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Power Factor Improvement Monitoring using IoT

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Certificate

This is to certify that this thesis entitled **"Power Factor Improvement Monitoring using IoT"** is done by the following students under my direct supervision and this work has been carried out by them in the laboratories of the Department of Electrical and Electronic Engineering Sonargaon University in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering. The presentation of the work was held on May, 2026.

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Dedicated

To

Our Supervisor and Our Parents

With

Love and Respects

Abstract

Energy conservation plays a significant role in this environment to save more energy. It thus presents the system that continuously transmits data on the various factors affecting the inductive and capacitive loads onto a webpage via the Internet of Things. It sends alert messages to the concerned person and activates an electronic relay if a defect is detected. The power factor decreases as the inductive load increases, so this system has a power factor improvement mechanism that switches capacitor banks when the inductive load increases. Power Factor Improvement Monitoring will be developed for variable loads to monitor energy consumption and automatically improve their power factor. Additionally, a low power factor will help to reduce the penalty and protect inductive loads as well as identify problems before they arise.

Acknowledgment

First of all, we thank Almighty Allah. Then we might wish to thank our project and thesis supervisor **Rudaina Tasnuva, Lecturer**, Department of EEE for being dedicated to supporting, motivating, and guiding us through this project. This project can't be avoided without her useful advice and help. Also, many thanks for allowing us to work on this project.

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List of Acronyms

APFC	Adaptive power factor controller
CCM	Continuous current mode
EMF	Electro Motive Force
IDE	Integrated Development Environment
IoT	Internet of Things
LCD	Liquid crystal dsplay
PF	Power Factor
PFC	Power Factor correction
PFI	Power Factor Improvement
RMS	Root-mean-square
UPS	Uninterrupted power supplies

List of Symbols

φ	Phi

Chapter 1

Introduction

1.1 Introduction

The maximum of the electrical energy we use in our regular survives is an alternating current. Our daily consumption is approximately this amount. AC is therefore the most useful form of electricity that is engendered, transferred, plus dispersed. Various types of electrical appliances plug into a 'load' to measure our consumption. Inductive, capacitive, and resistive loads might all be able to be applied to this load. The power factor is therefore a factor to consider. An electric system's power factor measures the energy perception of the system's power flow. Electrical systems consist of resistors, inductors, and capacitors. Electromagnetic fields drive inductive devices. Reactive and true power both are required to operate these inductive devices.

Most of the loads are which we use, such as electric generators, motors, transformers, arc welders, ceiling fans, and wireless cellphone chargers, are inductive. The inductive loads which are provided with a power factor are called lagging power factors, or less than 100 percent is based upon the ratio of the power factor. The stumpy power factor highly wasting of active power which results in additional losses throughout the entire process of power utilization. So the thought that crosses our mind is how this inductive load could be economically beneficial. The majority of electrical equipment in commercial and industrial settings functions as a resistor or inductor. As the low power factor is both non-profitable in the power sector and financial sector. To sustain the economical friendly utilization and make sure the best use of the scarce resource of power, we must make sure we have the power factor as close as possible to the unit.

To the correct power factor (PFC), shunt capacitor banks are utilized. Capacitor switching is increasingly being automated to gain maximum benefit in real-time. Due to their dependability and execution, microcontroller-based embedded systems are well suited to monitoring and controlling correction devices.

1.2 Purpose of the Study

High RMS and peak currents will result from a low power factor. This means a significant transmission loss on the part of electric companies. Larger transmission lines requiring frequent repairs may be required for higher currents. The losses are charged to consumers.

Excessive harmonics can cause flicker issues if there is a poor power factor. LED lighting, as well as other light sources, will exhibit a noticeable flicker effect.

Market competitiveness will be reduced when a product has a low power factor.

1.3 Statement of the Problem

The name of our project is Power Factor Improvement Monitoring using IoT. This is a modern project. We know that the power factor will fall when an inductive load is introduced in the industry. If the power factor is reduced, the electricity bill will be higher. Our system automatically connects the automatic capacitor bank when the power factor is low and restores the power factor to a specified value. The special aspect of our project is that we have worked with IoT (Internet of Things) systems in our project. In addition to monitoring from the project display, we will be able to monitor and control from anywhere via the Internet. We have utilized the Arduino Uno Microcontroller in this project.

1.4 State-of-the-art Solutions

The adaptive power factor controller (APFC) can help improve the reliability, cost, and effectiveness of three-phase induction generators utilizing correcting the power factor [1]. We tested the peak-current programmed boost topology using [2] to correct the power factor and reduce distortions. To optimize the operation of an adjustable speed slip power recovery drive [3], the power factor (PF) and speed were adjusted. Power factor controllers that combine buck and boost stages, as presented in [4], are advantageous for higher input voltages, the production of high output voltages, e.g. 400 V, the wide range of input voltages, and the elimination of inrush limits. In [5,] a single-switched fully-controlled three-phase rectifier was developed which allows high AC power factors and DC voltage regulation, while still allowing high-frequency lining.

The one-cycle controller also eliminated output voltage ripple, and the switch voltage pressure was narrow thanks to a lossless clamper circuit [6]. An analysis of ripple current in a boost-type PF control circuit incorporating an electrolytic capacitor was performed. The continuous current mode (CCM) operation of a family of power converters was proposed in [7] when testing the burn-in of synchronized uninterrupted power supplies (UPS) with sinusoidal output voltages. All works above do not examine the monitoring and control of electrical parameters using wireless technology. These features have been integrated into our developed PFC through this work.

1.5 Scope of Work

The scope of the project only covers up to:

- This project mainly focuses on the single-phase system 240VAC, 50Hz, for house applications.
- Current used below 20A.
- Using capacitor bank to improve the power factor for the single-phase residential system.

1.6 Design Goals

The main objectives of this project are

- Monitoring the load power factor uninterruptedly progresses the power eminence.
- Improve the PF of the system to greater than 0.95 using IoT-based correction improvement equipment.
- To decrease the drawback.
- To recognize the irregularity earlier it ensues.
- Monitoring the factors of the scheme accessible.
- IoT monitoring and controlling system.

1.7 Thesis Contribution

This thesis has made the following significant contributions to knowledge:

- An extensive review of past research on power factor determination against a motor load is made, ranging from no-load to full-load and over-load conditions.
- Several measurements of input power are presented to obtain the load and power factor in comparison with each other. Additionally, it contributes to finding the support vector regression method for estimating the power factor in missing points between no-load and over-load conditions.
- The combination of the input power measurement method and support vector regression method provides a reliable means to determine the active power and an initial power factor at any loading point. So, this combination makes a critical contribution to the knowledge of how to make the power factor unity and get the volt-ampere reactive.

1.8 Thesis Outline

- **Chapter 1: Introduction** provides a transitory synopsis of basic info, the problem statement, objectives, scope, thesis contribution, and organization of the thesis.

- **Chapter 2: Background and Motivation** presents the in-progress state of exploration in PFI and PF. And also discussed the benefits and methods of PFI and the justification of thesis work.
- **Chapter 3: The Design Methods and Procedures** dives deeper into the system architecture with block & circuit diagrams, methodology, hardware component lists, the IoT, and the working process of PFI.
- **Chapter 4: Performance Evaluation** analysis of the project outcome and also hardware setup, the performance metrics, and the result analysis and discussion of this project are presented.
- **Chapter 5: Conclusion** concludes the book by discussing the conclusion, practical implications, and future recommendations for research work.

Chapter 2

Background and Motivation

2.1 Introduction

Mechanized industries strive to maximize energy efficiency in their processes. Any electrical system's power factor tells us whether it can do a beneficial effort. Due to the underutilization of induction motors, most machines have notoriously low power factors. Inefficient use of the system. Load currents are high, resulting in poor voltage regulation and huge joule damages. Condensed voltage levels straight lead to warming of motor windings, thereby decreasing machine reliability and lifespan. Specifically, a lower voltage results in less available torque, reducing machine performance. Ordinarily, a slightly great portion of an electric utility's monthly bill is composed of the maximum kilovolt-ampere demand charge due to poor power factors.

