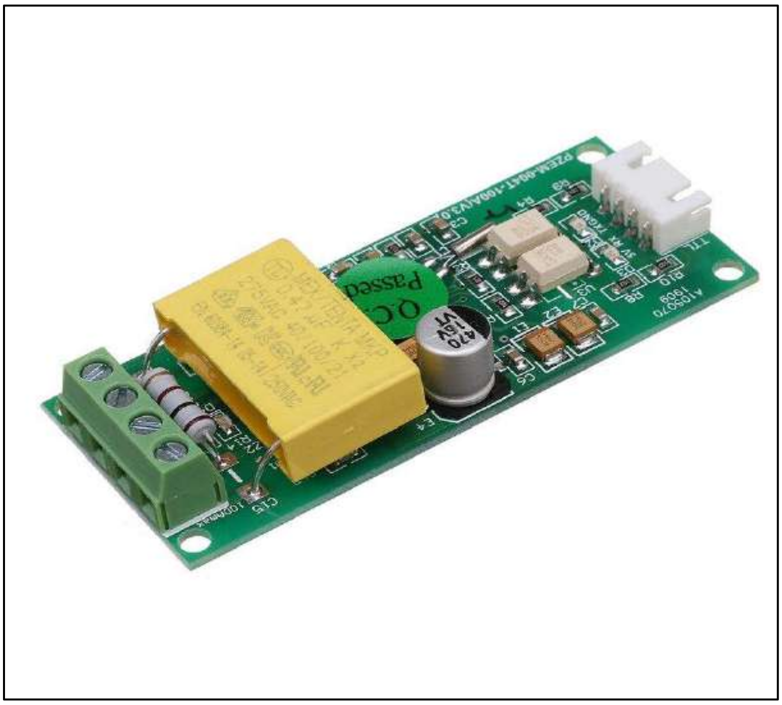


Figure 4.16: Energy Meter [24]

4.12.1 Detailed Description of its Applications and Features:

1. **Voltage (V):** The PZEM-004T can as it should be measure the voltage of an electrical supply, typically in the variety of 80V to 260V AC. This makes it appropriate to be used in various places and electrical structures.
2. **Current (A):** It is capable of measuring the current flowing through a circuit, often accommodating currents of as much as 100A AC. This capability is important for assessing the load on an electrical system or device.

3. **Active Power (W):** The meter calculates and presentations energetic energy intake in watts (W). This measurement allows users apprehend how a whole lot strength a load or tool is ingesting in real-time.
4. **Energy Consumption (kWh):** The PZEM-004T goes past immediate measurements and calculates cumulative electricity consumption in kilowatt-hours (kWh). This function is invaluable for retaining track of power utilization and optimizing strength efficiency.
5. **Frequency (Hz):** It can degree and show the frequency of the electric deliver in hertz (Hz). This data is critical for assessing the stability and quality of the power supply.
6. **Power Factor (PF):** The meter offers statistics approximately the electricity component, indicating how successfully electric electricity is being used. A better power factor indicates greater efficient strength utilization.
7. **Voltage Alarms:** Some variations of the PZEM-004T come ready with voltage alarm-functionality, allowing users to set top and lower voltage limits. In the event that the voltage goes past those thresholds, the meter can offer audible or visible signals.

Register address	Description	Resolution
0x0000	Voltage value	1LSB correspond to 0.1V
0x0001	Current value low 16 bits	1LSB correspond to 0.001A
0x0002	Current value high 16 bits	
0x0003	Power value low 16 bits	1LSB correspond to 0.1W
0x0004	Power value high 16 bits	
0x0005	Energy value low 16 bits	1LSB correspond to 1Wh
0x0006	Energy value high 16 bits	
0x0007	Frequency value	1LSB correspond to 0.1Hz
0x0008	Power factor value	1LSB correspond to 0.01
0x0009	Alarm status	0xFFFF is alarm, 0x0000is not alarm

Table 02: Arrangement of the Register for the Measurement Results

The PZEM-004T's consumer-pleasant virtual display gives real-time readings of those parameters, making it an crucial device for a extensive range of applications. Whether you're monitoring household electricity intake, assessing the health of electrical system, or making sure the stableness and high-quality of strength to your tasks, the PZEM-004T offers valuable insights and records to help you manipulate and optimize your electrical systems efficiently.

Please hold in mind that at the same time as the PZEM-004T is broadly appreciated for its functionality, there can be variations and particular utilization commands related to distinctive variations of this meter, so consulting the supplied documentation is essential for correct set up and accurate measurements.

4.13 PC817 OPTOCOUPLER

The PC817 is a widely utilized optocoupler or optoisolator in electronics, a tool that integrates an LED (mild-emitting diode) and a photodetector, generally a phototransistor, to allow the transmission of electrical alerts among separate circuits even as making sure entire electrical isolation. This thing, using a phototransistor as its photodetector, serves as a dependable method to save you electric interference and preserve isolation among input and output circuits, locating extensive application in industries starting from industrial manage structures to virtual conversation device due to its sturdy layout and versatile abilties.

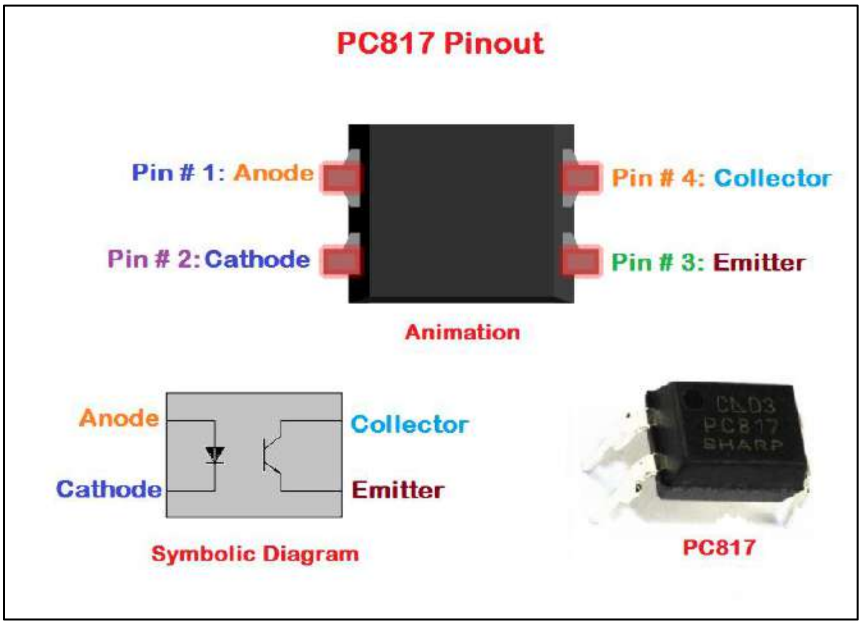


Figure 4.17: PC817 & its Pin-out [25]

4.13.1 Features of the PC817 :

1. **Signal Isolation:** Isolating virtual or analog indicators among extraordinary parts of a circuit to prevent noise, voltage spikes, or floor loops from affecting sensitive components.
2. **Voltage Level Shifting:** Converting voltage tiers among circuits that perform at unique voltage levels, while nonetheless keeping electrical isolation.
3. **Noise Immunity:** Enhancing noise immunity through isolating enter and output circuits in applications where noise can disrupt sign integrity.
4. **Protection:** Providing protection to sensitive components or microcontrollers by keeping apart them from potentially harmful voltages or currents.
5. **Switching and Control:** Using the optocoupler to govern excessive-voltage or high-modern-day hundreds, along with relays or triacs, the use of a low-voltage control signal.
6. **Feedback and Control Loops:** Isolating feedback indicators on top of things loops to enhance gadget stability and safety.

Parameter		Symbol	Rating	Unit
Input	Forward voltage	I_F	50	mA
	Reverse Voltage	V_R	6	V
	Power dissipation	P	70	mW
Output	Collector-Emitter voltage	V_{CEO}	80	V
	Emitter- Collector voltage	V_{ECO}	6	V
	Collector Current	Ic	50	mA
	Collector Power dissipation	P_C	150	mW
Total Power dissipation		P_{tot}	200	mW
Isolation voltage		Viso	5000	V rms
Rated impulse isolation voltage		V_{IOTM}	6000	V
Rated repetitive peak isolation voltage		V_{IORM}	630	V
Thermal resistance,junction to ambient air		$R_{\theta JA}$	430	℃/W
Thermal Resistance Junction-to-Case		$R_{\theta JC}$	350	℃/W
Operating temperature		Topr	-30~+100	℃
Storage temperature		Tstg	-55~+125	℃
Solding temperature		Tsol	260	℃
Junction temperature		T_j	125	℃

Table 03: Specifications of PC817 OptoCoupler

The PC817 is widely utilized in numerous digital gadgets and systems, such as industrial manipulate structures, strength substances, motor manipulate circuits, virtual communication system, and extra. Its capability to provide electrical isolation and signal transfer makes it a treasured aspect in programs wherein safety, noise immunity, and safety of touchy components are important concerns.

4.14 TRANSISTOR (BC547B)

The BC547B is a flexible and commonly employed NPN (Negative-Positive-Negative) bipolar junction transistor (BJT) belonging to the BC547 series. As a member of this series, the BC547B offers a fashionable-motive answer for diverse electronic programs. This particular variation, the BC547B, is characterized by its specific electrical and performance parameters, making it a reliable preference for a huge range of circuit designs and projects.
Transistors just like the BC547B are pivotal additives in electronics because of their capability to amplify signals, transfer electronic circuits on and stale, and serve as building blocks for more complicated electronic gadgets. This NPN transistor, like its opposite numbers inside the BC547 collection, features a three-layer semiconductor shape with an emitter, base, and collector. It can be applied in amplification circuits to reinforce vulnerable indicators or in switching programs to control the go with the flow of cutting-edge among its collector and emitter terminals.
The BC547B transistor is typically found in audio amplifiers, sign processing circuits, virtual logic gates, and various different electronic systems wherein NPN transistors are required. Its availability in special package deal types, such as TO-92 and SOT-23, lets in for flexibility in circuit design and integration into electronic assemblies. Engineers, hobbyists, and electronics fanatics often flip to the BC547B for its reliability, ease of use, and extensive availability, making it a essential element in the international of electronics.

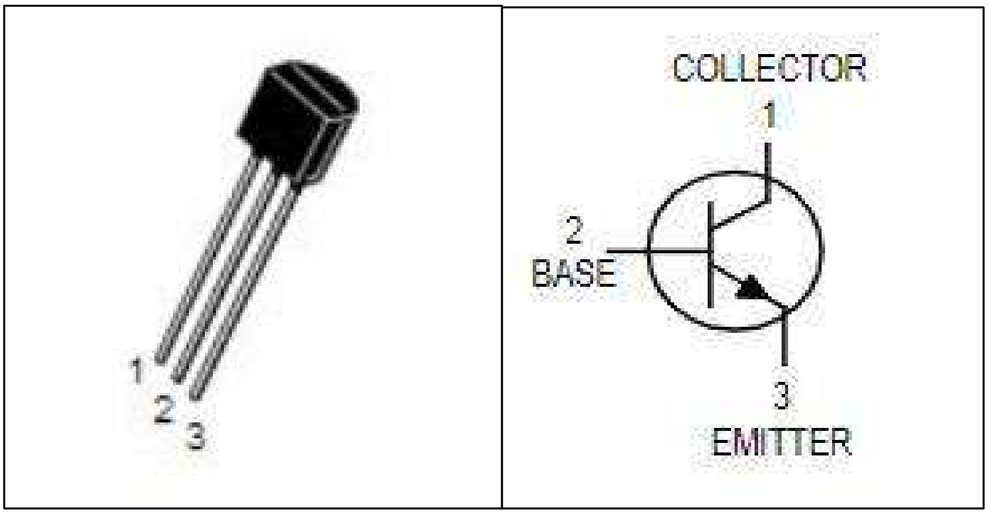


Figure 4.18: BC547B & its Symbol [26]

Pin Number	Pin Name	Description
1	Collector	Current flows in through collector
2	Base	Controls the biasing of transistor
3	Emitter	Current Drains out through emitter

Table 04: BC547B Pin-out

4.15 DIODE (1N4007)

The 1N4007 is a extensively used rectifier diode. It belongs to the 1N400x series of diodes, where "x" represents diverse numbers denoting one-of-a-kind voltage and modern ratings within the series. The 1N4007 is the most commonplace and effectively to be had diode on this series.

