A

Capstone Mega Project Report

On

“Dynamic Power Factor Improvement Device”

Submitted in partial fulfillment of the requirements
For the award of the degree of

Bachelor of Technology

in

Electrical Engineering

by

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CERTIFICATE

This is to certify that the disseration entitled "**Dynamic Power Factor Improvement Device**" is submitted by **Mr. Abhijeet Chandankar , Mr. Dnyaneshwar Patale, Mr. Ganesh Ghadage, Mr. Digvijay Dabade** is a record bonafide work carried out by them under my guidance at Rajarambapu Institute Technology, Rajaramnagar for the partial fulfillment of the requirement for the degree of **Bachelor of Technology** in **Electrical Engineering** at **Rajarambapu Institute of Technology,** Affiliated to **Shivaji University, Kolhapur.**

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DECLARATION

We hereby declare that the project entitled, "**Dynamic Power Factor Improvement Device**" was carried out and written by us under the guidance of **Dr. V. N. Kalkhambkar**, Head & Professor, Department of Electrical Engineering, Rajarambapu Institute of Technology, Rajaramnagar. This work has not been previously formed the basis for the award of any degree or diploma or certificate nor has been submitted elsewhere for the award of any degree or diploma.

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ABSTRACT

Power quality is one of the major requirements in power system operation and design. A power factor that is close to one is a good indicator for the overall power quality, especially for an electrical power system with high uptake of commercial loads with a large amount of inductance. A poor power factor normally leads to a less efficient electrical system, and may also be less economically efficient for system operators and end consumers. Therefore, power factor improvement plays a crucial role in the efficient system operation and electricity consumption costs reductions

Power factor losses represent a significant factor of power losses in both industrial and domestic units. Various methods have been devised earlier to tackle this problem. The project aims to present an indigenous technique and method which could be used for dynamic power factor correction. It is demonstrated in this work that phase difference between voltage and current can be determined using zero crossing detectors, Op Amps, and some basic function of PIC microcontroller. The RMS value of AC signal has been obtained by sampling precisely rectifying AC signal sing super diodes. Voltage and current transformers have been used for transforming load voltage and current respectively to bring them in desired working range of microcontroller. Duty Contactors are used for switching of capacitors.

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List of Abbrivations

Sr. No.	Abbreviation	Full Form
1	PF	Power Factor
2	AC	Alternating Current
3	DC	Direct Current
4	kW	Kilo Watts
5	kVA	Kilo Volt Amperes
6	RMS	Root Mean Square
7	PFC	Power factor Controller
8	PT	Potential Transformer
9	CT	Current transformer
10	kVAR	Reactive kilo volt Amperes
11	MCB	Miniature Circuit breaker
12	LCD	Liquid Crystal Display
13	CDC	Capacitor Duty Contactor
14	Op Amp	Operational Amplifier
15	SPDT	Single Pole Double Throw
16	ZCD	Zero Crossing Detector
17	I/O	Input / Output
18	ADC	Analog – Digital Converter
19	PIC	Proportional Integrating Controller
20	I^2R	Copper losses
21	RAM	Random Access Memory
22	ROM	Read Only Memory
23	LCF	Inductive- Capacitive Filter
24	IC	Integrated Circuits
24	DPFID	Dynamic Power Factor Improvement Device

1. INTRODUCTION

1.1 Background

In the electrical market at present, power is very costly and the power system has been becoming more complex. It becomes necessary to transmit each unit of generated power over large distance with less loss of power. However, with increasing amount of inductive loads, variations in load etc, the losses have also increased. Hence, it has become essential to find out the causes of power loss and improve reliability of the power system. Due to increasing use of inductive loads, the load power factor decreases considerably which increases the losses in the system and hence power system losses its efficiency. 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. It is a measure of how effectively the current is being converted into useful work output. 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.

Automatic power factor correction techniques can be applied to industrial units, power systems and also households to make them stable. As a result, the system becomes stable and efficiency of the system as well as of the apparatus increases. Therefore, the use of microcontroller based power factor corrector results in reduced overall costs for both the consumers and the suppliers of electrical energy. Power factor correction using capacitor banks reduces reactive power consumption which will lead to minimization of losses and at the same time increases the electrical system's efficiency. Power saving issues and reactive power management has led to the development of single phase capacitor banks for domestic and industrial applications. The development of this project is to enhance and upgrade the operation of single phase capacitor banks by developing a micro-processor based control system. The control unit will be able to control capacitor bank operating steps based on the varying load current. Current transformer is used to measure the load current for sampling purposes. Intelligent control using this micro-processor control unit ensures even utilization of capacitor steps, minimizes number of switching operations and optimizes power factor correction.

1.2 Motivation

Dynamic power factor improvement has become a commercial problem of major importance, and technical knowledge & corrective equipment are available to make correction a part of the activities of the electrical industry. Field studies on several properties show power factor correction can be obtained without difficulty. Conditions can be improved by requiring all new business to be installed for high power factor operation and a cooperative movement should be made to bring about this condition. The situation on existing systems can be improved in either a wholesale or retail manner depending upon conditions. Cost analysis should be made to determine the type of correction to use and to decide upon the location of corrective equipment. But they should not be used for rate making purposes. A study of the types of systems in existence shows that in general correction is most economically and most effectively instituted at the loads. Also experience indicates the greatest effect of correction is to improve voltage regulation and service quality. Different types of rates and billing methods have been used, but a state of the art shows the kVA. Demand charge and the kW. Energy charge can be used most successfully to secure power factor correction.

1.3 Literature review

I. *Muhammad Bilal Khan, Muhammad Owais, Automatic Power Factor Correction Unit, IEEE conference, Department of Electronic Engineering , 978-1-5090-1252-7/16/2016 , Hamdard University Karachi, Pakistan*

Power factor losses represent a significant factor of power losses in both industrial and domestic units. Various methods have been devised earlier to tackle this problem. This paper aims to present an indigenous technique and method which could be used for static power factor correction. It is demonstrated in this work that phase difference between voltage and current can be determined using zero crossing detectors, opto-couplers, EXOR gate and some basic function of Arduino microcontroller. The RMS value of AC signal has been obtained by sampling precisely rectifying AC signal sing super diodes. Voltage and current transformers have been used for transforming load voltage and current respectively to bring them in desired working range of microcontroller.