Power is a standout of the most critical things in one's daily life since practically every device we utilize is relying upon the power to work. So, electrical energy conservation is an essential requirement for ensuring that consumers consume the least amount of electricity. There are two approaches to reducing power consumption.

In the beginning, the consumer must use electrical energy effectively using manual techniques. For this scenario, the consumer must turn off any attachments or electric attachments whenever no machines are in use and only use electricity when necessary. The second step is to introduce the PFC expedient, which will function as an energy squirrel to improve electrical energy efficiency. There are certain points of interest in expanding energy proficiency by utilizing PFC. In this case, current-dependent damages are reduced, so expanding power generation due to CO2 emissions is not necessary [8]. This applies to both the client's system and open transmission and distribution systems. Along these lines, increased transmission limits are made possible, such as for the transmission of renewable energy.

2.2 Power Factor (PF)

Electrical power systems utilizing AC electricity define power factor as the proportion of the apparent power to the real power flowing to the load [2]. During a given period, the circuit can perform a specific amount of work. Current and voltage both are the components of apparent power. There are two possible reasons for the apparent power to be greater than the real power. Energy is stored in the load and returned to the source, and a non-linear load distorts the wave shape of the current drawn from the source. It is geometrically given away in Figure 2.2.

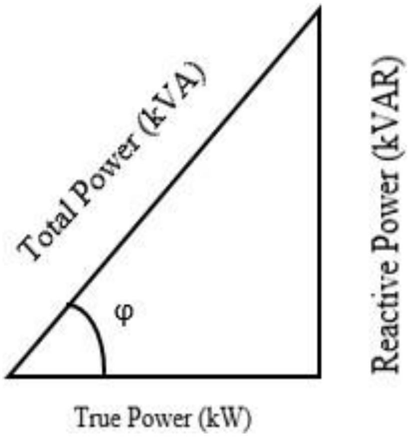


Figure 2.2: Graphic illustration for PF

True Power, Active Power, or Real Power all are standings describing the actual power eroded or used in an AC circuit. Kilowatts (kW) or megawatts (MW) are the measurement units.

Reactive power, which is the power that tides in equal directions in a circuit or reacts to it, is defined as that which flows back and forth. MVAR and kVAR are used to measure reactive power.

The root-mean-square (RMS) of voltage and the current is the apparent power. MVA or KVA is the unit of measurement. The factor can be determined from the ratio of true power to apparent power in the triangle above the power.

$$Power\ factor, \cos\varphi = \frac{True\ power}{Apparent\ power} = \frac{kW}{kVA} = \frac{kW}{\sqrt{kW^2 + kVAR^2}} \qquad (1)$$

The phase angle of inductive load results from a small current flowing through it, such as a transformer, welder, motor, or lighting ballast. Implementing power factor correction can improve power factor due to an inductive load. To gain an appreciable improvement in power factor, an abnormally distorted current waveform requires altering the design of the equipment or deploying expensive harmonic filters. To be efficient, the power factor should be close to one. Commercial customers with power factors less than some limit, typically between 0.9 and 0.95, are charged additional charges from their utilities.

2.2.1 Causes for Low PF

- Vapour lamps use mercury or lamps that use chokes.
- Transformers for power and distribution. The power factor of an unloaded transformer is very low because of its inductive properties.

- Load and unload conditions of induction motors.

2.3 Power Factor Improvement (PFI)

The word PF approaches performance simply in AC circuits. Arithmetically it is the cosine of the phase variation among the source voltage and current. The power which is employed for convenient effort is known as active power and represents the fraction of total power (apparent power).

$$\cos\varphi = \frac{Active\ power}{Apparent\ power}$$

2.3.1 Methods for PFI

The subsequent expedients and tools are intended for PFI

- Static Capacitor
- Synchronous Condenser
- Phase Advancer

i. Static Capacitor

Almost all industries and loads of electric power systems are inductive, resulting in lagged currents flowing and reducing the system's PF. Static capacitors are linked parallel to the low power factor devices, to improve the power factor.

As a result, they generate a leading current, which neutralizes, or in some cases eliminates, the lagging element of load current, improving the PF of the load circuit.

It is installed near inductive loads, including motors as well as transformers. This improves the PF of the load circuit and therefore increases the proficiency of the scheme.

Benefits:

- Compared with other ways to improve power factors, capacitor banks offer several advantages.
- Fatalities are little in static capacitors.
- There is no moving portion, so it requires little repairs.
- Normal atmospheric conditions can be used (e.g. normal temperatures).
- Do not oblige a source for setting up.
- As they are lightweight, they are easy to install.

Drawbacks:

- Static capacitor banks last 8 to 10 years on average
- Switching loads cause surges in the system whenever the capacitor bank is ON or OFF
- In case of an increase in rated voltage, it will cause damage to it
- When the capacitors are damaged, at that time renovation is expensive.

ii. Synchronous Condenser

Synchronized condensers are those that operate at no-load and over-exit. The synchronous motor provides a prominent current whenever it is over-enthusiastic and acts as a capacitor.

The parallel connection of a synchronous condenser eliminates the reactive component and improves the power factor. Large industries generally use synchronous condensers to improve PF.

Benefits:

- Lengthy lifespan (nearly 25 years).
- High consistency.
- Step-less regulation of PF.
- Not any produce of harmonics of repairs.
- The errors can be detached effortlessly.
- It’s not exaggerated via harmonics.
- Need stumpy maintenance (solitary interrupted manner smearing is compulsory).

Drawbacks:

- It is mostly affordable for large power users due to the cost of maintenance.
- Because the synchronous motor does not consume a self-starting torque, a supplementary expedient must be used for this operation.
- It delivers sound.

iii. Phase Advancer

For power factor improvement, phase advancers are connected to the motor's main shaft and operate with the motor's rotor circuit. An induction motor's power factor is improved with a phase advancer.

Induction motors have a low power factor because the stator windings are 90° beyond phase with the voltage. Exciting the ampacity turns from an exterior AC basis would not affect the stator windings. Consequently, the PF of an induction motor will be enhanced. This progression is completed using a phase advancer.

Benefits:

- Because the thrilling ampere-turns are provided at slip frequency (fs), lagging kVAR is sufficiently condensed.
- When synchronous motors are not an option, phase advancers can be employed instead.

Drawbacks:

- Consuming a phase advancer is not achievable for motors inferior to 200 HP (around 150kW).

2.4 Benefits of PFI

Improving an ability's PF can consume the subsequent paybacks [10]:

- PF supplements inspire greater proficiency.
- The condensed request concerns.
- Improved load carrying competencies in present circuits.
- Enhanced voltage.
- Lessening in power-system damages.

It is only through capacitance that the losses due to the kiloVARs (kVAR) current can be reduced. The losses increase with a squared current. Power factor improvements reduce current directly, so power factor damages are contrariwise proportionate to the square of the PF. There are losses in capacitors, however, they are comparatively minor, and they account for less than a third of a percent of the kVAR rating.

2.5 Justification of this Thesis Work

As a result of rearranging SR Mula's circuit of conventional thyristors with a line-frequency-controlled single-phase rectifier, the power factor has been improved [9]. After the circuit is modified, passive and economical correction techniques are cast-off to increase the reactive PF. In passive power factor correction (PFC), non-conducting resistors are added to the DC-side terminals of the rectifier to make the DC equivalent load fully resistive. By introducing a resistance electronic emulator, the power conversion is improved, and the resistance losses are minimized.

To improve the power factor, one must find electrical appliances that will produce noise and harmonics [10]. Power factor will be affected, or not, by the noise and harmonics produced. Fluke Meter is used to estimate harmonics at equipment, and the software presents a simulation of all the equipment tested.

One of the electrical appliances that will lower the power factor is the induction motor. The author certainly did extensive research about power factor and induction motors, and ways to improve power factor in industrial settings.

