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*RESEARCH ARTICLE*

# AUTOMATIC POWER FACTOR CORRECTION AND MONITORING BY USING PIC MICROCONTROLLER.

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## *Abstract*

In recent years, the power quality of the ac system has become great concern due to the rapidly increased numbers of electronic equipment, power electronics and high voltage power system. Most of the commercial and industrial installation in the country has large electrical loads which are severally inductive in nature causing lagging power factor which gives heavy penalties to consumer by electricity board. This situation is taken care by PFC. 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. In order to improve transmission efficiency, power factor correction research has become a hot topic. Many control methods for the Power Factor Correction (PFC) have been proposed. Power factor correction is the capacity of absorbing the reactive power produced by a load. In case of fixed loads, this can be done manually by switching of capacitors, however in case of rapidly varying and scattered loads it becomes difficult to maintain a high power factor by manually switching on/off the capacitors in proportion to variation of load within an installation. This drawback is overcome by using an automatic power factor correction (APFC) panel and measuring of power factor from load is done by using PIC microcontroller and trigger required capacitors in order to compensate reactive power and bring power factor near to unity.



## Introduction:-

In the present technological revolution power is very precious. So we need to find out the causes of power loss and improve the power system. In some cases the amount of reactive power consumed might even exceed the amount of active power it generates. This undesirable characteristic places an undue burden on the power network [1]. Due to industrialization the use of inductive load increases and hence power system losses its efficiency. So we need to improve the power factor with a suitable method [2] .The Automatic Power factor Correction (APFC) device is a

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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 (APFC) device reads power factor from line voltage and line current by determining the delay in the arrival of the current signal with respect to voltage signal. This time values are then calibrated as phase angle and corresponding power factor. Then the values are displayed in the LCD module. Then the motherboard calculates the compensation requirement and accordingly switches on different capacitor banks. This is developed by using PIC microcontroller. These values of voltage, current, power factor send to PC by using serial interface cable (RS232). PC saves the record of the power factor values, voltage and current values. Automatic 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.

**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. A poor power factor can be the result of a significant phase difference between the voltage and current at the load terminals. Poor load current, phase angle is generally the result of an inductive load such as an induction motor, power transformer, lighting ballasts, and welder or induction furnace. [3]

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.

P = True power $P = I^2R$ $P = E^2/R$
Unit = Watts.

Q = Reactive power $Q = I^2X$ $Q = E^2/X$
Unit = Volts- Amps- Reactive (VAR)

S = Apparent power $S = I^2Z$ $S = IE$
Unit Volt –Amps (VA)

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.

**System Description:-**

**Step 1:-**

Alternating voltage of 230 volts is applied to the input of a step down voltage transformer. The output of step down transformer is connected to the diode which acts as a rectifier and clips negative part of the sinusoidal waveform as microcontroller cannot detect negative cycle of the waveform. Microcontroller cannot operate upon voltages which are greater than 5 volts.
The proposed work uses current transformer and potential transformer.

**Current transformer:-**

A transformer transfers electrical energy from one circuit to another by the transformer's coils. A varying current is produced in primary winding. It creates a varying magnetic flux in the secondary winding. This varying magnetic field induces a varying emf or voltage in the secondary winding. The varying emf is called mutual induction.
Input signal is connected to the step down current transformer .A step down current transformer is used to convert high current in to low current for the use of different electrical circuits. The amount of current which is step down

depends on the number of turns in primary coil and number of turns in secondary coil and also on the step down ratio.

