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Power Factor Correction Using SCR and Microcontroller

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ABSTRACT: Power factor correction has always been a challenging task. We may not realize that we are wasting electrical energy due to lagging power factor in inductive loads that we use. With increasing regulations and standards from electricity board, it becomes necessary for industrial and factory units to abide them without affecting their efficiency and other standards. This has increased competition among manufacturers to design different PFC stages for different applications. There are stages for loads that do not vary with power supply known as a passive stage and for loads that vary with power supply known as an active stage.

This paper presents passive stage power factor correction using a capacitor bank. It aims to enhance the operation with the help of intelligent microcontroller that controls the capacitors in the bank by continuously monitoring power factor. Voltage transformer and current transformer are used to sense the voltage and current while op-amp measures their zero crossing. Microcontroller intelligently calculates the power factor and controls the firing of SCR. SCR acts as a switch for capacitor bank. Moreover, the firing angle of SCR can be altered to efficiently handle the charging of capacitor bank.

This cost effective and newer method of controlling capacitors can be used in future PFCs that will limit the peak current, harmonics, EMI noise and can monitor the operation of capacitors, inductors, current limiting chokes with the help of controlled SCR [1].

KEY WORDS: Power Factor, capacitor bank, Microcontroller, SCR.

I. INTRODUCTION

- **NEED for Power factor improvement:**

In the 21st century, as the technology enhances, the need to transmit power over large distances has increased and power systems have become more complex. Due to many inductive loads, the power utilization goes on decreasing reducing the power factor. This increases the losses and reduces the efficiency of the system.

Another reason to use PFC is due to regulations posed by the IEC61000-3-2 standard applicable for appliances with the input power of 75W (Class D) and above (Class C) [1].

Definition:

Power factor correction is simply defined as the ratio of real power to apparent power.

$$PF = \frac{\text{Real Power (expressed in watts)}}{\text{Apparent Power (expressed in VA)}}$$

Where, the real power is the average of the instantaneous product of voltage and current over one cycle. And apparent power is the product of the RMS value current and RMS value of voltage. If voltage and current are not in phase, then power factor is $\cos(\phi)$ where (ϕ) is the phase angle between them [2].

- **Methodology used:**

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Automatic power factor correction device accurately senses the delay between current signal and voltage signals. Microcontroller calculates the phase angle (ϕ) between them that gives the value of power factor $\cos(\phi)$. It then controls the required compensation with the switching of SCRs that are connected to a number of capacitors. Capacitors will charge and the phase angle between current and voltage signals reduces, improving the power factor [4].

- **SCR and Capacitor control:**

The value of capacitor required for compensation depends on the Load and efficiency required by the system. By controlling the firing angle of SCR, these capacitors are evenly charged.

II. LITERATURE SURVEY

- **POWER FACTOR THEORY**

Power factor is defined as 'the cosine of the angle between the voltage and current'. In AC circuits, the voltage and current are ideally in phase. But, in practically phase difference is exists between them. The cosine of this phase difference is named as power factor.

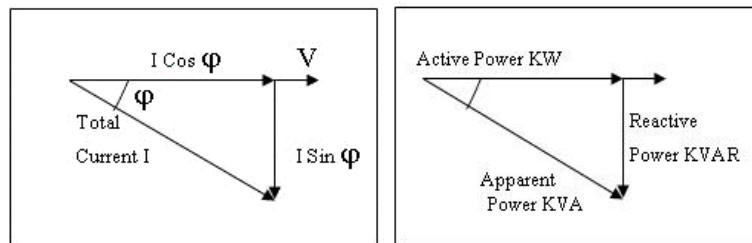


Fig.1 Power factor

Fig.1 shows the active current, reactive current and total current which is related to Active, Reactive and Apparent power respectively.

$$\text{Total current} = I = \sqrt{(I \cos \phi)^2 + (I \sin \phi)^2}$$

Where, $I \cos \phi$ = Active current, $I \sin \phi$ = Reactive current.

At a given voltage, V , the active, reactive and apparent powers are proportional to current and are related as follows:

$$VI = \frac{((VICos\phi)^2 + (VISin\phi)^2)^{1/2}}$$

Where, VI = apparent power, $VICos\phi$ = Active power, $VISin\phi$ = Reactive power.

Effect of Low Power Factor:

- Load current drawn will be higher.
- Copper losses (I^2R) will be high; because of this efficiency of the equipment will get decreased.
- I^2R losses produce heat, which increases the temperature and affects the stress on the insulator [5].

