IoT Based Power Factor Monitoring & Improvement System

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Declaration

It is declared hereby that this thesis paper or any part of it has not been submitted to anywhere else for the award of any degree.

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Certification

This is to certify that this project entitled **"IoT Based Power Factor Monitoring & Improvement System"** is done by the following students under my direct supervision. This project work has been carried out by them in the laboratories of the Department of Electrical and Electronic Engineering under the Faculty of Engineering, Sonargaon University (SU) in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering.

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Abstract

The project is designed to reduce the power loss in industries by power factor compensation through a number of shunt capacitors. This results in reduction in amount of electrical bill for industries and commercial establishments. Power factor is defined as the ratio of real power to apparent power. This definition is often mathematically represented as KW/KVA, where the numerator is the active (real) power and the denominator is the (active + reactive) or apparent power. Reactive power is the non-working power generated by the magnetic and inductive loads, to generate magnetic flux. The increase in reactive power increases the apparent power, so the power factor also decreases. Having low power factor, the industry needs more energy to meet its demand, so the efficiency decreases. In this proposed system the time lag between the zero voltage pulse and zero current pulse duly generated by suitable operational amplifier circuits in comparator mode are fed to two interrupt pins of the microcontroller. Microcontroller displays the power loss due to the inductive load on the LCD. The program takes over to actuate appropriate number of relays at its output to bring shunt capacitors into the load circuit to get zero power loss. The 8 bit microcontroller used in the project belongs to Arduino family. Further the project can be enhanced by using thyristor control switches instead of relay control to avoid contact pitting often encountered by switching of capacitors due to high in rush current. We will see an Lcd display of this data. In addition, we will be able to monitor from anywhere in the world through the Internet using software on mobile. Here we have used Arduino Uno Microcontroller as a programming device.

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List of Abbreviation and Acronyms

SL. No	Short Form	Full From / Meaning
01	A	Ampere
02	Wi-Fi	Wireless Fidelity
03	IoT	The Internet of Things
04	ATP	Alternative Transient Program
05	CT	Current Transformer
06	KVA	Kilo Volt Ampere
07	KVAR	Kilo Volt Ampere Reactive
08	KW	Kilo Watt
09	kWh	Kilo Watt Hour
10	APFC	Automatic Power factor Correction
11	LCD	Liquid Crystal Display
12	MCL	Mahanadi Coalfields Limited
13	PCB	Printed Circuit Board
14	PF	Power Factor
15	PFC	Power Factor Correction
16	PT	Potential Transformer
17	R	Resistive
18	R-L	Resistive-Inductive
19	RMS	Root Mean Square
20	THD	Total Harmonic Distortion
21	V	Volt
22	ZCS	Zero Current Sensor
23	ZVS	Zero Voltage Sensor

Chapter 1

Introduction

1.1 Introduction

Electrical energy efficiency is the major importance of industrial and commercial companies operating in the today's competitive markets. Prime use of plant and equipment is one of the main concerns that industries try to balance with energy efficiency for both economic and environmental reasons. As society becomes more and more conscious of its control of the environment, reduced energy consumption becomes more necessary, which is an achievable goal for everyone. Over the use of measures such as electricity consumption, power factor correction is optimized, which ultimately leads to reduced energy consumption and reduced CO2 greenhouse gas emissions. Within a cost conscious market and payback considerations are also essential. The most appropriate application for power factor correction based on energy consumption, cost payback, emission reduction and tariff metering. Power factor correction is an appropriate which is used to improve the power quality of an installation. Its application is dependent though on the size of the installation and the extent that power factor correction needs to be applied. Automatic power factor correction techniques can be applied in the power systems, industrial units and also households to make the system stable. As a result, the system becomes stability and efficiency of the system as well as of the apparatus increases. The use of microcontroller based power factor correction system is used to reduce the overall costs for consumers and the suppliers of electrical energy. Power factor correction is made by capacitor banks it is a very efficient method.it reduces reactive power consumption and also minimize the losses and at the same time increases the electrical system’s efficiency. Power saving problems and reactive power management have led to the development of single phase capacitor banks for industrial and domestic applications. The development of the project is to improve and upgrading the operation of single phase capacitor banks by developing a micro-processor based control system. The control unit will be able to control the capacitor bank; it’s based on the varying load current. Current transformer is used to measure the load current for sampling purposes current transformer plays a major role in it. The special aspect of our project is that we have worked with IoT(Internet of Things) system in our project. In addition to monitoring from the project display, we will be able to monitor and control from anywhere via the Internet. Intelligent control using this micro-controller control unit ensures even utilization of capacitor steps, minimizes number of switching operations and optimizes power factor correction.

1.2 Background

N. D. Rao developed software called fkom which has the strengths of mathcad and excel spreadsheet. And it has a program determines the value of the series inductor in the harmonic filter bank that would shift the parallel resonant frequency to a value less than the lowest-order harmonic term of the load to correct the power factor. [1] Nader Barsoum 2006, said that the design and development of a three-phase power factor corrector using PIC (Programmable Interface Circuit) microcontrolling chip. This

involves sensing and measuring the power factor value from the load using PIC and sensors, then using proper algorithm to determine and trigger sufficient switching capacitors to made power factor to unity Yasin Kabir, Yusuf Mohammad Mohsin, and Mohammad Monirujjaman Khan are made a project to monitor the energy consumption of a system and automatically improve its power factor. An open source energy monitoring library was implemented in the design for accurate power calculation.

Power factor correction [2] equipment designed based on microcontroller and capacitor banks using IoT was used for measurement and monitoring of modelled electrical load and the following deductions were obtained: The power factor correction device was able to improve the power factor from 0.76 to 0.97 under the test load conditions. The average savings in energy consumption were about 1.7% of the designed load and different load patterns. With the proper amount of reactive power compensation, the system capacity is released as there is a reduction in current drawn. The economic analysis suggested the payback period to be around 9 months with a significant amount of savings in energy cost.

1.3 Objectives

The main objective of this project is to **IoT Based Power Factor Monitor & Improvement System** Project for The main purpose is to create a smart system so that we can take many benefits from one project.

- The load power factor is continuously monitored it improves the power quality.
- Design an Arduino based correction equipment to improve the power factor of the system to the desired value of greater than 0.95.
- To monitor the parameters of the system through an online software by implementation of the IoT concept.
- IOT monitoring and controlling system.

1.4 Iot System

The Internet of Things (IoT) is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. The definition of the Internet of Things has evolved due to the convergence of multiple technologies, real-time analytics, machine learning, commodity sensors, and embedded systems.



Fig-1.1: Iot System

Traditional fields of embedded systems, wireless sensor networks, control systems, automation (including home and building automation), and others all contribute to enabling the Internet of Things. In the consumer market, IoT technology is most synonymous with products pertaining to the concept of the " **IoT Based Power Factor Monitor & Improvement System**", covering devices and appliances (such as lighting fixtures, thermostats, home security systems and cameras, and other home appliances) that support one or more common ecosystems, and can be controlled via devices associated with that ecosystem, such as

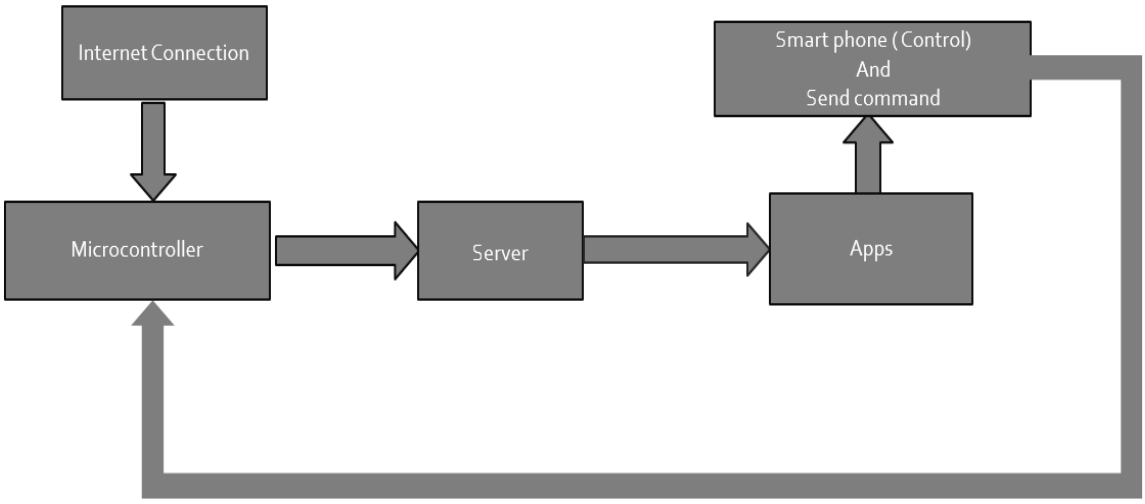


Fig-1.2: Block Diagram of IOT

Smart phones and smart speakers. There are a number of serious concerns about dangers in the growth of IoT, especially in the areas of privacy and security; and consequently industry and governmental moves to begin to address these.

