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Design of Control Circuit Using PIC Microcontroller for Automatic Power Factor Correction

Miss D. A Suryawanshi, Mr. Sujit Subodh Phatak, Miss. Rutuja Dinesh Kapase, Mr. Sagar Kailas Sadafule, Mr. Omkar Magan Didul
Department of Electrical Engineering
Annasaheb Dange College of Engineering & Technology, Ashta, Maharashtra, India

Abstract: *The power quality of AC systems has been a key issue in recent years because to the ever-increasing quantity of electronics equipment, power electronic equipment, and high voltage power systems. The majority of industrial installations in countries have substantial inductive electrical loads, resulting in a lagging power factor that has serious effects for energy users. As a result, reactive power compensation must be performed in the proper manner. Hence, we worked on this project and created Automatic Power Factor Correction (APFC) system using the PIC18f4520 microcontroller. APFC device measures the power factor, line voltage, and line current. The power factor is calculated using the system's voltage and current, and if it falls below a specified value defined by the utility provider, the device immediately activates capacitor banks to compensate for the reactive power. The phase angle and corresponding power factor are calibrated at that time. The mother board calculates the required compensation and activates the appropriate capacitor banks. This strategy can be used to increase the system's stability and efficiency in both industries and homes.*

Keywords: Power Factor, Microcontroller PIC18F4520, Capacitor Bank, Relay, Load

I. Introduction

In electrical systems, the power factor is crucial because it dictates how efficiently electrical power is utilized by the load. P.F is a quantity that doesn't have any units attached to it. A resistive load with a power factor of 1 is the most efficient, but if the power factor is lagging, the efficacy of electrical power is reduced, resulting in bigger losses and higher expenditures for customers.[1]

Inductive load consumption is high in industries, necessitating reactive power for current magnetization. This reactive power isn't used in any way. As a result, more electricity is required to run a machine beyond its maximum capacity. This results in a low trailing power factor, which can cause voltage fluctuations, power outages, operational losses, increased electricity bills, and utility penalties.[2-3] APFC panels also help to overcome this problem by keeping the power factor near to unity. The ratio of the real power absorbed by the load to the apparent power flowing in the circuit is the power factor of an ac power system.[4]

$$PF = \frac{\text{Active Power}}{\text{Apparent Power}}$$

The amount of actual power used in a circuit is known as active power (P). The measurement units are watts.

Reactive power is the amount of energy consumed in an ac circuit due to inductive and capacitive fields. Reactive power is measured using the VAR unit. The outcome of combining active and reactive power is apparent power. The units of measurement are volts-amps.[5] [VA] It has greater strength than both active and reactive power.

By raising the power factor of a connected load, power factor correction increases the efficiency of the distribution system to which it is connected.[6-7] Linear loads with poor power factor can be improved with the help of a passive network of capacitors or inductors. Non-linear loads, such as rectifiers, induce a distortion in the current pulled from the system. There are three methods for increasing power factor:

1. Bank of Capacitors
2. Synchronous Condensers
3. Advancers in Phases

To rectify the power factor, this system employs capacitor banks. One technique to improve power factor is to reduce the phase angle between voltage and current. A capacitor or bank of capacitors connected in parallel with the load provides this reactive power.[8] Less reactive power flows across the line as a result of their role as a reactive power source. Capacitor banks are used to reduce the phase difference between voltage and current.[9-10]

II. METHODOLOGY

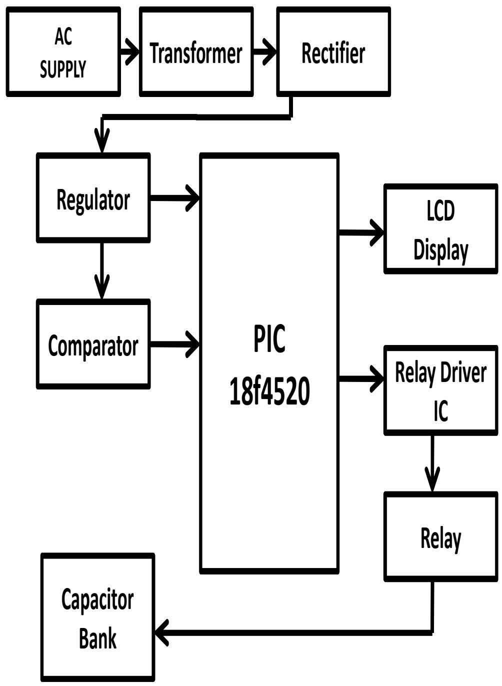


Figure 1: Block Diagram of APFC Circuit.