III. BLOCK DIAGRAM DESCRIPTION

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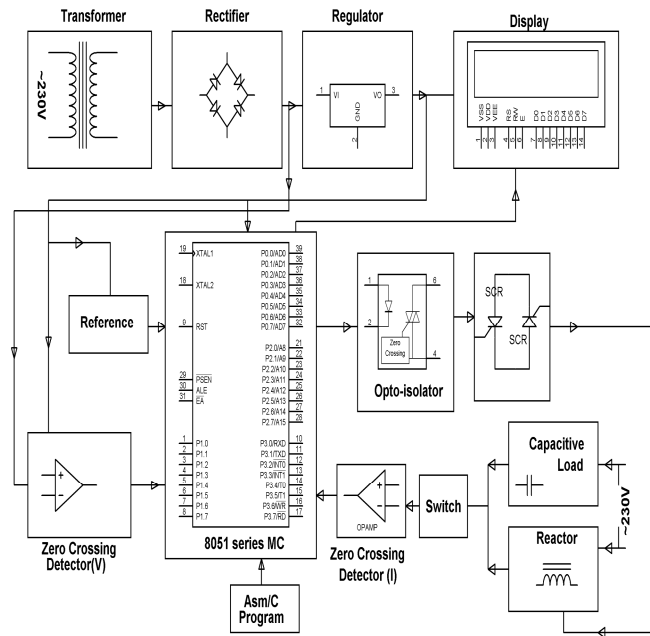


Fig.2 Block Diagram of the System

There are mainly 3 sections in the block diagram (Fig.2).

- A. Input Section: - Which consists of Transformer, rectifier, Voltage regulator and comparators.
- B. Interfacing Section: - It involves Interfacing of Microcontroller with LCD and ZCD.
- C. Capacitors and SCR matrix: - This matrix connects or releases the capacitors from the load.

A. INPUT SECTION

In this project, the circuit uses standard power supply comprising of a step-down transformer from 230V to 12V and 4 diodes forming a bridge rectifier that delivers pulsating DC which is then filtered by a capacitor. This filtered DC supply is unregulated, so it is regulated by IC LM7805. The output of this IC is 5V DC supply. This supply is given to ZCD as well as Microcontroller IC.

B. INTERFACING SECTION

The Microcontroller IC gets the input from 5V input supply. Calculation of power factor by the Microcontroller needs digitized voltage and current signals. The voltage signal is taken from the mains and it is converted into pulsating DC by the bridge rectifier and it is given to the zero crossing detector voltage (V) which generates the digital voltage signal. Same way, the zero crossing detector (I) will generate a digital Current signal [4], [5].

The microcontroller will calculate the time difference between inputs received from the both Zero Crossing Detectors, which is directly proportional to the power factor and it will determine the power factor range.

The microcontroller will send this information regarding time difference for displaying to LCD display. According to the difference, the capacitors will get selected via SCR and power factor will be improved [5].

C. Capacitors and SCR matrix

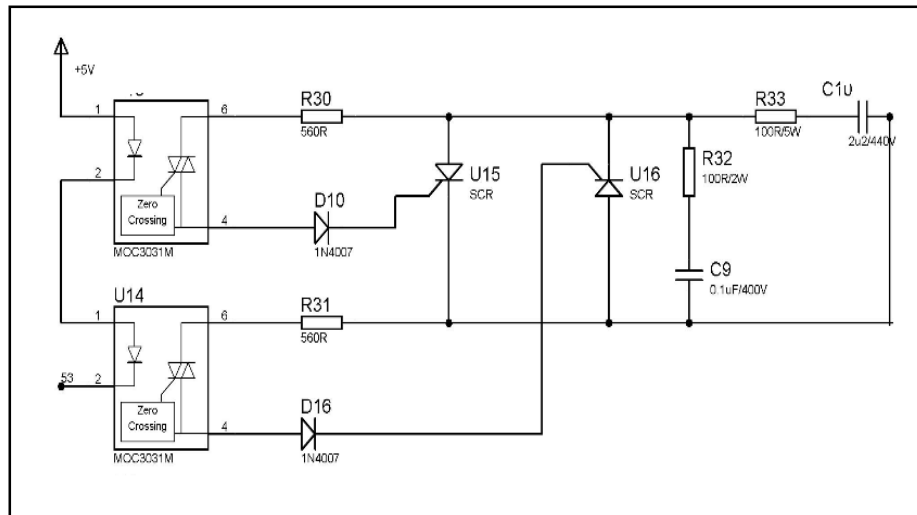


Fig.3 Capacitor and SCR matrix

Fig.3 shows the connection of SCR and Capacitors through opto-isolator. Opto-isolator IC transfers the voltage & current signal to load part. Load part includes Capacitor Bank which is electrically isolated from input part. Depending upon the difference between zero crossing of voltage and current wave microcontroller either switches on or off required number of capacitors through Opto-isolator IC.

- **Hardware Requirements:**

Transformer,
Op-amp,
Rectifier,
Voltage Regulator (IC 7805),
LCD (16x2),
Microcontroller (AT89s52),
Opto-isolator,
SCR,
Switch,
Capacitive Bank,
Choke,
Bulb.

- **Software requirements:**

Keil debugger.

Transformer

The Transformer is used for reducing or increasing the voltage of AC. In this project step-down transformer is used to step down the input AC 230V. Then this AC output voltage is given to the rectifier.

Bridge Rectifier

The main function of this rectifier is to convert the AC voltage into DC voltage.

Voltage Regulator

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In this project LM7805 IC is used to convert the variable DC voltage to constant DC voltage. The output of this regulator is 5V. It is then given to the Microcontroller IC, Op-amp and LCD.