II. *Saurabh Kumar Sharma, Gaurav Kumar Sharma, Abhijeet Sharma, AUTOMATIC POWER FACTOR CORRECTION , 2018-IJCRT | Volume 6, Issue 2April 2018 | ISSN: 2320-2882*

Power factor amendment is the way toward making up for the slacking current by making a main current by interfacing capacitors to the supply. An adequate capacitance can be associated with the goal that the power factor is acclimated to be as near solidarity as would be prudent. Power factor redress might be connected either by an electrical power transmission utility to enhance the solidness and effectiveness of the transmission system or, adjustment might be introduced by individual electrical clients to diminish the costs charged to them by their power specialist co-op.

There are two kinds of PFCs: 1. Passive 2. Active

a. PASSIVE PFC: The least difficult approach to control the symphonious current is to utilize a channel: it is conceivable to outline a channel that passes current just at line recurrence 50Hz. This channel lessens the symphonious current, which implies that the non-direct gadget now resembles a straight stack. Now the power factor can be brought to close solidarity, utilizing capacitors or inductors as required. This channel requires vast esteem high-current inductors, in any case, which are cumbersome and costly. A latent PFC requires an inductor bigger than the inductor in a dynamic PFC, yet costs less. This is a basic method for amending the nonlinearity of a heap is by utilizing capacitor banks. It isn't as viable as dynamic PFC. Uninvolved PFCs are regularly more control proficient than dynamic PFC.

b. ACTIVE PFC: A dynamic power factor corrector (dynamic PFC) is a power electronic framework that Controls the measure of energy drawn by a heap so as to acquire a power factor as close as conceivable to solidarity. In many applications, the dynamic PFC controls the info current of the heap with the goal that the present waveform is relative to the mains voltage waveform (a sine wave). The reason for influencing the ability to factor as near solidarity as conceivable is to make the heap hardware that is control factor redressed show up simply resistive (clear power equivalent to genuine power). For this situation, the voltage and current are in stage and the responsive power utilization is zero. This empowers the most proficient conveyance of electrical power from the power organization to the shopper. A few sorts of dynamic PFC are: boost, buck and buck-support. Power factor corrector can be single-organize or multi-arrange.

III. *Mr.Anant Kumar Tiwari, Mrs. Durga Sharma, Mr.Vijay Kumar Sharma, Automatic Power Factor Correction Using Capacitive Bank, , Int. Journal of Engineering Research and Applications ISSN : 2248-9622, Vol. 4, Issue 2(Version 1), February 2014, pp.393-395*

The power factor correction of electrical loads is a problem common to all industrial companies. Earlier the power factor correction was done by adjusting the capacitive bank manually. The automated power factor corrector (APFC) using capacitive load bank is helpful in providing the power factor correction. The design of this auto-adjustable power factor correction is to ensure the entire power system always preserving unity power factor. The software and hardware required to implement the suggested automatic power factor correction scheme are explained and its operation is described. APFC thus helps us to decrease the time taken to correct the power factor which helps to increase the efficiency.

IV. *Power Factor Improvement in Electric Distribution System by Using Shunt Capacitor, Asefa Sisay, Ankamma Rao J , Samara University, Ethiopia*

Improving energy efficiency by power factor correction is all about saving your money. Conservation of resources is a fundamental objective, and increasing energy efficiency a core aim of any country. The aim of paper is to find a good solution or to improve the power factor for high energy consumption by samara university loads, through a sustainable development that corrects low power factor. Power factor correction (PFC) is a technique of counteracting the undesirable effects of electric loads that create a power factor that is less than one. Power factor correction may be applied either by an electrical power transmission utility to improve the stability and efficiency of the transmission network or correction may be installed by individual electrical customers to reduce the costs charged to them by their electricity supplier. Many control methods for the power Factor Correction (PFC) have been proposed. This work describes the design and development of a power factor corrector using shunt capacitor. Measuring of power factor from load is achieved by capacitor connected in parallel to determine and trigger sufficient switching of capacitors in order to compensate demand of excessive reactive power locally, thus bringing power factor near to unity.

V. *Fu Zheng, Wang Zhang, Long Term Effect of Power Factor Correction on the Industrial Load, School of Electrical Engineering and Telecommunications, University of New South Wales, NSW 2038, Australia*

Power quality is one of the major requirements in power system operation and design. A power factor that is close to one is a good indicator for the overall power quality, especially for an electrical power system with high uptake of commercial loads with a large amount of inductance. A poor power factor normally leads to a less efficient electrical system, and may also be less economically efficient for system operators and end consumers. Therefore, power factor improvement plays a crucial role in the efficient system operation and electricity consumption costs reductions. This paper provides a detailed implementation of the technical and economic value of power factor improvement, and it is verified through an analysis of a real-world electrical system and loads. The efficiency of the method to determine the optimum location and size of capacitor installations to achieve desired goals is demonstrated.

VI. D.Reddy, K.Pavankumar Goud, Pradeepkumar Reddy," Analysis Of Different Topologies For Active Power Factor Correction," IJATER, vol.4, Jan.2014.

Capacitive Power Factor correction is applied to circuits which include induction motors as a means of reducing the inductive component of the current and thereby reduce the losses in the supply. There should be no effect on the operation of the motor itself. An induction motor draws current from the supply that is made up of resistive components and inductive components.

The resistive components are: i. Load current
ii. Loss current

The inductive components are: i. Leakage reactance
ii. Magnetizing current

1.4 Aim and Objectives

1) To analyze real time problems related to power factor in industry and provide suitable solutions.
2) To integrate hardware, software and real time applications into a generalized device to improve power factor.
3) To develop a device that will improve power factor as well as consume less power and provide less disturbances in system.

1.5 Problem Statement

An electrical load that operates on alternating current requires apparent power, which consists of real power plus reactive power. Real power is the power actually consumed by the load. Reactive power is repeatedly demanded by the load and returned to the power source, and it is the cyclical effect that occurs when alternating current passes through a load that contains a reactive component. The presence of reactive power causes the real power to be less than the apparent power, and so, the electric load has a power factor of less than 1. The reactive power increases the current flowing between the power source and the load, which increases the power losses through transmission and distribution lines. This results in operational and financial losses for power companies.

