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Automatic Power Factor Control Equipment using Micro Controller

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***Abstract*— The use of various inductive equipment like electric motors, furnaces etc. in the industries adversely affects the power factor of the supply. Due to inductive loads, the apparent power becomes greater than the real power that increases the phase difference between voltage and current. So, the power factor drops below unity and the system becomes less efficient. This project deals with correcting the power factor so that it becomes approximately unity. The available power factor correction equipment are very expensive which prevent their use in households and small scale industries. A power transducer is used to get the power factor of the electric circuit. The collected information is given to a microcontroller which is programmed to connect the required capacitors in parallel across the load so that the power factor becomes approximately unity. Our aim is to make a low cost power factor correction equipment, which reduces the power consumption in common households and industries.**

Keywords*— Power Factor, Power Factor Transducer, ATmega 16, Reactive Power, LCD Display

I. INTRODUCTION

In most industrial and commercial facilities, a majority of the electrical equipment is inductive loads such as AC induction motors, induction furnaces, transformers and ballast-type lighting. Under normal operating conditions certain electrical loads draw not only active power from the supply (kilowatts kW) but also reactive power (reactive kVA, kVAr). Problems of power quality in industrial plants are growing due to the increasing number of rectifier controlled motors and the overall increase of harmonics and inter harmonics[6]. These loads cause poor power factor in industrial plants. A poor power factor indicates ineffective utilization of electricity and affects total energy costs. If the power factor of the plant is low, it uses more power than it needs to do the work. Poor power factor should be corrected as it substantially increases costs. Capacitors generally are the most economical means to improve power factors. Power factor correction is the term given to a technology that has been used since the turn of the 20th century to restore the power factor to as close to unity as is economically stable. This is normally achieved by the addition of capacitors to the electrical network which compensate for the reactive power demand of the inductive load and thus reduce the burden on the supply. There should be no effect on the operation of the equipment [2]. This paper deals with correcting the power factor to make it closer to unity. We used a power factor transducer for measuring the pf and correction process is controlled by **Atmega16** microcontroller.

II. POWER FACTOR AND ITS IMPORTANCE

Power factor is a measure of how effectively electrical power is being used by a system. To understand power factor, we first have to know that power has three components: working, reactive and apparent power. Working power is the current and voltage actually consumed. It performs the actual work, such as creating heat, light and motion. Working power is expressed in kilowatts (kW), which register as kilowatt-hour on electric meter. Reactive is not useful work, but it is needed to sustain the electromagnetic field associated with many commercial/industrial loads. It is measured in kilo volt amperes-reactive, or kVAR[1]. The total required capacity, including working and reactive power, is known as apparent power. It is expressed in kilovolt-amperes or KVA. Power factor is the ratio of working power to apparent power or kW/kVAR. Power factor values can carry from 0 to 1.00. Typically, values range from 0.80 to 0.98. A power factor below 0.80 is considered low.

A. Power Factor Correction

There are different forms or PF that must be consider, displacement PF and total PF. Displacement PF (cosφ) as shown by the power triangle is the relationship between the real power (P) in Watts (W), and the apparent power (S)[7], in Volt-Amp (VA) of the fundamental wave. The remaining side of the right angle triangle is the reactive power (Q) as shown in Fig 1. Total PF is the relationship between real power and apparent power when including the distortion effects of harmonics. Because total PF is always changing based on the harmonics in the system, it is difficult to track at all operating conditions and basic metering equipment cannot accurately measure it. As such the PF generally referred to in electrical discussions as well as this paper is displacement PF.

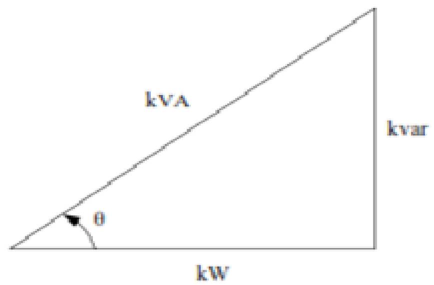

Fig. 1. Power Triangle

cos(φ) = PF =P/S

The copper losses increase by the square of the current; refer fig 2, therefore, an increase in current results in significantly more power loss. Two common equations for calculation of loss in 3 phase system are:

$$Ploss(watts) = \frac{P(watts)}{\sqrt{3} \times Vi \times PF} \times R(ohms) \quad (1)$$

$$Ploss(watts) = \frac{S(VA)}{\sqrt{3} \times Vi} \times R(ohms) \quad (2)$$

Where Vi is the voltage[5].