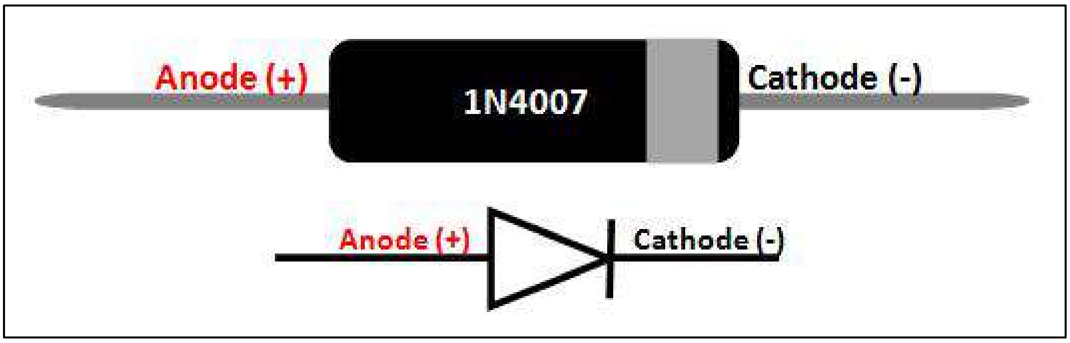


Figure 4.19: 1N4007 & its Symbol [27]

4.15.1 Key Characteristics of the 1N4007 Diode:

1. **Diode Type:** It is a silicon rectifier diode, which means it's far in the main used for rectifying alternating contemporary (AC) into direct cutting-edge (DC). Rectifier diodes permit present day to waft in a single direction most effective.
2. **Voltage Rating:** The 1N4007 has a height reverse voltage (also called top inverse voltage, or PIV) rating of a thousand volts (1 kV). This means it can manage voltages as much as 1000V in the reverse direction with out breaking down.
3. **Current Rating:** The 1N4007 has a mean ahead modern rating of one ampere (A). This makes it appropriate for low to mild modern programs.
4. **Package:** It is usually available in a cylindrical glass or plastic package deal with leads (anode and cathode) that are regularly color-coded for smooth identification. Common colors are black for the anode and white or gray for the cathode.
5. **Polarity:** Like all diodes, the 1N4007 has a polarity, with one lead detailed because the anode (nice) and the alternative as the cathode (negative). Current can waft from the anode to the cathode, however it is blocked in the reverse route.
6. **Applications:** The 1N4007 is typically used in electricity supply circuits to convert AC voltage to DC voltage. It is likewise used in diverse digital gadgets and circuits for rectification and safety purposes.
7. **Reverse Recovery Time:** The 1N4007 has a particularly slow reverse recovery time compared to other diodes, because of this it may not be appropriate for excessive-frequency applications however is well-acceptable for widespread rectification purposes.

The 1N4007 is comfortably available and affordable, making it a famous desire for a huge variety of digital initiatives and programs in which low to moderate voltage and modern rectification is needed. It is an vital thing in lots of energy substances and voltage conversion circuits.

4.16 RESISTOR (220-Ohms)

A resistor is a passive two-terminal digital thing that opposes the flow of electrical current. It is one of the essential constructing blocks of digital circuits. The primary feature of a resistor is to offer resistance or impedance to the go with the flow of electrical cutting-edge, which in flip regulates the quantity of cutting-edge passing through it

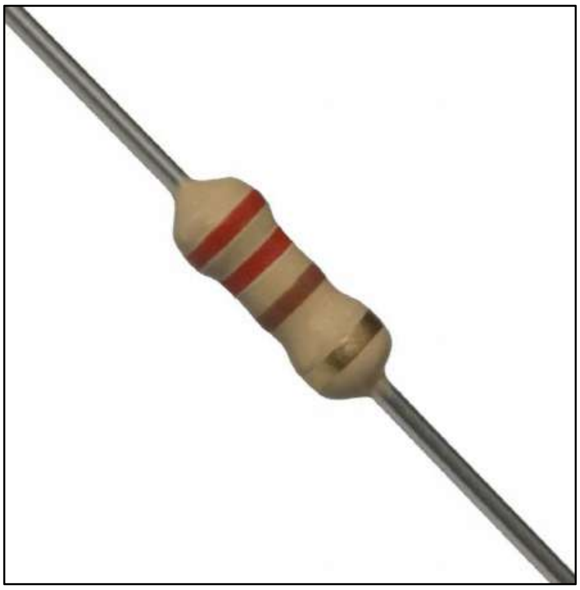


Figure 4.20: 220 Ohms Resistor [28]

4.16.1 Essential features of Resistors:

1. **Voltage Division:** Resistors are used to create voltage dividers, which can produce a fragment of the enter voltage for numerous purposes, such as putting reference voltages, controlling biasing, or providing comments in operational amplifiers.
2. **Current Limiting:** Resistors limit the float of current in a circuit, supporting protect additives from excessive present day, and making sure that devices operate within their designated present day limits.
3. **Signal Conditioning:** In signal processing circuits, resistors are used to attenuate or scale signals, regulate sign levels, and manage benefit in amplifiers.
4. **Pull-Up and Pull-Down Resistors:** They are typically used in virtual circuits to establish common sense levels, making sure that indicators are in the precise excessive or low state.

5. **Temperature Sensing:** Some sorts of resistors, like thermistors, trade resistance with temperature. These are used for temperature sensing and control programs.
6. **Filtering:** Resistors are utilized in aggregate with capacitors to create passive filters that attenuate or pass specific frequency components of signals.

Specifications	
Resistance (Ohms)	220
Power (Watts)	0.25W, 1/4W
Tolerance	±5%
Packaging	Bulk
Composition	Carbon Film
Temperature Coefficient	350ppm/°C
Lead Free Status	Lead Free
RoHS Status	RoHS Compliant

Table 05: Specification of Resistor

Resistors are fundamental additives in electronics, and they are observed in nearly every electronic device and circuit. Their capacity to control modern and voltage plays a crucial role in shaping the behavior and capability of electronic structures.

4.17 ESP8266 (ESP 01)

The ESP-01 represents a distinct iteration within the ESP8266 module series, commonly applied in IoT and embedded ventures. This specific version is among the earlier, more rudimentary renditions of the ESP8266 module, integrating Wi-Fi capabilities and GPIO (General Purpose Input/Output) pins for interfacing with various electronic components.

Compared to later ESP8266 variants, the ESP-01 module possesses fewer GPIO pins. Typically, it features GPIO0 and GPIO2, alongside transmit/receive pins, and basic connections for ground, power, and serial communication. Despite its compact size and limited pin count, the ESP-01 is widely employed in projects necessitating fundamental Wi-Fi connectivity and GPIO functionality, such as basic IoT devices, sensor nodes, and DIY electronics.

Programming for the ESP-01 module generally involves utilizing platforms like the Arduino IDE, MicroPython, or other compatible software environments. This module's reduced pin count and compact form factor make it suitable for scenarios prioritizing size and cost-effectiveness over a greater number of GPIO pins or advanced functionalities found in other ESP8266 models.

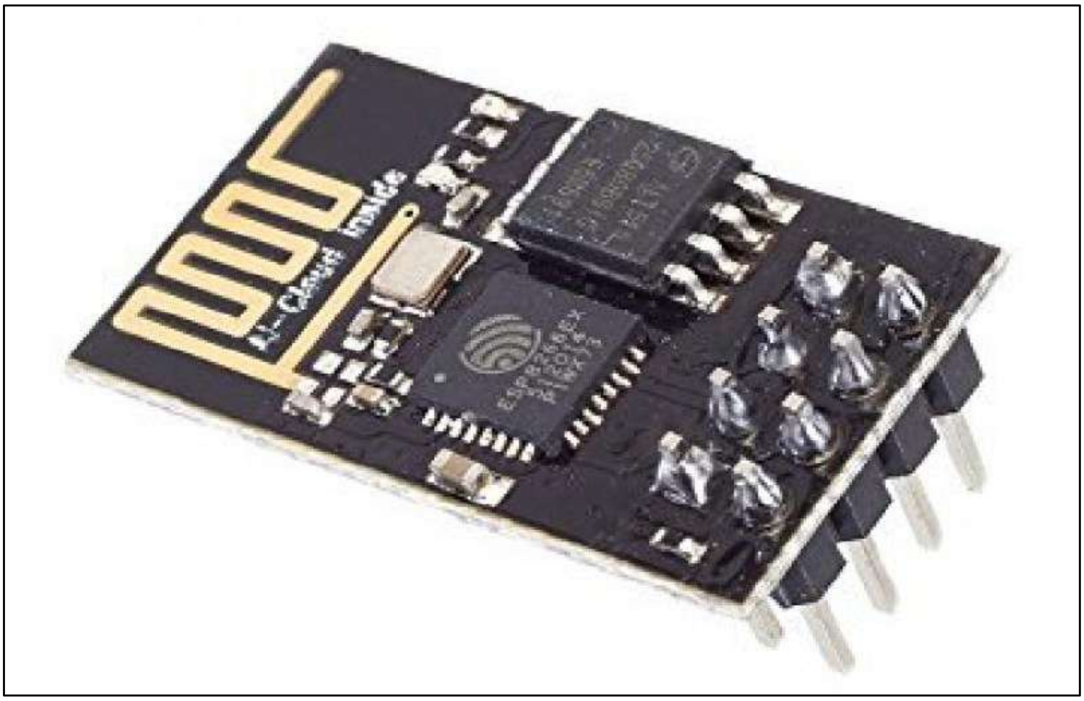


Figure 4.21: ESP8266 (ESP 01) [29]

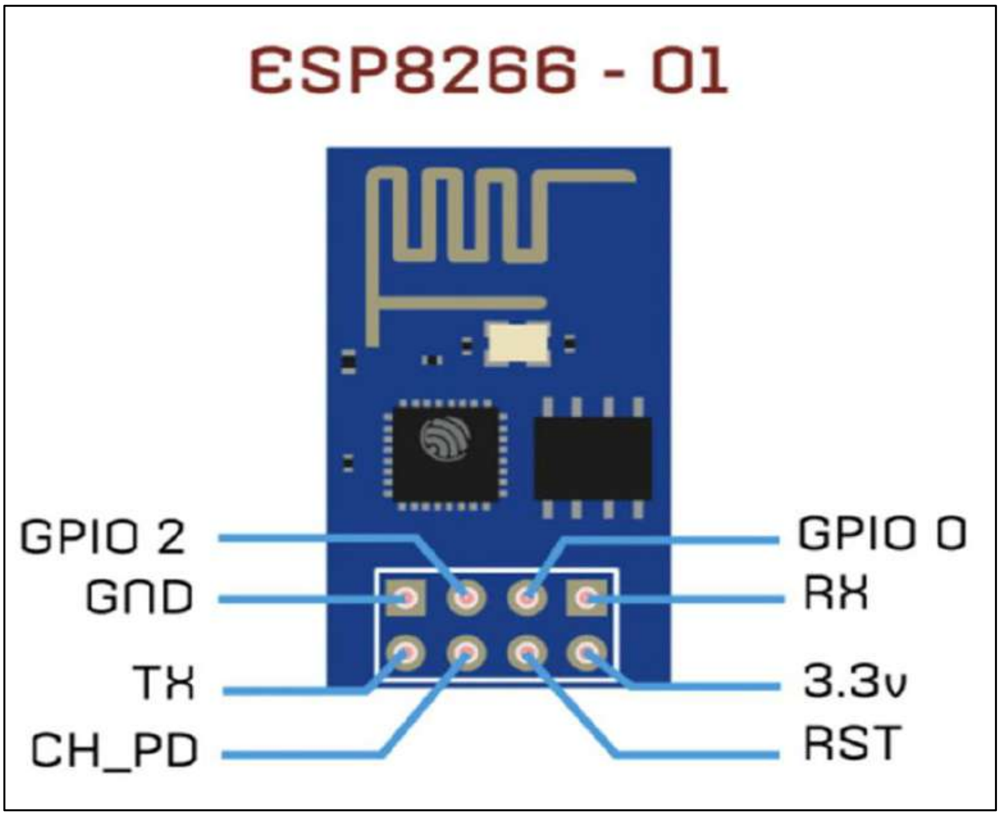


Figure 4.22 : ESP8266 (ESP 01) Pin-out [29]