III. COMPONENTS

3.1 Potential Transformer

A potential transformer (P.T.) is used in this project. It is a type of instrument transformer used to protect and measure electricity systems. A potential transformer is used to step down the incoming higher level primary voltage and secondary voltage to lower primary and secondary voltage. It is connected in parallel with the circuit. 440 V ac voltage is fed to the transformer and it will reduce voltage upto 5V.

3.2 Current Transformer

A current transformer is a device that changes the quantity of alternating current in a circuit by reducing or multiplying it. It generates a secondary current that is proportional to the primary current. The current transformer measures the high current drawn from the supply. It is connected in series with the circuit. 5A CT is used for the system. The reason of using CT in the project is Op-amp needs current less than 50mA.

3.3 Relay

A relay is a switch that is activated or deactivated by electricity. The relay's input terminals can be set to accept a single or several control signals. The switch can have an infinite number of contacts, as well as any combination of contact types, such as make, break, and combination contacts. 12V relay is used in the system. The main function of relay in this system is switch on and switch off of capacitor banks according to the improvement in power factor.

4.4 Diode

The diode 1N4007 is used. It is a semiconductor diode with a single junction. It is typically designed for use as a rectifier in electronic circuits to convert AC voltage to DC voltage. It is employed for the purpose of rectification.In the system ,it receives step down voltage and then coverts into DC voltage which is further given to the microcontroller.

4.5 LCD (liquid crystal display)

The LCD is a type of electronic display. A 16x2 LCD display can be found in a wide range of circuits and devices. On this LCD each character is displayed on a matrix of 5x7 pixels. The 16×2 LCD is used to display message and data. It shows the parameters like value of PF, HIGH, LOW etc.

4.6 PIC18F4520

The main part of this project is PIC18f4520 microcontroller. By using algorithm microcontroller does function for the system. The PIC18F4520 is a 40-pin, fully-static 8-bit microcontroller with 36 I/O pins. It's low-cost, low-power, fast, and completely static. With a programming range of 4 to 131 milliseconds, it has Power-on-Reset (POR) and Extended Watchdog Timer (WDT) circuits. It is ideal for low-power applications because of its Power Management features. There are three power management options to choose from.

1. Running Mode
2. 2.Sleep mode
3. Inactive mode

4.7 Operational Amplifier

An operational amplifier is a DC-coupled high-gain electronic voltage amplifier having a differential input and, in most cases, a single-ended output. Operational amplifiers were first used in analogue computers to perform mathematical operations in linear, nonlinear, and frequency-dependent circuits. The main function of an Op-amp is to amplify the differential between two inputs and result output. It has two terminals v+ and v-.when the input at v+ is more than v- then output is positive signal and when the input at v- is more then output is negative signal.

4.8 Zener Diode

A zener diode is a type of diode that allows current to flow backwards once a certain reverse voltage, known as the Zener voltage, is reached. In small circuits, zener diodes are widely used as voltage references and shunt regulators.

4.9 Voltage Regulator

Voltage regulators generate and maintain a consistent output voltage regardless of load or supply input fluctuations. Voltage regulators keep power supply voltages within a safe range for other electrical components. The regulators used in this project are 7805,7812,7912.

4.10 Capacitors

In this project the capacitors are used for filtering purpose and to reduce harmonics. Capacitor bank is used to provide the reactive power to the inductive load and increase the voltage according to system strength. It is connected through contactors and relays. Capacitors used in system are 2200µf,220µf,1000µf.