In 2008, Chaudhury designed and implemented a low-cost PFI device for little power masses. Modeling the small-signal load, choosing appropriate capacitors, and designing appropriate switching circuits were all essential to the design [11].

To achieve desired efficiency and low cost, Shahid and Anwar (2013) [12] developed an improved power factor circuit with a programable interface controller chip. To increase the power factor value, an algorithm is used to conclude and activate switching capacitors based on information gathered from the load. This is done to determine and compensate for excessive reactive components [13].

2.6 Summary

In this section, we present the in-progress state of exploration in PFI and PF. And also discussed the benefits and methods of PFI and the justification of thesis work.

Chapter 3

The Design Methods and Procedures

3.1 Introduction

PFI shows the utmost significant character in energy maintenance in this context to preserve further energy in the prospect. Using IoT, the system continuously monitors the induction motor besides then apprises the information directly on a webpage. In the event of a malfunction, the system sends alert messages and an electronic relay goes into operation. The PF will reduce as the inductive load rises, so this scheme incorporates a switch to improve the power factor. In this project, we intend to build a computer system that can spontaneously progress the PF of induction motors. In this way, their power factor is automatically modified based on their energy consumption. In addition to reducing the consequence due to low power factor and keeping utilities protected from induction motor failures, the system also identifies potential problems beforehand.

3.2 Block Diagram

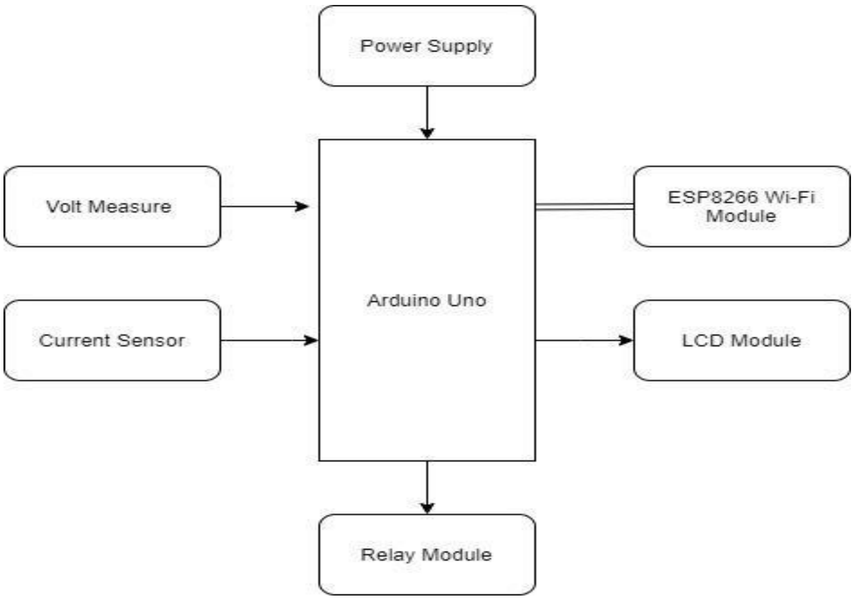


Figure 3.2: Block illustration of the whole system

The Arduino Uno, sensor, also Wi-Fi module are used in this proposed method. This project uses a power supply to power the entire system. The main aim of **Power Factor Improvement** with IoT. In the above block diagram, there is the current sensor, voltage sensing system, LCD, relay module, and Wi-Fi module. The microcontroller continuously checks the output of the sensor and gives a signal to the IoT system circuit which drives the apps.

3.3 Circuit Diagram

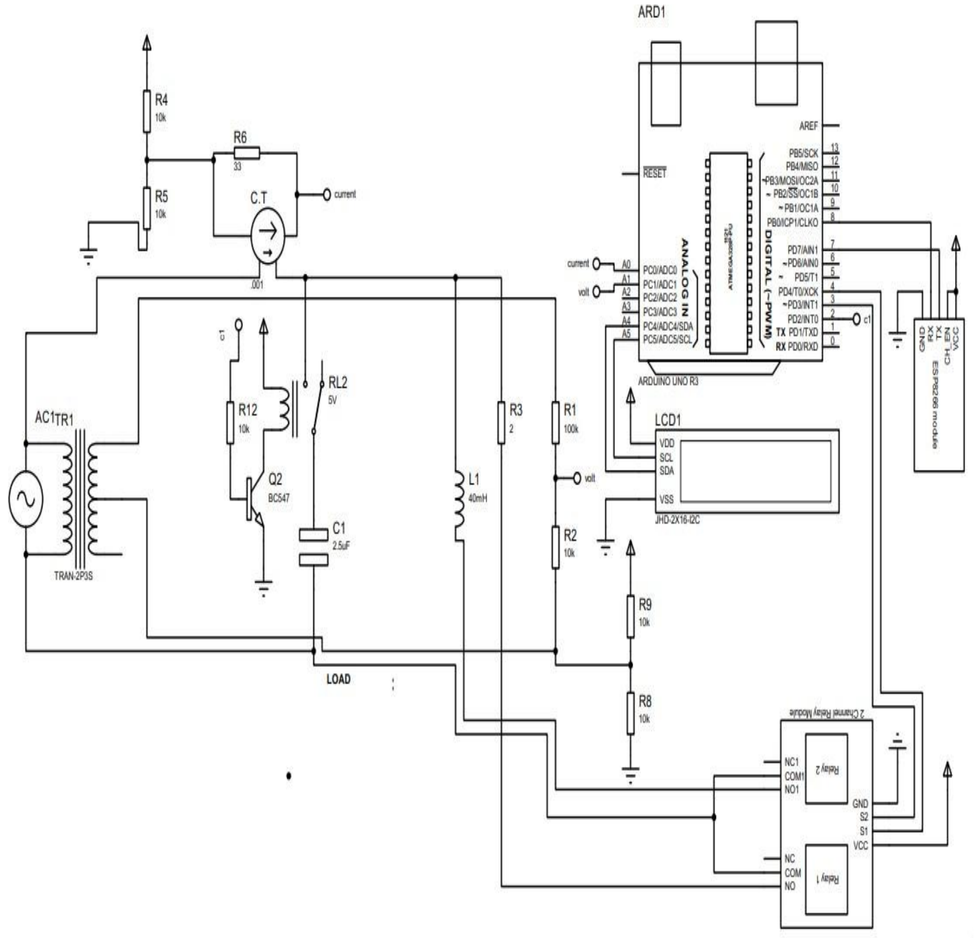


Figure 3.3: Circuit illustration

3.3.1 Circuit Description

By connecting all the circuit devices, we have created a circuit design. To estimate the line voltage at this time, we have reduced the voltage and used a combination of registers, a current sensor to estimate current, a capacitor to improve the PF, a display to display project data, and a wireless module through which we can control the load, and an Arduino Uno to program the project.

3.4 The list of devices

- Arduino Uno (ATmega 328p).
- Relay Module.
- LCD Display.
- Current Sensor.
- Power Capacitor.
- Adaptor.
- Transformer

- AC Voltage sensor
- ESP8266
- Jumper Wire

3.4.1 The Arduino Uno (ATMega328)

In a nutshell, the Arduino Uno is an open-source microcontroller board built on the ATmega328P microcontroller. Several extension boards or shields, besides additional circuits, can be interfaced with the board's digital and analog input/output pins. A form B USB cable is essential to program the board using the Arduino IDE (Integrated Development Environment). It has 6 Digital pins and 12 Analog pins. An external 9-volt battery can be used to power it, or a USB cable can be used. It is correspondingly related to the Arduino Nano and Leonardo. It can be downloaded from the Arduino website and dispersed beneath the Creative Commons Attribution-Share Alike 2.5 license. Various outline and production files are also available.