4.17.1 Key Features of the ESP8266

The ESP-01 module, a variant of the ESP8266, provides several basic functions:

1. **Wi-Fi connectivity:** Facilitates connection to Wi-Fi networks, allowing devices to connect to the Internet.
2. **Cost Effectiveness :**Known for its affordability, allowing budget-constrained This is the preferred option for projects.
3. **Compact design:** Its small form factor is useful where space is limited**.**
4. **GPIO Pin:** Specifies the minimum number of GPIO pins, typically GPIO0 and GPIO2, that enable digital operations, sensor interfaces, and actuator control.
5. **Programmability :** Arduino supports programming with various environments such as IDE and MicroPython, empowering developers to create custom applications.
6. **Serial Communication:** A UART (Universal Asynchronous Receiver-Transmitter) communicates with other devices through serial communication.
7. **IoT Suitability:** This is particularly suitable for IoT projects, which facilitates communication and communication over Wi-Fi networks.
8. **Flash Memory:** Included on board

Pin Number	Pin Name	Pin Function
1	Ground	Ground
2	GPIO1	General purpose IO, Serial Tx1
3	GPIO2	General purpose IO
4	CH_PD	Active High Chip Enable
5	GPIO0	General purpose IO, Launch Serial Programming Mode if Low while Reset or Power ON
6	RESET	Active Low External Reset Signal
7	GPIO3	General purpose IO, Serial Rx
8	VCC	Power Supply

Table 06: Configuration of ESP8266 (ESP 01) Pin-out

The ESP8266 has been utilized in a extensive variety of IoT initiatives, consisting of home automation, clever gadgets, weather stations, and far flung tracking structures, because of its affordability and simplicity of use. Additionally, Espressif Systems has released more recent modules just like the ESP32, which builds upon the success of the ESP8266 with the aid of including more processing power, Bluetooth connectivity, and other capabilities.

4.18 CIRCUIT DIAGRAM

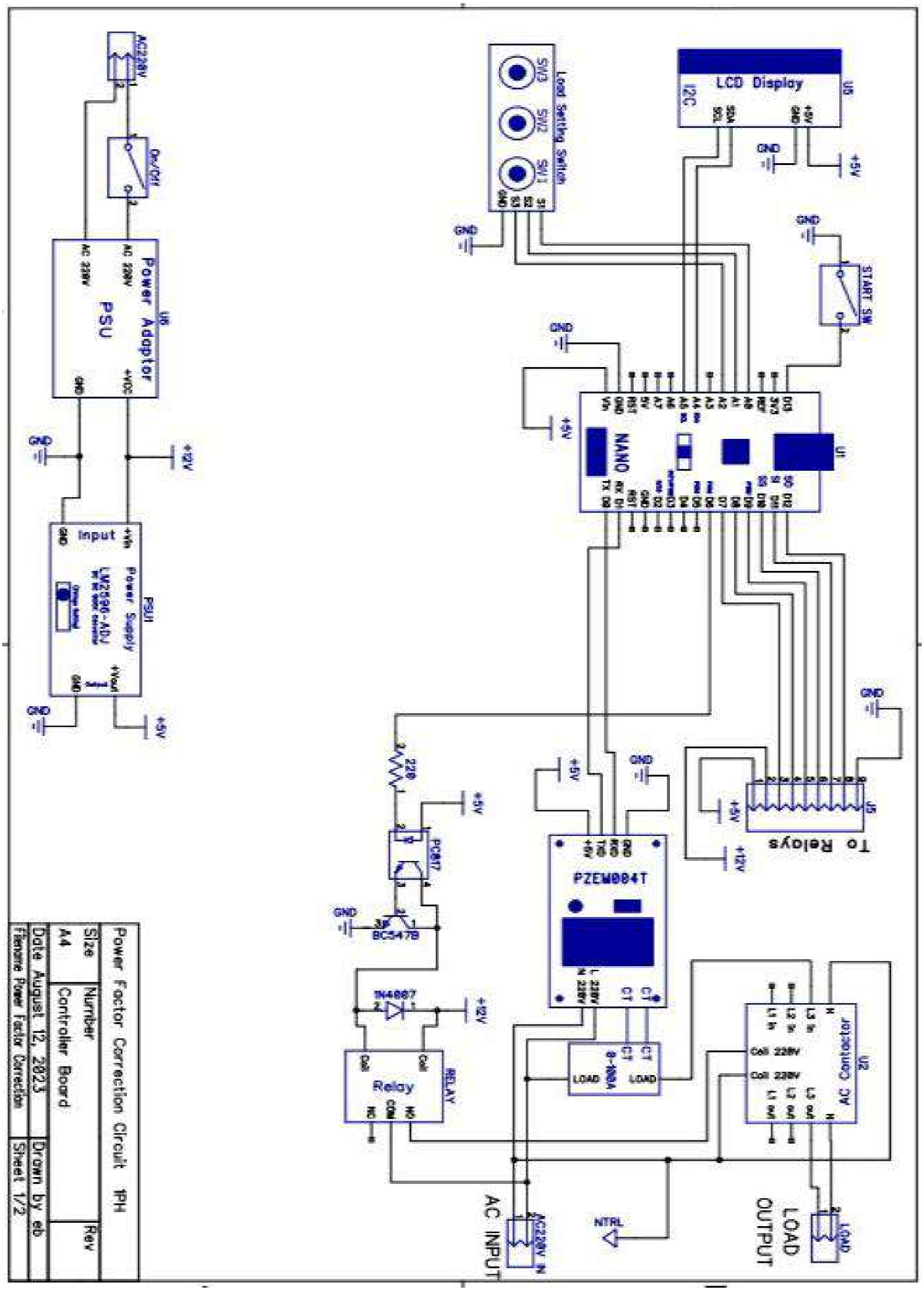


Figure 4.23: Complete Circuit Diagram of Correction Device Part (a)

4.18.1 CIRCUIT DIAGRAM

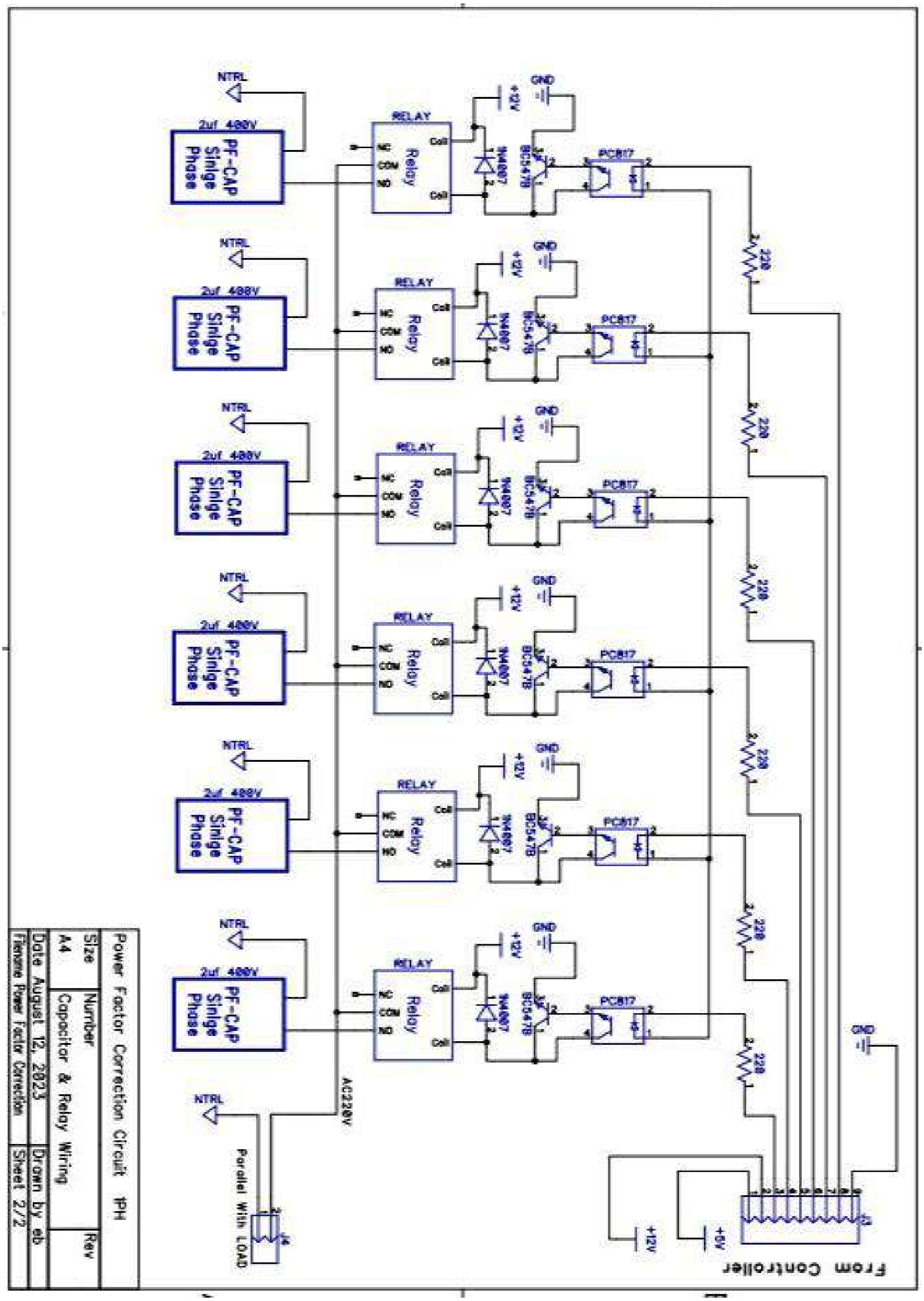


Figure 4.24: Complete Circuit Diagram of Correction Device Part (b)

4.19 HARDWARE IMPLEMENTATION

We carefully soldered all of the components onto the Vero-Board, following the circuit schematic step by step. Connections for the relays, current transformer, and capacitor bank were made exactly where they needed to be. We used a multimeter to ensure there were no unintentional short-circuits. The programme was then loaded into the microcontroller using the Arduino IDE Software. You can see how everything is set up graphically in the figures below (Figures 4.25 & 4.26).