4.11 Push Button Or Keys

This system uses keys to set the value of power factor .The four keys are as follows: SET, UP, DOWN, ENTER. Controller is protected by password .Password is set by using these keys.

V. Circuit Diagram

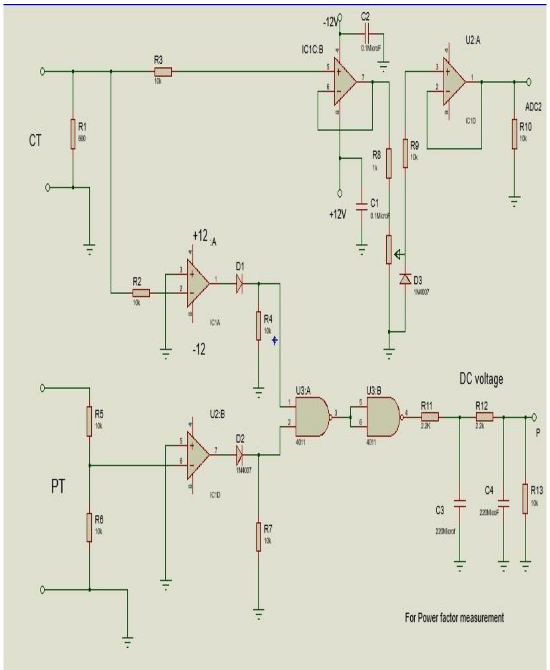


Fig.2. CT and PT connection and current measurement

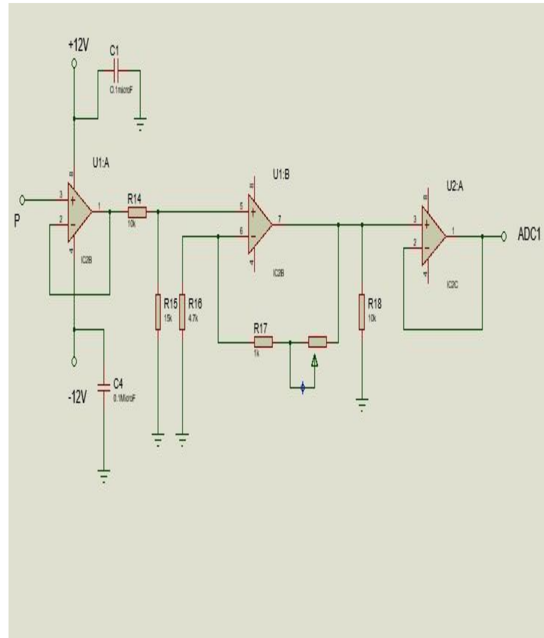


Fig.3

VI. Working

The developed system consist of voltage sensing unit, current sensing unit, data collection and calculation unit, and display the output. Two phases of the supply are connected to PT, which provides voltage, and one phase is connected to CT, which provides current. 440 AC voltage is fed to PT and this voltage is step down to 5V which is given to diode. Diode is used as a rectifire which converts ac voltage into pulsating DC. Voltage regulators maintains the DC voltage which is fed to the microcontroller. CT measures the high current and then it converts high current into low current. Because Op-amp requires low current. The PIC microcontroller receives the PT and CT data. These values are sensed by the PIC controller, which is coupled to the relays. PIC microcontroller uses algorithm for the calculation of power factor .It compares the measured pf with the set value which is already set by user using keys. When the system's P.F drops below the set point, the relay activates, sending a signal to the contactor, which activates the capacitor banks. When capacitor banks are turned on, lagging is eliminated, and by increasing capacitance, P.F improves, and the system becomes more stable and efficient.