Therefore, power companies require their customers, especially those with large loads, to maintain their power factors above a specified amount (usually 0.90 or higher) or be subject to additional charges. Electrical engineers involved with the generation, transmission, distribution and consumption of electrical power have an interest in the power factor of loads because power factors affect efficiencies and costs for both the electrical power industry and the consumers. In addition to the increased operating costs, reactive power can require the use of wiring, switches, circuit breakers, transformers and transmission lines with higher current capacities. Power factor correction attempts to adjust the power factor of an AC load or an AC power transmission system to unity (1.00) through various methods. Simple methods include switching in or out banks of capacitors or inductors which act to cancel the inductive or capacitive effects of the load, respectively. Non-linear loads create harmonic currents in addition to the original AC current. The simple correction techniques described above do not cancel out the reactive power at harmonic frequencies, so more sophisticated techniques must be used to correct for non-linear loads.

2. PROJECT DESCRIPTION

2.1 Methodology

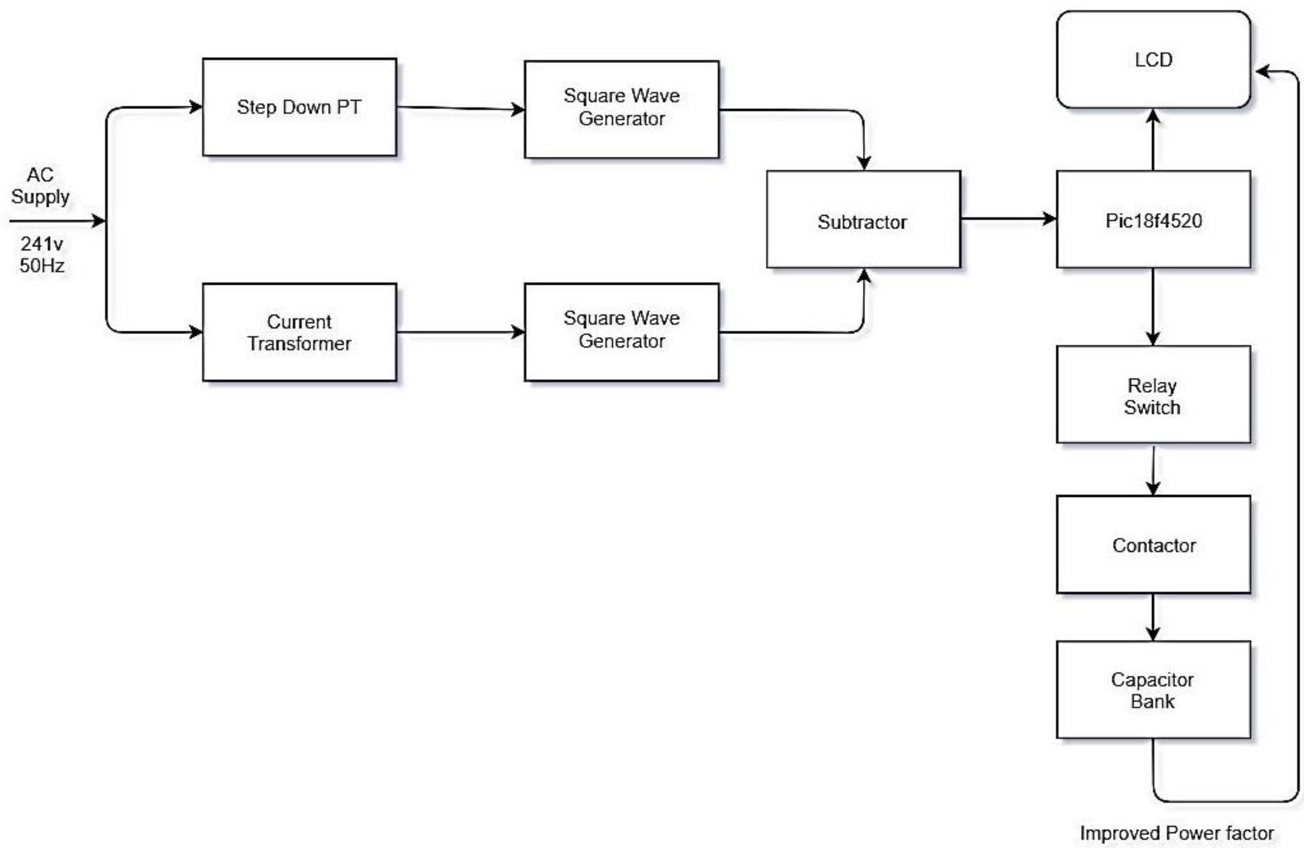

Fig. No. 1: Block Diagram of Power Factor improvement device

Above Fig. shows the flow of steps to be followed. They are briefly described as below.

1. The input for PT is taken from one phase and neutral and for CT, it is taken from one of the remaining phases.
2. Actual current wave is stepped down by CT and voltage wave is stepped down by PT.
3. The sinusoidal waves are converted to square waves using Operational Amplifiers.
4. Current waves and voltage waves are subtracted and then fed to microcontroller.

5. The Microcontroller will calculate the original power factor and then how much kVAR is to be added is found out.
6. Then appropriate capacitor banks are switched ON using contactors and switches.
7. The capacitors are turned OFF or turned ON as per the real time requirement of reactive kVAR power.
8. The display will show improved power factor and voltages and currents by taking input from microcontroller.