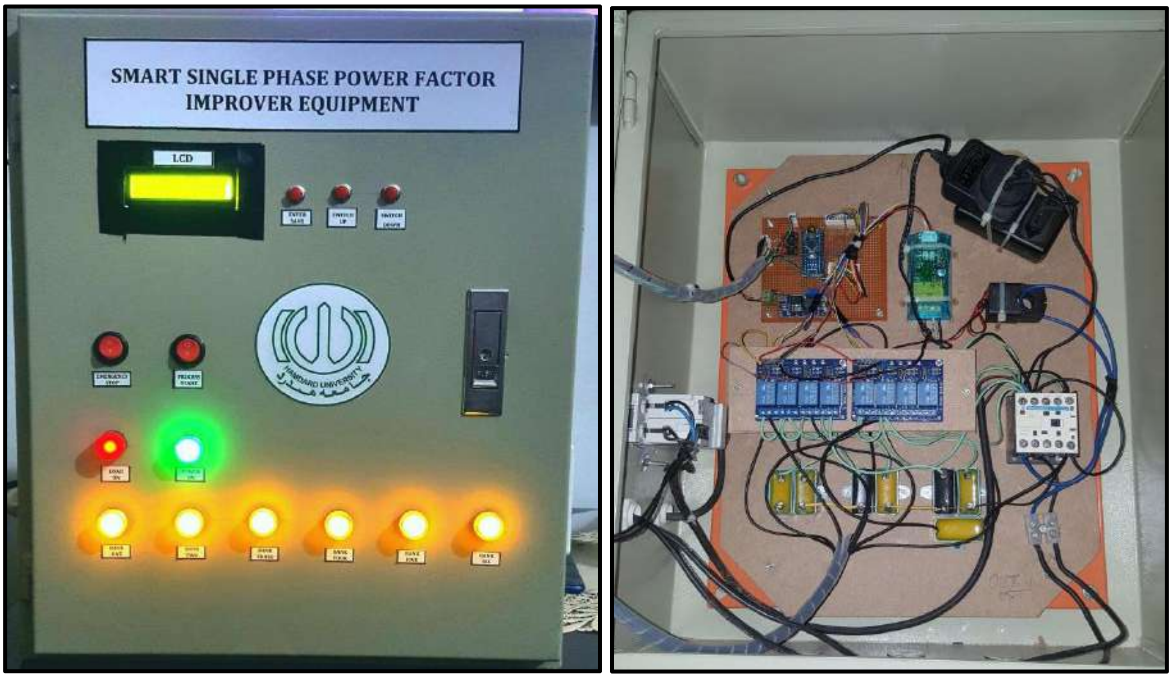


Figure 4.25: The Completed PF Correcting Equipment

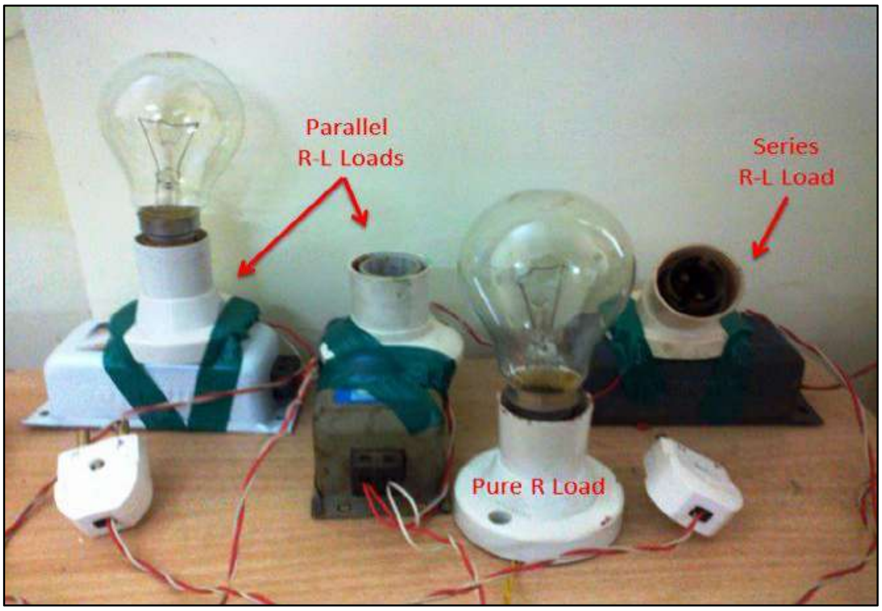


Figure 4.26: The Different Types of Loads

4.20 PROTEUS SIMULATION

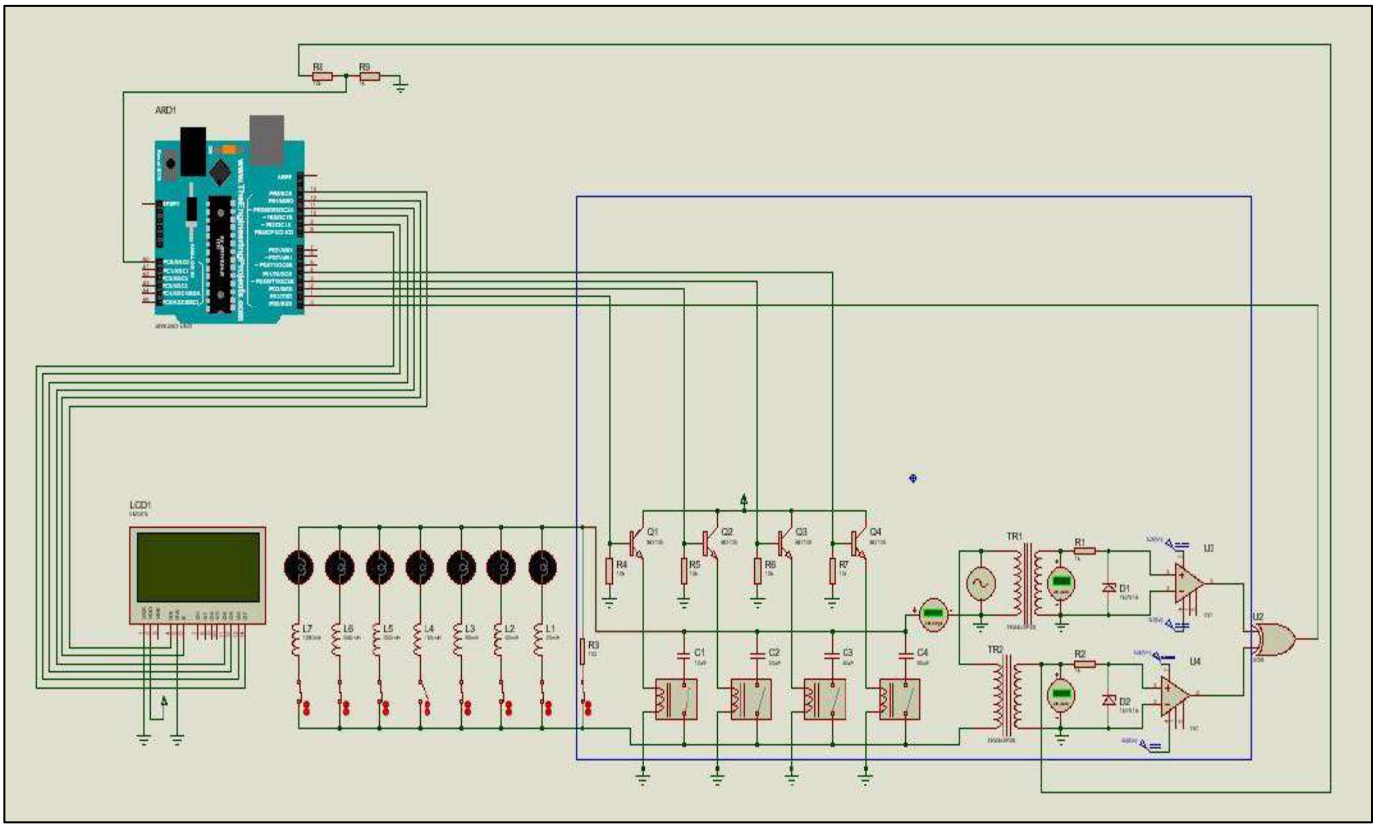


Figure 4.27 : Complete Simulation of Power factor Correction Equipment

4.20 RESULTS

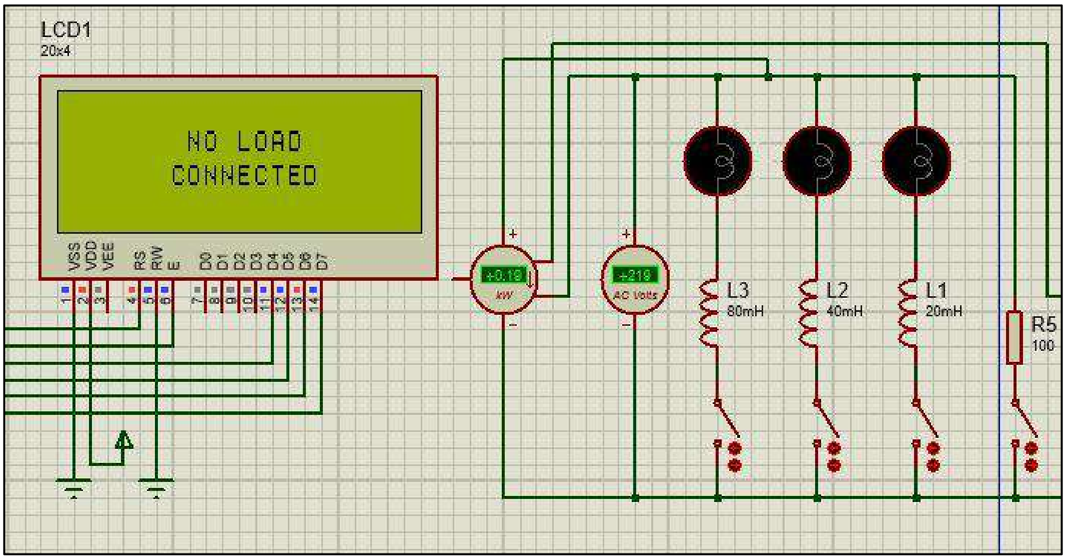


Figure 4.28 : Result on No Load

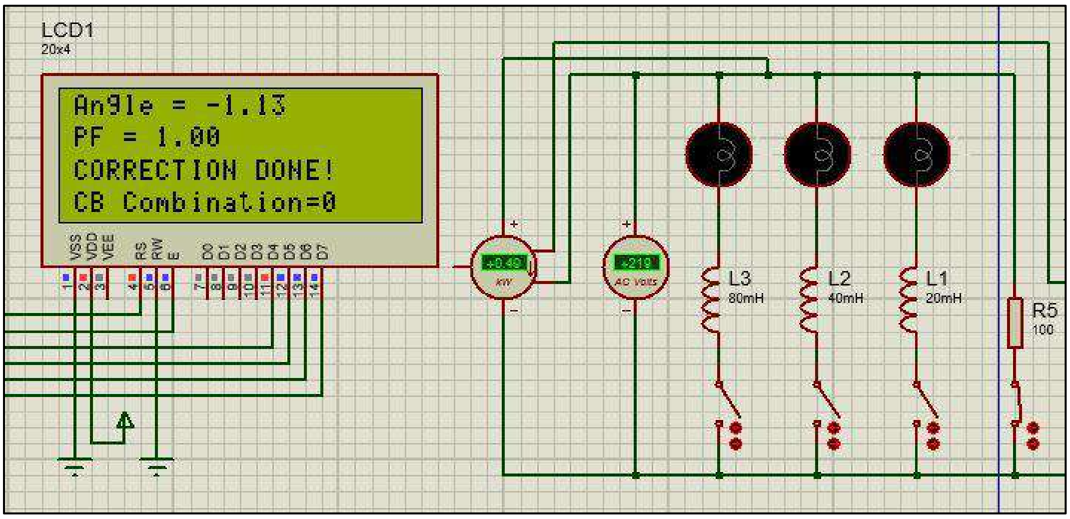


Figure 4.29 : Result on Resistive Load

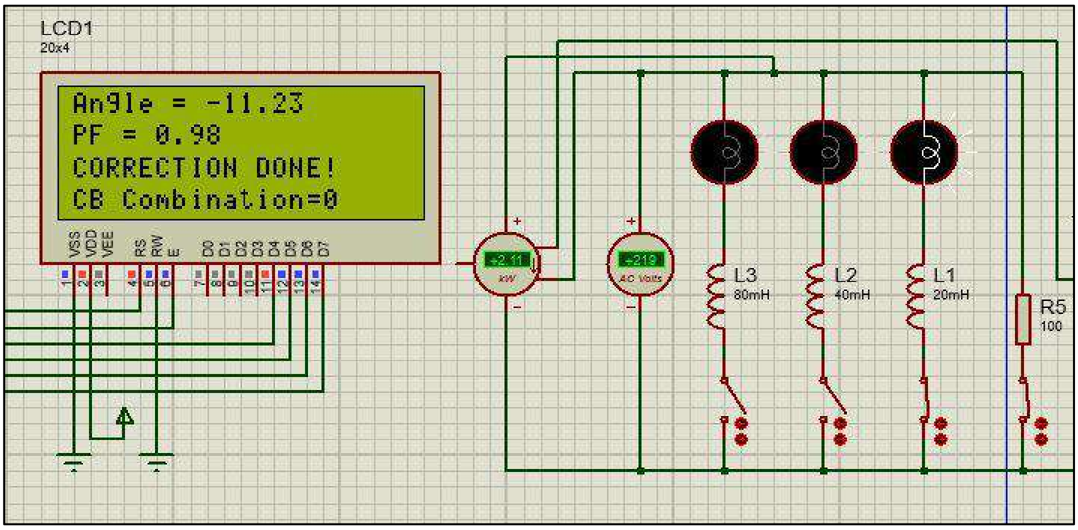


Figure 4.30 : Result on Inductive Load

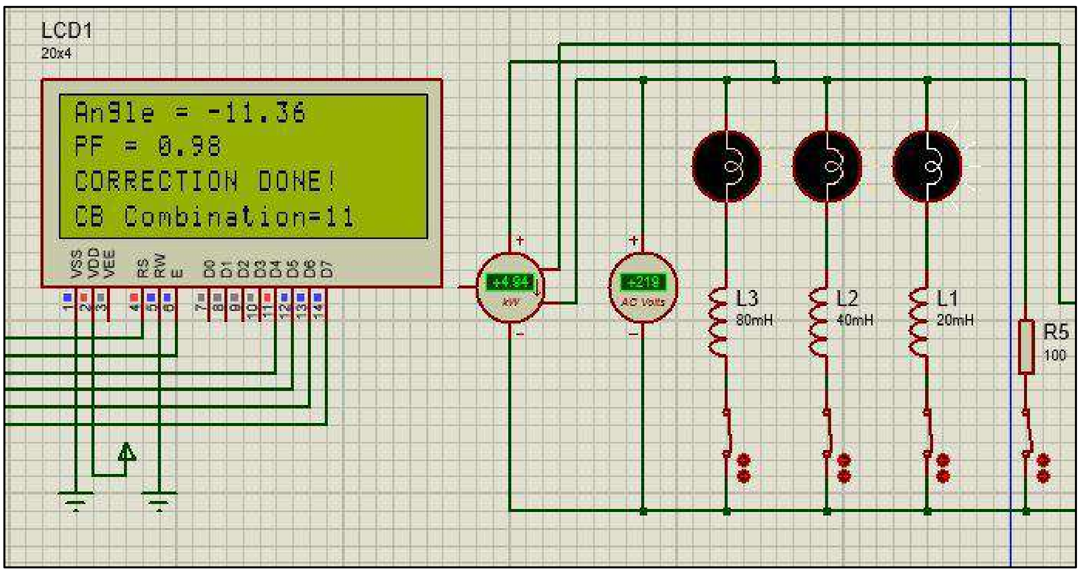


Figure 4.31 : Result on Full Load

CHAPTER 5

EXPERIMENTAL RESULTS & CALCULATION

Chapter Overview

In this chapter, we present a comprehensive overview of the experimental outcomes received throughout the implementation of the Power Factor Improver equipment. We detail the readings and calculations carried out to evaluate the effectiveness of the electricity thing correction machine, consisting of measurements of voltage, cutting-edge, and energy thing earlier than and after the application of the capacitor bank. The chapter elucidates how the capacitor financial institution impacted the load's power issue and quantifies the volume of development done. Additionally, it provides insights into the practical implications and performance of the Power Factor Improver equipment, presenting precious data and evaluation to assist the assignment's goals and conclusions.

5.1 INTRODUCTION

The ultimate test of a device's worth is when we use it and see if it accomplishes what we expect. Once we've assembled the power component correction circuit, we must verify that it accomplishes the task of correcting the power component as intended. This entails periodically testing key electrical parameters and keeping a careful eye on them to guarantee they continuously give the intended outcomes over time. This constant verification and testing is critical to ensuring that the circuit operates properly and continues to give the adjustments required.

5.2 MEASUREMENTS

We must measure everything individually for each of the three load types—once with and once without the corrective mechanism. We're talking about things like checking the supply voltage, frequency, load current, power usage, and power factor. To ensure that the improvements truly save energy, we will monitor the applied power over a set time period. And, by the way, we utilised a fantastic instrument called the Smart Socket to take all of these measurements and keep track of everything.

.

Figure 5.1: PF of pure Inductive Load

5.2.1 Load Calculation Before Correction

We examined the pure resistive load (R Load), series resistive-inductive loads (Series R-L Load), and parallel resistive-inductive loads (Pure L Load) without utilising the corrective equipment. We connected the designed loads to the Smart Socket and took readings for various electrical characteristics.

Table 07: Load Calculation Before Correction

S.No	Load Types	Input Voltages (V)	Frequency (Hz)	Load Current (A)	Power Consume (Watts)	Power Factor	Remarks
1	Pure R load	232	50.0	0.45	101.2	0.99	No Correction Required
2	Series R-L load	234	50.0	2.80	402	0.65	Correction Required
3	Pure L load	234	50.0	2.40	301	0.61	Correction Required

5.2.2 Load Calculation After Correction

To ensure that the Series R-L load and Pure L load, both of which required power factor enhancement, were corrected, we connected them to the power supply using our specially built correction equipment. We attached the loads to the correction equipment's output point and tested all three intended loads after plugging in the correction equipment. During these experiments, we documented the observed data.