VII. Calculations

Total Load = 250KVA
KVA to KW = 250×0.8= 200KW
KW To HP = 200/0.746=268.09HP
Capacitor rating KVAR=268.09/3 =89.36
Capacitor bank used is 90 KVAR

Total Load is 500 KVA.
Actual P.F. is 0.8. Required PF is 0.98.
KW=KVA×PF
=500×0.8 =400
$\phi_1 = COS^{-1}(0.8) = 36.86$
$\phi_2 = COS^{-1}(0.98) = 11.47$

Improvement Factor=tan(ϕ_1- ϕ_2)

=tan(36.86-11.47)

= 0.47

Required Capacitor Bank rating = KW × Improvement Factor

= 400×0.47 =188KVAr

VIII. Hardware Model

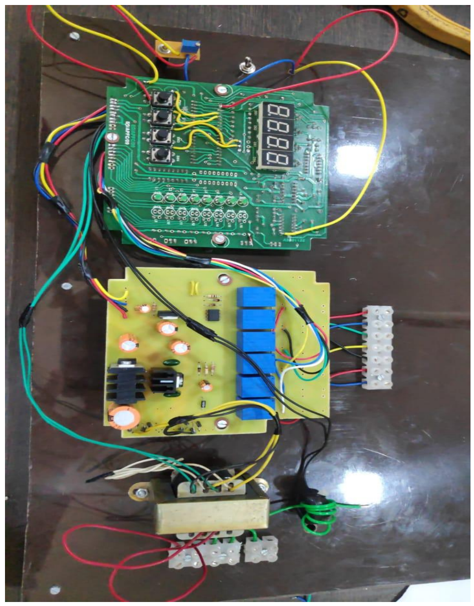
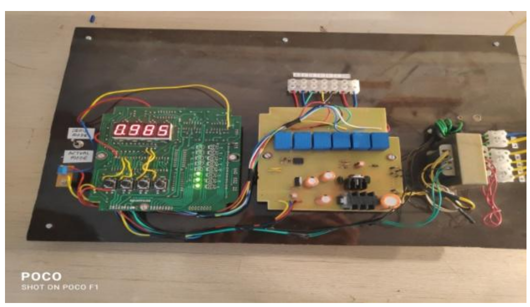


Figure 4: Working Model

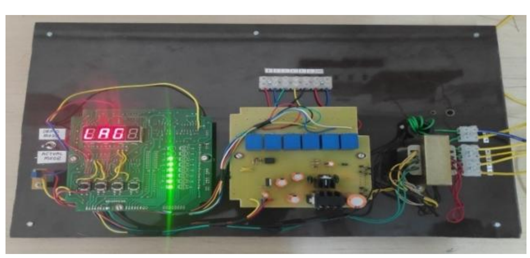
IX. Results

9.1 PF at Resistive Load



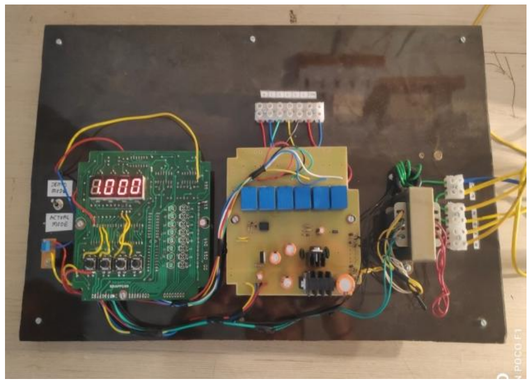
When the connected load is purely resistive then the PF is nearly equal to unity. To improve the PF relay driver will ON the capacitor banks and their respective LED will get ON.

9.2 PF at Inductive Load



When the connected load is inductive then the PF value is less than unity. If the PF is less than the lower PF value which is already set by user then it will display as LAG.To improve the PF relay driver will ON the capacitor banks according to the requirement and their respective LED will get ON.

9.3 PF at Unity under Load Condition



After getting the required PF value that is unity or nearly equal to unity the relay driver will OFF the capacitor banks and LED will get off.

X. Conclusion

In this proposed system, we created a PIC microcontroller-based APFC panel that can be used in both real-time and demonstration mode. It boosts power factor in less time by turning on capacitor banks and then turning them off when the needed value is reached. The number of ON capacitor banks is indicated by an LED that illuminates in response to the on and off of capacitor banks.

Future Scope

Implemented project is studied in laboratory scale, it can be designed in various industries with proper protection to identify power factor in real time application. Also this project can further be extended for speed control and reduce harmonics problem.

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