2.2 Circuit Diagram

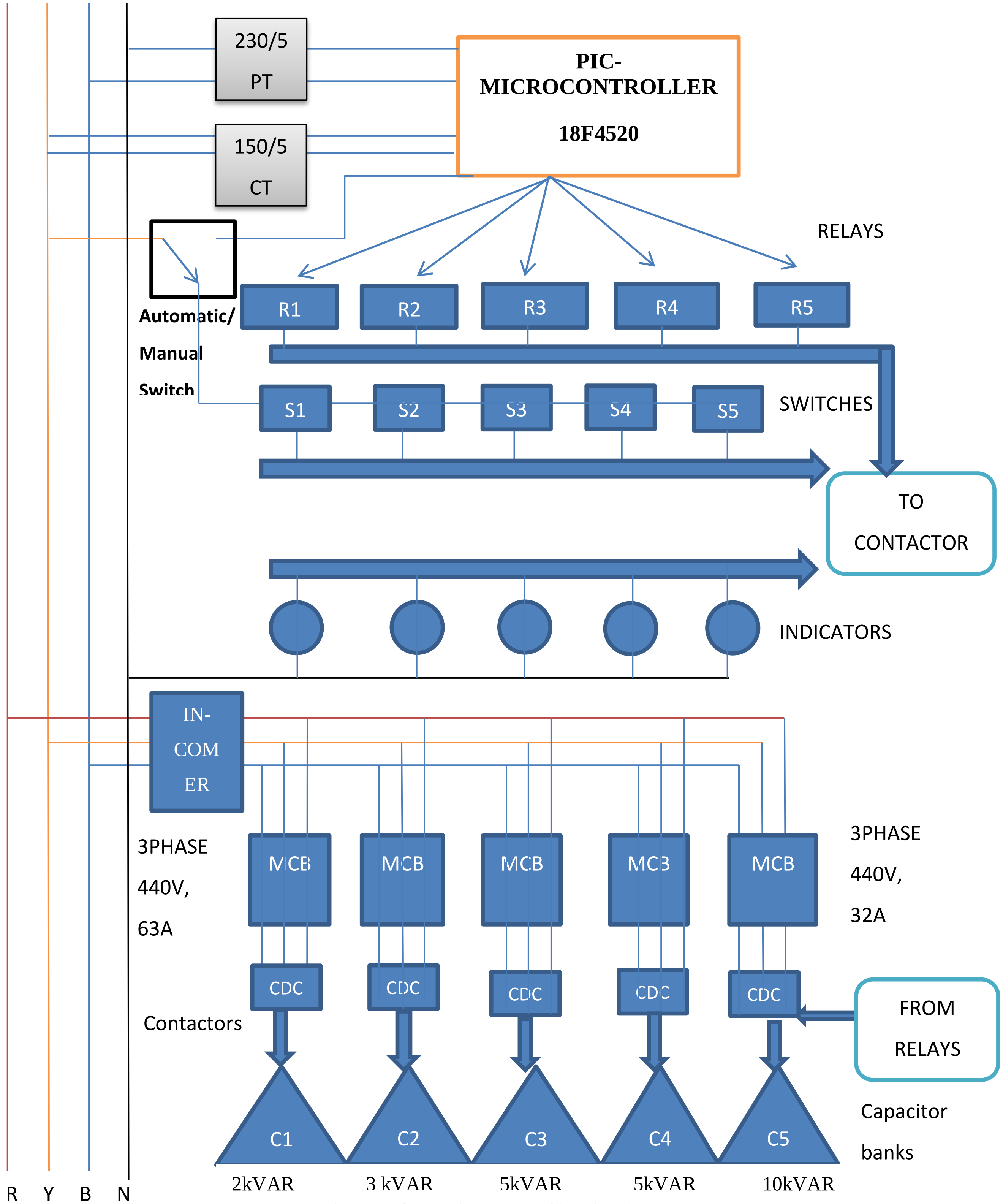

Fig. No. 3 : Main Power Circuit Diagram

2.2.1 Working of power circuit

For measurement of current and voltage, CT and PT are used in load circuit bus bar. CT of ratio 150/5 is used and PT of 230/6 is used. The voltage across CT is taken through burden resistance and given to microcontroller to measure and to find power factor; same follows for voltage measurement. After measurement and computation, appropriate relays are switched through microcontroller. These relays will operate contactors accordingly and hence capacitors are switched. When manual operation is selected, supply from one phase is given to the all switches. When Personnel makes operation of switch to ON then respective capacitor bank will be turned ON through contactor and capacitor bank gets connected to the system.

Indicators are used for indicating which capacitor banks are open at a time. MCBs are added in the circuit to prevent capacitors and contactors from high inrush currents. The incomer MCB is also added to provide overall protection for device. The Single Pole Double Throw switch is used for whether to operated device manually or automatically.