Table 08: Load Calculation After Correction

S.No	Load Types	Input Voltages (V)	Frequency (Hz)	Load Current (A)	Power Consume (Watts)	Power Factor	Remarks
1	Pure R load	232	50.0	0.42	101.2	0.99	No Improvement Required
2	Series R-L load	234	50.0	1.64	330	0.98	Correction Done
3	Pure L load	232	50.0	1.22	230	0.98	Correction Done

5.3 MONITORING

Monitoring generally means to be aware of the state of a system and may refer to observe a situation for any modifications which may arise over the time, using a monitor or measuring device. To measure the energy consumed, it is necessary to monitor the load for a specific period of time. The Smart Socket can be used to monitor the time as well as measure the energy consumption for each type of load. The loads are connected continuously for the definite time and continuous monitoring was done with extreme care.

5.3.1 Load Monitoring Before Correction

We monitored the pure resistive load (R Load), series resistive-inductive loads (Series R-L Load), and parallel resistive-inductive loads (Pure L Load) without employing the corrective equipment. We used the Smart socket to connect the intended loads and recorded the energy usage, time, and average power factor values.

Table 09: Load Monitoring Before Correction

S.No	Load Types	Time (Hour)	Energy Consumed (kWh)	Average PF
1	Pure R	2	0.20	0.99
2	Series R-L	2	0.52	0.65
3	Pure L load	2	0.36	0.61

5.3.2 Load Monitoring After Correction

In the Series R-L load and Pure L load, we saw an opportunity to enhance the power factor. We connected them to the power source along with our correction equipment to validate this. The Smart socket was plugged in, and the loads were linked to its output. For a while, we kept a watch on all three designed loads and recorded the figures we saw.

Table 10: Monitoring of Load After Correction

S.No	Load Type	Time (Hour)	Energy Consumed (kWh)	Average PF
1	Pure R	2	0.19	0.99
2	Series R-L	2	0.44	0.98
3	Pure L load	2	0.24	0.98

5.4 MONITORING OF A FLUCTUATING LOAD IN REAL TIME

We created 10 hour load patterns to test how effectively the corrective unit functions with shifting loads in real time. We maintained a watch on the energy figures and average power factor over these periods. Graphs were created to indicate how the power factor changed before and after the correction unit was turned on throughout the duration of the operation.
Over a 10-hour period, we applied three load patterns—A, B, and C. We varied the loads to examine how the control circuit swapped capacitors automatically depending on power factor and reactive power requirements.

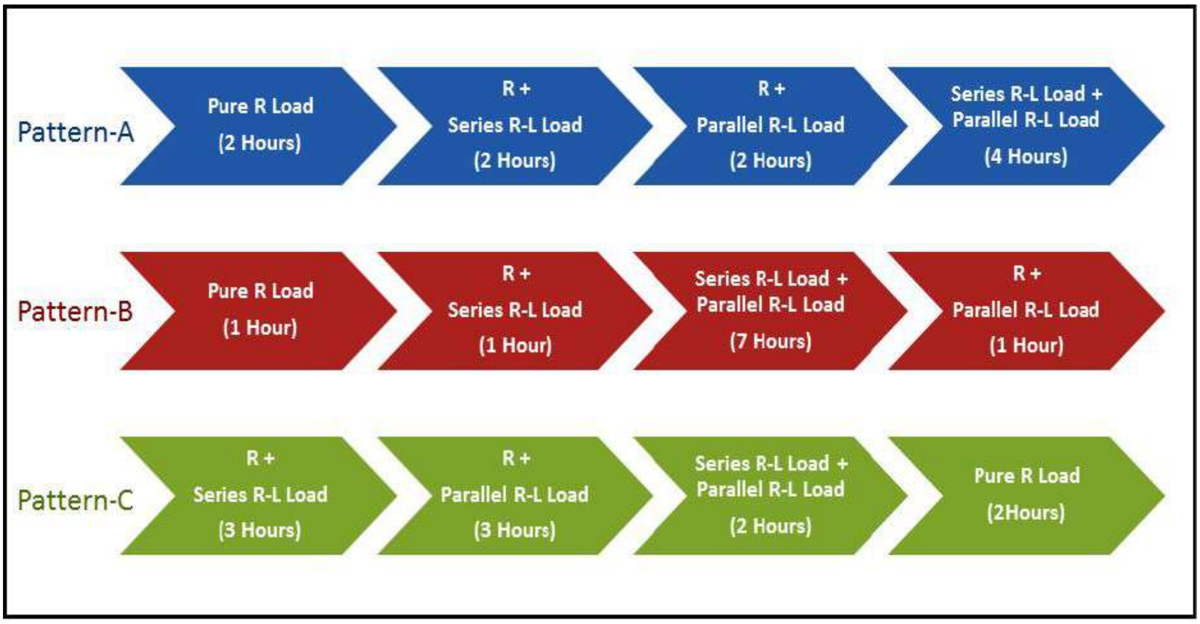


Figure 5.2: Monitoring of Three Samples of Load Patterns

Here's a chart of the recorded data that shows energy usage and average power factor over time, both before and after power factor correction was implemented.

Table 11: Monitoring of a Fluctuating Load in Real Time

S.No	Pattern	Without Correction		With Correction	
		Energy Consumed (kWh)	Average PF	Energy Consumed (kWh)	Average PF
1	A	1.92	0.84	1.59	0.98
2	B	2.13	0.80	1.77	0.98
3	C	1.86	0.82	1.50	0.98

We're seeing an average 1.7% decrease in energy use across the board. The power factor has also increased noticeably, ranging from 9% to 20% depending on the load type. Excitingly, we have achieved our goal power factor of 0.98 in all three circumstances.