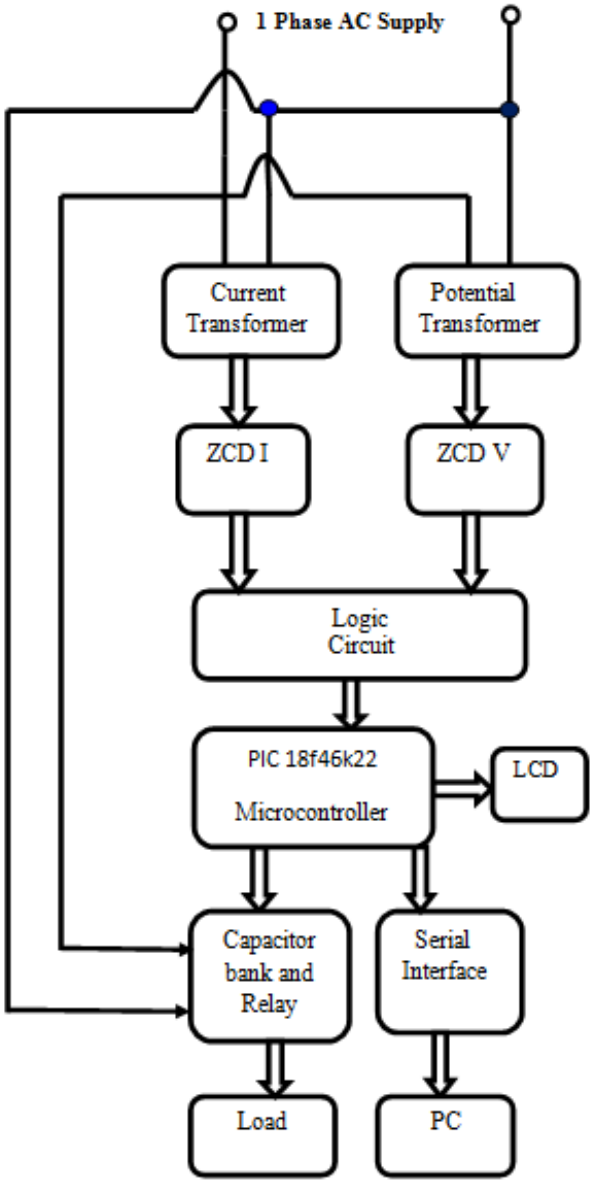


**Fig.1:-** Automatic power factor correction and monitoring by using PIC Microcontroller

**Potential transformer:-**

It is used to step down or step up the ac voltage levels. Here we use the potential transformer to measure the voltage level of the ac line. These type potential and current transformers are working with the concept of mutual inductance.

The current and voltage signal are acquired from the main AC line by using Current Transformer and Potential Transformer. These acquired signals are then pass on the zero crossing detectors [4], [5].

**Step 2:-**

**Zero crossing detectors: -** Zero crossing detection is used to detect sine wave zero crossing from positive half cycle to negative half cycle or negative half cycle to positive half cycle. Zero crossing of two waves must be detected to measure the phase difference between two waves. Zero crossing detector circuit basically converts the sinusoid

wave to square wave. The outputs from step down current (C. T.) and voltage transformers (P.T.) are fed in to zero crossing detector circuit which convert the sinusoid waveform in to square waveform. These digital square waves are used by microcontroller to calculate phase difference and thus power factor [6]. Op-amp is used as a comparator for the purpose of zero crossing detector circuit. Two analogue voltage levels are compared with one another using Op-amp circuit and output depends upon the comparison of these voltage levels. The voltage which is higher in magnitude appears at the output.

In zero crossing detector circuit one input (inverting) of Op-amp is set at zero reference and second input (non-inverting) is fed with sinusoidal wave to be converted in to square wave. Whenever the sinusoidal signal has value greater than zero reference, the output of Op-amp has positive value. As soon as the sinusoidal signal falls below zero reference, the output of op-amp falls to zero. In this way zero crossing detector circuit converts a sinusoidal signal to a square waveform.

The LM358 operational amplifier is equivalent to half of the LM324. Such amplifiers are preferable over usual operational amplifiers for several applications. Such type of amplifiers can operate upon low voltages such as only 3.0 volts and also high voltages up to 32 volts. The input which is common mode includes negative power supply; therefore it eliminates the necessity of external biasing components for many applications. Output voltage includes negative part of the supply voltage.

In proposed circuit LM358 is used as zero crossing detectors. When AC signal is applied to LM358, the output of LM358 is high that is '1' when sinusoid signal is positive and in case of negative value of sinusoid waveform the output of the LM358 is low that is '0'. Finally the zero crossing detector circuits convert both the voltage and current sinusoid waveforms in to square signal or PWM.

**Step 3:- Logic circuit**
**Precision rectifier:-**
The precision rectifier is called as super diode; this is obtained with an operational amplifier in order to have a circuit behave like an ideal diode and rectifier. It uses Op-Amp and diode in the feedback loop, this effectively cancels the forward voltage drop of the diode, so very low level signals can still be rectified.