2.2.2 Microcontroller Connections

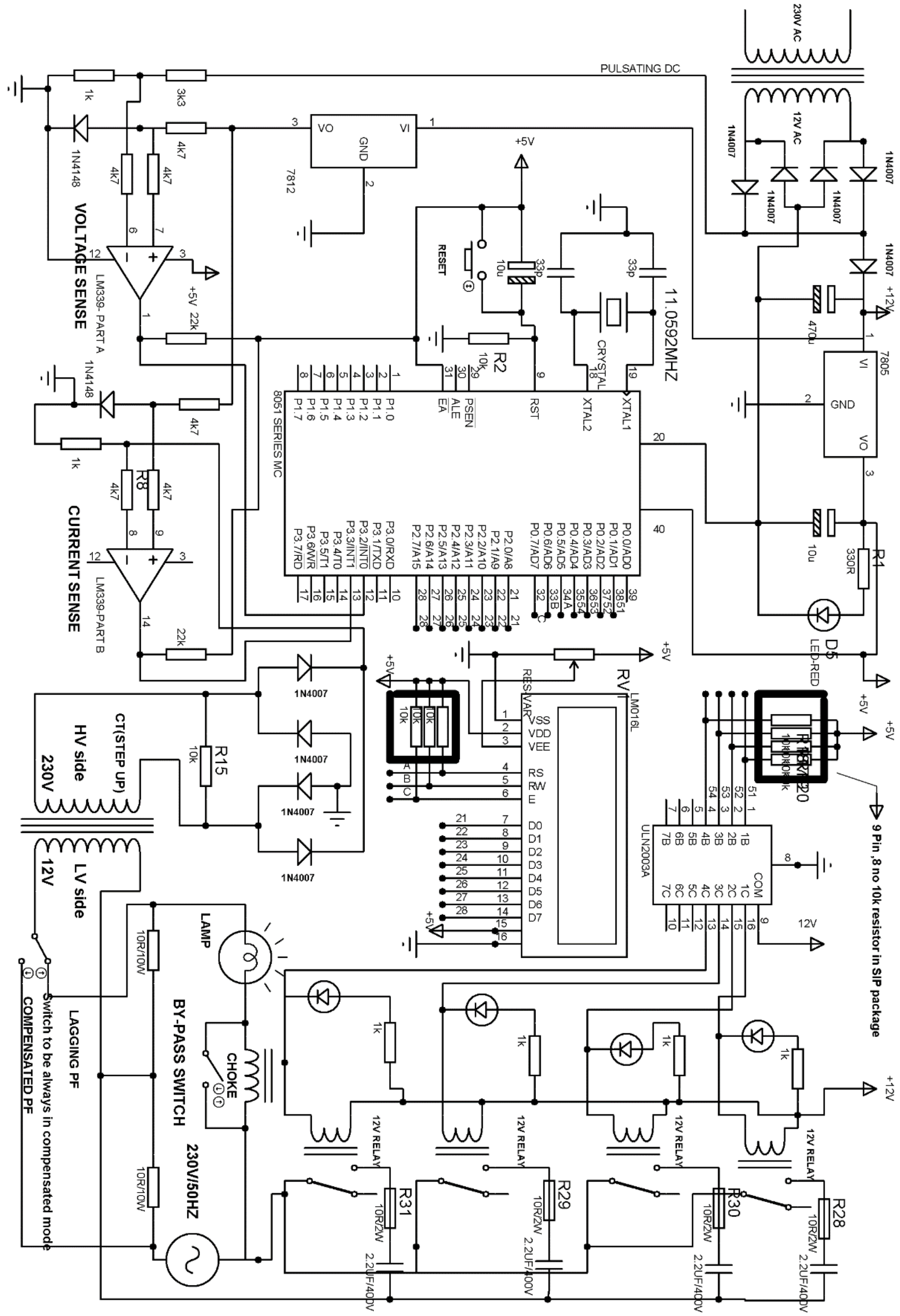

Fig. No. 3 : Main Control Circuit Diagram

2.2.3 Working of Control Circuit

Control scheme is used for measurement of current and voltage and finding power factor of system. Current and voltage waves are stepped down using current & voltage transformer. For power factor measurement, first both waves are taken to op-amp where waves are converted to square waves. By using comparator both waves are compared and phase difference is found as function of time difference. Time difference is then converted to phase angle. The most appropriate combination of capacitor banks are then decided to turn ON. The readings of current, voltage, power factor and reactive power consumed by load are shown on LCD display.

By reactive power measurement, appropriate bank of capacitor is selected to connect to the system. This selected bank is turned on through microcontroller output by turning ON relays and hence contactor**.** An improved power factor is then shown again on LCD display.

2.3 Components

2.3.1 Potential Transformer

A potential transformer, a voltage transformer or a laminated core transformer is the most common type of transformer widely used in electrical power transmission and appliances to convert mains voltage to low voltage in order to power low power electronic devices. They are available in power ratings ranging from mW to MW. The Insulated laminations minimize eddy current losses in the iron core.

A potential transformer is typically described by its voltage ratio from primary to secondary. The potential transformer here has a voltage ratio of 230/6 i.e., when the input voltage is the single phase voltage 230V, the output is 6V.

The potential transformer here is being used for voltage sensing in the line. They are designed to present negligible load to the supply being measured and have an accurate voltage ratio and phase relationship to enable accurate secondary connected metering. The potential transformer is used to supply a voltage of about 6V to the Zero Crossing Detectors for zero crossing detection. The outputs of the potential transformer are taken from one of the peripheral terminals and the central terminal as only a voltage of about 6V is sufficient for the operation of Zero crossing detector circuit.

Fig. No. 4: Potential Transformer

2.3.2 Current Transformer

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 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. Current transformers of ratio 150/5 are used for stepping down the current.

Fig. No. 5: Current transformer

2.3.3 Capacitor Bank

Role of capacitor

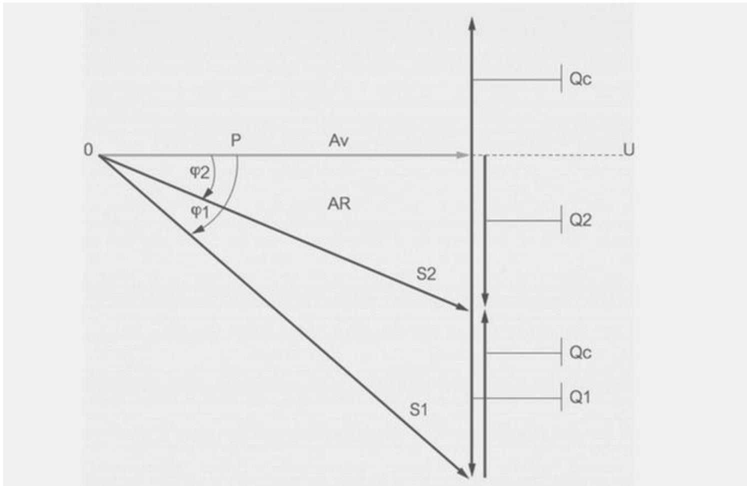

Fig. No. 6: Phasor diagram for Capacitor added power circuit

- **P** – Active power
- **S_1 and S_2** –Apparent powers (before and after compensation)
- **Q_c** – Capacitor reactive power
- **Q_1** – Reactive power without capacitor
- **Q_2 –** Reactive power with capacitor

Here as shown in above phasor diagram, capacitor adds reactive power and new reactive power is Q_2. The phase difference angle hence is decreased and it results in increase in power factor. Fig. 6 shows increase in power factor due to addition of Capacitor in circuit.

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 5 capacitors, all rated at 400V, 50 Hz i.e., the supply voltage and frequency. 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. The value of capacitors is different and it consists of five capacitors reactive power capacities as a 2kVAR, a 3kVAR, two of 5kVAR and a 10kVAR. Capacitors are 10.97 microfarads, 16.45 microfarads, two of 27.42 microfarads, 54.83 microfarad.

Fig. No. 7: Capacitor Bank

2.3.4 RELAY

The relays used in the control circuit are high-quality Single Pole-Double Throw (SPDT), sealed 5V Sugar Cube Relays. These relays operate by virtue of an electromagnetic field generated in a solenoid as current is made to flow in its winding. The control circuit of the relay is usually low power, a 5V supply here and the controlled circuit is a power circuit with voltage around 230V ac. The relays are individually driven by the relay driver through a 5V power supply. Initially the relay contacts are in the Normally Open 'state. When a relay operates, the electromagnetic field forces the solenoid to move up and thus the contacts of the external power circuit are made. As the contact is made, the associated capacitor is connected in parallel with the load and across the line. The relay coil is rated up to 8V, with a minimum switching voltage of 4.5V. The contacts of the relay are rated up to 7A - 270C AC and 7A - 24V DC.

Fig. No. 8: RELAY

2.3.5 Zero crossing detector and Amplifiers

A zero crossing is a point where the sign of a mathematical function changes (e.g. from positive to negative), represented by the crossing of the axis (zero value) in the graph of the function. It is a commonly used term in electronics, mathematics, sound and image processing. In alternating current, the zero-crossing is the instantaneous point at which there is no voltage present. Ina a sine wave this condition normally occurs twice in a cycle.