Chapter 2

Theoretical Review

2.1 Introduction

The power factor of an AC electric power system is defined as the measurement of the degree to which a given load matches that of a pure résistance. It is a ratio of average power of any given load to average power of a resistive load for same voltage and current magnitude and its value is also between 0 and 1. Active power is the actual amount of the power being used, or dissipated, in a circuit is called active power (P), and it is measured in watts. Active power is the product of the sinusoidal voltage and current wave form. Reactive power is the power consumed in the ac circuit because of the inductive and capacitive field. The unit used for measuring reactive power is KVAR. Apparent power is the combination of the active power and reactive power. It is the product of a circuit voltage and current without reference to phase angle. Apparent power(S) is measured in the unit of volt-amps (VA). It is greater than the active power and reactive power. Because of the reactive power is the energy stored in the circuit and it is negative or the current lags the voltage by phase angle goes back to the source or due to mismatched load that distorts the generated wave form the power source. A load with a power factor unity is the purely resistive load, because the sinusoidal voltage and sinusoidal current wave form is in phase or the phase angle difference between the voltage and the current is zero. A poor power factor can be the result of a significant phase between the applied voltage and the current at the load terminals or it can be due to a high harmonic content or distorted (discontinuous current wave form). The poor load current phase angle can be generally the result of inductive loads such as induction motor, power transformers and lighting ballasts. A distorted current wave form can be the result of rectifier, variable speed drive, switched mode power supply and other electric loads. Low power factor loads increases losses in power supply and distribution system and it increases the cost in electricity in bills. Since the purely resistive ac circuit of the sinusoidal voltage and current waveforms are in phase; changing polarity at the same instant in each cycle circuits containing purely resistive heating elements such as filament lamps and cooking stoves have a power factor of 1.0. Circuits containing inductive or capacitive elements such as lamp ballasts and motors often have a power factor below 1.0. Reactive power compensation has been increasing, mainly because of the way in which energy supplier charge a customer for reactive power. In addition to the above explanation, the energy price is growing, what force the industry plants and individual customers to minimize energy consumption, including reactive power. Generally there are solutions that allow handle the problem of reactive power compensation. The first one is reactive power compensator using power factor capacitors. This is very important compensating device, due to economic reasons and they are very cheap comparing with active filters by means of electric motors. To be successive with work they accomplish the main thing is power uses for any organization mean that whether governmental or non-governmental the key problem always they face are the power quality. This occurs due to the loss of power happen on transmission and also due to improper distribution of the system especially in industry. This situation presents problem of poor power factor by the result of either a significant phase

difference between the voltage and the current at the load terminals. Due to the occurrence of Poor power factor the cost of the electricity bills in the customer's increases.

In the present scenario of technological revolution it has been observed that the power is very precious. The industrialization is primarily increasing the inductive loading, the inductive loads affect the power factor so the power system losses its efficiency (by: Prof. S. Ghosh, 2007). The automatic power factor correction device is a very useful device for improving efficient transmission of active power. If the consumer connect inductive load, then the power factor lags,when the power factor goes below 0.97(lag) then the electric supply company charge penalty to the consumer. So it is essential to maintain the power factor below with in a limit. Automatic power factor correction device reads the power factor from line voltage and line current, calculating the compensation requirement switch on different capacitor banks .The current drawn by inductance lags the voltage while the one by capacitance leads the voltage. Al most all industrial loads are inductive in nature and hence draw lagging wattles current, which unnecessarily load the system, performing no work. Since the capacitive currents is leading in nature, loading the system with capacitors wipes out them. The lower the power factor, the worse the situation becomes from the supply authorities' viewpoint. Accordingly, consumers are encouraged to improve their load power factor and in many cases are penalized if they do not. Improving the power factor means reducing the angle of lag between supply voltage and supply current. Power factor correction brings the power factor of an AC power circuit closer to 1 by supplying reactive power of opposite sign, adding capacitors or inductors which act to cancel the inductive or capacitive effects of the load, respectively.

2.2 Techniques Used for Estimation of Power Monitoring

In this project proposed a power consumption and monitoring system of the area that continuously monitor the consumption of consumer. If this consumption is beyond the limit of the meter in that case it cut off the power supply of the whole area.The whole process is based on the Ohm's law which states that," the electric power in watts associated with a complete electric circuit or a circuit component represents the rate at which energy is converted from the electrical energy of the moving charges to some other form, e.g., heat, mechanical energy, or energy stored in electric fields or magnetic fields". For a resistor in a D C Circuit the power is given by the product of applied voltage and the electric current".

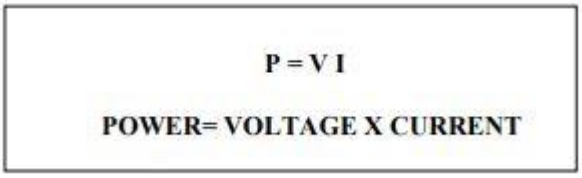


Fig-2.1: Power Law

Here taking a voltage as a predefined data and on the calibration of current the power will be calculated. At this point of technological development the problem of illegal usage of electricity can be solved electronically without any human control along with that meters are connected to the internet using IoT concept. IoT concepts are used so that the information regarding meter status will be send wirelessly from the place where the meter is placed to the server from there it sends the information to the main station or substation. This method eliminates the need of human power during disconnection and reconnection of the load.

2.3 Power Triangle

The cosine of the angle blow is also equal to KW per KVA so you can think of the power factor as the ratio of real power to what you measure with a volt and amp meter (apparent power). If they are equal, then your power factor is one. Reactive power is not a problem for a motor and is required for its operation. It is a problem for the electric utility company when they charge for KW only. If two customers both use the same amount of real energy but one has a power factor of 0.5, then that customer also draws double the current.

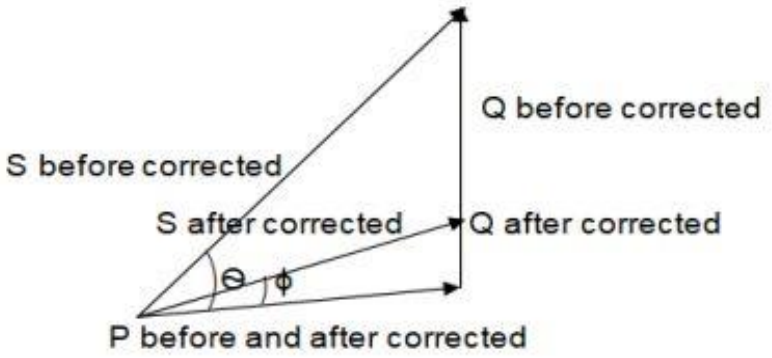


Fig-2.2: Power Angle Circuit

The main objective of the proposed system is design of automatic power factor correction using microcontroller software. Specifically;

I. To design an automatic power factor correction using an arduino micro-controller in C language for improving the poor power factor by adding parallel capacitors to the motor terminals.
II. To develop an automatically corrected power factor to establish design parameters.
III. To simulate the established control concepts relative to its corresponding input and output relationship and control frame work.

This study significantly provides an important study results for cost effective, reliable and faster power factor corrector. Thus the result of designing power factor corrector for small industrial enterprises will have the following significances.

I. It minimizes value of reactive power in the power triangle by connecting the capacitance of the capacitor to the motor terminals to make the apparent and real power to become in phase.
II. It reduces of voltage drop in long cables.
III. It minimizes the reactive power and phase angle difference between the sinusoidal voltages and current wave shapes. This can result to decrease the power consumption and power losses, the cost will also be less than the recent.
IV. It improve low power factor by using power factor correction and this method is important in minimizing the wasted energy.
V. It improves efficiency of a plant and reducing the electricity bill but not necessary to reach power factor unity.

2.4 Power Factor

For a DC circuit the power in the circuit is given by P=VI and this relation also holds good for the instantaneous power in an AC circuit. However, the average power in an AC circuit expressed in terms of rms voltage and current is:

$$P_{avg=V\times I\times \cos\ \theta}$$

Where, φ is the phase angle between the voltage and current. The term cosφ is called the power factor. Power factor is the ration between the KW and the KVA drawn by an electrical load where the KW is the actual load power and the KVA is the apparent load power. It is a measure of how effectively the current is being converted into useful work output and more particularly is a good indicator of the effect of the load current on the efficiency of the supply system.

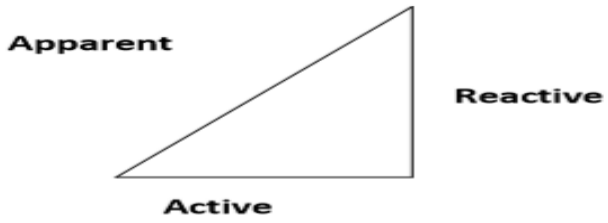


Fig-2.3: Power Triangle

A load with a power factor of 1.0 result in the most efficient loading of the supply and a load with a power factor of 0.5 will result in much higher losses in the supply system. A poor power factor can be the result of either a significant phase difference between the voltage and current at the load terminals or it can be due to a high harmonic content or distorted/discontinuous current waveform. Poor load current phase angle is generally the result of an inductive load such as an induction motor, power transformer, lighting ballasts, welder or induction furnace. A distorted current waveform can be the result of a rectifier, variable speed drive, switched mode power supply, discharge lighting or other electronic load.

A poor power factor due to an inductive load can be improved by the addition of power factor correction, but, a poor power factor due to a distorted current waveform requires a change in equipment design or expensive harmonic filters to gain an appreciable improvement. Many inverters are quoted as having a power factor of better than 0.95 when in reality, the true power factor is between 0.5 and 0.75. The figure of 0.95 is based on the Cosine of the angle between the voltage and current but does not take into account that the current waveform is discontinuous and therefore contributes to increased losses on the supply.

2.5 Causes of Low Power Factor

The first and the foremost cause of a low power factor is the operation of highly inductive loads in the power system. As in a pure inductive circuit, current lags voltage by 90^0, this large difference in phase angle between the current and voltage causes zero power factor. Basically, all those circuits having capacitance and inductance (except tuning circuit or resonant circuit, where inductive reactance (Xl)

is equal to capacitive reactance (Xc), so the circuit becomes a resistive circuit), will cause a low power factor because the inductance and capacitance causes a difference of phase (φ) between the current and voltage.

Following are the causes of low power factor:

- Single Phase and Three Phase Induction motors, having a power factor of 0.8-0.9 at full load and 0.2-0.3 at small load while it may be at no-load.
- Varying load in the power system is another major cause of low power factor. As we know the load on a power system varies as is evident from the load curves. During low load period, supply voltage is increased which increases the magnetizing current which causes the decreased power factor.
- Industrial heating furnaces are highly inductive and thus cause a low power factor on the power system.
- Electrical discharge lamps (high intensity discharge lamps), Arc lamps etc. operate at a very low power factor.