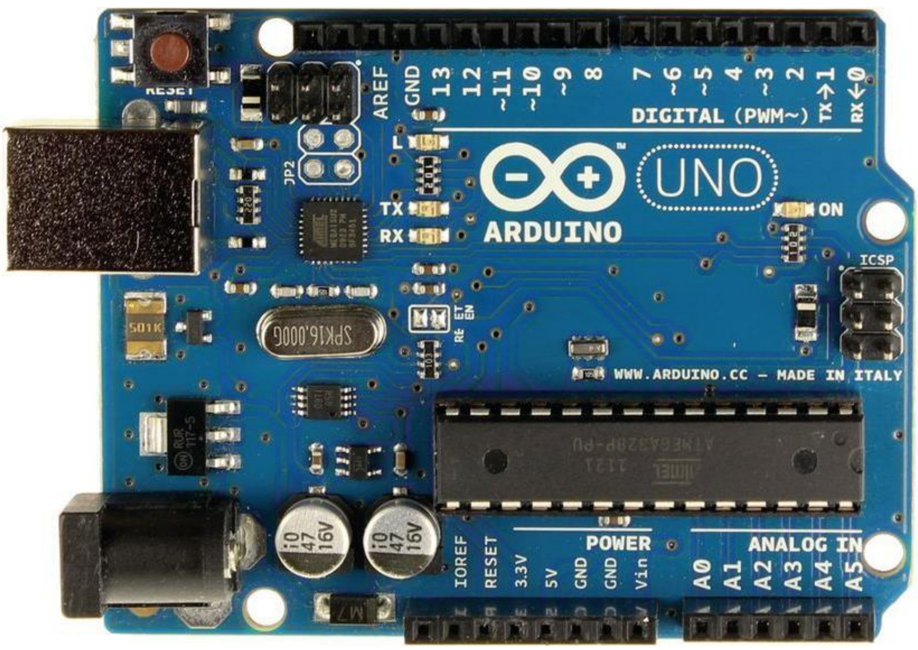


Figure 3.4.1: The Arduino Uno

This initial release of the Arduino Software was given the name "Uno" for its Italian meaning. Arduino Uno was the leading of a series of USB-based Arduino boards, and the Arduino IDE and Uno together were the first releases of Arduino software. A bootloader is already preprogrammed into the ATmega328, allowing programmers to upload a new code deprived of an exterior hardware systems analyst.

It is the first board not to include the FTDI USB-to-serial driver chip while using the STK500 protocol as its communication protocol. The USB-to-serial converter uses the Atmega16U2 (Atmega8U2 capable of version R2) as an analog input.

3.4.2 Relay Module

A relay is an electrical operated expedient. An input circuit or input contactor may be referred to as a control system or controlled system for the device. It is habitually utilized in the spontaneous control circuit. The device uses a low-current signal to control a high-current circuit.

Figure 3.4.2: Relay module

Structures:
The structures of the 1-Channel Relay module are, for instance, trails:

- Safety is good. A lower current can control a higher one in power systems and high voltage systems.
- Providing a single-channel output for high voltage systems.
- The extensive variety of controllable voltage.
- A high load current can be controlled, up to 240V, 10A.
- This switch is normally open (NO) and normally closed (NC).

3.4.3 LCD Display

Figure 3.4.3: LCD

16*2 LCD is the LCD most often connected to an Arduino Uno. There are 16 characters per line by 2 lines, and LCD is increasingly replacing LED in recent years.

The good news is that a precise prevalent standard exists which enables us to converse with most LCDs, irrespective of their manufacturer. An LCD is connected directly to HD44780U chip that obtains data commencing an exterior source and speaks straight with it.

The 44780 standard specifies 3 control lines along with any 4 or 8 I/O lines for the data bus. The LCD can be configured to operate with a 4-bit or an 8-bit data bus. For a 4-bit data bus, an LCD obliges 7 data lines (3 control lines plus 4 lines for the data bus). An LCD with an 8-bit data bus will need a full of 11 data lines, including three control lines and eight lines for the data bus.

Features

- Demonstration data RAM
- Character creator ROM
- 160 dissimilar 57 dot matrix character outlines.
- The microprocessor can access demonstration data RAM also character creator RAM.
- Numerous instruction.
- Clear Display, Cursor Home, Display ON/OFF, and Cursor ON/OFF, Blink Character, Cursor Shift.
- The incorporated reset circuit is activated at power ON.

Table 3.4.3: Pin symbol description

PIN	Sign	Function
1	VSS	GND
2	VDD	+5V
3	V0	Contrast adjustment
4	RS	H/L Register select signal
5	R/W	H/L Read/write signal
6	E	H/L Enable signal
7	DB0	H/L Data bus line
8	DB1	H/L Data bus line
9	DB2	H/L Data bus line
10	DB3	H/L Data bus line
11	DB4	H/L Data bus line
12	DB5	H/L Data bus line
13	DB6	H/L Data bus line
14	DB7	H/L Data bus line
15	A	+4.2V for LED
16	K	Power supply for BKL (0V)

3.4.4 Current Sensor

This device detects and converts electricity into a quantifiable output voltage proportional to the current moving over it. Every sensor is appropriate for a particular variety of current also ecological conditions, and each sensor is priced differently. Current sensing resistors are commonly used for these sensors. Through the use of a resistor, a voltage is linearly converted from a current. For different sensors to apply to various applications, the technology used in the current sensor must be relevant.

Current sensors are based on either open or closed-loop Hall-Effect technology. During a closed-loop sensor, a coil produces a magnetic field that opposes that of the current being measured. Null-detecting devices use the hall sensor, which outputs a signal proportional to the current that is driven through the coil, which is proportionate to the current being measured.

Using a hall device, open-loop current sensors measure the magnetic flux from the primary current, which is concentrated in a magnetic circuit. Hall devices are designed to output a signal that represents the primary current exactly (instantaneously).

Figure 3.4.4: Current Sensor

Description

- The chip is ACS712ELC-30A.
- Pin 5V power source involved power light.
- The module can be dignified plus otherwise minus 30A current, with the equivalent analog output of 66 mV/A.
- No experiment current over the output voltage is VCC/2.
- PCB dimension: 31 (mm) × 13 (mm).

3.4.5 Power Capacitor

In a capacitor bank, several capacitors are connected in parallel or series to form a single unit. Compared with continuous current power supplies, power factor lag or phase shift is among the undesirable characteristics for these sets of capacitors to accurate or counter.

Figure 3.4.5: Power capacitor

Power supplies that use the direct current can also benefit from capacitor banks to store more energy and improve their ripple current capabilities. Eight (8) 230V, 50 Hz capacitors are installed in the capacitor bank, which is the power supply voltage and frequency. In addition, each capacitor has a different value. It contains four capacitors each measuring 50 microfarads. Capacitors and loads are all interconnected in parallel. The relay module controls the capacitor bank, which is connected across the line. When a relay is in operation, it connects the associated capacitor to the load and other capacitors in parallel.

3.4.6 The Adaptor

It is a 12V 5A MicroPower Adapter. This board is designed to work with Arduino/Raspberry Pi 3 Model A+/B/B+/Zero and other current-intensive expedients.
Stipulations:

Input: 100V - 240V AC, 50Hz/60Hz
Output: 12V 5A

Figure 3.4.6: The adapter

3.4.7 Step-down Transformer

With a step-down transformer, high primary voltage is turned into low secondary voltage. Primary coils in step-down transformers have more turns than secondary coils.

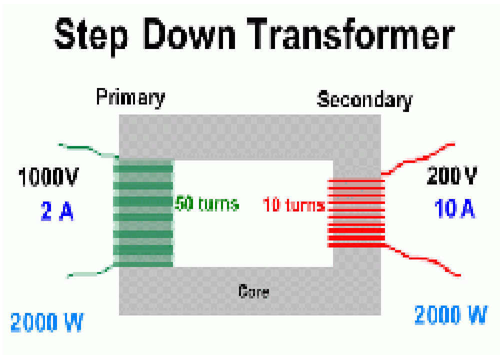


Figure 3.4.7: Step-down transformer

Transformers develop the opinion of “Faraday’s law of electromagnetic induction”. Transformers transmit their power through mutual induction between their windings. Faraday’s law states that “a magnetic flux linkage changes in proportion to the rate at which the flux changes in a circuit”.