A zero crossing detector is an important application of op-amp comparator circuit. It can also be referred to as a sine to square wave converter. Anyone of the inverting or the non-inverting comparators can be used as a zero crossing detector. The reference voltage in this case is set to zero. The output voltage waveform shows when and in what direction an input signal crosses zero volts. If input voltage is a low frequency signal, then output voltage will be less quick to switch from one saturation point to another. If there is noise in between the two input nodes, the output may fluctuate between positive and negative saturation voltage. Here IC UA741 is used as a square wave generator which gets input from zero crossing detector.

Fig. No. 9: Operational Amplifier IC 741

2.3.6 Liquid Crystal Display (LCD)

LCD panel consist of two patterned glass panels in which crystal is filled under vacuum. The thickness of glass varies according to end use. Most of the LCD modules have glass thickness in the range of 0.70 to 1.1mm.

Normally these liquid crystal molecules are placed between glass plates to form a spiral stair case to twist the light. These LCD cannot display any information directly. These act as an interface between electronics and electronics circuit to give a visual output. The values are displayed in the 16 × 2 LCD modules after converting suitably. The liquid crystal display (LCD), as the name suggests is a technology based on the use of liquid crystal. It is a transparent material but after applying voltage it becomes opaque. This property is the fundamental operating principle of LCDs.

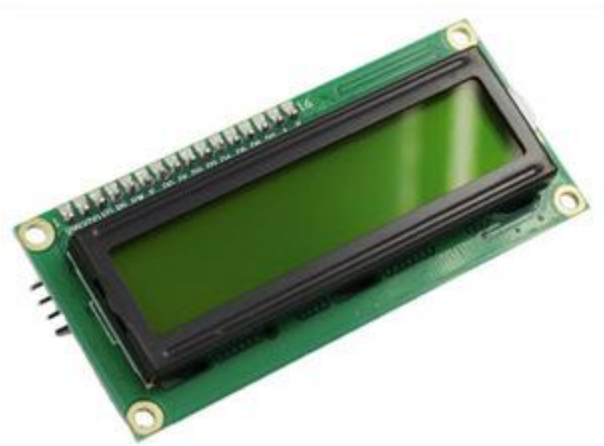

Fig. No. 10: LCD 16 × 2 Display

2.3.7 Capacitor Duty Contactor

Capacitor duty contactors are two-stage contactors designed to prevent high inrush currents. It transmits inrush currents over damping resistors and enables excess currents to stay within acceptable limits. Its auxiliary coil senses signal from relay or switches and accordingly adds capacitor bank to the circuit.

Fig. No. 11: Capacitor Duty Contactor

2.3.8 Microcontroller Specifications

Microcontroller	PIC Microcontroller 18F4520
Operating Voltage	5
Input Voltage (recommended	7-12
Permeable Voltage limits	6-20
I/O pins	36
DC Current per I/O Pin DC	40 mA
Current for 3.3V Pin	50 mA
Flash Memory	32 KB
EEPROM	256
SRAM	1536
Clock speed	40MHz

Fig. No. 12: Microcontroller

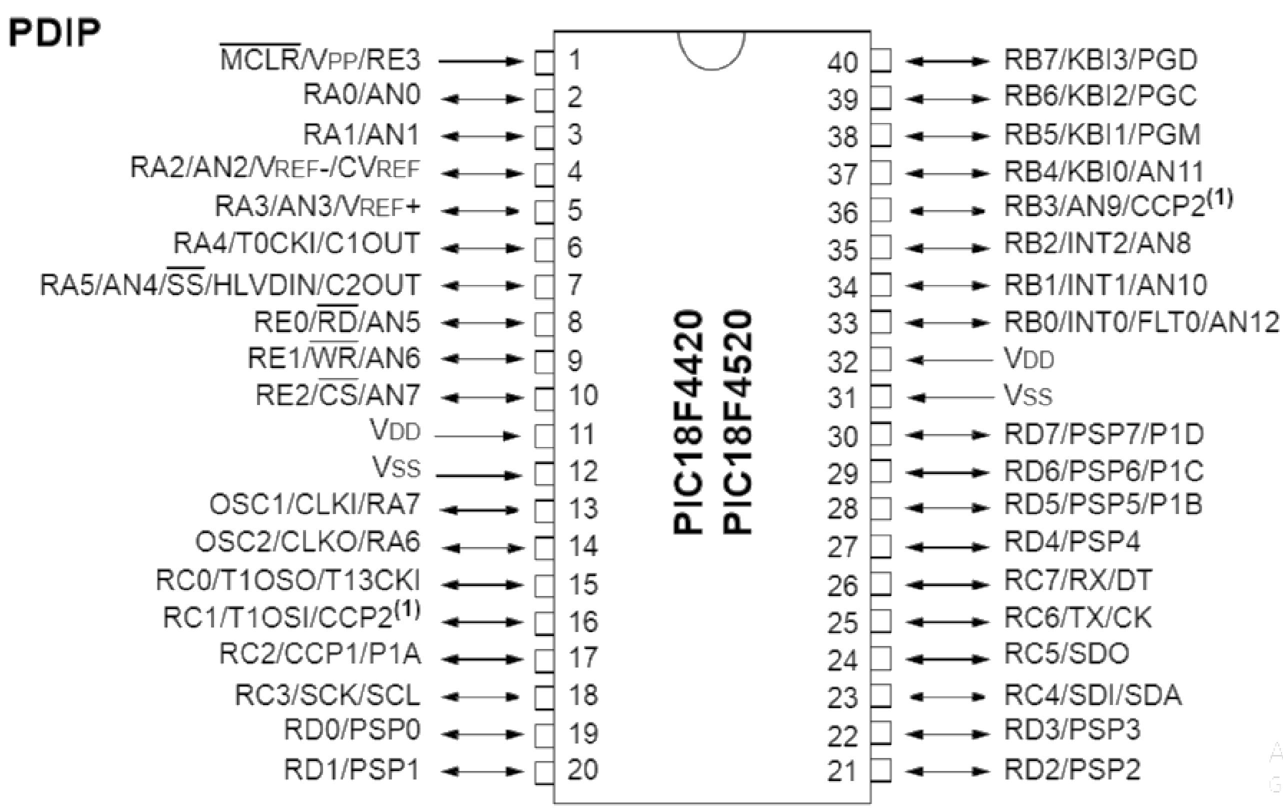

Fig. No. 13: Pin Diagram of Microcontroller

2.3.9 Miniature Circuit Breakers (MCB)

MCB stands for Miniature Circuit Breaker in electrical terminology. It is used to protect equipment and cables against overload currents and short circuits. They are normally resettable, close protection and capable of handling multiple operations without failure. When the circuit current exceeds the current printed on the electrical fuse, MCB protects the load by allowing it's contacts to open easily. When MCB is switched off it isolates the load from the main supply.