2.6 Disadvantage of Low Power Factor

Power factor plays an important role in AC circuits and power dissipation in the power system is dependent on the power factor of the system. We know that the power in a three phase AC circuit is:

$$\mathbf{P = \sqrt{3}\ V \times I \cos\varphi}$$

The current on a three phase AC circuit is:

$$\mathbf{I = P / (3\ V \times \cos\varphi)}$$

Also the power in a single Phase AC circuit is:

$$\mathbf{P = V \times I \cos\varphi}$$

And the current on a three phase AC circuit is:

$$\mathbf{I = P / (V \times I \cos\varphi)}$$

It is evident from the equations for the currents that the current is proportional to cosφ i.e. power factor. In other words, as the power factor increases the net current flowing in the system decreases and when the power factor decrease the net current in the system increases. The increased current incase of low power factor condition leads to following disadvantages

Large Copper Losses: We know that the line loss or copper loss is the loss of power in the transmission lines or the windings in case of machines and it is directly proportional to the square of current (I2). The total power loss is given by:

$$\mathbf{P = I^2 \times R}$$

Where R is the line resistance in Ohms (Ω). That means the larger the current the larger is the line loss.

Large kVA Rating and Size of Electrical Equipment and Switch Gear: As we know that almost all electrical machinery (Transformers, alternators, switchgear etc.) are rated in kVA. But from the given equation:

$$\mathbf{Cos\varphi = kW / kVA}$$

It is clear that the power factor is inversely proportional to the kVA. Therefore, the lower the power factor, the larger the kVA rating of machines and also larger the size of machines.

Greater Conductor Size and Costs: In case of low power factor conditions on the power system the current will be increased. In order to transmit this high current the conductor size will have to be increased. As the size of conductor increases, the cost of the material, support structure, manpower required also increases manifold, leading to an overall increase in the cost.

Poor Voltage Regulation and large voltage drop: The voltage drop in the power system is given by:

$$\mathbf{V = I \times Z}$$

Now, in case of a low power factor, the overall current in the circuit will be increased. So the larger the current the larger is the voltage drop. As Voltage Regulation is the change in voltage from no-load to full-load expressed as a percentage of no-load voltage and is given by:

$$\mathbf{V.R = ((V\ no\text{-}load - V\ full\text{-}load)/V\ full\text{-}load) \times 100}$$

In case of low power factor (lagging) there would be a large voltage drop which leads to a low voltage regulation. Therefore, in order to maintain the voltage drop within permissible limits we have to install extra regulation equipments such as voltage regulators.

Low efficiency: In case of low power factor, it results in a large voltage drop and line losses, which decrease the efficiency of the equipment in particular or the whole of the power system in general to decrease. In addition, as a result of increased line losses, the alternator would require higher excitation, thus generation efficiency would be low.

Penalty from Power Supply Company: Electrical power supply companies have to bear the brunt of low power factor by installing equipments and transmission lines of higher ratings, larger sizes and of higher ratings. In addition they may have to install power factor correction equipment. Thus, the power utility companies impose a penalty on the consumers whose power factor is below 0.95 lagging in the electric power bill.

2.7 Types of Power Factor Controllers

Generally there are three types of techniques that are employed to control the power factor. They are:

Passive PFC: This is a simple way of correcting the non-linearity of a load by using capacitor banks. It is not as effective as active PFC, switching the capacitors in or out of the circuit causes harmonics, which is why active PFC or a synchronous motor is preferred.

Active PFC: An Active Power Factor corrector is a power electronic system that controls the amount of power drawn by a load in order to obtain a power factor as close as possible to unity. In most

applications, the active power factor controls the input current of the load so that the current waveform is proportional to the mains voltage waveform (a sine wave). Some types of active PFC are: Boost, Buck and Buck Boost. Active power factor correctors can be single-stage or multi-stage. Active power factor controller is the most effective and can produce a PFC of 0.99 (99%).

Synchronous Power factor controller: Synchronous motors can also be used for power factor correction. A shaft less motor is used, so that no load can be connected and run freely on the line at capacitive power factor for the purpose of power factor correction.

2.8 Internet of Things

The Internet of Things (IoT) is a new revolution for Data Transfer and Storage. Objects that make themselves recognizable and they obtain intelligence by making or enabling context related decisions to the situations. They can transfer information about themselves. They can access information that has been used by other things, or they can be components of other services. The three factors that makes IoT look forward are Sensing Nodes, Embedded Processing and Communication. This transformation is accompanied by the emergence of cloud computing capabilities supported by an increased storage capacity and high-end data processing and the Machine-to-Machine communication for data transport with complete security for data. By introducing cloud computing, we can make a full call to the storage resource pool and computing resource pool in the cloud computing architecture, and provide high reliability for IoT cloud storage service and efficient cloud computing services to users. This Machine-to-Machine service layer will provide the needed services like data transport, security, devices, management and device discovery in a harmonized manner across a vertical domain to the application layer.

2.9 Arduino Software (IDE)

The Arduino Integrated Development Environment (IDE) contains message area, the text console, text editor for writing code, a toolbar with buttons for common functions and a series of menus. It connects to Arduino and Genuine hardware upload programs written using the Arduino software (IDE) are called sketches. The programs are written in the text editor and are saved with the file extension of'. ino'. The editor has features for cutting/pasting and for saving/replacing text. The message area gives feedback and displays errors. The console displays text output by the Arduino software (IDE), including complete error message and other information.The configured board and serial port are displayed in the right hand corner of the window. The toolbar buttons permit to verify and upload programs, create,open, and save sketches, and open the serial monitor.

2.10 Android Apps

For visualization and authentication, in this research work, the team has an Android App. The Android Application does not restrict itself to Thing Speak but also has a Firebase login system. Firebase is a Google-provided API to create a database and fetch from it in real time. It also provides enhanced security for the developed App. Also, it is used for backend support and other functionalities like data storage, user authentication and hosting. Real-time data variations are recorded automatically and updates are sent to clients. The HTTP protocol works on a simple request and response

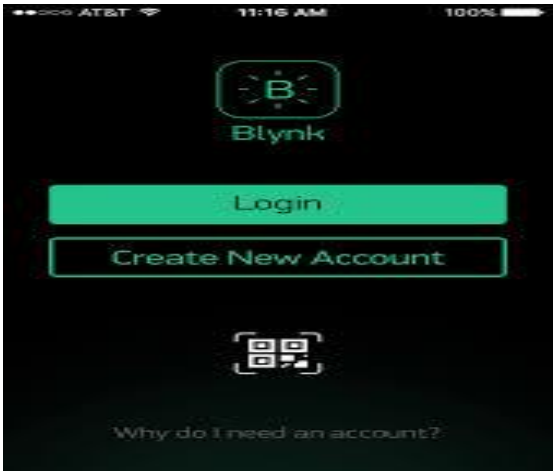


Fig-2.4 Android Apps

system but firebase is different as its real-time database uses data synchronization. It can be used for user authentication purposes as the user credentials are securely stored using bcrypt. Firebase authentication to the android studio is added using Firebase Android Studio tool. Whenever someone authenticates during the sign-in process either using an Email or Google, it handovers a firebase user object that represents that the authentication is successfully done by the user. This object contains the basic information about the user. Once the firebase API is included in Android or iOS App, firebase features like Analytics, Authentication, Storage, Messaging, Hosting, Crash reporting, Real-time Database etc.

2.11 Motivation for Project

A poorly motivated team has been known to unravel even the best project plan. A good project manager needs to know how to harness the initial excitement that comes with starting a project and use it to maintain motivation – leading to success throughout the project's lifecycle. We now know that contemporary project managers need to be more than just schedulers and contract managers. They need excellent skills in managing those complex human elements that have the potential to bring any project down.

Chapter 3

Hardware Development

3.1 Introduction

In this environment, to save more energy for the future the power factor correction plays a major role in energy conservation. Therefore, this paper presents the system which monitors different factors of the induction motor and these data are continuously updated onto a webpage using IoT. If any defect occurs, the system sends alert messages to the concerned person and an electronic relay activates. As the inductive load rises there will be a fall in power factor, therefore this system incorporates a power factor improvement mechanism by switching the capacitor banks. The main objective is to build an Automatic Power Factor Correction (APFC) Unit, for variable load which is able to monitor the energy consumption of an induction motor and automatically improve its power factor. It will help to reduce the penalty due to low power factor and the utilities in the protection of induction motor in addition the problems are identified before any failure.

3.2 The Project Block Diagram

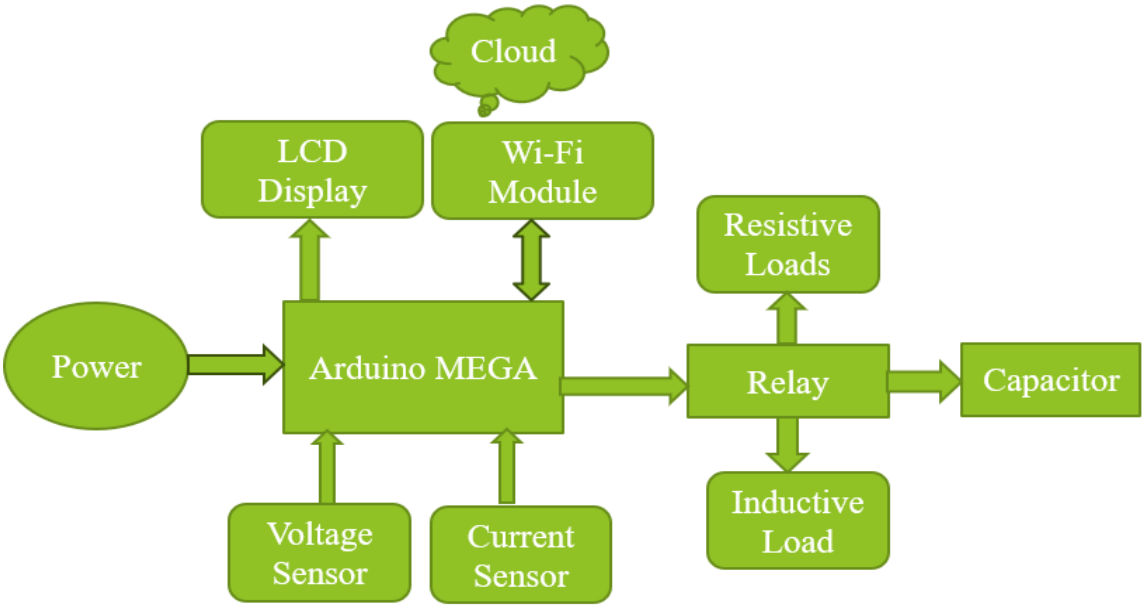


Fig-3.1: Block Diagram of the Overall System

In this proposed system we have used the Arduino Uno Development board, sensor and wifi module. In this project the system is been totally operated by power supply. The main aim of **Automatic Power Factor Control** with IOT. In above block diagram there are Current sensor, voltage sensing system, LCD display, relay module and wifi module. Microcontroller continuously check the output of sensor and gives signal to the IoT system circuit which drives the apps.