Input to the precision rectifier is the line from current transformer and potential transformer. Output of the precision rectifier is fed to analog to digital converter (ADC) pin of microcontroller. ADC process on the output then gives the value of voltage and current and these values display on LCD.

**Step 4:-PIC Microcontroller**
The output from the zero crossing detectors are now fed to the pins of PIC of microcontroller separately which uses its internal timers to measure the time duration of signals in which their value is high or '1'.Timer is a register which counts from 0 to 255 and then start from 0 again. 0, 1, 2, 3, 4…255….0, 1, 2, 3……etc. Timers are available in all PIC microcontrollers and when timer overflows it generates interrupt. Timer can use external clock or external clock to calculate time and it depends upon programmer how to use it.

The time difference between two waves can be easily measured using external interrupts. Whenever interrupt is received on the pin of microcontroller, timer starts and as soon as another external interrupt is received time stops counting. One interrupt is generated with the help of current signal and other interrupt will be generated with the help voltage signal zero crossing. Timer value will be stored for further use. This variable value is basically a time difference between two waves. For good results take 20-30 values and then calculate their average.

In proposed work software program works in a similar manner such that as soon as the output of one zero crossing detectors become high the timer starts incrementing from 0 to 255 and then starts from 0 again. Timer continues to measure time period until the output of second zero crossing detector becomes high. By using simple and basic calculations of timer and it's prescalar, the time difference at which the outputs of zero crossing detectors become high can be calculated easily.

**Step 5:- Calculation of power factor (program)**
Microcontroller then uses its abilities and program to calculate the phase angle and phase difference between two waveforms. Time difference between two waveforms can yield phase difference easily using following formula. Time difference = average values of timer /1000

In above equation 1000 is used to convert time into seconds because half of the sine wave is about 10us
And there will 1000 counts per second.

$$\theta = \text{time difference} * 2\pi$$
$$\text{Power factor} = \cos(\theta)$$

2 π is multiplied to time difference value to convert it in to radians as phase angle is to be expressed in radians. Phase difference which is expressed as an angle is known as phase angle. Now using information power factor can be calculated easily. These calculations are done by writing software program in microcontroller.

**Step 6:- Relay driver**
The pins of microcontroller are connected to the relay IC and then to relays. When a low voltage circuit is used to derive a load which is connected to high voltage an IC is used which is known as Relay driver
**Step 8:-**
If the power factor is less than a prescribed value then microcontroller generate command to turn on the relay. Turning on relay will add capacitor in to the circuit which will help to improve power factor. Capacitors add reactive load in the circuit which will help to increase power factor. Number of capacitors which are to be added depends upon the power factor of the circuit. As soon as the power factor drops from a specific value, the relay will act to add capacitor to the circuit. If power factor value drops a little to the prescribed value then one capacitor is added. In case of power factor drops much more than prescribed value then second capacitor is also added and the system goes on this way. The circuit will continue to add capacitor in parallel to the load until a good value of power factor is IC. A relay coil requires more current as compared to other devices. Integrated circuits such as Op-amp circuits cannot supply such larger currents to derive relays. Relays are unique in properties and have taken the place of solid state switches and are stronger than solid state devices. Relays have high current capacities. They are capable to stand ESD and can also drive circuit isolation.

Electromagnetic relay is simply consists of a coil which is wrapped around an iron core. An iron core is a source of providing low reluctance path to pass magnetic flux. Relay also includes moveable iron armature and one or more contacts. The armature is connected to the yoke and is mechanically connected to the contacts of the relays. A spring is used to place the contacts in place so that whenever relay is de-energized there is an air gap in magnetic circuits. In this work relays are used to connect and disconnect capacitors in the circuits.

**Step 7:- Liquid Crystal Display (LCD)**
Microcontroller program calculates the phase difference between two sinusoid waves and then power factor using this information and displays on LCD. Liquid Crystal Display screen is very basic module and is used very commonly in various circuits for display purpose. It finds a wide range of applications. LCD display is preferred over LED display and seven segment display. LCD's are easily programmable, economical and can easily display characters, animations and so on.16×2 LCD has 2 lines and each line can display 16 characters. In this LCD 5×7 pixel matrix is used to display each character. LCD has two registers which are named as command and data.