MCB are used to protect the contactors and capacitors from inrush overcurrent. These are also used for switching off the device for maintenance purpose. MCB used in this circuit is 3pole, 63A.

Fig. No. 14: 3 Pole MCB

2.4 Switching of capacitors:

Switching Capacitors is essential for Selection of capacitor bank. To decide which bank to be made ON, Microcontroller must give proper instructions to CDC. There are mainly two types of switching. 1. Manual 2. Automatic.

2.4.1 Manual switching

Manual switching of capacitors is selected by SPDT switch which consisted of two throws. 1^{st} is manual switching and other is automatic switching. Then switches are to be operated manually whenever individual capacitors need to be added in the circuit. After that each capacitors can be added individually by switching on its switch. While the SPDT switch is in manual operation, capacitors will not be operated automatically through the microcontrollers.

2.4.2 Automatic Switching

For automatic switching, SPDT switch is to be kept on automatic mode. Once the circuit is connected to the loads, the microcontrollers will get input from CTs and PTs and using the logical calculations specified in microcontroller, it will energize the particular CDC through relays which will ultimately connect the required number of capacitors to be added in circuit.

2.4.3 Determination of Value of Capacitor:

Let P = total active power,

And Original PF = Cos X

And Final PF = Cos Y

Then, Required kVAR = P (Tan X – Tan Y)

Now we know that,

$kVAR = V * I_c / 1000$

Then $I_c = V/ X_c$ & $X_c = 1 \div (2 \times \pi \times f \times C)$

As we have Capacity of Capacitor in kVAR, we can find out value in Farads

2.4.4 Logic of microcontroller

Current and voltages will be stepped down using Current transformer and Voltage transformer. These signals are then passed through zero crossing detectors. Here zero crossings of alternating waves of voltages and currents are noted. The time difference between current and voltages is then calculated by using Op amp as comparator. And using time to degree conversion, this phase difference is converted into degrees. After that original Power Factor is calculated and then kVAR to be added is determined using formula given for selection of capacitors. After calculation particular pin is made high which will make the relay contact to go on normally open and relay will give signal to the contactors coil. Then Capacitors are automatically switched and hence power factor is improved.

The table for Automatic switching is shown below :

Sr. No.	Reactive Power measured	Capacitors to be turned on in VAR
1	2000 to 3000	2000
2	3000 to 5000	3000
3	5000 to 7000	5000
4	7000 to 8000	3000 + 2000
5	8000 to 10000	5000 + 3000
6	10000 to 12000	10000
7	12000 to 13000	10000 + 2000
8	13000 to 15000	10000 + 3000
9	15000 to 17000	10000 + 5000
10	17000 to 18000	10000 + 5000 + 2000
11	18000 to 20000	10000 + 5000 + 3000
12	20000 to 22000	10000 + 5000 + 5000
13	22000 to 23000	10000 + 5000 + 5000 + 2000
14	23000 to 25000	10000 + 5000 + 5000 + 3000
15	25000 and more	10000 + 5000 + 5000 + 2000 + 3000

Table No. 1: Table for Automatic Switching

3. HARDWARE IMPLEMENTATION

The development of dynamic power factor improvement device has two main hardware sections.

i. Power Scheme
ii. Control Scheme

3.1 Power Scheme

Power circuit mainly consists of Capacitors, Contactors, MCBs, CT-PT and switches. First supply is taken from grid to CT and PT. From output of CT via burden resistance voltage is taken and given to microcontroller for power factor measurement and for current measurement through ADC pin also from PT voltage is directly given to microcontroller for measurement and power factor calculation. The same single phase supply taken through main incomer is given to Automatic/Manual Switch and after manual it is given to switches. From switches supply directly go to Contactors. The contactors get energized and hence particular delta connected capacitor bank is turned on. ON state of capacitor bank can be observed through indicator.

3.2 Control Scheme

It includes PIC Microcontroller 18F4520, Op Amps for square wave generation and substraction, ZCDs and power relay. Current and Voltage waveforms are taken from CT and PT respectively at lower ranges. Then using OP-Amps these waves are converted into square waves. ZCDs are used to find zero crossings of waves and hence by finding out time lag between two waves using Op amp as comparator signal given to microcontroller where it calculates power factor and then using values of current, voltage and power factor it decides which capacitor bank should be switched and accordingly those relays will get turned ON and hence connected contactor coils get energized which switches contacts.

3.3 Cost for Hardware of Project

Sr. No.	Component	Quantity	Rate	Amount
1	Capacitor 10 kVAR, 440V, 3Phase, delta	1	1800	1800
2	Capacitor 5 kVAR, 440V, 3Phase, delta	2	860	1720
3	Capacitor 3 kVAR, 440V, 3Phase, delta	1	576	576
4	Capacitor 2 kVAR, 440V, 3Phase, delta	1	385	385
5	Power Contactors, 22A, 3 phase	1	936	936
6	Power Contactors, 9A, 3 phase	2	600	1200
7	Power Contactors, 18A, 3 phase	2	870	1740
8	MCB, 3 phase, 63A	1	1100	1100
9	MCB, 3 phase, 6 A	2	660	1320
10	MCB, 3 phase, 10A	2	783	1565
11	MCB, single phase, 6A	2	140	280
12	SPDT	6	215	1290
13	Wires 2.5 sq. mm	10 meter	40	400
14	Lighting Lamps	5	60	300
15	Microcontroller 18F4520	1	400	400
16	Relays	5	40	200
17	CT	1	512	512
18	PT	1	80	80
19	Op Amps	3	15	45
20	Contacts	6	10	60
21	LCD	1	200	200
22	Regulators	2	15	30
23	PCB	1	500	500
24	IC Base	4	10	40
25	Jumper Wires	50	1	50
26	Resistors, Diodes, Capacitors	-	100	100
27	GST			7,617
28	Casing & Powder Coating			11,041
	Grand Total			36,017