5.5 HARDWARE RESULTS

BEFORE IMPROVEMENT

AFTER IMPROVEMENT

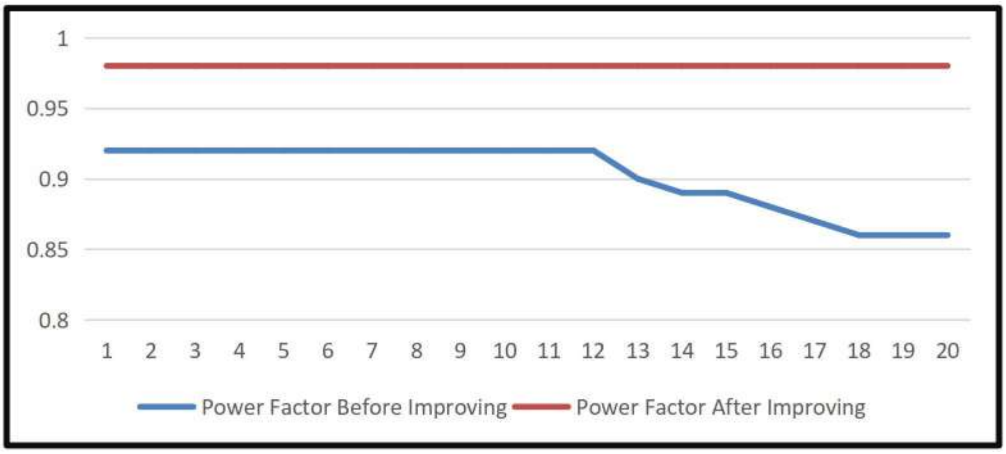


Figure 5.3: Graphical Representation of Power Factor

VOLTAGE

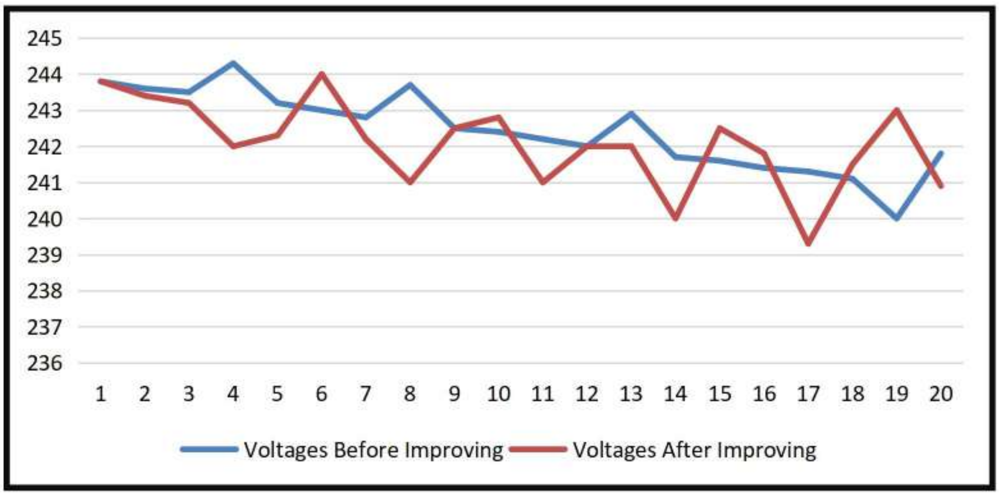


Figure 5.4: Graphical Representation of Voltages

CURRENT

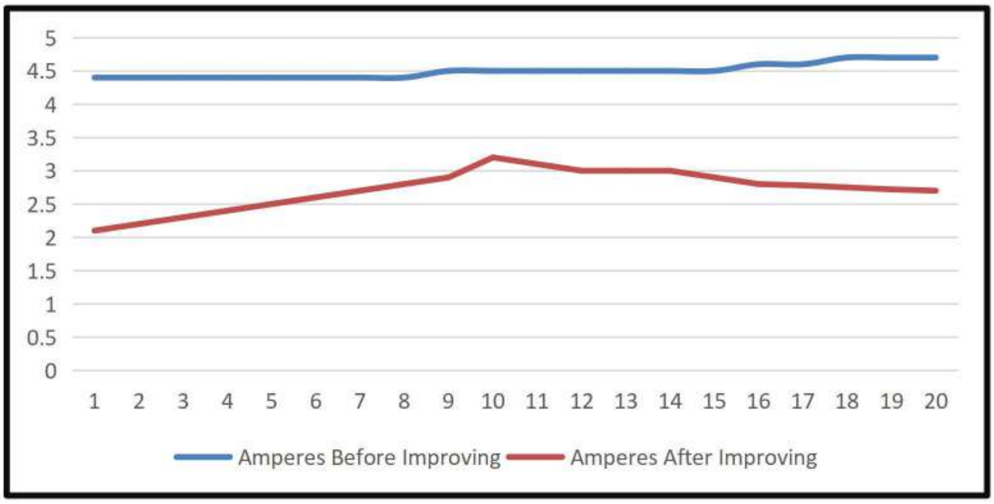


Figure 5.5: Graphical Representation of Current

WATTAGE

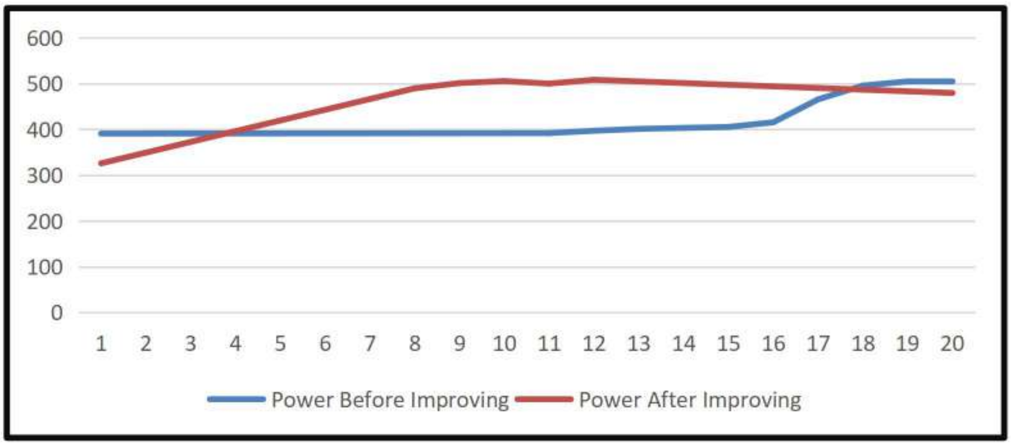


Figure 5.6: Graphical Representation of Watts

UNITS CONSUMPTION

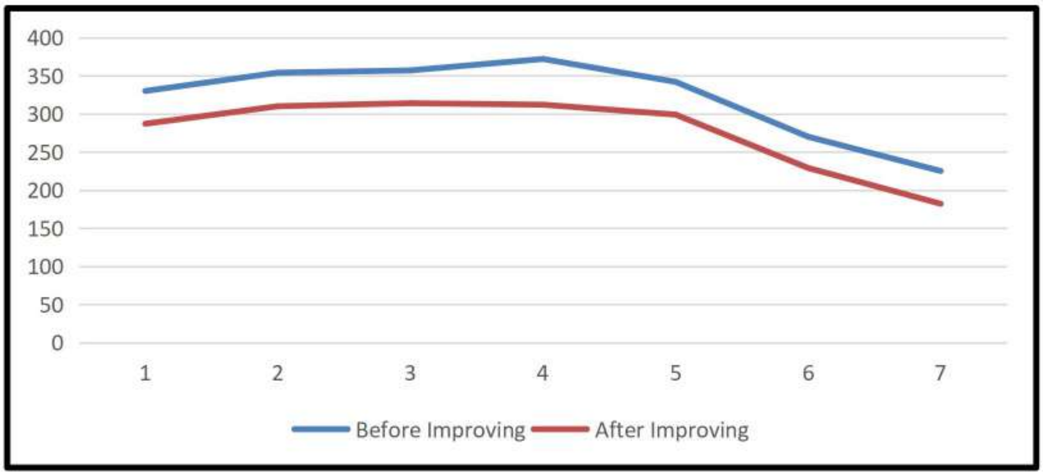


Figure 5.7: Graphical Representation of Units

5.6 RESULTS OF IoT SERVER

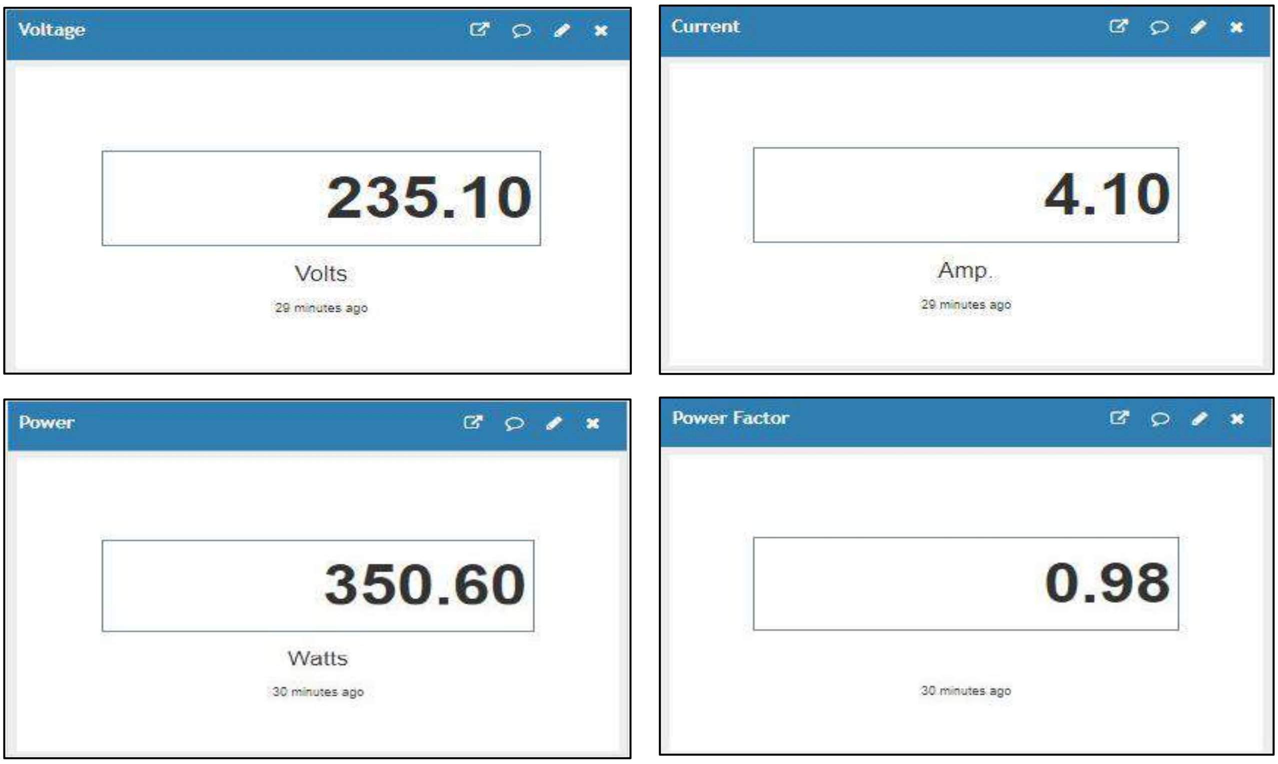


Figure 5.8: Readings on IoT Server

Figure 5.9: Graphs on IoT Server

5.7 CAPACITOR BANK CALCULATION:

Figure 5.10: Capacitor Bank Calculation

5.8 CALCULATIONS BEFORE CORRECTION

According to the above Experimental Results on different load patterns the calculations are:

BEFORE CORRECTION

fridge 7 unit 20 hrs/day	210 units	(100 x 16.48= 1648)
motor 10 hrs/month	4.2 units	(200 x 22.95= 2295)
fan 4.32 per day	129.6 units	(300 x 27.14= 2714)
Total = 343 units		(41 x 32.03= 1313.23)
Total = 7970.23		

5.9 CALCULATIONS AFTER CORRECTION

AFTER CORRECTION

fridge 6.5 units 20 hrs/day	195 units	(100 x 16.48= 1648)
motor 10 hrs/month	3.7 units	(200 x 22.95= 2295)
fan 3.4 per day	102 units	(300 x 27.14= 2659.72)
Total = 300 Units		
Total = 6602.72		

(Saving = 43 Units per Month)
(Saving = 1366/= Rs per Month)

(Saving = 516 Units per Year)
(Saving = 16,404/= Rs per Year)

The cost of the project which is 48,000 will be recovered in 2.5 Years.

CHAPTER 6

SUSTAINABLE DEVELOPMENT GOALS (SDGs)

Chapter Overview

In this chapter, we delve into the heart of our undertaking's significance within the context of worldwide sustainability and development. As we navigate the intricate landscape of the Sustainable Development Goals (SDGs) set forth by using the United Nations, we are able to explore how our challenge aligns with and contributes to those critical worldwide targets. These 17 interconnected dreams embody financial, social, and environmental dimensions, representing a common call to action. Within those pages, we are able to light up the precise SDGs that our mission at once addresses, losing mild on the fantastic impacts we goal to make in pursuit of a extra sustainable and equitable future for all.