Another cost associated with poor PF is the penalty imposed by the utilities as part of their demand side energy management. If a consumer's meter ever reads outside of the acceptable PF (typically 0.95), the electric utility assesses a penalty consistent with the utility's rate structure. Fig.2 shows the variation of power loss with power factor. Due to the costs associated with energy, today's power systems must be designed to maximize energy efficiency. Applying the values from Fig. 2, a PF of 0.9 increase the energy costs associated with losses by a factor of approximately 1.23 whereas a PF of 0.7 more than doubles the cost associated with the system copper losses.

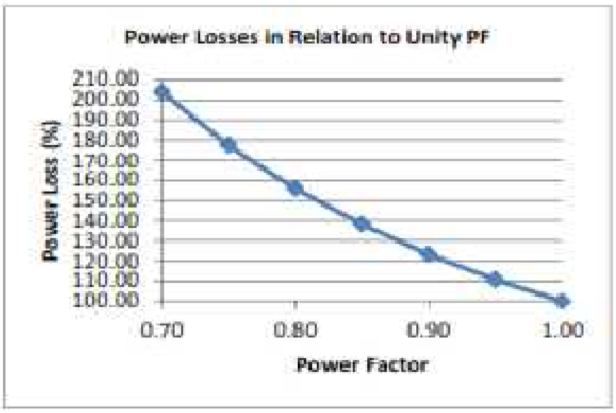

Fig. 2. Variation of power loss with power factor

III. OPERATING PRINCIPLE

The block diagram of the system is shown in Fig. 3. The main power line is taken through the current transformer. The output of the current transformer gives the current input to the pf transducer .The voltage output is taken directly. Voltage and current from the supply line is given to the power factor transducer. The output of the power factor transducer is a dc voltage proportional to the power factor of the system. This voltage is given to the ADC pin of microcontroller ATmega16. The microcontroller converts the analog value to digital value using ADC conversion and calculates the pf. The microcontroller now produce output signals that are applied to the control terminals of relay. Relay switches the required capacitors based on the calculated pf and reference pf set in the program. The capacitors[3] are included in the power supply providing leading power which improves the power factor.

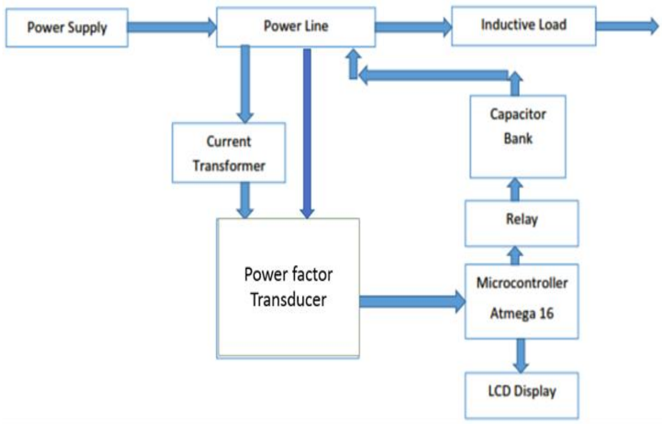

Fig. 3. Block Diagram

A. *Circuit Diagram*

The circuit diagram of the APFC is shown in Fig 4. The PF transducer takes inputs from CTs connected in three lines and directly from 3 phases and neutral for voltage measurement. An auxiliary supply of 230 V AC is applied to the transducer

