

## ARDUINO BASED POWER FACTOR CORRECTION

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**Abstract-** Power factor correction 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 electric power utility to improve the stability and efficiency of system or by customer at the premises. This is required to ensure long term, effective and economic operation and utilization of electrical power. In present paper we present automatic power factor correction scheme based on Arduino platform and triac based capacitor switching.

**Keywords-** TSC (Thyristor Switched Capacitor), Capacitor bank, Arduino platform, Triac, SVC (Static VAR Compensator).

### I. INTRODUCTION

MOST loads in modern electrical distribution systems are inductive. Examples include motors, transformers, gaseous tube lighting ballasts and induction furnaces. Inductive loads consume two kinds of power viz. So, with the presence of inductive load, power consumption and hence electric bill increase for same amount of work done

What is power factor?

e. Such condition is recognized as lagging power factor.

Most loads in modern electrical distribution systems are inductive. Examples include motors, transformers, gaseous tube lighting ballasts, and induction furnaces. Inductive loads require two kinds of power:

- Working power (kW) to perform the actual work of creating heat, light, motion, machine output, and so on.
- Reactive power (kVAR) to sustain the magnetic field

Working power consumes watts and can be read on a wattmeter. It is measured in kilowatts (kW). Reactive power doesn't perform useful "work," but at times is required for proper functioning of system and circulates between the generator and the load. Reactive power is measured in kilovolt-amperes-reactive (kVAR). Working power and reactive power together make up apparent power. Apparent power is measured in kilovolt-amperes (kVA).

Thus the magnitude of reactive power consumed in load is understood as cosine of angle between apparent power and true power.

$$\text{Power factor} = \cos(\theta)$$

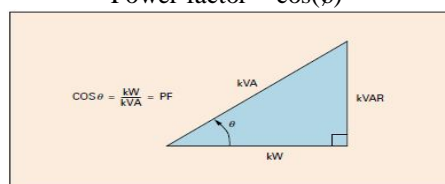


Figure 1: Power triangle

Our goal is to design system that would allow for PFC in both systems viz, single and three phases. Hence we decided to go with capacitor bank method. In this regard, there is "design, fabrication and testing of microcontroller based Static VAR Compensator (SVC)" consisting of Thyristor Controlled reactor (TCR) and Thyristor Switched Capacitor (TSC) has been done in a paper.[1]

To reduce harmonics introduced because of relay switching the author has used thyristor based switching of capacitor bank. Further PIC microcontroller is used which according to us unnecessarily complicates system programming.[2] It describes the design and development of a three-phase power factor correction using PSoC (Programmable System on Chip) micro-controlling chip. The scheme used here is to measure the angle between the voltage of Y and B phase and current of R phase, this gives value of  $\sin(\theta)$  relation. Also from the voltage of YB phase and current of R phase reactive and active power in KVAR and KWA of the system are calculated. From these parameters current power factor found. Here we see that same work can be obtained from cheap and easy to used Arduino platform.

The project work describes the design and development of a power factor corrector using PIC microcontroller chip. Measuring of power factor from load is achieved by using PIC Microcontroller-based developed algorithm 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.

In conclusion microcontroller based automatic power factor correction using capacitor switched method seems a very flexible solution. But unlike above mentioned attempts we have avoided using PIC or similar microcontroller to avoid difficulty in

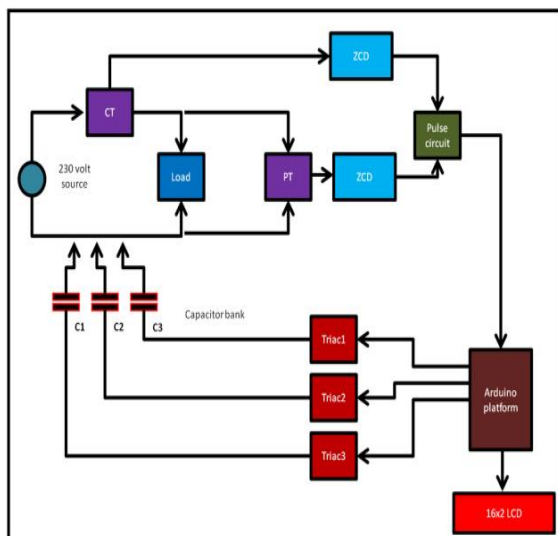
programming and debugging. Instead we use open source Arduino platform which is easy to program and debug. Further phase measurement between voltage and current is simplified using Opamp and EXOR gate based circuit. To avoid adverse effect on THD we have used thyristor based capacitor switching instead of relay driver.