Zero Crossing Detectors

These detectors convert the sine-wave to square-wave. In this project, two zero crossing detectors are used. One for voltage and another one for current. These zero crossing detectors are also called as a comparator. The output of these comparators is given to the microcontroller.

LCD

LCD used is 16x2. It is a flat panel display that uses the property of liquid crystals. In this project, LCD is used to show the current Power factor of the system. The output of the microcontroller is given to the LCD.

Capacitor Bank

It is used to improve the power factor of the overall system. When the power factor is lower than unity it adds the capacitors at the load and when the power factor is higher than unity it subtracts the capacitors.

Microcontroller (89S52):

The AT89S52 is a high-performance 8-bit microcontroller with in-built programmable flash memory. It is compatible with the industry standard 8052 instruction set and pin-out. In this project, microcontroller calculates the time delay between voltage and current waveforms and sends the signal to SCRs so that capacitors get connected automatically and power factor correction is achieved.

SCR

In this project, SCRs are connected in anti-parallel manner. During the positive half cycle of the main current, the current flows from phase to the load through SCR. During the negative half cycle current flows from load side to the phase during this time another SCR comes into the picture.

Opto-Isolator

The two SCRs which are connected in anti-parallel are triggered back to back through Opto-isolators.

IV. WORKING

The block diagram (Fig.2) mainly consists of power supply unit, microcontroller, zero crossing detector IC, the load unit, opto-isolator IC, LCD display, SCRs and capacitor bank. 7805 regulator IC provides 5v supply to the microcontroller, LCD display, and opto-isolator IC. The 12v voltage required for zero crossing detectors IC LM339-A is given through 7812 regulator IC. The input signal from the mains that is the supply signal voltage and current is given by CT and PT transformer and then to the rectifier unit which converts these AC signal to pulsating dc. Then this digitized voltage and current signals are sent to the interrupt pins of micro-controller through zero crossing detectors. Internal timer circuit of microcontroller calculates the time difference between the zero crossing points of current and voltage, in ms which then convert into phase angle which is directly proportional to the power factor and it determines the range in which the power factor lies. The information regarding time difference between current and voltage and power factor is sent to the LCD display. Depending upon the range the signal is sent to the opto-isolators that turn on back to back connected SCRs and bring the capacitors into the circuit. In this way, power factor correction is achieved by adding capacitors to offset the inductive load present in the power system [3] [4] [5].

V. RESULTS

1. With the DPDT switch is in lagging position, no capacitors are switched on but the inductor comes into the circuit and the lagging current flowing through the inductor causes a voltage drop across the 10R/10W which is proportional to lagging current and displays lagging PF. Thus the primary voltage from the CT provides lagging current reference to

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the current sensing circuit. The microcontroller gets zero current reference and then compares it with the zero voltage reference for calculating the power factor based on their time difference and displays the same.

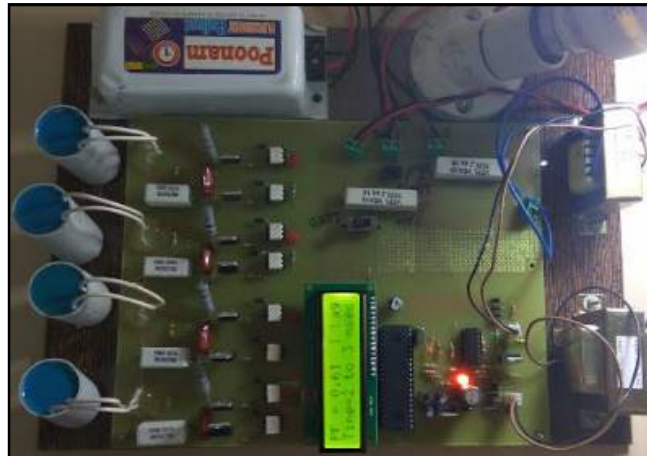


Fig.4 Output in LAG position

Fig.4 shows the output when DPDT switch is in LAG position. Therefore, no capacitor comes into the circuit.

2. Now with the DPDT switch is in leading position, no inductor comes in the circuit but capacitors are switched on through the lamp and back to back SCRs one after another automatically in a definite time span and leading current increases to show leading PF accordingly. Thus the leading current goes on increasing with each capacitor added resulting in brighter and brighter the lamp glowing and displays the leading PF.



Fig.5 Output in LEAD position

As shown in Fig.5, Three capacitors get connected with power factor displaying on LCD 0.61. The brightness of the bulb increases & time difference between the waves is 2 to 3 mS.

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Fig.6 Output in LEAD position with improved PF

As shown in Fig.6, Four capacitors get connected with improved power factor 0.80. The brightness of the bulb increases & time difference between the waves is 1 to 2 mS.

VI. CONCLUSION

This is the paper about the advanced method of power factor correction by using micro-controller which automatically corrects the power factor of the circuit. As demonstrated, by using this method low power factor and efficiency of the system can be increased.

For increasing, power factor capacitor bank gets selected through SCR at load. Thus, the possible advanced method of correcting the power factor is presented in this paper.

Care should be taken for overcorrection of power factor otherwise, the system will become unstable.

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