A command is an instruction which is fed to LCD, commands are used to execute some tasks which are predefined already such as initialize LCD, clear its screen, controlling display and brightness and setting cursor position etc. Command register stores such predefined instructions. Data register in LCD stores data which is to be displayed on screen. The data is in the ASCII form of the character which is to be displayed.

To display values on LCD hex values are converted in to decimal and then each decimal value is converted to respective ASCII code and finally sends to LCD display.
This system uses 16×2 LCD. 4 things are displayed on the LCD:

- Power Factor.
- AC Voltage.
- AC Current.

achieved. And power factor can tolerated for only over 0.8 [7]. These values of voltage, current, power factor send to PC by using serial interface cable (RS232). PC saves the record of the power factor values, voltage and current values.

**Coding of automatic power factor Controller:-**

Code for APFC is written using MikroC compiler. Power factor function calculated power factor of load and displays it on LCD.

**Software Specification:-**

A. MikroC Pro for PIC MikroC PRO is an ANSI C compiler for PIC devices from Microchip. The main features are intuitive IDE powerful compiler with advanced optimizations, lots of hardware and software library. Some of the tools that is integrated with this compiler are active comment editor, ASCII chart, EEPROM editor, GLCD bitmap editor, HID terminal, LCD custom character, Mikro boot loader, UDP terminal and USART terminal. Software simulator simulates the code flow in PC and supports all debugging modes s MikroICD.

**Hardware Specification:-**

**PIC18F46K22:-**

The microcontroller is a cheaper solution for computational work in portable devices like this. PIC microcontroller is an advance microcontroller with many advance features low power utilization, high performance, high frequency, multiple special functions and vast memory space

PIC 18F family has RISC architecture with standard on chip features like RAM, ROM, ADC, Timers, Interrupts, I/O ports, EEPROM and USART. The PIC 18F devices have diverse interrupt sources and interrupt priority customization as well. It consist timer interrupts, serial interrupts, external interrupts, peripheral interrupts, watch dog timer interrupt. It has a 10- bit ADC with 13 channels. PIC has multiple oscillator and clock frequency options; The USART allows serial communication to pass on the data to the computer or the wireless systems that work on serial protocol. The microcontroller consists of 4 timers with each having interrupts as well.

**Relay driver IC:-**

ULN2003 IC is a high current and voltage Darlington pair IC, 7 common emitter and open collector Darlington pairs are connected in it. One Darlington pair compromises of two bipolar transistors. This ULN2003 IC is for 5V TTL and CMOS logic devices. This IC is used to drive loads of various loads, line drivers etc. This IC is used to drive motors. The pair of Darlington can drive loads of current 500mA to 600mA. Each driver also has a suppression diode to dissipate voltage spikes while driving inductive loads. There are many ways to drive relays. Some of the Relay Driver ICs are as follows:

- High side toggle switch driver
- Low side toggle switch driver
- Bipolar NPN transistor driver
- N-Channel MOSFET driver and
- Darlington transistor driver
- ULN2003 driver

**Liquid Crystal Display (LCD):-**

Liquid Crystal Display screen is very basic module and is used very commonly in various circuits for display purpose. It finds a wide range of applications. LCD display is preferred over LED display and seven segment display. LCD's are easily programmable, economical and can easily display characters, animations and so on.16×2 LCD has 2 lines and each line can display 16 characters. In this LCD 5×7 pixel matrix is used to display each character. LCD has two registers which are named as command and data. To display values on LCD hex values are converted in to decimal and then each decimal value is converted to respective ASCII code and finally sends to LCD display.

**Future Work:-**

The automatic 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 are not required and this Automated Power factor Correction using capacitive load banks can be used for the industries purpose in the future.

In future PWM techniques can be employed in this scheme. Along with power factor correction also speed control can be done in future. In future, Work can be done for harmonics reduction.

## Conclusion:-

This project work is an attempt to design and implement the power factor controller using PIC micro controller. In this work there is a provision to define the own current minimum range and power factor minimum and maximum range. PIC monitors both continuously and then according to the lagging or leading power factor it takes the control action. This thesis gives more reliable and user friendly power factor controller. This thesis makes possible to store the real time action taken by the PIC microcontroller. This thesis also facilitates to monitor the power factor changes on LCD in real time.

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