**II. METHODOLOGY**

Our system would be targeted towards power factor detection and correction in single phase and also 3 phase system with minor modifications. For this we plan to use Arduino microcontroller platform based system. The reason is ease of using and programming Arduino platform. Arduino is open source general purpose prototyping platform based on AVR 8 bit microcontroller series. [5]

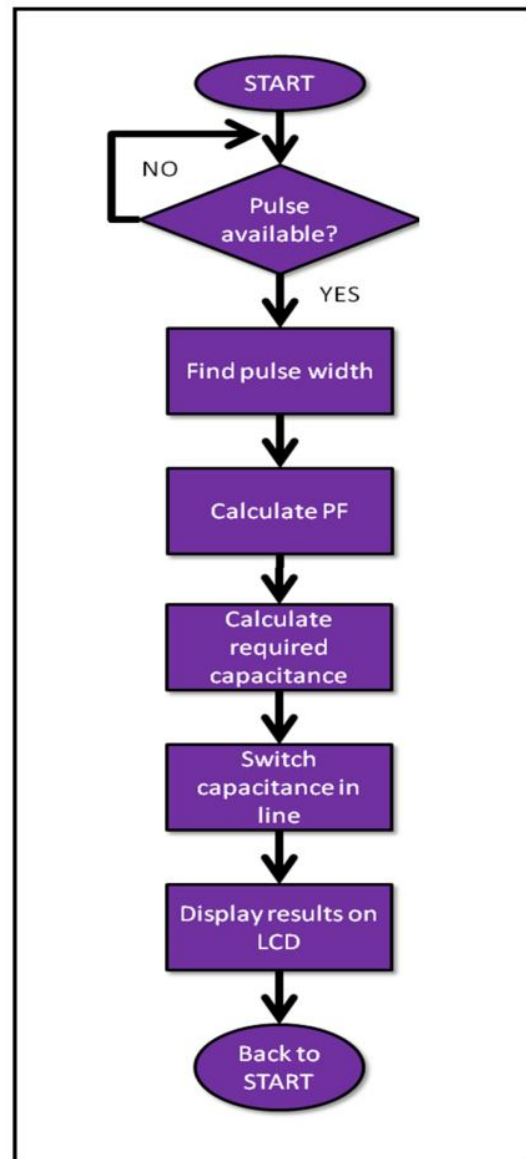
Voltage and current from power line is stepped down to low power level suitable for Arduino processing using PT and CT transformers. Then zero crossing of both signals is found using Opamp based ZCD circuit. From the two ZCD signals a pulse is generated using digital EXOR gate. The width of this pulse is proportional to the phase difference between voltage and current in power line. From this data power factor can be estimated.

Further this value will be used to find the required size of capacitor to be switched in power line to bring power factor back to unity. Arduino is programmed to find pulse width, calculate power factor and calculate required capacitance value. Then arduino will add estimated capacitor in power line for PFC. Further improvement in PF is monitored on continuous basis by Arduino to see if PFC is carried out by addition of estimated capacitor in power line. The entire process flow will be displayed on LCD. Figure shows the simplified block level arrangement of system.



**Fig 2 Block diagram of system**

**III. FLOW CHART MODELS DESIGNS**



**Fig 3 Algorithm**

In above algorithm the flow of project is shown, our project works in such process and we are designing our project in such manner that all above processes are covered under it.

Thus, the software model is designed and it can be observed as in following sections as well as a hardware model for the same.

**IV. SOFTWARE MODELS DESIGNS**

In software we are going to handle phase difference measurement between voltage and current in power line, calculation of power factor and required capacitance to bring power actor back to unity and adding that capacitance to line. Also we do displaying of process flow on LCD for user feedback.

Following is circuit plan for Arduino based automatic PFC.

Schematic in figure is simplified is representing driver for Triac circuit. The complete driver circuit for Triac can be seen in following software model figure.

This software model gives us a graphical as well as the numerical outputs from this software model we are able to design the hardware model and be analyzing software and hardware we had completed our project.

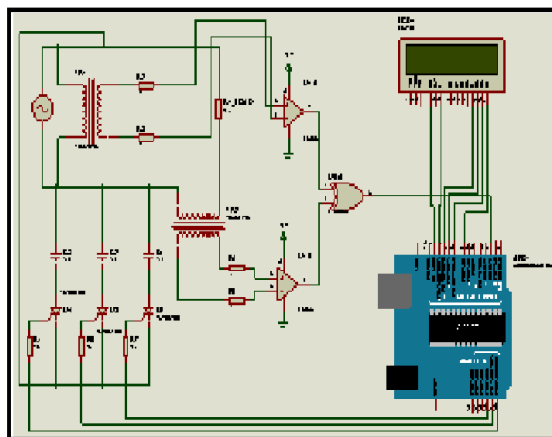


Fig 4 Proteus VSM simulation for system

Here system is divided into following major components.

#### A. Zero crossing detection of voltage and current signal:

Zero crossing detection is done for both voltage and current signals. The power signal voltage is stepped down to lower level using 6-0-6/750mA step down transformer and then is applied to LM358 based ZCD circuit. The ZCD circuit then gives zero crossings for voltage signal. For power line current we use non-invasive current transformer to step down it to lower level. This signal is then applied to ZCD to get its zero crossing. From these to ZCD outputs we know the phase difference between voltage and current signals using single XOR gate.