3.3 Circuit Diagram

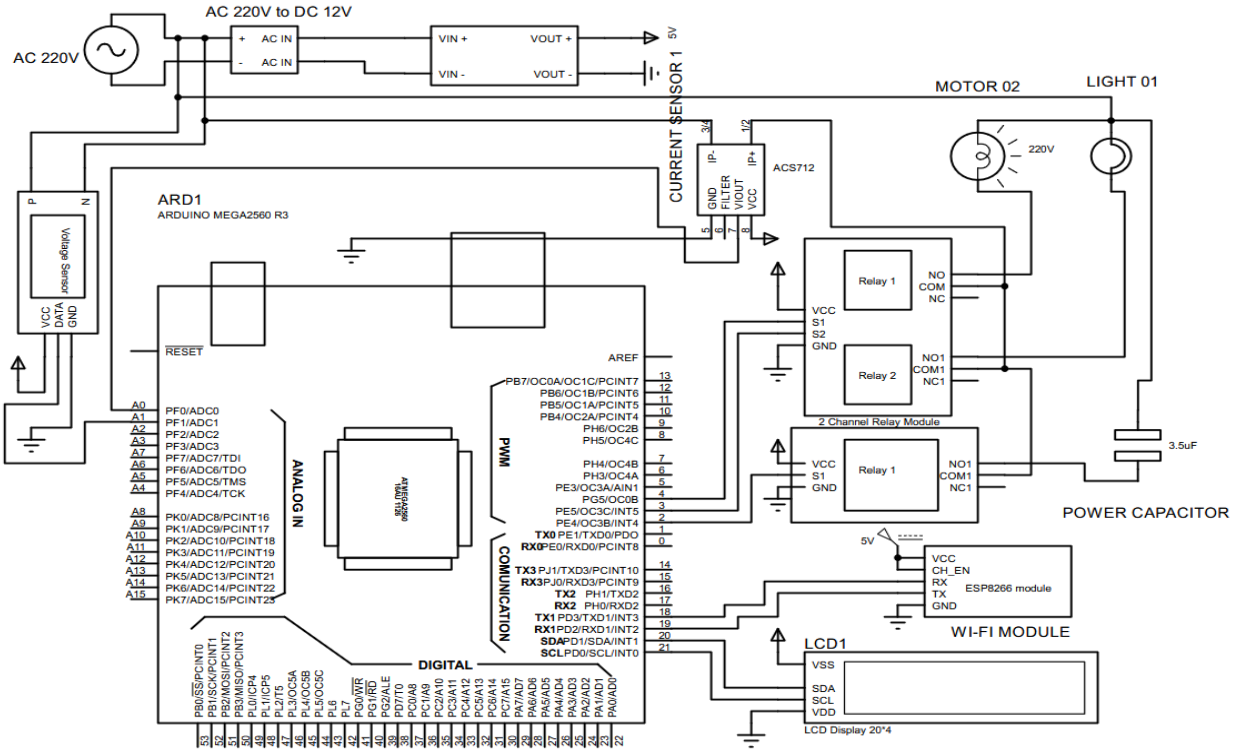


Fig-3.2: Circuit Diagram

3.4 The list of devices used in the project is given below

- Arduino MEGA.
- Buck Converter.
- Wi-Fi Module.
- Relay Module.
- Lcd Display.
- Current Sensor.
- Power Capacitor.
- SMPS.
- Voltage Sensor.

3.5 Arduino MEGA

Arduino Mega 2560 R3 (Revision 3) is a microcontroller board designed for your most ambitious projects which require additional pins and extra memory. This board is based on the 8-bit AVR microcontroller ATmega2560, it comes with 54 digital I/O pins, 16 analog inputs, 4 UARTs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. The board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits.The board has Digital pins, 6 Analog pins, and programmable with the Arduino IDE (Integrated Development Environment) via a type B USB cable.It can be powered by the USB cable or by an external 9-volt battery, though it accepts voltages between 7 and 20 volts.

It is also similar to the Arduino Nano and Leonardo.The hardware reference design is distributed under a Creative Commons Attribution Share-Alike 2.5 license and is available on the Arduino website. Layout and production files for some versions of the hardware are also available.

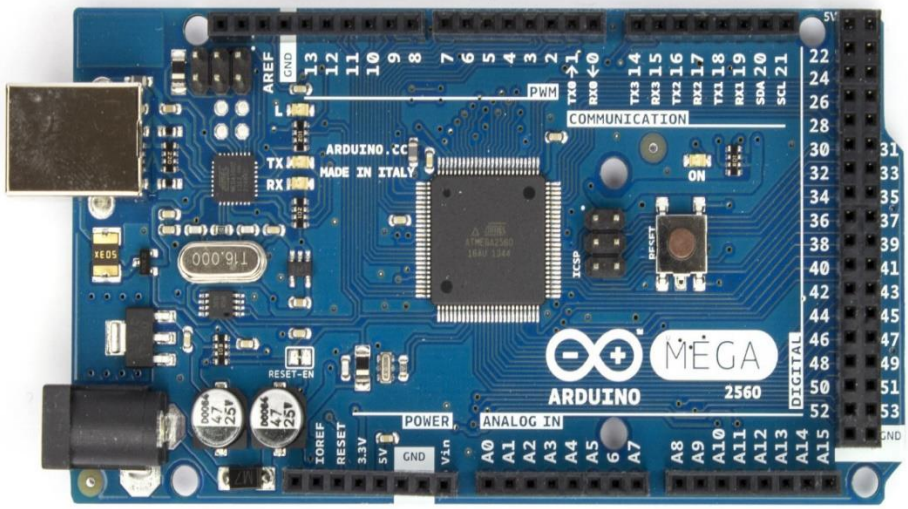


Fig-3.3: Arduino MEGA

Specifications:

- Microcontroller: CH340
- Operating Voltage: 5V
- Input Voltage (recommended): 7-12V
- Input Voltage (limits): 6-20V
- Digital I/O Pins: 54 (of which 15 provide PWM output)
- Analog Input Pins: 16
- DC Current per I/O Pin: 40 mA
- DC Current for 3.3V Pin: 50 mA
- Flash Memory: 256 KB of which 8 KB used by bootloader
- SRAM: 8 KB
- EEPROM: 4 KB
- Clock Speed: 16 MHz

3.6 Buck Module

The LM2596 series of regulators are monolithic integrated circuits that provide all the active functions for a step-down (buck) switching regulator, capable of driving a 3-A load with



Fig-3.4: LM2596 Voltage Converter

excellent line and load regulation.These devices are available in fixed output voltages of 3.3 V, 5 V, 12 V, and an adjustable output version. Requiring a minimum number of external components, these regulators are simple to use and include internal frequency compensation, and a fixed frequency oscillator. The LM2596 series operates at a switching frequency of 150 kHz, thus allowing smaller sized filter components than what would be required with lower frequency switching regulators. Available in a standard 7-pin TO-220 package with several different lead bend options, and a 7-pin TO-263 surface mount package.

3.7 Wi-Fi Module

The ESP8266 is a low-cost Wi-Fi microchip with full TCP/IP stack and microcontroller capability produced by manufacturer Espress if Systems in Shanghai, China. The chip first came to the attention of Western makers in August 2014 with the ESP-01 module, made by a third-party manufacturer Ai-Thinker. This small module allows microcontrollers to connect to a Wi-Fi network and make simple TCP/IP connections using Hayes-style commands. However, at first there was almost no English-language documentation on the chip and the commands it accepted.

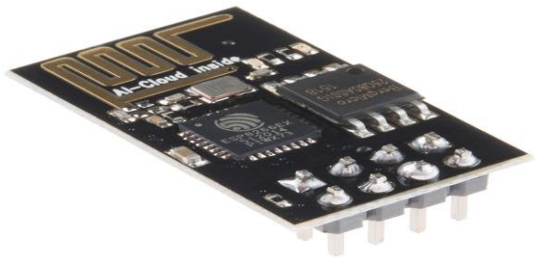


Fig-3.5: Wifi Module

The very low price and the fact that there were very few external components on the module, which suggested that it could eventually be very inexpensive in volume, attracted many hackers to explore the module, chip, and the software on it, as well as to translate the Chinese documentation.The ESP8285 is an ESP8266 with 1 MiB of built-in flash, allowing for single-chip devices capable of connecting to Wi-Fi.The successor to these microcontroller chips is the ESP32, released in 2016.

Features: Processor L106 32-bit RISC microprocessor core based on the TensilicaXtensa Diamond Standard 106Micro running at 80 MHz

Memory:

- 32 KiB instruction RAM
- 32 KiB instruction cache RAM
- 80 KiB user-data RAM
- 16 KiB ETS system-data RAM
- External QSPI flash: up to 16 MiB is supported (512 KiB to 4 MiB typically included)
- IEEE 802.11 b/g/n Wi-Fi
- Integrated TR switch, balun, LNA, power amplifier and matching network
- WEP or WPA/WPA2 authentication, or open networks
- 16 GPIO pins
- SPI
- I²C (software implementation)
- I²S interfaces with DMA (sharing pins with GPIO)
- UART on dedicated pins, plus a transmit-only UART can be enabled on GPIO2
- 10-bit ADC (successive approximation ADC)

Pinout of ESP: The pinout is as follows for the common ESP-01 module:

- VCC, Voltage (+3.3 V; can handle up to 3.6 V)
- GND, Ground (0 V)
- RX, Receive data bit X
- TX, Transmit data bit X
- CH_PD, Chip power-down
- RST, Reset
- GPIO 0, General-purpose input/output No. 0
- GPIO 2, General-purpose input/output No. 2

3.8 Relay Module

A relay is an electrically operated device. It has a control system and (also called input circuit or input contactor) and controlled system (also called output circuit or output cont actor). It is frequently used in automatic control circuit. To put it simply, it is an automatic switch to controlling a high-current circuit with a low-current signal.