6.1 INTRODUCTION

The Sustainable Development Goals (SDGs), mounted with the aid of the United Nations as a part of the 2030 Agenda for Sustainable Development, serve as a conventional name to motion to give up poverty, defend the planet, and make certain prosperity for all. These 17 interconnected dreams are designed to cope with a wide variety of worldwide demanding situations, spanning economic, social, and environmental dimensions. This chapter explores how our project aligns with and contributes to the attainment of numerous key SDGs.

6.2 Sustainable Development Goals:

There are 17 Numbers of sustainable Development Goals which are adopted across over the world.
Now we check and match some of these which are meet to our Final Year Project (FYP). These Goals are:

6.2.1 These Goals are

1. NO Poverty
2. Zero Hunger
3. Good Health and Well being
4. Quality Education
5. Gender Equality
6. Clean water and sanitation
7. Affordable and Clean Energy
8. Decent Work and Economic Growth
9. Industry Innovation Infrastructure
10. Reduce Inequalities
11. Sustainable Cities and Communities
12. Responsible Consumption and Production
13. Climate and Action
14. Life Below water
15. Life on Land
16. Peace Justice and Strong Institutions
17. Partnership for the Goals.

GOAL 7: AFFORDABLE & CLEAN ENERGY

Our project focuses on improving the performance of energy usage thru power aspect improvement. By reaching a greater green use of electricity, we make contributions to the goal of low-cost and smooth power get entry to.

GOAL 9: INDUSTRY, INNOVATION & INFRASTRUCTURE

Our project involves the development and deployment of innovative power factor correction equipment. This aligns with the goal of promoting innovation and improving infrastructure.

GOAL 11: SUSTAINABLE CITIES & COMMUNITIES

Efficient energy use within domestic settings contributes to the sustainability of cities and communities. Our project supports this objective by optimizing power factor.

GOAL 12: RESPONSIBLE CONSUMPTION & PRODUCTION

Power factor correction reduces wastage of energy, promoting responsible energy consumption and efficient resource use.

GOAL 13 : CLIMATE ACTION

Improved energy efficiency and reduced greenhouse gas emissions result from power factor correction, contributing to climate action efforts.

GOAL 17 : PARTNERSHIPS FOR THE GOAL

Collaboration with utility providers, government agencies, and stakeholders is essential for the successful implementation of our project, aligning with the goal of fostering partnerships.

6.3 CONCLUSION

Our project plays a important role in addressing more than one SDGs, showcasing its commitment to sustainability and international development. By improving energy issue and selling efficient electricity use, we contribute to the wider time table of creating a extra equitable, rich, and sustainable international for gift and future generations.

In the following sections of this report, we can delve deeper into the precise details of our project's implementation, effects, and the techniques employed to help these sustainable improvement goals.

CHAPTER 7

CONCLUSIONS & FUTURE EXTENSIONS

Chapter Overview

This chapter provides a concise summary of the project's key findings, dreams achievement, implications, and significance. It highlights the undertaking's contributions to the field, accompanied by way of a dialogue of destiny extensions and guidelines for similarly studies or improvement. Finally, the chapter concludes via emphasizing the overall importance of the mission and expressing acknowledgments to those who contributed, if applicable.

7.1 CONCLUSIONS

1. A power factor correction system, utilizing a microcontroller and capacitor banks, was employed to measure and monitor a simulated electrical load, leading to the following findings:
2. Throughout the tests with various load situations, the power factor correction device greatly improved the power factor, raising it from 0.66 to 0.98.
3. Across the various intended load situations, we found an average 1.7% decrease in consumption of energy.
4. By implementing the appropriate reactive power compensation, the system's capacity was freed up, resulting in a reduced current draw.
5. Economic analysis indicated a payback period of approximately 9 months, along with substantial energy cost savings.

7.2 FUTURE EXTENSION

1. **Predictive Maintenance and Anomaly Detection:** Implement advanced machine learning algorithms to predict equipment failures or anomalies based on real-time data. This extension can help users proactively address potential issues, reduce downtime, and save on maintenance costs.
2. **Integration with Smart Assistants:** Connect your IoT monitoring system to popular smart assistants such as Amazon Alexa or Google Assistant. Users may easily monitor data and operate devices using simple voice commands, making everything more accessible and user-friendly.
3. **Energy Demand Forecasting:** Develop an energy demand forecasting feature that uses historical data and machine learning to predict future energy consumption patterns. This can aid users in optimizing their energy usage and potentially reduce utility costs.
4. **Multi-Language Support:** Extend the mobile app's language options to cater to a global audience. This feature makes your monitoring system accessible and user-friendly for users from different regions and language preferences.
5. **Environmental Impact Assessment:** Create a module that calculates and displays the environmental impact of users' energy consumption and power usage. This information can include carbon emissions, water usage, or other relevant environmental metrics, helping users make eco-friendly choices.

These extensions can add significant value to the IoT data monitoring system by improving predictive capabilities, user accessibility, energy efficiency, and environmental awareness. Prioritize these features based on your project's goals and your target audience's needs.

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APPENDIX

Code of Proteus Simulation

Source code:

```
void Measure();
void Correction(int x);
void Print();
void OC_Print();
void CB_Print();
#include<LiquidCrystal.h>
LiquidCrystal LCD(13,12,11,10,9,8);

float PF, Angle;
int dur = 0;
int Case = 0;
float IL,IL1;

int R1 = 1;
int R2 = 2;
int R3 = 3;
int R4 = 4;
int ReadDur = 0;

void setup() {

  LCD.begin(20, 4);

  pinMode(ReadDur, INPUT);
  pinMode(A0,INPUT);
  pinMode(R1, OUTPUT);
  pinMode(R2, OUTPUT);
  pinMode(R3, OUTPUT);
  pinMode(R4, OUTPUT);
```

```
  digitalWrite(R1, LOW);
  digitalWrite(R2, LOW);
  digitalWrite(R3, LOW);
  digitalWrite(R4, LOW);

}

void loop() {

  Case=0;
  Correction(Case);
  Measure();
  delay(500);

  while(IL<1 && IL1<1)
 {
  LCD.clear();
  OC_Print();
  delay(300);
  Measure();
  delay(500);
  }

  Case=0;
  Correction(Case);
  Measure();
  delay(500);

  LCD.clear();
  Print();
  CB_Print();
```

```
while(PF<0.98)
  {
   LCD.setCursor(0,2);
   LCD.print("Correcting PF");
   Case++;
   if (Case>15)
   {Case=0;
   break;}
   Correction(Case);
   delay(100);
   Measure();
   delay(500);
   Print();
   CB_Print();
   if(Angle>15 || PF>0.98)
   break;
   delay(400);
  }

  delay(400);

  LCD.setCursor(0,2);
  LCD.print("                    ");
  LCD.setCursor(0,2);
  LCD.print("WAIT");
  delay(1000);
  Print();
  CB_Print();

  while(1)
  {
   if(PF<0.98)
```

```
      {
        break;
      }

      LCD.setCursor(0,2);
      LCD.print("                    ");
      LCD.setCursor(0,2);
      LCD.print("CORRECTION DONE!");

      delay(700);
      Measure();
      Print();
      CB_Print();
      }

      delay(500);

}

void Measure()
{
  dur = pulseIn(ReadDur, HIGH);
  Angle = dur * 0.018; //time to angle (in degree) convert
  Angle = Angle-90; // (-90) is for offseting the angle
  PF = cos(Angle*0.0174533); //angle conversion from degree to radian, then PF calcultion
 IL= analogRead(A0);
 delay(500);
 IL1= analogRead(A0);
}
```

```
void Print()
{
 LCD.setCursor(0,3);
 LCD.print("                    ");
 LCD.setCursor(0,0);  //setCursor(x,y)    x=column  y=row
 LCD.print("Angle = ");
 LCD.print(Angle);
 LCD.setCursor(0,1);
 LCD.print("PF = ");
 LCD.print(PF);

}
void CB_Print()
{
 LCD.setCursor(0,3);
 LCD.print("CB Combination=");
 LCD.print(Case);
}

 void OC_Print()
{
 LCD.clear();
 LCD.setCursor(0,1);  //setCursor(x,y)    x=column  y=row
 LCD.print("     NO LOAD");
 LCD.setCursor(0,2);
 LCD.print("    CONNECTED");
 }

void Correction(int x)
{
 if(x==1)
```

```
{
  digitalWrite(1, HIGH);
  digitalWrite(2, LOW);
  digitalWrite(3, LOW);
  digitalWrite(4, LOW);
}

else if(x==2)
{
digitalWrite(1, LOW);
digitalWrite(2, HIGH);
digitalWrite(3, LOW);
digitalWrite(4, LOW);

}

else if(x==3)
{
   digitalWrite(R1, HIGH);
  digitalWrite(R2, HIGH);
  digitalWrite(R3, LOW);
  digitalWrite(R4, LOW);
}

else if(x==4)
{
   digitalWrite(R1, LOW);
  digitalWrite(R2, LOW);
 digitalWrite(R3, HIGH);
  digitalWrite(R4, LOW);
}
```

```
else if(x==5)
{
  digitalWrite(R1, HIGH);
 digitalWrite(R2, LOW);
  digitalWrite(R3, HIGH);
 digitalWrite(R4, LOW);
}

else if(x==6)
{
  digitalWrite(R1, LOW);
 digitalWrite(R2, HIGH);
  digitalWrite(R3, HIGH);
  digitalWrite(R4, LOW);
}

else if(x==7)
{
  digitalWrite(R1, HIGH);
  digitalWrite(R2, HIGH);
  digitalWrite(R3, HIGH);
  digitalWrite(R4, LOW);
}
else if(x==8)
{
  digitalWrite(R1, LOW);
  digitalWrite(R2, LOW);
 digitalWrite(R3, LOW);
  digitalWrite(R4, HIGH);
}
else if(x==9)
```

```
{
  digitalWrite(R1, HIGH);
  digitalWrite(R2, LOW);
  digitalWrite(R3, LOW);
  digitalWrite(R4, HIGH);
}
else if(x==10)
{
  digitalWrite(R1, LOW);
  digitalWrite(R2, HIGH);
  digitalWrite(R3, LOW);
  digitalWrite(R4, HIGH);
}
else if(x==11)
{
  digitalWrite(R1, HIGH);
  digitalWrite(R2, HIGH);
  digitalWrite(R3, LOW);
  digitalWrite(R4, HIGH);
}
else if(x==12)
{
  digitalWrite(R1, LOW);
  digitalWrite(R2, LOW);
  digitalWrite(R3, HIGH);
  digitalWrite(R4, HIGH);
}
else if(x==13)
{
  digitalWrite(R1, HIGH);
  digitalWrite(R2, LOW);
  digitalWrite(R3, HIGH);
  digitalWrite(R4, HIGH);
}
```

```
  else if(x==14)
  {
    digitalWrite(R1, LOW);
    digitalWrite(R2, HIGH);
    digitalWrite(R3, HIGH);
    digitalWrite(R4, HIGH);
  }
  else if(x==15)
  {
    digitalWrite(R1, HIGH);
    digitalWrite(R2, HIGH);
    digitalWrite(R3, HIGH);
    digitalWrite(R4, HIGH);
  }
  else
  {
    digitalWrite(R1, LOW);
    digitalWrite(R2, LOW);
    digitalWrite(R3, LOW);
    digitalWrite(R4, LOW);
  }
}
```

Code of Hardware (Arduino Nano)