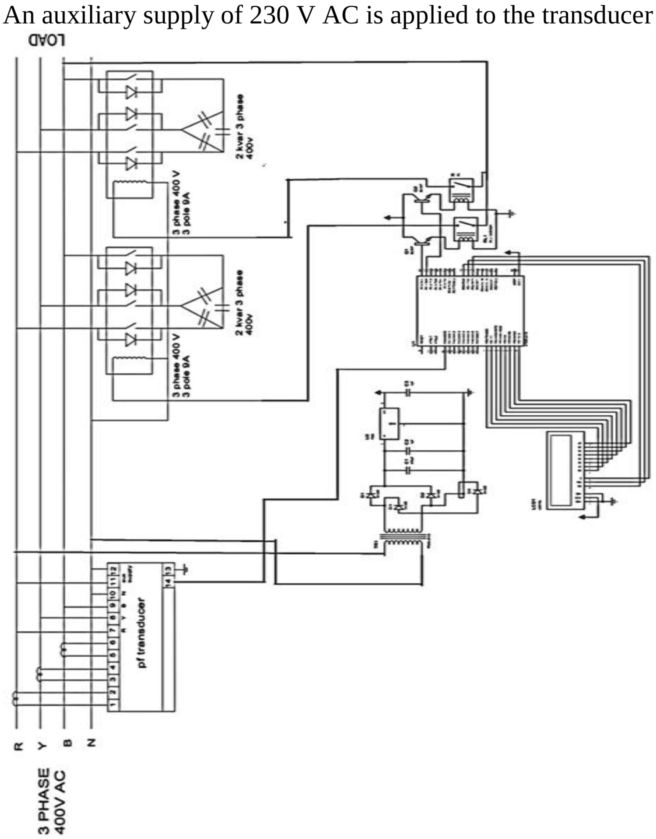

Fig. 4. Circuit Diagram

for its working. A voltage regulator circuit is used to produce 5V DC from 230 V AC for powering micro controller and relays.

B. *Program Algorithm*

Flow chart of the micro controller program is given in Fig. 5. The program algorithm is explained below .

1. Analog Voltage is obtained in pin A0 of ATmega 16.
2. Analog input converted to digital value using ADC

conversion process. 10 bit ADC is used.

3. Power Factor is obtained from ADC value using suitable mathematical conversions.
4. Power Factor displayed in LCD screen.
5. Obtained ADC value is compared with reference value corresponding to lower limit of power factor required. If ADC value is less than reference value, one capacitor is added[4].
6. If obtained ADC value is greater than lower limit, the ADC value is then checked with the upper limit. If it is greater than upper limit, one capacitor is removed. Refer Fig. 5