Fig-3.6: Relay Module

The advantages of a relay lie in its lower inertia of the moving, stability, long-term reliability and small volume. It is widely adopted in devices of power protection, automation technology, sport, remote control, reconnaissance and communication, as well as in devices of electromechanics and power electronics. Generally speaking, a relay contains an induction part which can reflect input variable like current, voltage, power, resistance, frequency, temperature, pressure, speed and light etc. It also contains an actuator module (output) which can energize or de-energize the connection of controlled circuit. There is an intermediary part between input part and output part that is used to coupling and isolate input current, as well as actuate the output. When the rated value of input (voltage, current and temperature etc.) is above the critical value, the controlled output circuit of relay will be energized or de-energized.

NB: input into a relay can be divided into two categories: electrical quantities (including current, voltage, frequency, power etc.) and non- electrical quantities(including temperature, pressure, speed, etc.)

Features:

The features of 1-Channel Relay module are as follow:

1) Good in safety. In power system and high voltage system, the lower current can control the higher one.

2) 1-channel high voltage system output, meeting the needs of single channel control

3) Wide range of controllable voltage.

4) Being able to control high load current, which can reach 240V, 10A

5) With a normally-open (NO) contact and a normally-closed (NC) contacts

Interface specifications:

The output contacts of a relay (including NO, NC, and the common port) works as a SPDT – Single Pole Double Throw switch. Its operating principle is as follow: VCC----5V,

GND----for ground

IN1 connects to the control valve which output 3V-5V

Output contacts: connect to applications

Interface Connecting and Setting:

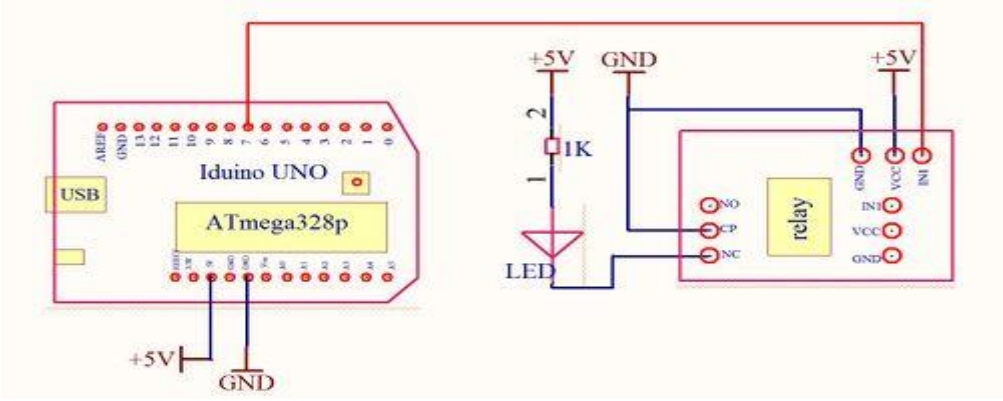


Fig-3.7: Stematic of Relay Module

Get Started: Firmware resources: Arduino board (any versions), wires, LED, 5v power supply. Software resource: Arduino IDE The one-channel relay can be programmed to realize the open and close automatically. NB: customers can use any software or firmware to control the module as long as the IN1 of which can input a voltage of 3V-5V.



Fig-3.8: Pinout of Relay Module

We can do further development with the development tool you like as well as test it in the way of testing firmware. Firmware test: after the connection as in picture1-4, pay attention to the blink of LED, listen to the flicker of relay when it is working. After the upload of code, connect the IN1 pins to the 7th pin of Arduino board separately, you can hear the ticktack of the relay (it keeps opening and closing), in addition, the LED-G is blinking every 2s.

3.9 LCD

LCD20*04 or 20 character-type liquid crystal display, is a kind of dot matrix module to show letters, numbers, and characters and so on. It's composed of 5x7 or 5x11 dot matrix positions; each position can display one character. There's a dot pitch between two characters and a space between lines, thus separating characters and lines. The model 20*04 means it displays 4 lines of 20characters.

Pin	Function
VSS	connected to ground
VDD	connected to a +5V power supply
VO	to adjust the contrast
RS	A register select pin that controls where in the LCD's memory you are writing data to. You can select either the data register, which holds what goes on the screen, or an instruction register, which is where the LCD's controller looks for instructions on what to do next.
R/W	A Read/Write pin to select between reading and writing mode
E	An enabling pin that reads the information when High level (1) is received. The instructions are run when the signal changes from High level to Low level.
D0-D7	to read and write data
A	Pins that control the LCD backlight. Connect A to 3.3v.
K	Pins that control the LCD backlight. Connect K to GND.

Tabel-01: LCD Display Outline

Generally, LCD20*04 has parallel ports, that is, it would control several pins at the same time. LCD20*04 can be categorized into eight-port and four-port connections. If the eight-port connection is used, then all the digital ports of the SunFounder Uno board are almost completely occupied. If you want to connect more sensors, there will be no ports available. Therefore, the four-port connection is used here for better application.

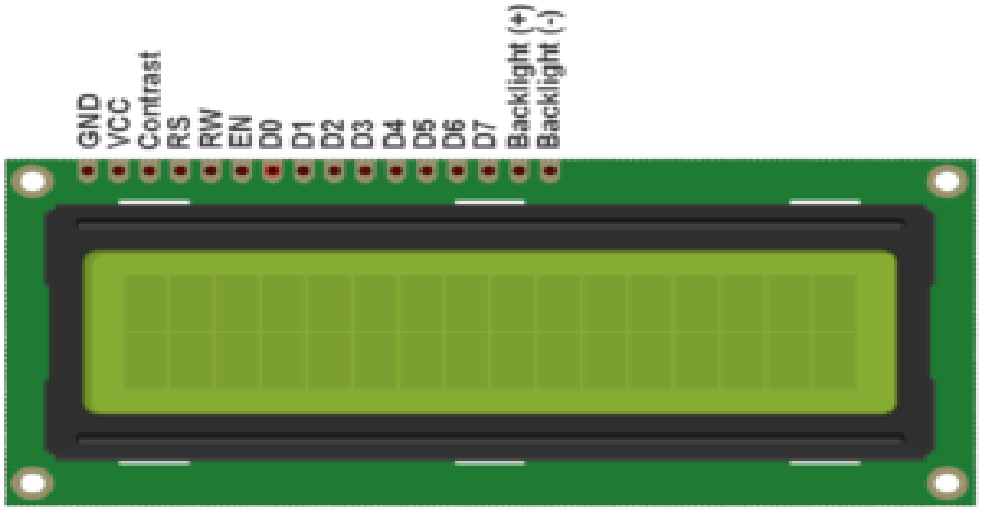


Fig-3.9: LCD Display

3.10 Current Sensor

The current transformer is an instrument transformer used to step-down the current in the circuit to measurable values and is thus used for measuring alternating currents. When the current in a circuit is too high to apply directly to a measuring instrument, a current transformer produces a reduced current accurately proportional to the current in the circuit, which can in turn be conveniently connected to measuring and recording instruments. A current Transformer isolates the measuring instrument from



Fig-3.10: Current Sensor

what may be a very high voltage in the monitored circuit. Current transformers are commonly used in metering and protective relays. Like any other transformer, a current transformer has a single turn wire of a very large cross-section as its primary winding and the secondary winding has a large number of turns, thereby reducing the current in the secondary to a fraction of that in the primary. Thus, it has a primary winding, a magnetic core and a secondary winding. The alternating current in the primary

produces an alternating magnetic field in the magnetic core, which then induces an alternating current in the secondary winding circuit. An essential objective of a current transformer design is to ensure the primary and secondary circuits are efficiently coupled, so the secondary current is linearly proportional to the primary current.

Description:

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

3.11 Power Capacitor

A capacitor bank is a grouping of several identical or non-identical capacitors interconnected in parallel or in series with one another. These groups of capacitors are typically used to correct or counteract undesirable characteristics such as power factor lag or phase shifts inherent in alternating current electrical power supplies.



Fig-3.11: Power Capacitor

Capacitor banks may also be used in direct current power supplies to increase stored energy and improve the ripple current capacity of the power supply. The capacitor bank consists of a group of eight (8) a.c capacitors, all rated at 230V, 50 Hz i.e., the supply voltage and frequency. The value of capacitors is different and it consists of four capacitors of 50 microfarad. All the capacitors are connected in parallel to one another and the load. The capacitor bank is controlled by the relay module and is connected across the line. The operation of a relay connects the associated capacitor across the line in parallel with the load and other capacitors

3.12 SMPS

12V 5A Micro Power supply. For using with Arduibo /Raspberry Pi 3 Model A+/B/B+/Zero and running any other high current devices.

Specifications:

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



Fig-3.12: SMPS

3.13 AC Voltage Sensor

A voltage sensor is a sensor is used to calculate and monitor the amount of voltage in an object. Voltage sensors can determine both the AC voltage and DC voltage level. The input of this sensor can be the voltage whereas the output is the switches, analog voltage signal, a current signal, an audible signal, etc.

Sensors are basically a device which can sense or identify and react to certain types of electrical or some optical signals. Implementation of voltage sensor and current sensor techniques have become an excellent choice to the conventional current and voltage measurement methods.



Fig-3.13: Voltage Sensor

Specification:

*Drive Voltage: 5VCharacteristics: Analog output Up to 250V AC detection range Calibration potentiometer.

*Chipset: ZMPT101B.

*Mounting holes: M2 46/16mmPin pitch: 2.54Connectors: Screw Terminals.