Source Code:

```
//=============================================//
#include <PZEM004Tv30.h>
PZEM004Tv30 pzem(2, 3); // Software Serial pin 8 (RX) & 9 (TX)
#include <LiquidCrystal_I2C.h>
LiquidCrystal_I2C lcd(0x27, 16, 2); // set the LCD address to 0x27 for a 16 chars and 2 line display
#include <EEPROM.h>
//==================Online Data Transfer==================//
#define SSID "TP-Link MSK"
#define PASS "Please1967"
String apiKey = "TV2Q57CEQPM4LWU5"; // thingspeak api key

/*==================input Sensor==================*/
#define SetSwitchInput    A0
#define UpSwitchInput    A1
#define DownSwitchInput  A2
#define EmergencySwitchInput  A3
/*==================input Sensor==================*/
int RelayOutput[6] = {12, 11, 10, 9, 8, 7};
#define _ON LOW
#define _OFF HIGH
byte RelayCount = 0;
/*==================Vibration Sensor==================*/
#define LoadOutputRelay  6
#define StartButton  4
//=======================VARIABLEDECLARATION=======================//
float Current1SmoothAnalogValue = 0.0;// to store data from analogue
float Current1Reading = 0.0;
float CurrentCalibrationFactor = 3000.0;
float VoltSmoothAnalogValue = 0.0;// to store data from analogue
```

```
float VoltReading = 0.0;
float PowerReading = 0.0;
float PFReading = 0.0;
float VoltCalibrationFactor = 13.0;
int setPower = 0;
//=================Variable to Store Temperature
Reading================================//
byte lcdCount = 0, secondCount = 0;
byte OnOffOutputDelay = 300;
int LcdRefreshCount = 0;
int CurrentDisplayAtCount = 2;
int VoltPowerDisplayAtCount = 4;
int OtherDisplayAtCount = 6;
String Response;
bool PowerCheck = false;
float setCurrent = 0.0;
bool EmergencyCheck = false;
//=================Relay
ON/OFFProperty==============================================//
int tempdelay = 0;
int SecondsCount = 0;
String LoadCondition = "OFF";
String LoadMedium = "";

void setup() {
  // put your setup code here, to run once:
  Serial.begin(9600);
  DefinePinModeForDigital();
  AllOutputOff();
  HomeScreen();
  StopProcess();
  setPower = (EEPROM.read(0)) * 10;
  if (setPower > 2000)
  {
```

```
    EEPROM.write(0, 0);
    setPower = 0;
  }
}
void loop()
{
  if ((digitalRead(EmergencySwitchInput)) == LOW)
  {
    EmergencyCheck = true;
    LoadCondition = "OFF";
    DisplayAlertScreen();
    AllOutputOff();
    RelayCount = 0;
    return;
  }
  else
  {
    EmergencyCheck = false;
  }
  if ((digitalRead(SetSwitchInput)) == LOW)
  {
    delay(1000);
    int count = 0;
    while ((digitalRead(SetSwitchInput)) == LOW)
    {
      count++;
      if (count > 3)
      {
        AllOutputOff();
        lcd.clear();
        LcdDisplayForSettingNumber(setPower, "Power");
        PowerCheck = true;
        settingPower();
        break;
    }
```

```
    delay(1000);
   }
  }
  //  else if (lcdCount >= 2 && lcdCount < 4 )
  //  {
  //    GetSetVoltCalculation();
  //    GetSetPowerCalculation();
  //    LcdDisplayVoltPowerScreen();
  //  }
  lcdCount = 2;
  secondCount++;

  if (lcdCount == 2)
  {
   lcdCount = 0;
   GetSetCurrentCalculation();
   GetSetVoltCalculation();
   GetSetPowerCalculation();


  }
  if (lcdCount >= 0 && lcdCount < 2 )
  {
   LcdDisplayParameterScreen();
  }

  if (secondCount == 3)
  {
   secondCount = 0;
   AutoProcess();
   send_data();
  }
  delay(1000);
  if (((digitalRead(StartButton)) == LOW) && (LoadCondition == "OFF") && (EmergencyCheck ==
false))
  {
```

```
    StartProcess();
    send_data();
  }
  else if (((digitalRead(StartButton)) == HIGH) && (LoadCondition == "ON") && (EmergencyCheck
== false))
  {
    send_data();
    StopProcess();
  }
  if ((digitalRead(StartButton)) == HIGH)
  {
    ControllRelay();
  }
}
void ControllRelay()
{
  if ((digitalRead(UpSwitchInput)) == LOW)
  {
    //Serial.println(RelayCount);
    if ((RelayCount >= 0) && (RelayCount < 6))
    {
      digitalWrite(LoadOutputRelay, LOW);
      MannualOperateRelay(RelayCount, _ON);
      RelayCount = (RelayCount < 6) ? RelayCount + 1 : RelayCount = 6;
      delay(100);
      while ((digitalRead(UpSwitchInput)) == LOW)
      {

      }
    }
  }
  else if ((digitalRead(DownSwitchInput)) == LOW)
  {
```

```
    //Serial.println(RelayCount);
    if ((RelayCount >= 0) && (RelayCount < 7))
    {
      RelayCount = (RelayCount > 0) ? RelayCount - 1 : RelayCount = 0;
      MannualOperateRelay(RelayCount, _OFF);
      delay(100);
      while ((digitalRead(DownSwitchInput)) == LOW)
      {

      }
    }
    else
    {
      digitalWrite(LoadOutputRelay, HIGH);
    }
  }
}

void settingPower()
{
  while (PowerCheck)
  {
    if ((digitalRead(UpSwitchInput)) == LOW)
    {
      if ((setPower >= 0) && (setPower < 2000))
      {
        setPower = setPower + 100;
        LcdDisplayForSettingNumber(setPower, "Power");
        delay(1000);
        while ((digitalRead(UpSwitchInput)) == LOW)
        {
          if ((setPower >= 0) && (setPower < 2000))
          {
```

```
        LcdDisplayForSettingNumber(setCurrent, "Power");
        setPower = setPower + 100;
      }
      delay(100);
    }
  }
}
if ((digitalRead(DownSwitchInput)) == LOW)
{
  if ((setPower > 0) && (setPower < 2100))
  {
    setPower = setPower - 100;
    LcdDisplayForSettingNumber(setPower, "Power");
    delay(1000);
    while ((digitalRead(DownSwitchInput)) == LOW)
    {
      if ((setPower > 0) && (setPower < 2100))
      {
        setPower = setPower - 100;
        LcdDisplayForSettingNumber(setPower, "Power");
      }
      delay(100);
    }
  }
}
if ((digitalRead(SetSwitchInput)) == LOW)
{
  delay(1000);
  int count = 0;
  while ((digitalRead(SetSwitchInput)) == LOW)
  {
    count++;
    if (count > 3)
    {
```

```
          AllOutputOff();
          EEPROM.write(0, setPower / 10);
          LcdDisplayParameterScreen();
          PowerCheck = false;
          break;
        }
      }
    }
  }
}
int LcdDisplayForSettingNumber(int number, String entity)
{
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Set ");
  lcd.print(entity);
  lcd.print(" =");
  lcd.print(number);
}
void StopProcess()
{
  AllOutputOff();
  LoadCondition = "OFF";
  LoadMedium = "";
  RelayCount = 0;
}
void StartProcess()
{
  delay(1000);
  digitalWrite(LoadOutputRelay, LOW);
  LoadCondition = "ON";
  RelayCount = 1;
}
```

```
void AutoProcess()
{


 if (LoadCondition == "ON")
 {
  if (PFReading > 0)
  {
   if (PFReading <= 0.98)
   {
    MannualOperateRelay(RelayCount, _ON);
    RelayCount++;
   }
   else if (PFReading >= 0.99)
   {
    RelayCount--;
    MannualOperateRelay(RelayCount, _OFF);
   }

  }
  else
  {
   RelayCount = 0;
   MannualOperateRelay(0, _OFF);
  }

 }
}
void DefinePinModeForDigital()
{
 pinMode(LoadOutputRelay, OUTPUT);
 pinMode(StartButton, INPUT_PULLUP);
 pinMode(SetSwitchInput, INPUT_PULLUP);
```

```
  pinMode(UpSwitchInput, INPUT_PULLUP);
  pinMode(DownSwitchInput, INPUT_PULLUP);
  pinMode(EmergencySwitchInput, INPUT_PULLUP);
  for (int i = 0; i < 6; i++)
  {

    pinMode(RelayOutput[i], OUTPUT);
    digitalWrite(RelayOutput[i], _OFF);
  }
}
void AllOutputOff()
{
  digitalWrite(LoadOutputRelay, _OFF);
  for (int i = 0; i < 6; i++)
  {
    digitalWrite(RelayOutput[i], _OFF);
  }
}
void LcdDisplayParameterScreen()
{
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("A:");
  lcd.print(Current1Reading, 1);
  lcd.setCursor(9, 0);
  lcd.print("V:");
  lcd.print(VoltReading, 1);
  lcd.setCursor(0, 1);
  lcd.print("W:");
  lcd.print(PowerReading, 1);
  lcd.setCursor(9, 1);
  lcd.print("PF:");
  lcd.print(PFReading, 2);
}
```

```
void send_data()
{
  Serial.print("<" + String(Current1Reading) + "|" + String(VoltReading) + "|" + String(PowerReading) +
"|" + String(PFReading) + ">");
}

void HomeScreen()
{
  lcd.init();                      // initialize the lcd
  // Print a message to the LCD.
  lcd.backlight();
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("  Power Factor  ");
  lcd.setCursor(0, 1);
  lcd.print("   Controller   ");
  delay(3000);
}
void DisplayAlertScreen()
{
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("   Emergency   ");
  lcd.setCursor(0, 1);
  lcd.print("     Alert     ");
  delay(2000);
}
void DisplayHighVoltScreen()
{
  lcd.clear();
  lcd.setCursor(0, 1);
  lcd.print("Volt: ");
  lcd.print(pzem.voltage());
  lcd.setCursor(0, 1);
```

```
  lcd.print(" HIGH Voltage  ");
  delay(2000);
}
void DisplayLowVoltScreen()
{
  lcd.clear();
  lcd.setCursor(0, 1);
  lcd.print("Volt: ");
  lcd.print(pzem.voltage());
  lcd.setCursor(0, 1);
  lcd.print(" LOW Voltage   ");
  delay(2000);
}

void SoundActivate()
{
  //  digitalWrite(BuzzerOutput, HIGH);
}
void SoundDeactivate()
{
  //  digitalWrite(BuzzerOutput, LOW);
}

void GetSetCurrentCalculation()
{
  //  Current1SmoothAnalogValue = GetAnalogReading(Phase1Current);
  //
  //  if (Current1SmoothAnalogValue > 6)
  //  {
  //    Current1SmoothAnalogValue = Current1SmoothAnalogValue + 1200;
  //  }
  Current1Reading = pzem.current();
}
```

```
void GetSetVoltCalculation()
{
  //  VoltSmoothAnalogValue = GetAnalogReading(PhaseVolt);
  //  if (VoltSmoothAnalogValue > 20)
  //  {
  //    VoltSmoothAnalogValue = VoltSmoothAnalogValue + 180;
  //  }
  VoltReading = pzem.voltage();
  if (VoltReading > 280)
  {
    LoadCondition = "OFF";
    DisplayHighVoltScreen();
    AllOutputOff();
  }
  else if ((VoltReading > 0) && (VoltReading < 170))
  {
    LoadCondition = "OFF";
    DisplayLowVoltScreen();
    AllOutputOff();
  }
}
void GetSetPowerCalculation()
{
  PowerReading = pzem.power();
  PFReading = pzem.pf();
}

void MannualOperateRelay(int val, int cn)
{

  for (int i = val; i < 6; i++)
  {
```

```
    digitalWrite(RelayOutput[i], _OFF);
  }
  digitalWrite(RelayOutput[val], cn);
}
void send_data_thingspeak(){
  String cmd = "AT+CIPSTART=\"TCP\",\"";  // TCP connection
  cmd += "184.106.153.149"; // api.thingspeak.com
  cmd += "\",80";
  SoftSer.println(cmd);

  if (SoftSer.find("Error")) {
    Serial.println("AT+CIPSTART error");
    return;
  }
  String getStr = "GET /update?api_key=" + apiKey + "&field1=" + String(Current1Reading) +
"&field2=" + String(VoltReading) +
                  "&field3=" + String(PowerReading) + "&field4=" + String(PFReading) + "\r\n\r\n";
  cmd = "AT+CIPSEND=" + String(getStr.length());  // send data length
  SoftSer.println(cmd);
  if (SoftSer.find(">")) {
    SoftSer.print(getStr); // Send data.
  }
  else {
    SoftSer.println("AT+CIPCLOSE");
    Serial.println("AT+CIPCLOSE"); // If this shows on the serial monitor the data did not send.
  }
  SoftSer.println("AT+RST");  // The AT+RST command resets the ESP8266
  delay(15000); // Thingspeak Data Catch Interval
}
```