A primary coil has extra turns than a secondary coil, which determines the EMF (Electro Motive Force) persuaded between them. This ratio is called the *Turns Ratio*.

A step-down transformer's aptitude to decrease voltage is dependent on the turn ratio between the primary plus secondary coils. There are fewer coils in the secondary coil compared to the primary coil, therefore, the quantity of flux that flows through the secondary coil of the transformer will be fewer than that flowing through the primary coil.

Accordingly, the emf generated in the secondary coil will be less. Consequently, the secondary winding voltage is lower than the primary winding due to this phenomenon.

3.4.8 AC Voltage Sensor

For DIY projects requiring accurate AC voltage measurements, the ZMPT101B AC Voltage Sensor is the ideal choice. Arduino/ESP8266/Raspberry Pi is an ideal open-source platform for measuring AC voltage. Engineers often deal directly with measurements in electrical projects with limited elementary necessities such as galvanic segregation, inclusive range, high accurateness, and reliable constancy.

The dynamic phase AC output voltage transformer module committed includes an exactness miniature voltage transformer. A precision op-amp circuit, signals sampling, and the necessary reparation onboard ensure precise functions. Within 250V AC voltage, modules can be measured, and their analog outputs can be accustomed. The device is pristine, and it is of very high quality.

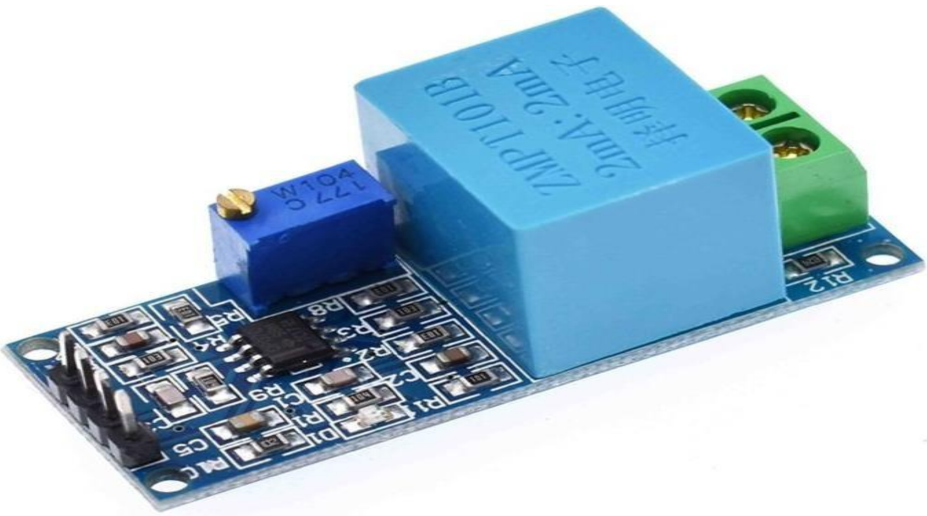


Figure 3.4.8: AC Voltage Sensor Module ZMPT101B

Topographies:

- Little price
- Lesser size and lightweight
- Simple PCB intensifying
- Good reliability
- Extensively commended.

3.4.9 ESP 8266

Espressif Systems produces the ESP8266 ESP8266 a stumpy-rate Wi-Fi chip with GPIO and TCP/IP networking proficiency incorporated into a microcontroller, and it is available for purchase in Shanghai, China. English-speaking makers were first introduced to the chip through Ai-Thinkers' ESP-01 module.

The ESP8266 is a liberated Wi-Fi arranged controller proposing an allowance to the present small-scale regulator via Wi-Fi, as well as being able to run independent software programs. It has a built-in USB port and a variety of stick-outs. Using a lesser USB link, we can easily connect NodeMCU to our laptop and use it the same way as Arduino. It is also immediately inviting with its breadboard.

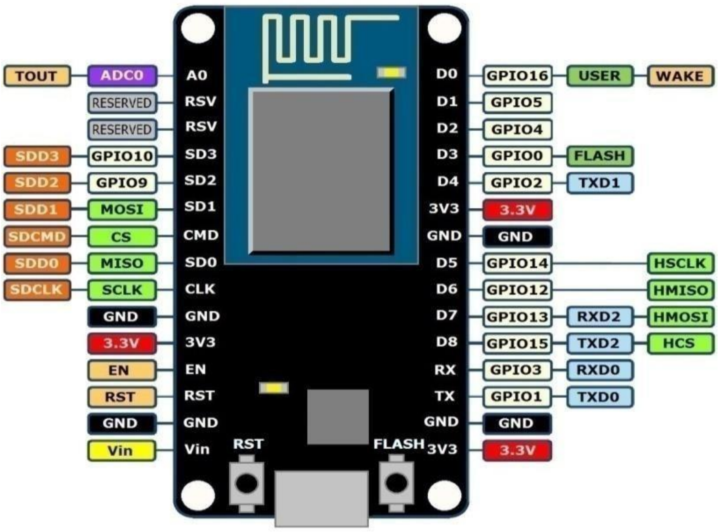


Figure 3.4.9: ESP8266 Node MCU

Description:

- Voltage: 3.3V.
- Wi-Fi Direct (P2P), soft-AP.
- Current ingestion: 10uA~170mA.

- Flashy memory removable: 16MB max (512K normal).
- Incorporated TCP/IP decorum pile.
- Processor: Ten silicaL106 32-bit.
- Processor speediness: 80~160MHz.
- RAM: 32K + 80K.
- GPIOs: 17 (multiplexed with other functions).
- Analog to Digital: 1 input with 1024 step determination.
- +19.5dBm output power in 802.11b mode
- 802.11 support: b/g/n.
- Extreme synchronized TCP associates: 5.

3.4.10 Jumper Wire

In the electronics field, a jumper wire is a wire, or a group of wires, with a connector on either end (or sometimes without a connector), used either within a breadboard or with further prototypes or tests, deprived of welding. Plugging jump wires into breadboards, circuit boards, or test equipment requires appropriate "end connectors" hooked on apertures provided on a breadboard, the header connector of a circuit board, or a portion of experiment apparatus.

Figure 3.4.10: Jumper wire

3.5 The IoT

The Internet of Things (IoT) is a network of interconnected devices, such as computers, machines, substances, animals, or people who can interact via networks without requiring human or computer interaction. Several tools, containing simultaneous analytics, machine erudition, commodity sensors, as well as surrounding systems have been combined to define the Internet of Things.

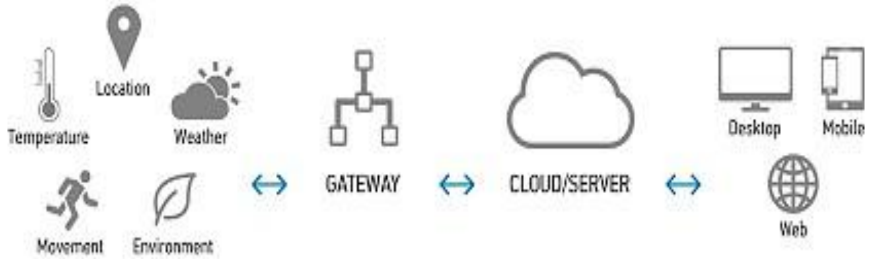


Figure 3.5.1: IoT System

The Internet of Things supports traditional fields for instance entrenched systems, wireless sensor networks, control systems, automation (together with home plus building automation), and lots of others. As far as IoT technology is concerned, it comes most frequently in the form of devices that improve the power factor. These devices include lighting features, thermostats, home safety systems, cameras, and other machines compatible with single or extra communal ecological units. These devices can be controlled using the expedients related to those ecosystems, for instance, smartphones plus smart speakers. In the area of privacy and security, there are several serious concerns about IoT, and the industry and government are taking steps to address them.