*Operating Temperature: -40°C to 85°C (unconfirmed)

This module is ideally suited to measuring an AC voltage. When connected to the screw terminals the sensor will sample the input and output an analog voltage, in the region of 0 - 5V. This makes it easy to use in power monitoring applications and checking supplies.

Chapter 4

Software Development

4.1 Introduction

Software part is one of the main parts of the project, controlling & protection system. The Algorithm is based on different conditions & measuring parameters. Total function of the system is controlled by the software. The code is written on C.

4.2 Project Flow Chart

In any programming related project there is a part named “flowchart” is must. As per rules we made our project flowchart then wrote our proposed project program. There are several parts of our project thus many flowcharts we made.

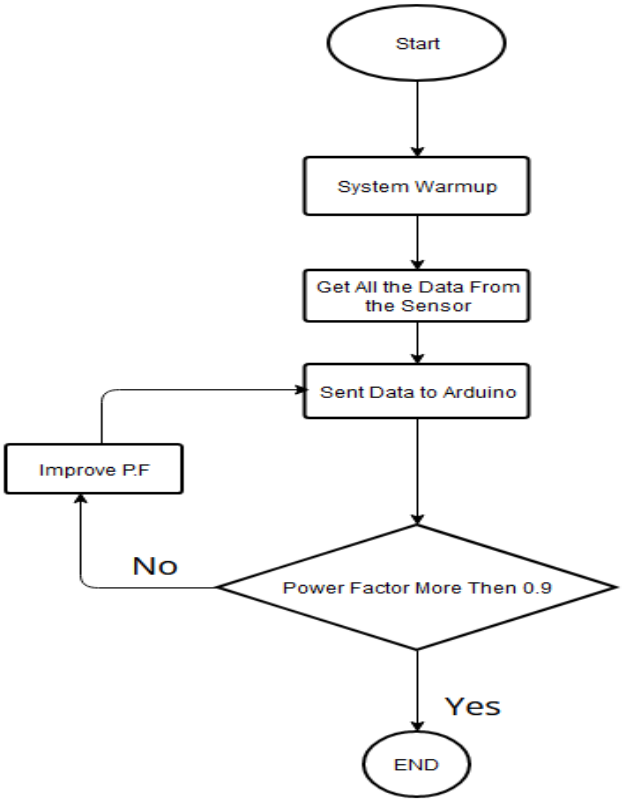


Fig 4.1: Project Flow Chart

4.3 Software Tools

The software that is used to program the microcontroller is open-source-software and can be downloaded for free on www.arduino.cc. With this “Arduino software” we can write little programs with the microcontroller. These programs are called “Sketch”.

In the end the sketches are transferred to the microcontroller by USB cable. More on that later the subject “programming”.

Installation

Now one after another the Arduino software and the USB driver for the board have to be installed.

Installation and setup of the Arduino software

1. We have downloaded the Arduino software from www.arduino.cc and installed it on the computer (This was NOT connected to the PC). After that we opened the software file and installed the program named arduino.exe.

Two set ups on the program are important and should be considered.

a) The board that we want to connect must be selected on the Arduino software. The “Arduino Uno” is here known as “Arduino / Genuine Uno”.

b) We must choose the right “Serial-Port”, to let the computer know to which port the board has been connected. That is only possible if the USB driver has been installed correctly. It can be checked this way:

At the moment the Arduino wasn’t connected to the PC. If we now choose “Port”, under the field “Tool”, we will already see one or more ports here (COM1/ COM2/ COM3…). The quantity of the shown ports doesn't depend on the quantity of the USB ports on the computer. When the board gets connected to the computer, we will find one more port.

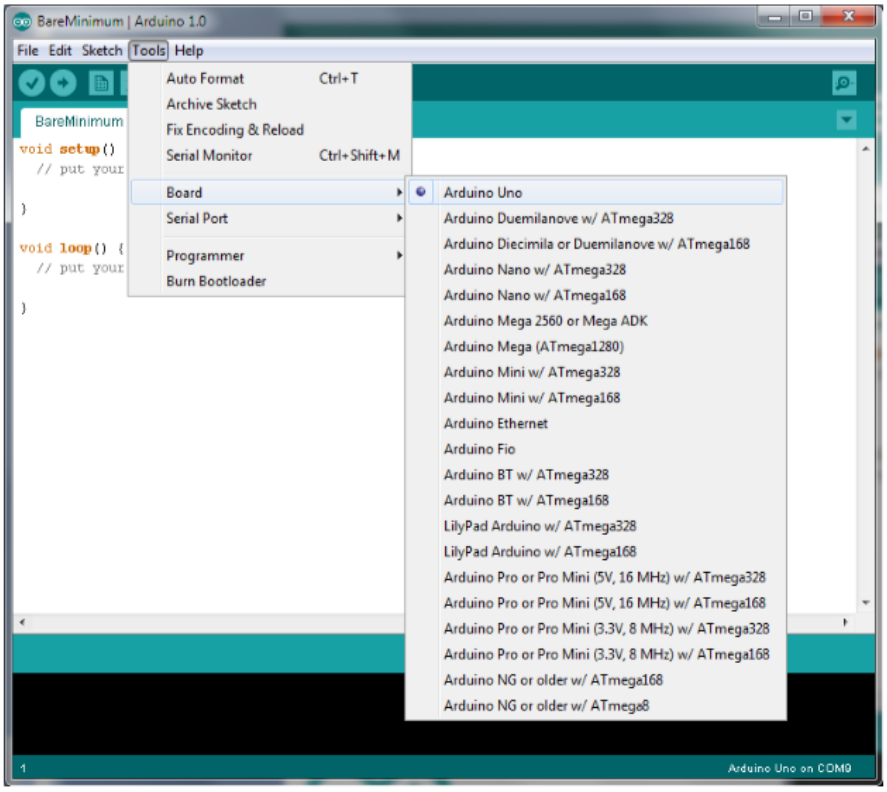


Fig 4.2: Program Installation Process-01

4.4 Programming

The development cycle is divided into 4 phases:

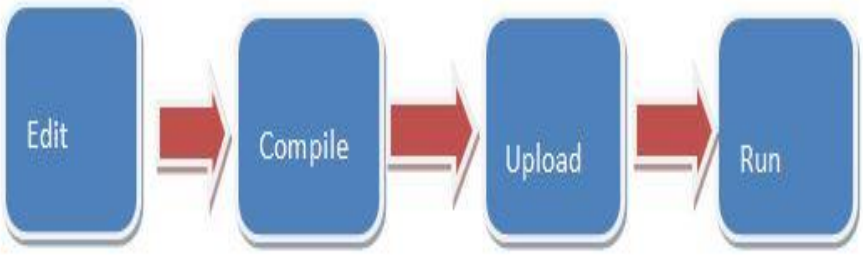


Fig-4.3: Flowchart of the Compiling Process-02

Compile: Compile means to translate the sketch into machine language, also known as object.
Code Run: Arduino sketch is executed as soon as terminates the step of uploading on the board.

4.5Arduino Program Development

- Based on C++ without 80% of the instructions.
- A handful of new commands.
- Programs are called 'sketches'.
- Sketches need two functions:
- void setup ()
- Void loop ()
- Setup () runs first and once.
- loop () runs over and over, until power is lost, or a new sketch is loaded.

4.6 Proteus8.1

Proteus 8 is best simulation software for various designs with microcontroller. It is mainly popular because of availability of almost all microcontrollers in it. So, it is a handy tool to test programs and embedded designs for electronics hobbyist. You can simulate your programming of microcontroller in Proteus 8 Simulation Software. After simulating your circuit in Proteus 8 Software you can directly make PCB design with it so it could be a all-in-one package for students and hobbyists. So, I think now you have a little bit idea about what is proteus software. Proteus 7.0 is a Virtual System Modeling (VSM) that combines circuit simulation, animated components, and microprocessor models to co-simulate the complete microcontroller-based designs. This is the perfect tool for engineers to test their microcontroller designs before constructing a physical prototype in real time. This program allows users to interact with the design using on-screen indicators and/or LED and LCD displays and, if attached to the PC, switches, and buttons. One of the main components of Proteus 7.0 is the Circuit Simulation -- a product that uses a SPICE3f5 analogue simulator kernel combined with an event-driven digital simulator that allow users to utilize any SPICE model by any manufacturer. Proteus VSM comes with extensive debugging features, including breakpoints, single stepping, and

variable display for a neat design prior to hardware prototyping. In summary, Proteus 7.0 is the program to use when you want to simulate the interaction between software running on a microcontroller and any analog or digital electronic device connected to it.