Table No. 2: Cost of project

Figure No. 15: Hardware

4. RESULTS AND DISCUSSION

4.1 Theoretical results:

Voltage	Current	Original Power Factor	Improved Power Factors
440	40	0.982	0.995 (2kVAR)
440	45	0.969	0.991 (3kVAR)

Table No. 3: Expected Results

4.2 Actual hardware results:

Voltage	Current	Previous Power Factor	Improved Power Factors
432.5	42.3	0.982	0.992 (2kVAR)
426.3	32.4	0.969	0.989 (3kVAR)

Table No. 4: Actual Hardware

4.3 Discussion

The automotive power factor correction using capacitive load banks is very efficient as it reduces the cost by decreasing the power drawn from the supply. As it operates automatically, manpower is not required and this Automated Power Factor Correction using capacitive load banks can be used for the industries purpose. The stepped capacitor banks let us use the reactive power as per requirements and hence dynamic reactive power transfer is observed. This will also lead to avoid penalty from distribution side to the industrial loads due to low power factor.

4.3.1 Adverse effect of leading power factor

1. Power system becomes unstable –
   Power factor goes to leading due to over correction or capacitive load. This will increase the rated voltage. Hence voltage regulation will occur which will disturb system reliability. This may also lead to reverse power flow if receiving end voltage is greater than sending end voltage.

2. Resonant frequency is below the line frequency –

   Adding the capacitors to the grid will make resonant circuit with line inductances. This will make resonant frequency below system frequency and hence frequency variations for oscillations are observed.

3. Current and voltage increases –

   Reactive power supplied to the load is more hence charging current and voltage supplied by project increases. This may cause overheating of load applications.

4.3.2 Advantages of improved power factor

1. Reactive power decreases –

   Reactive power is supplied by the capacitor hence total reactive power drawn from the utility will decrease.

2. Avoid poor voltage regulation-

   Voltage will be increased when system is suddenly loaded with inductive load and hence rated voltage is obtained at load terminals. This will result in less voltage regulation.

3. Copper loss decreases –

   Current drawn by load is less because of less reactive power requirement. Hence I^2R = copper losses by the system will be decreased for large loads.

4. Transmission loss decreases

   kVAR capacity of line will be decreased and hence less losses will occur over transmission line as power is decreased.

5. Efficiency of supply system and apparatus increases –

   Power Factor is proportional to efficiency and improved power factor will deliver rated voltage and current to the load. Hence system and load will work efficiently.

5. CONCLUSION

The automatic power factor detection and correction provides an efficient technique to improve the power factor of a power system by an economical way. Static capacitors are invariably used for power factor improvement in factories or distribution line. However, this system makes use of capacitors only when power factor is low otherwise they are cut off from line. Thus, it not only improves the power factor but also increases the life time of static capacitors.

It can be concluded that power factor correction techniques can be applied to the industries, power systems and also households to make them stable and due to that the system becomes stable and efficiency of the system as well as the apparatus increases. The use of microcontroller reduces the costs. Due to use of microcontroller multiple parameters can be controlled and the use of extra hard wares such as timer, RAM, ROM and input output ports reduces. Also dynamic switching is available using microcontroller which lets improve power factor in real time without going under certain limit.

6. FUTURE SCOPE

Capacitors can only be used to improve lagging power factor to make it leading but not vice-versa. Also possibility of resonance can be introduced for inductive load. Variation in power factor will not be much smoothened as steps of banks are used. So, there is scope for device to be improved.

- Series – Parallel Operation of capacitors :

  The capacitors connected now are in the parallel branches. If they are connected in series – parallel combination, multiple steps of switching can be done and hence power factor improvement can be done more smoothly.

- Addition of inductances to prevent leading PF :

  If power factor goes beyond unity and becomes leading, then inductance must be added in parallel with the load to lower down the power factor. The switching of inductor is also to be considered in that case.

- Capacitorless Power Factor :

  In this, capacitors are not directly connected to the circuit. The supply is 1^{st} converted to DC using rectifier circuits and then it is stored in DC batteries. The inductors are used for boosting the voltage. This boosted voltage is fed to inverters. Inverter is used to convert DC into AC supply. This supply is again fed to load. Pulse Width Modulation techniques are used for controlling voltage waveform. Switching of thyristors are essential to maintain the voltage level. Harmonics are observed in current waves and are removed using active L-C filters. Flexible AC Transmission System (FACTS) is applied to manage a number of varied situations of the power line. The Unified Power Flow Controller (UPFC) as one of the FACTS is used in order to keep conditions of the power line. The UPFC consists of two components. One is connected in parallel to the power line, and the other is connected in series. By the parallel system, the reactive power and 3 -phase unbalance can be compensated to improve the power factor and to keep the common DC inductor voltage constant. By the series component, the voltage drop can be compensated to maintain proper line voltage. In these operations, quick response is required in order to respond variable situations. Deadbeat control is used for advantage of quick response and easy setting. It uses state space model of system to calculate reference voltage vector, in order to set the controlled variable error. Reference voltage vector is realized by modulator. This method is being used when fast dynamic response is required.

The high-brightness white light-emitting diode (LED) has attracted a lot of attention for its high efficacy, simple to drive, environmentally friendly, long lifespan, and compact size. The power supply for LED also requires long life, while maintaining high efficiency, high power factor, and low cost. However, typical power supply design employs an electrolytic capacitor as the storage capacitor, which is not only bulky, but also with a short lifespan, thus hampering performance improvement of the entire. LED lighting system. A power factor correction (PFC) topology is proposed by inserting the valley-fill circuit in the single-ended primary inductance converter (SEPIC)-derived converter, which can reduce the voltage stress of the storage capacitor and output diode under the same power factor condition. This valley-fill SEPIC-derived topology is then proposed for LED lighting applications. By allowing a relatively large voltage ripple in the PFC design and operating in the discontinuous conduction mode (DCM), the proposed PFC topology is able to eliminate the electrolytic capacitor, while maintaining high power factor and high efficiency. Under the electrolytic capacitor-less condition, the proposed PFC circuit can reduce the capacitance of the storage capacitor to half for the same power factor and output voltage ripple as comparing to its original circuit. To further increase the efficiency of LED driver proposal, a twin-bus buck converter is introduced and employed as the second-stage current regulator with the PWM dimming function.

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