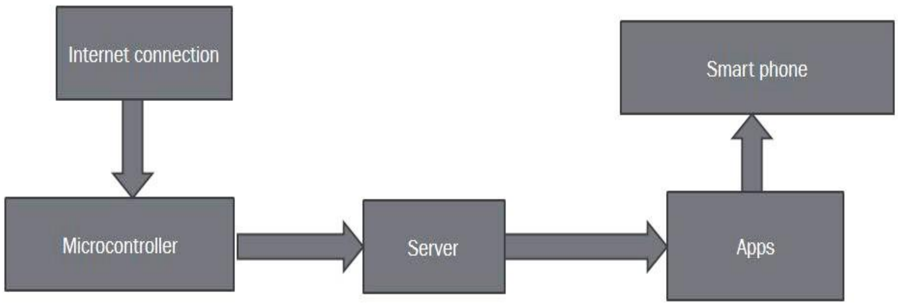


Figure 3.5.2: Block diagram of IoT

3.6 Working Process

To improve the power factor, it is necessary to use an expedient that takes the leading current and connects it parallel to the lagging current. This will offset its effect. The capacitor is the only such device. To better understand power factor improvement, let us look at an example. A single-phase inductive load is shown in figure 3.5.1 connected to a single-phase supply voltage V.

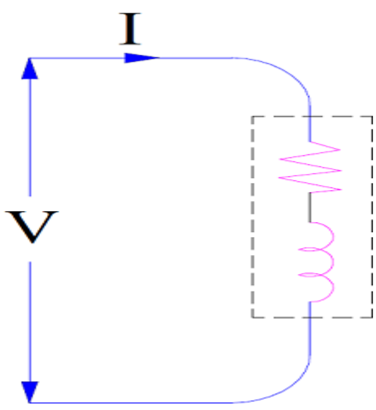


Figure 3.6.1: An inductive load linked to supply voltage

Taking lagging current from an inductive load implies a power factor of cos φ_1. In the figure below, a capacitor attached to this cargo will take current I_c at an angle of 90 degrees with the supply voltage V.

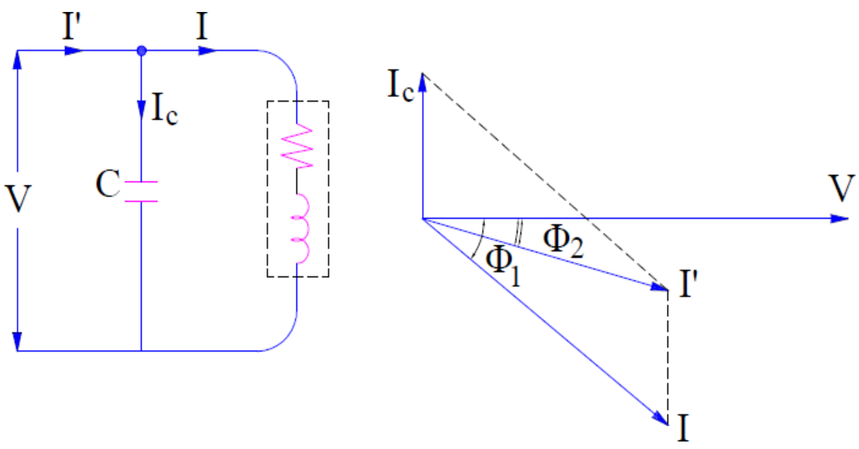


Figure 3.6.2: A capacitor connected across the inductive load

Consequently, the avg line current I' is the phasor quantity of load current I plus capacitor current I_c . Meanwhile the reactive current element (i.e. $I\sin\varphi_1$) of the load is incompletely counteracted using the leading capacitor current I_c , hence the resultant line current I' will lag with the quantity voltage at an angle fewer than φ_1. This current I' is displayed to be lagging through an angle φ_2 in the figure. Meanwhile $\varphi_2<\varphi_1$, this means that $\cos\varphi_1<\cos\varphi_2$. Thus PF of the load is improved to cos φ_2 from the former value of cos φ_1.

Subsequent opinions are value observing:

i. The circuit current I' subsequently, p.f.c is beneath the innovative circuit current *I*.

ii. As a result of PFC, simply the reactive element has been condensed, not the active or wattful component.

$$I\,cos\varphi_1 = I' cos\varphi_2$$

iii. The lagging reactive component is condensed subsequently PFI is equivalent to the dissimilarity among a lagging reactive element of the load ($Isin\varphi_1$) also capacitor current (I_c) i.e.,

$$I' sin\varphi_2 = Isin\varphi_1 - I_c$$

iv. As

$$I\,cos\varphi_1 = I' cos\varphi_2$$

$$\therefore \quad VI\,cos\varphi_1 = VI' cos\varphi_2 \qquad [Multiply\ by\ V]$$

Therefore, active power (kW) remains unchanged due to PFI.

v.

$$I' sin\varphi_2 = Isin\varphi_1 - I_c$$

$$VI' sin\varphi_2 = VIsin\varphi_1 - VI_c \qquad [Multiply\ by\ V]$$

So, Net kVAR later p.f. correction = Lagging kVAR previously p.f. correction- leading kVAR of apparatus.

3.7 Methodology

A functional flowchart of the system is presented in the ensuing figure:

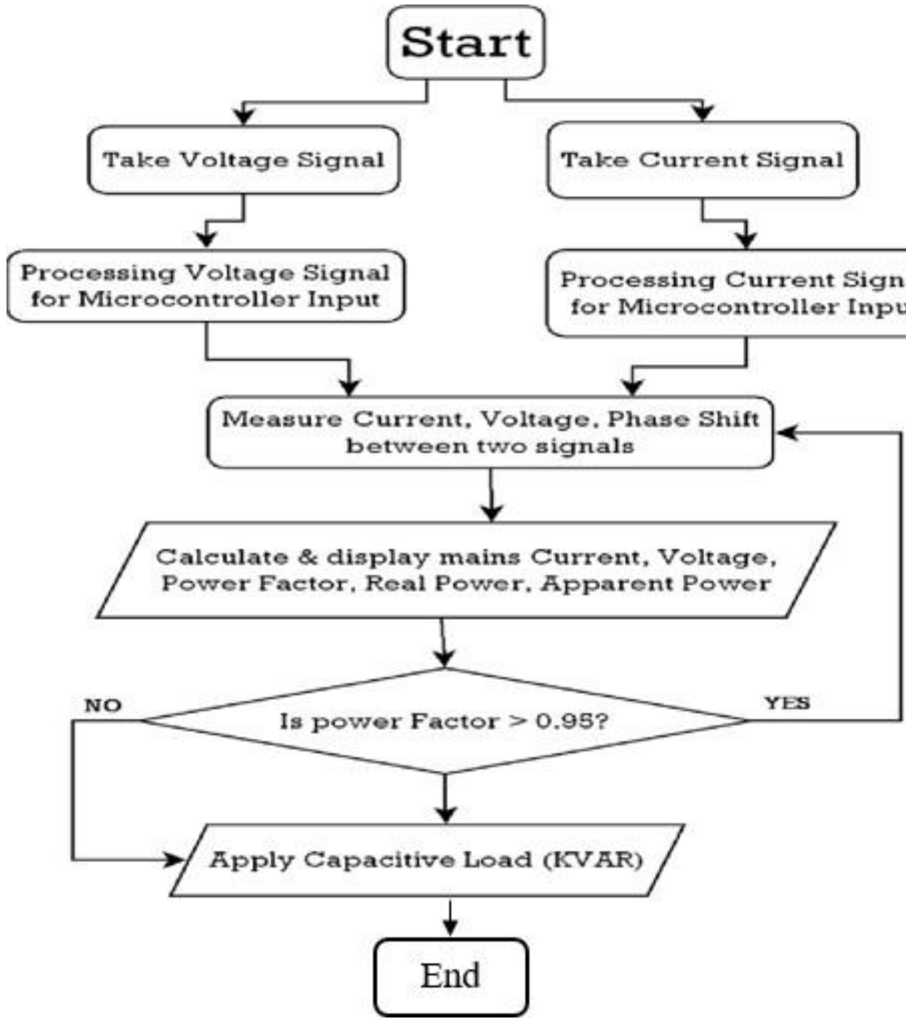


Figure 3.7: Flow chart

3.8 Summary

In this chapter, block & circuit diagrams, hardware component lists, the IoT, and the working process of PFI are presented.