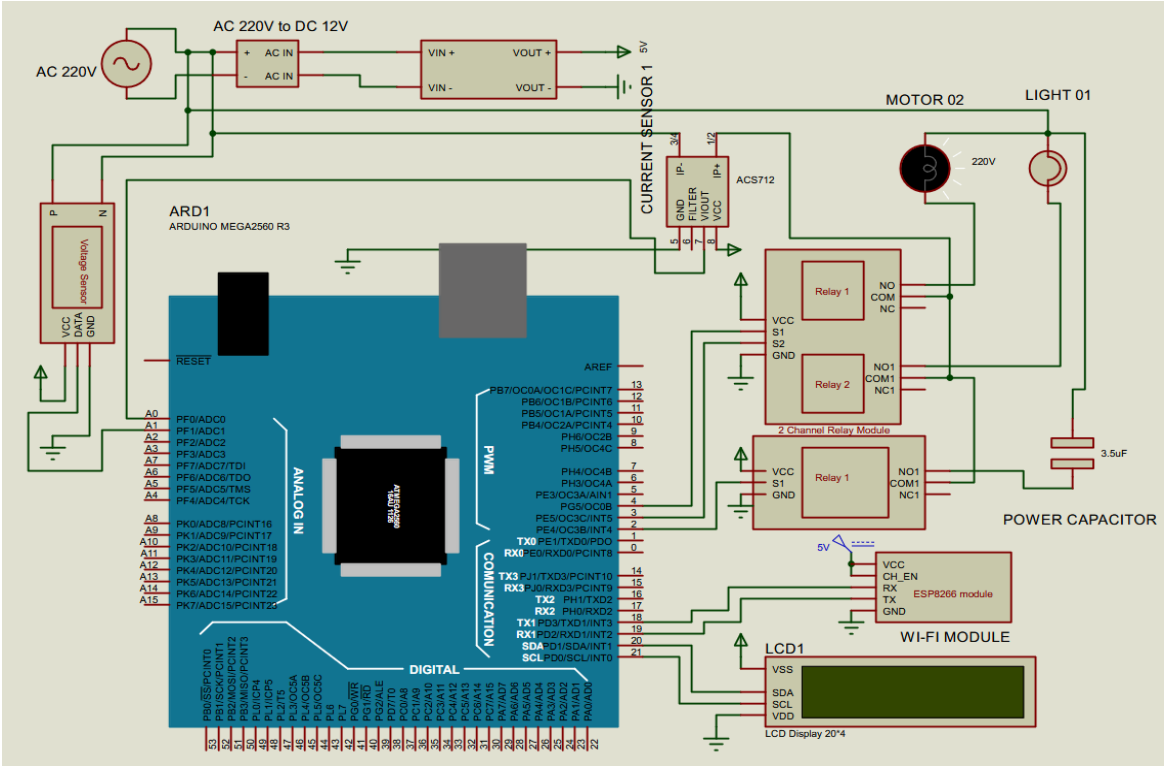


Fig 4.4: User Interface of Proteus 8.1

Chapter 5

Result & Output Observations

5.1 System physical appearance

The below image is showing the total system is in OFF mode. There is no power is supplied & device is not connected with power.

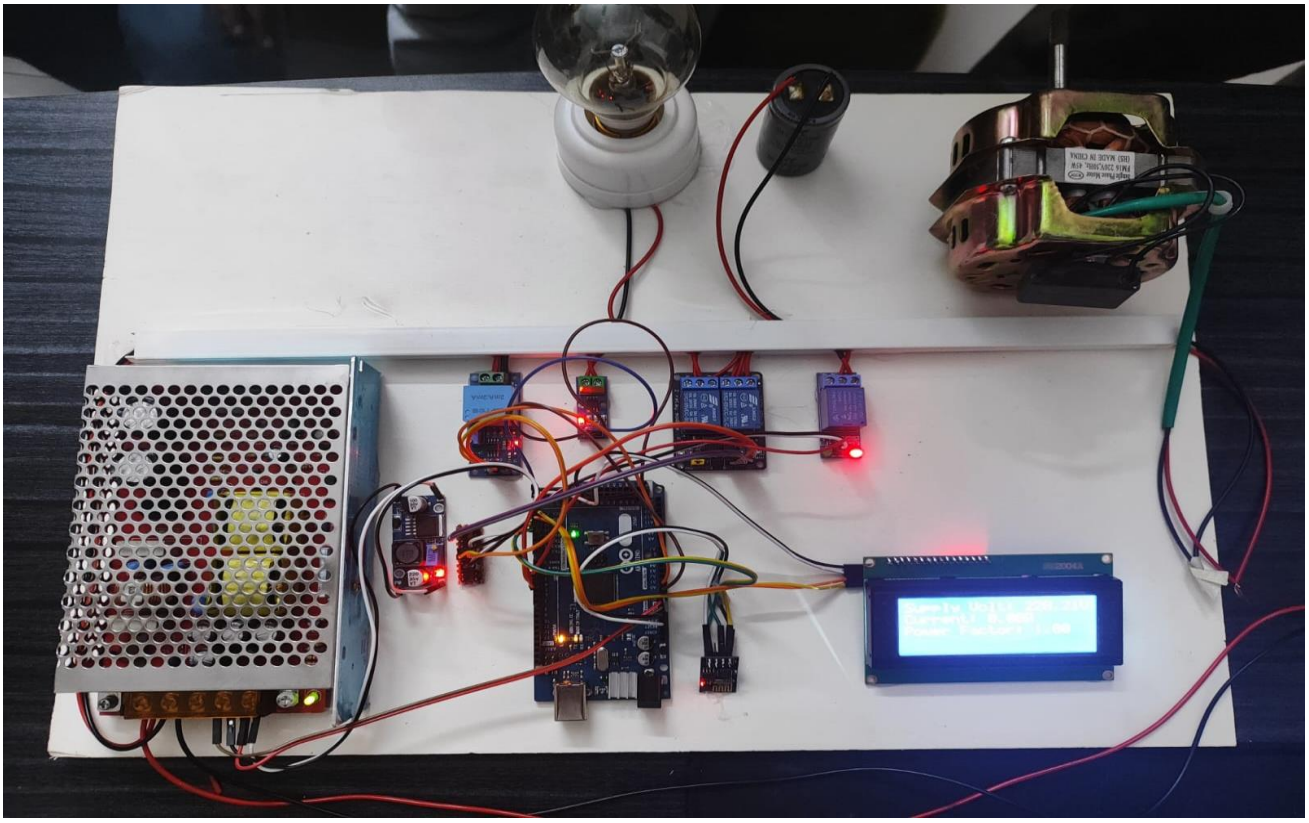


Fig-5.1: Project Picture

5.2 Working Principle

Our project has created a circuit design by connecting all the devices in the circuit. To measure the line voltage here, we use AC voltage Sensor and connect to Arduino Analog pin, connected current sensor to Arduino Analog pin measure current, we have a capacitor to improve the power factor system, we have attached a display to monitor the project data we have used the wifi module for controlling and monitoring over the internet, by using relays we can control the loads with we can improve the quality of power factor by connecting capacitor bank with command through internet and in the project we have used arduino Mega as programming device.

5.3 Result

When we give power to our project, the project will start, Then the project will have to provide internet connection.

- From the project display we can monitor voltage, current and power factor as well as monitor via internet.
- With the command of the Internet we can turn the loads on and off, and if the value of the power factor decreases, we can increase the power factor with the command of the Internet.

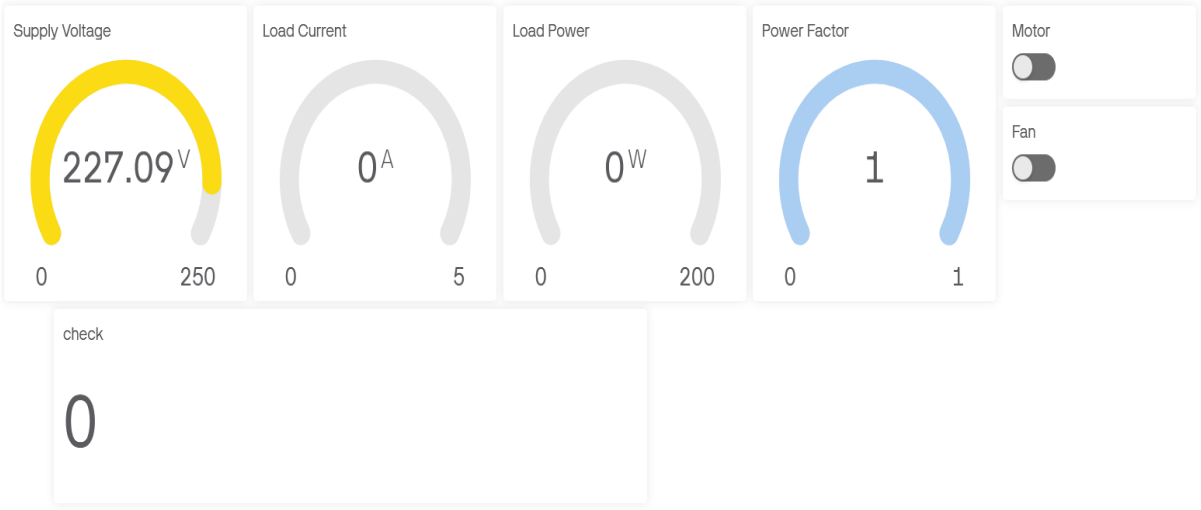


Fig-5.2: Apps Monitoring System

Chapter 6

Discussion and Conclusions

6.1 Discussion & Conclusion

Power factor correction equipment designed based on microcontroller and capacitor banks using IoT was used for measurement and monitoring of modelled electrical load and the following deductions were obtained: The power factor correction device was able to improve the power factor from 0.76 to 0.97 under the test load conditions. The average savings in energy consumption were about 1.7% of the designed load and different load patterns. With the proper amount of reactive power compensation, the system capacity is released as there is a reduction in current drawn. The economic analysis suggested the payback period to be around 9 months with a significant amount of savings in energy cost.

6.2 Advantages

- Monitoring and controlling should be done through internet.
- Whenever the power factor in the system is reduced, the automatic capacitor bank will be connected and the power factor will be taken to the specified level.
- Low cost and very easy to implement.

6.3 Application

- Industry
- Shopping complex

6.3 Future Scopes of the Work

In future this method will be implemented in most of the organization and industry. It can be implemented even in the small scale industries because energy conservation and paying penalty cause a major issue in all scale industry and this method rectifies all the problem and so this will be a compulsion to minimize their expenses. This will be the best solution in future because man power will be eradicated completely and will be automated. This will play a major role in it.