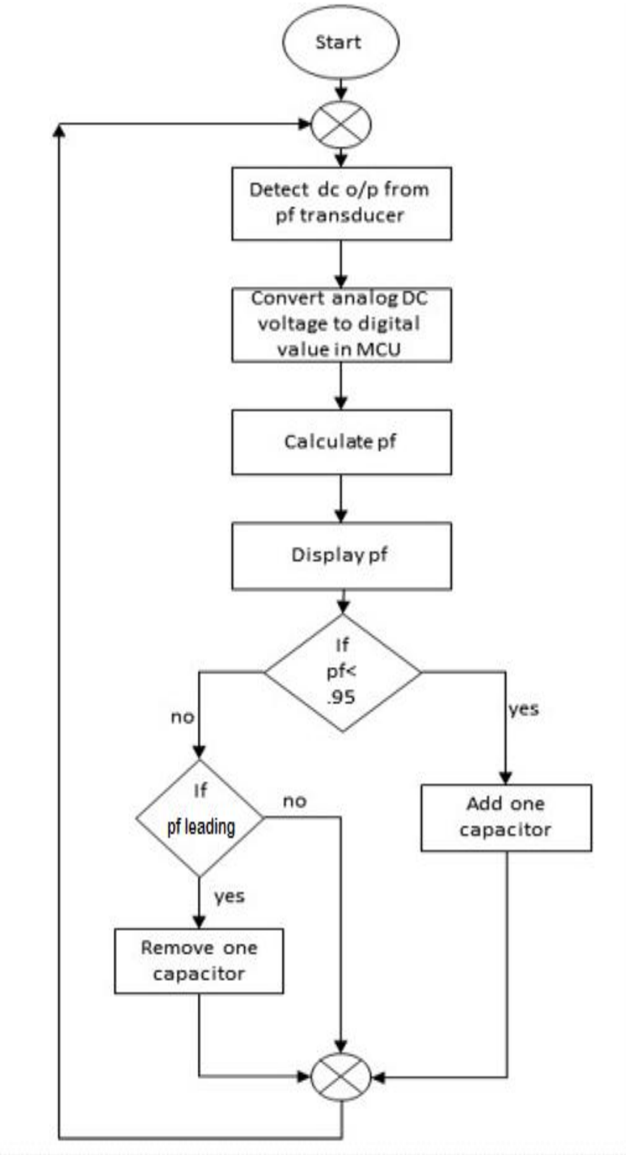

Fig. 5. Program Flow Chart

C. Operation of Relay

If microcontroller output is high then transistors turns on, establishing sufficient current through the coil of the electromagnet to close the relay and capacitor will be connected parallel to the load. Problem can now develop when the microcontroller signal is removed from the base to turn off the transistor and de-energize the relay. Trying to change the current through an inductive element too quickly may result in an inductive kick that could damage surrounding elements or the system itself. This destructive action can be subdued by placing a diode across the coils shown in Fig.6..During the on state of transistor, the diode is back-biased; it sits like an open circuit and doesn't affect a thing. However, when the transistor turns off the voltage across the coil will reverse and will forward-bias the diode, placing the diode in it's on state. The current through the inductor established during the on state of the transistor can then continue to flow through the diode, eliminating the sever change in current level. The diode must have a current rating to match the current through the inductor and the transistor when in the on state. Thus the capacitor is connected parallel across the load by relay without any hazard [4].

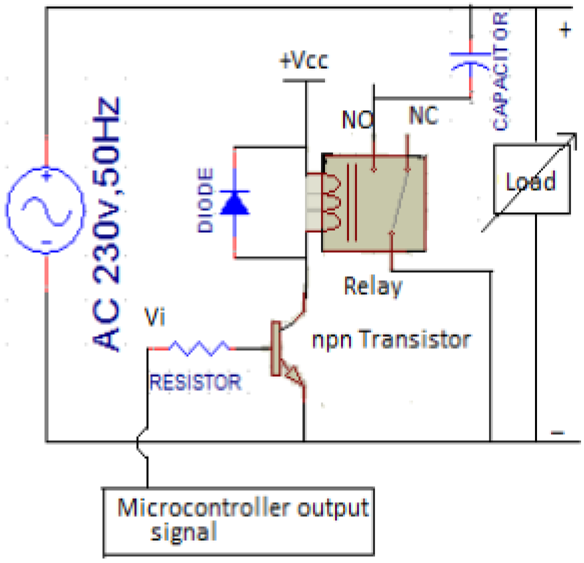

Fig. 6. Relay Circuit

IV. CONCLUSION

This paper presents a system that uses 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. This system with static capacitor can improve the power factor of any distribution line from load side. As, if this static capacitor will apply in the high voltage transmission line then its rating will be unexpectedly large which will be uneconomical and inefficient. So a variable speed synchronous condenser can be used in any high voltage transmission line to improve power factor and the speed of synchronous condenser can be controlled by micro controller or any controlled device. A reduction in the overall cost of electricity can be achieved by improving the power factor to a more economic level. The supply will be able to support additional load which may be of benefit for an expanding company. Reducing the load on distribution network components by power factor improvement will result in an extension of their use. It can also be installed in a shorter period of time and is not subject to environmental considerations such as shading or weather. The benefits of installing power factor correction equipment, irrespective of the lack of Enhanced Capital Allowances, are very clear.

Electricity costs are reduced, sometimes by thousands of pounds each year. The reduced electrical burden on cables and electrical components leads to increased service life. Finally, by using power factor correction equipment, additional capacity is created in the users systems for other loads to be connected.

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