Chapter 4

Performance Evaluation

4.1 Introduction

It is only possible to verify whether an item designed is useful after it has been used and the expected result has been obtained. It is imperative to check whether the power factor correction circuit is working and achieving the desired correction. For this purpose, periodic monitoring of the desired outcome combined with the measurement of appropriate electrical parameters is necessary.

4.2 Test-bed Implementation

Each type of load designed requires separate measurements, both with and without correction equipment. A power supply must be measured for voltage supply, frequency, load current, power consumed, and the power factor. The monitoring of electricity usage for a specified period is also useful for determining whether any savings were achieved. For all measuring and monitoring, Proteus software systems, Arduino Uno, ESP8266, etc. were used.

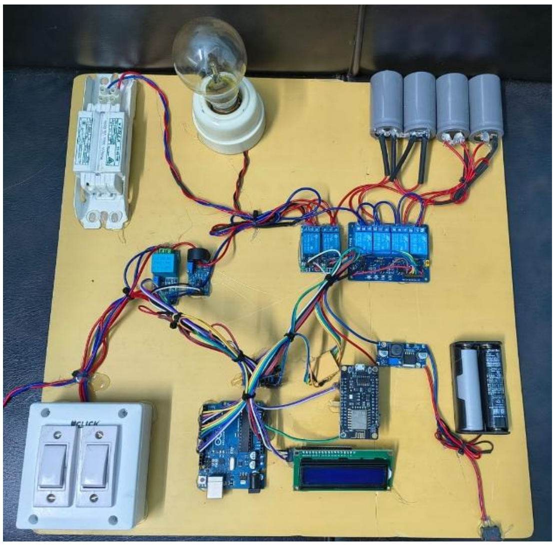


Figure 4.2: The picture of the project

4.3 Performance Metrics

Here are metrics of the project performance:

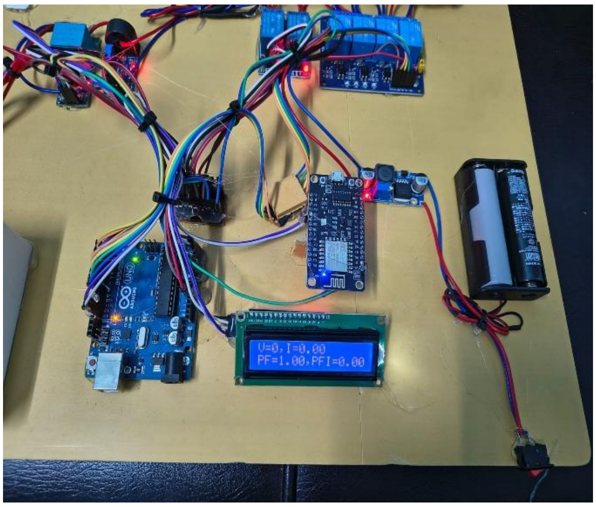


Figure 4.3.1: No AC connection is provided on the load

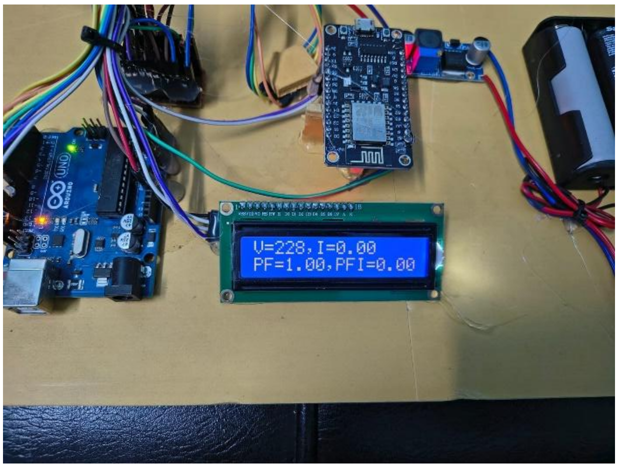


Figure 4.3.2: AC connection is provided on the load

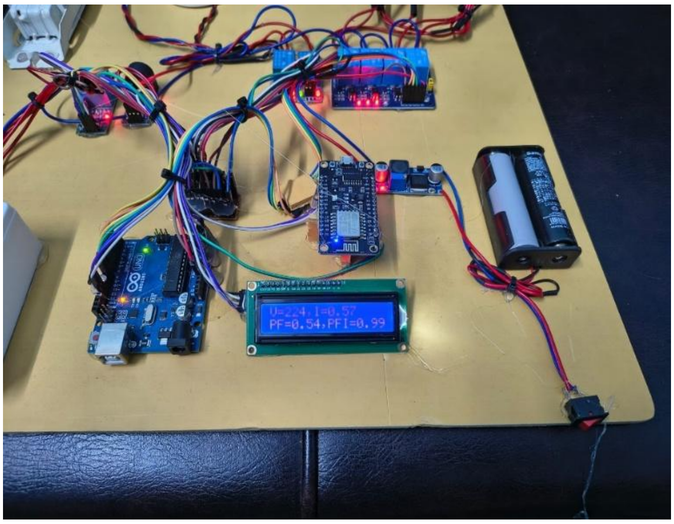


Figure 4.3.3: When the inductive load is ON

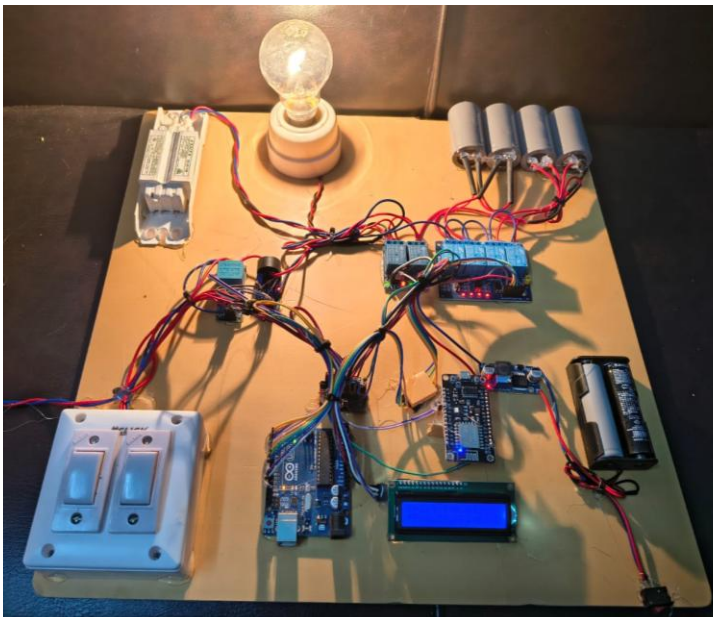


Figure 4.3.4: When the only capacitive load ON

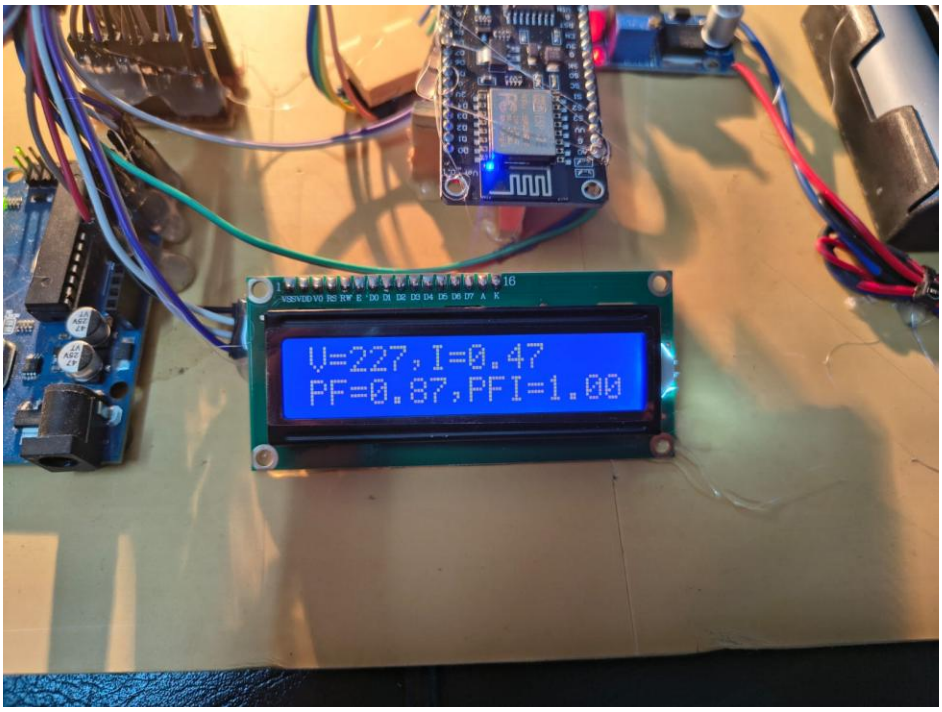
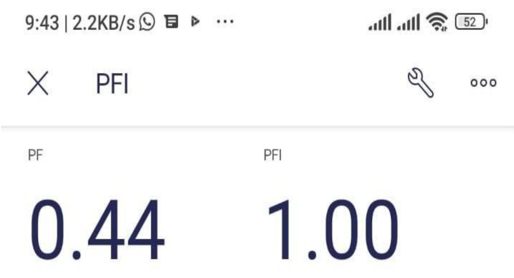


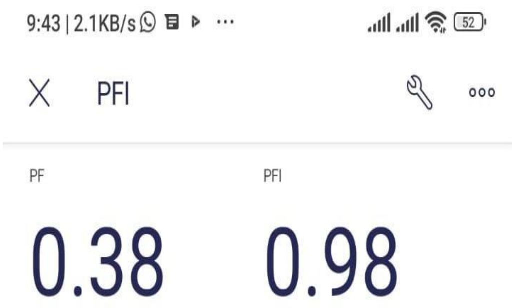
Figure 4.3.5: When the capacitive and inductive loads both are ON

4.4 Results and Discussions

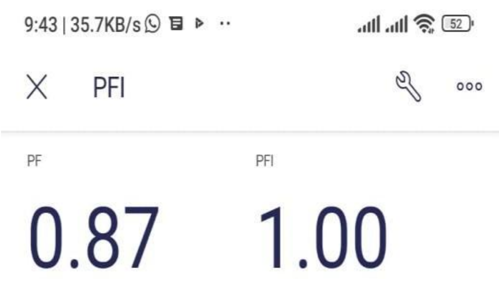
4.4.1 Results



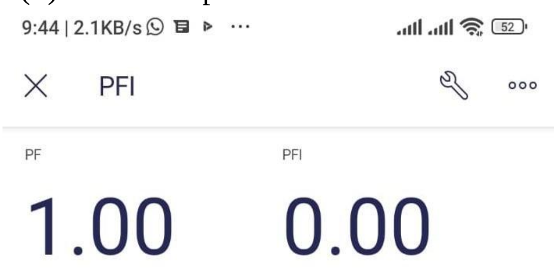
(i) The inductive load



(ii) The capacitive & inductive load



(iii) The capacitive load



(iii) No load

Figure 4.4.1: Project outcomes in different test load conditions

Figure 4.4.1 shows that PFI at different load conditions using IoT.

In figure 4.4.1 (i), when the inductive load is ON, PFI is 1.00 from 0.44. In figure 4.4.1 (ii), when both the inductive load and the capacitive load are ON, PFI is 0.98 from 0.38. In figure 4.4.1 (ii), when the capacitive load is ON, PFI is 1.00 from 0.87. And figure 4.4.1 (iv), when an AC connection is provided at the load, PFI is 0.00 from 1.00.

4.4.2 Analysis and Outcome

Several highly inductive and capacitive loads created a load network to show how the PF Improvement Monitoring system works. The system can measure and detect a load network's power factor. This table shows how the data is recorded.

Table 4.4.2: Results analysis

Load	PF	PFI
No load	1.00	0.00
Inductive	0.44	1.00
Capacitive	0.87	1.00
Both inductive and capacitive	0.98	0.38

4.4.3 Discussion

The PF improvement expedient was capable of progressing the PF from 0.38 to 0.98 when used with Arduino Uno and capacitor banks connected through the Internet of Things. The system was used for the measurement as well as monitoring of demonstrated electrical loads. Reactive power compensation reduces the current drawn from the system, which releases system capacity. It was estimated that payback would take around 9 months with substantial savings in energy costs.

4.5 Summary

In this chapter, hardware setup, the performance metrics, and the result analysis and discussion of this project are presented.

Chapter 5

Conclusion

5.1 Introduction

In conclusion, this section recommends future work to further improve the framework. It also discusses the significance and potential impact of the research findings.

A revolutionary method of power factor correction has been proposed, which uses a microcontroller and offers many advantages over conventional methods of PFI. The relay is used to control the switching of capacitors, and as a result, the power factor correction is more accurate. Adding a capacitor bank will result in a profitable consumer flow. Adding a capacitor bank can reduce reactive current use and reduce losses.

The power factor, when taken into account in its entirety, is the most significant factor for a utility both at the corporate level and from a consumer perspective. The utility companies are relieved of power losses, and consumers are relieved of low power factor penalties.

The capacitive load banks used in self-propelled PFC are very useful and practical. This is because they reduce the power drawn from the supply, which is why the cost is reduced. Using capacitive load banks, the PFC system operates automatically, so a human operator is not required. It can be used on a large scale in the future to significantly improve system efficiency and save on energy costs, thus contributing to energy conservation.

5.2 Concluding Remarks

Microcontroller and capacitor banks were used for power factor correction equipment, and the subsequent conclusions were acquired:

- During test conditions, a power factor correction device improved the PF from 0.38 to 0.98.
- The reduction in the current draw is due to the correct amount of reactive power compensation.
- It is estimated that the payback period would be nine months since there would be a significant reduction in energy costs.

5.3 Practical Implications

An electrical system's PF is a measure of in what way effectively incoming the power is utilized. An electrical system uses electric power more effectively if the power factor is high.

With an improved power factor, the distribution system will operate more efficiently and energy costs associated with a low power factor will be reduced. Throughout an electrical system's lifespan, low power can be both inefficient and costly.

Maintaining good profits requires a high-power generator for a power system. If one million MW of power is generated annually with a 50% power factor, this is one million megawatts. This means 50% of generated electricity is consumed. Another energy is wasted. Therefore, a power system must have a higher power factor to avoid these losses.

5.4 Future Recommendations

Eventually, most organizations and industries will use this method. The system can be employed straight in minor businesses for energy preservation also recompensing penalties are the main issues in entirely industries; this technique resolves all these problems, besides hence companies will have to reduce their expenditures. Automating all human labor will prove to be the most effective solution for the future.

The weakness and limitations of the project have indicated the following areas as recommendations for further work.

- The size of the PFC casing
    - Using a different size for the PFC box may allow the user to install the system more easily since the box weighs too much for one person to handle.
    - This large casing takes up a lot of space in the house, and it looks very disturbing as it requires more space.

- Use a suitable capacitor bank
    - A capacitor bank must be appropriate for the load inside the housing system so that the device can improve the PF more efficiently.

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