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Appendix:

Program for Arduino MEGA:

```
#define BLYNK_PRINT Serial

/* Fill-in your Template ID (only if using Blynk.Cloud) */

#define BLYNK_TEMPLATE_ID "TMPL67dsLTIcr"
#define BLYNK_TEMPLATE_NAME "IoT Power Factor Monitoring"
#define BLYNK_AUTH_TOKEN "5UAvyFeIBGH2apbqT04ntwr-tQjfKPaS"


#include <ESP8266_Lib.h>
#include <BlynkSimpleShieldEsp8266.h>
// #include <SoftwareSerial.h>
#include "EmonLib.h"
#include <Wire.h>
#include <LiquidCrystal_I2C.h>


LiquidCrystal_I2C lcd(0x27, 20, 4);


EnergyMonitor emon1;
float supplyVoltage = 0.00;




//variable for current sensor
#define acs712 A0
int acspower = 5;
float amperage = 0.00;
float power;
//float amp = 0.00;
//double kilos = 0.00;
//double kilossate = 0.00;
//unsigned long last_time = 0;
//unsigned long current_time = 0;
float mean = 0.0;
float ampf;
```

```
//current sample count
long lastsample = 0;
long samplesum = 0;
int sampleCount = 0;
float vpc = 4.8828125;



char auth[] = BLYNK_AUTH_TOKEN;
char ssid[] = "student";
char pass[] = "iotstudent";
// SoftwareSerial EspSerial(7, 8);  // RX, TX
#define ESP8266_BAUD 9600
ESP8266 wifi(&Serial1);// for mega
// ESP8266 wifi(&EspSerial);  // for uno and nano

int relay = 3;
int relay1 = 4;
int relay2 = 2;

int flag = 0;
int flag1 = 0;
int flag2 = 0;
int flag3 = 0;

float pf = 0.00;
int resistive;
int inductive;
int capacitor;


// Non blocking delay
long lastDebounceTime = 0;   // the last time the output pin was toggled
long debounceDelay = 10000;  // the debounce time; increase if the output flickers

void setup() {
  pinMode(relay, OUTPUT);
  pinMode(relay1, OUTPUT);
  pinMode(relay2, OUTPUT);
  //  pinMode(cout, OUTPUT);
  //  pinMode(fout, OUTPUT);


  digitalWrite(relay, HIGH);
  digitalWrite(relay1, HIGH);
  digitalWrite(relay2, HIGH);
```

```
  Serial.begin(9600);
  emon1.voltage(1, 432.25, 1.7);  // Voltage: input pin, calibration  234.26, phase_shift


  lcd.init();
  lcd.backlight();

  // EspSerial.begin(ESP8266_BAUD);
  Serial1.begin(ESP8266_BAUD);
  delay(10);
  Blynk.begin(auth, wifi, ssid, pass);
}

BLYNK_WRITE(V4)  // V0 is the number of Virtual Pin
{
  resistive = param.asInt();
  Serial.println(resistive);
}
BLYNK_WRITE(V5)  // V0 is the number of Virtual Pin
{
  inductive = param.asInt();
  Serial.println(inductive);
}
//BLYNK_WRITE(V5) // V0 is the number of Virtual Pin
//{
//  capacitor = param.asInt();
//  Serial.println(capacitor);
//}

void loop() {
  Blynk.run();
  emon1.calcVI(20, 2000);  // Calculate all  2000. No.of half wavelengths (crossings), time-out
  //emon1.serialprint();           // Print out all variables (realpower, apparent power, Vrms, Irms, power
factor)
  supplyVoltage = emon1.Vrms;  //extract Vrms into Variable


  for (sampleCount = 0; sampleCount <= 1000; sampleCount++) {
    samplesum += analogRead(acs712);
    //    sampleCount++;
    delay(1);
  }

  if (supplyVoltage < 100) {
    supplyVoltage = 0.00;
  }
```

```
mean = samplesum / 1000;
Serial.println(mean);
if (mean <= 115) {
  mean = 0;
}

float value = sqrt(mean);
float mv = value * vpc;
amperage = (mv / 175);  //66 for 30A  100 for 20A  185 for 5A

//  Serial.println(" Miliamp: " + String(amperage));

samplesum = 0;



Blynk.virtualWrite(V0, supplyVoltage);
//  Blynk.virtualWrite(V1, amperage);


//  Serial.println(frequency);
//  Serial.println(supplyVoltage);
//  Serial.println(temp);
//  Serial.println("");
//  delay(1000);
lcd.clear();
lcd.setCursor(0, 0);
lcd.print("Supply Volt: ");
lcd.print(supplyVoltage);
lcd.print("V");



if (resistive == 0 && inductive == 0)  //&& capacitor == 0)
{
  pf = 1;

  lcd.setCursor(0, 1);
  lcd.print("Current: ");
  lcd.print(amperage);
  lcd.print("A");

  lcd.setCursor(0, 2);
  lcd.print("Power Factor: ");
  lcd.print(pf);
```

```
  Blynk.virtualWrite(V1, amperage);
  Blynk.virtualWrite(V2, amperage*supplyVoltage*pf);
  Blynk.virtualWrite(V3, pf);
  capacitor = 0;
 }

 if (resistive == 1 && inductive == 0 && capacitor == 0) {
  delay(1000);

  //    float ampf = random(45,47)/100.00;

  if (amperage > 0.15) {
   pf = random(98, 100) / 100.00;
  }

  lcd.setCursor(0, 1);
  lcd.print("Current: ");
  lcd.print(amperage);
  lcd.print("A");

  lcd.setCursor(0, 2);
  lcd.print("Power Factor: ");
  lcd.print(pf);
  Blynk.virtualWrite(V1, amperage);
  Blynk.virtualWrite(V3, pf);
  Blynk.virtualWrite(V2, amperage*supplyVoltage*pf);

  capacitor = 0;
 }

 if (resistive == 0 && inductive == 1 && capacitor == 0) {
  delay(1000);
  //    pf = random(72, 75) / 100.00;
  //    float ampf = random(32,34)/100.00;
  if (amperage > 0.15) {
   pf = random(78, 80) / 100.00;
  }



  lcd.setCursor(0, 1);
  lcd.print("Current: ");
  lcd.print(amperage);
  lcd.print("A");

  lcd.setCursor(0, 2);
```

```
  lcd.print("Power Factor: ");
  lcd.print(pf);
  Blynk.virtualWrite(V1, amperage);
  Blynk.virtualWrite(V3, pf);
  Blynk.virtualWrite(V2, amperage*supplyVoltage*pf);
  flag = 0;
 }

 if (resistive == 1 && inductive == 1 && capacitor == 0) {
  delay(1000);
  //    pf = random(80, 85) / 100.00;
  //    float ampf = random(32,34)/100.00;
  if (amperage > 0.30) {
    pf = random(80, 85) / 100.00;
  }

  lcd.setCursor(0, 1);
  lcd.print("Current: ");
  lcd.print(amperage);
  lcd.print("A");

  lcd.setCursor(0, 2);
  lcd.print("Power Factor: ");
  lcd.print(pf);
  Blynk.virtualWrite(V1, amperage);
  Blynk.virtualWrite(V2, pf);
  Blynk.virtualWrite(V2, amperage*supplyVoltage*pf);
 }

 if (pf < 0.90)  // && flag2 == 0)
 {
  digitalWrite(relay1, LOW);
  lcd.setCursor(0, 3);
  lcd.print("Calculating....");
  Blynk.virtualWrite(V6, "Calculating..");
  //    Serial.println("hi");
  delay(3000);
  lcd.clear();
  Blynk.virtualWrite(V6, " ");
  capacitor = 1;

  //    if (capacitor == 0)
  //    {
  ////      Serial.println("hi");
  //
  //      digitalWrite(relay, HIGH);
```

```
  //      digitalWrite(relay1, HIGH);
  //      Blynk.virtualWrite(V3, 0);
  //    Blynk.virtualWrite(V4, 0);
  ////      int Vdata = 0;
  ////      Blynk.virtualWrite(V4, Vdata);
  //      pf = 1;
  //    }

  //    if (capacitor == 1)
  //    {
  ////      Serial.println("hi1");
  //    }
  //    flag2 = 1
}

if (resistive == 1 && inductive == 0 && capacitor == 1) {
  delay(1000);
  pf = random(96, 99) / 100.00;
  ampf = random(42, 44) / 100.00;
  if (amperage < 0.20) {
    pf = 1;
    ampf = 0.0;
  }
  lcd.setCursor(0, 1);
  lcd.print("Current: ");
  lcd.print(ampf);
  lcd.print("A");

  lcd.setCursor(0, 2);
  lcd.print("Power Factor: ");
  lcd.print(pf);
  Blynk.virtualWrite(V1, ampf);
  Blynk.virtualWrite(V3, pf);
  Blynk.virtualWrite(V2, amperage*supplyVoltage*pf);
}

if (resistive == 0 && inductive == 1 && capacitor == 1) {
  digitalWrite(relay1, LOW);
  delay(1000);


  pf = random(95, 98) / 100.00;
  ampf = random(28, 31) / 100.00;
  if (amperage < 0.20) {
    pf = 1;
    ampf = 0.0;
```

```
  }
  lcd.setCursor(0, 1);
  lcd.print("Current: ");
  lcd.print(ampf);
  lcd.print("A");

  lcd.setCursor(0, 2);
  lcd.print("Power Factor: ");
  lcd.print(pf);
  Blynk.virtualWrite(V1, ampf);
  Blynk.virtualWrite(V3, pf);
  Blynk.virtualWrite(V2, amperage*supplyVoltage*pf);
}

if (resistive == 1 && inductive == 1 && capacitor == 1) {
  digitalWrite(relay1, LOW);
  delay(1000);
  pf = random(96, 99) / 100.00;
  ampf = random(67, 70) / 100.00;
  if (amperage < 0.20) {
    pf = 1;
    ampf = 0.0;
  }
  lcd.setCursor(0, 1);
  lcd.print("Current: ");
  lcd.print(amperage);
  lcd.print("A");

  lcd.setCursor(0, 2);
  lcd.print("Power Factor: ");
  lcd.print(pf);
  Blynk.virtualWrite(V1, ampf);
  Blynk.virtualWrite(V3, pf);
  Blynk.virtualWrite(V2, amperage*supplyVoltage*pf);
}



if (resistive == 1 && flag == 0) {
  digitalWrite(relay, LOW);
  flag = 1;
}

if (resistive == 0 && flag == 1) {
  digitalWrite(relay, HIGH);
  flag = 0;
```

```
  }

  if (inductive == 1 && flag1 == 0) {
    digitalWrite(relay1, LOW);
    flag1 = 1;
  }

  if (inductive == 0 && flag1 == 1) {
    digitalWrite(relay1, HIGH);
    capacitor = 0;
    flag1 = 0;
  }

  if (capacitor == 1) {
    digitalWrite(relay2, LOW);
  }

  if (capacitor == 0) {
    digitalWrite(relay2, HIGH);
  }
}
```