#### B. Pulse generation corresponding to phase difference between voltage and current:

The two ZCD outputs are then applied to EXOR logic gate to get a pulse corresponding to phase difference between voltage and current signal.

##### Arduino based decision making:

The arduino microcontroller forms the main decision maker here. Its functions can be divided into following component parts.

#### C. Phase difference measurement:

The pulse output from EXOR gate is applied to Arduino. The Arduino then measures the width of pulse. The pulse width corresponds to phase difference measurement. Thus by measuring pulse

width we have effectively measured phase difference between voltage and current signal.

#### D. Power factor measurement:

From the value of measured pulse width the Arduino now finds out the power factor.

#### E. Capacitor calculation:

From power factor it finds out required value of capacitor to bring power factor back to unity. For this we use following formula.

$$C = \text{KVAR} / (2\pi \text{pix} \times V_{\text{rms}} \times V_{\text{rms}})$$

#### F. Capacitor switching:

Arduino then adding required capacitor value across the load using thyristor based switching scheme.

It generates the required gate drive for thyristor to switch it ON.

#### G. Thyristor based capacitor bank:

The capacitor bank used in our project is thyristor based. capacitor is added in line.

### V. HARDWARE MODELS DESIGNS

Following is the snap of complete system. The system was tested with 2 inductive loads in series with 200 watt resistive load. The inductive load can be added/removed from circuit using switch. Detection of power factor by system was checked once for resistive load and than for added inductive load.



Figure 5: Actual setup

When the load is purely resistive the system detects so and also the corresponding PF of 0.99 is displayed on lcd. The in-phase waveforms of V and I can be seen on oscilloscope.

When the load is made inductive by adding an inductance is series with resistance, the net load is inductive and the corresponding lag created between V and I can be clearly seen on oscilloscope. The system detects this condition and corresponding PF is displayed on LCD.

The system reliably detects leading and lagging PF conduction and switches capacitor from bank to correct it.

Following is the table to illustrate calculated PF and detected PF by system for various load conditions. The calculated values are based on measured current



in line using clamp meter.

The following figures show the characteristics from project and the readings with respect to those characteristics.

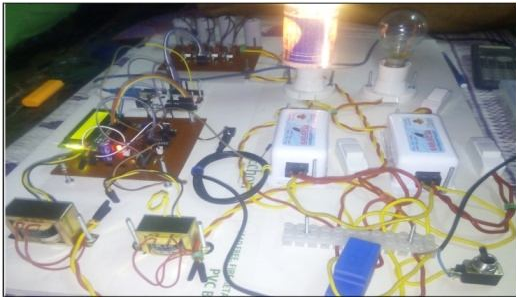


Figure 6: Purely resistive load

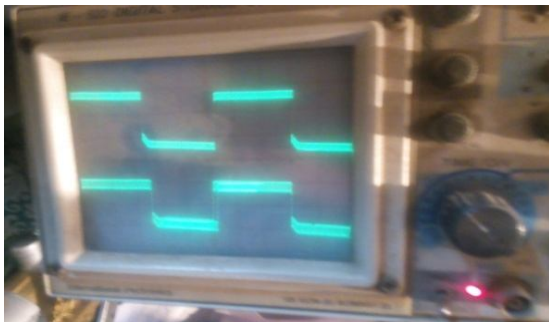


Figure 7: V and I waveforms when load is purely resistive



Figure 8: V and I waveforms when load is inductive



Figure 9 Lagging PF detected by system



Figure 10: PF correction by system

## VI. RESULT ANALYSIS

TABLE 1 Result Comparison

Sr. No.	Load	Calculated	Detected	Software
1	Resistive	0.99	0.99	0.99
2	Purely Inductive (100w)	0.84	0.84	0.88
3	Purely inductive (200w)	0.70	0.70	0.72

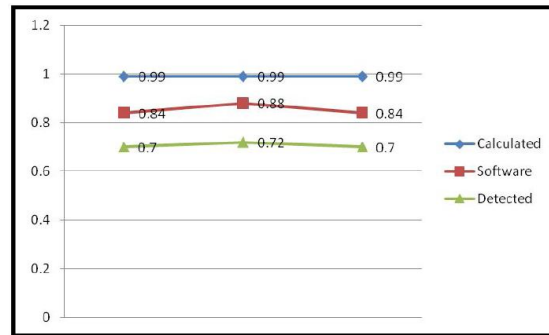


Fig 11 Characteristics Analysis

## CONCLUSION

By using Arduino microcontroller platform the system is made automatic detector of PF lag/lead condition. Again by using Triac based switching of capacitor bank the THD is reduced compared to relay based switching. The results obtained with various load conditions are satisfactory and the system would make a cost effective solution for automatic power factor improvement in industrial environment. Further the system can be modified for monitoring power changes over period using Data logging methods. Also same data logging techniques can be used for more scientific analysis of PF of a certain facility.

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