

# PLC Based Power Factor Correction and SCADA Monitoring

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**ABSTRACT:** Power factor correction (PFC) is a process of negotiating the unwanted effects of electric loads that create a power factor less than one. Power factor correction may be applied either by an electrical power transmission utility to enhance the efficiency of transmission network. In this paper three transformers of different ratings have been used which acts as inductive load each of which produce different power factor variation. The power factor of the supply line is directly monitored by the Power Meter which is connected in parallel to the supply line. The value of the capacitance (capacitor bank) required for correcting the power factor variation due to each transformer and their combination is found out separately. Capacitor bank for the respective load is triggered by using PLC, which connects the capacitor bank parallel to the load and thereby bringing the power factor near to unity.

**KEYWORDS:** Power Factor, Programmable Logic Controller, Supervisory Control and Data Acquisition, Power meter, Industrial control system, Remote control unit.

## I. INTRODUCTION

Power Factor can be explained as relationship between the active power and apparent power. For understanding power factor, look at the figure 1 in which a horse is dragging a car along a track. As the railroad path is not even, the horse should pull the car at an angle to the track. Now the horse pulls the car at some angle to the direction in which car is travelling. The force needed to pull the car along the given track is working power. Total power in this case is horse power. As a result of the angle created by the horse's pull, (not all horse power taken into account) is utilized to drag the car along the given path. The car cannot move in sideways direction; thus the effort made by horse in sideways is not taken into account.

The angle which the horse force is applied is basis of power factor. It can be defined as the ratio between real power to apparent power. If the horse is present between the centre of the track, the angle made by force because of side pull decreases and the real power apparent power becomes almost equal. As a result, the ratio between real and apparent power or the power factor of given system becomes equal to 1. As the power factor tends to 1, the reactive power tends to 0.

$$\text{Power Factor (pf)} = \frac{\text{Real Power}}{\text{Apparent Power}}$$

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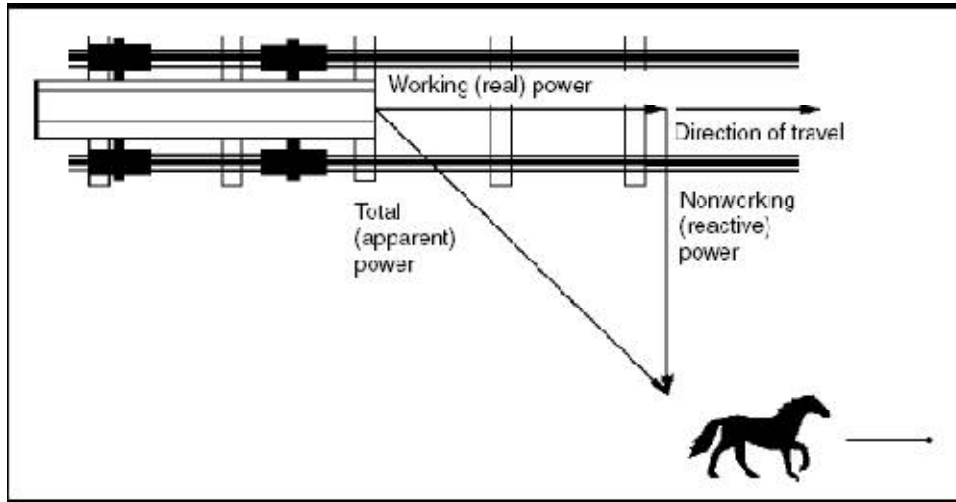


Fig. 1 Relation between active power and reactive power

The relation between the types of power used to run the given force system is generally as a right-angled triangle as in figure 1. Active power is indicated at right angles to reactive power, generally known as waste as it is out-of-phase, and work done is not taken into account. So, because of the angle created horse needs to do more work compared to the required original work.

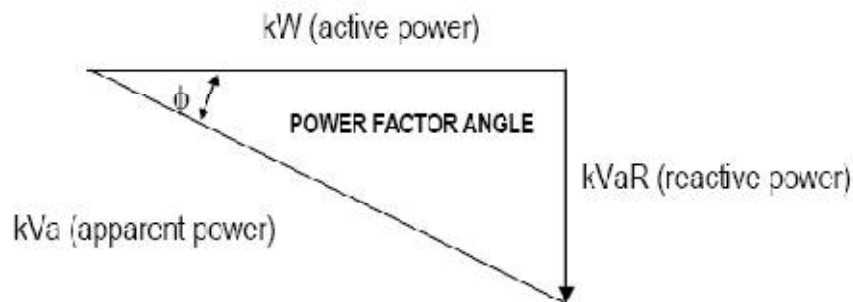


Fig. 2 Power Angle Triangle

Power Factor of a system has generally a value between 0 and 1 which is equal to the ratio of active power to apparent power or  $\cos \phi$  as shown in fig 2. The bigger the number is, the more powerful the system becomes. So, a system with a Power Factor of 0.9 is much superior to one with a low Power Factor of 0.6. An electrical system which has power factor of 1 uses 100% useful current without any power loss.

## II. RELATED WORKS

Though correction of power factor is very old practice, many of the authors below have suggested and prescribe many ways of power factor correction:

1. Starting from 1988, Sharkawi et al. suggested a continuous trial to develop adaptive power factor controller (APFC). The APFC was capable for compensating adaptively the apparent power in case of changing loads rapidly without any addition of harmonics to the power system. (Sharkawi et al. 1988)
2. Ioannides and Papadopoulos proposed the speed and power factor of a slip power recovery which had adjustable speed drive and for optimizing the process speed. They used variable-voltage-variable-frequencies

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- power converter to vary the speed. Digital controller was used which had the function of power converter which will provide power factor regulation and online speed. (Ioannides and Papadopoulos 1991)
- Manual et al. proposed microcomputer-based model power factor controller (PFC) for counter acting the reactive power of fast changing loads by switching capacitors which are present in binary ratio size. Zero voltage static switches were used. Control strategies of four different types were tested, e.g. (1) binary search (2) unit step control (3) look up table method and (4) successive approximation. Characteristics of independent current control in each phase, switching of capacitor in one cycle after sensing reactive current. For prevention of the occurrence of transients zero voltage switches were used. Logic for switch failure detection is also taken into account in the software programming. (Manual et al. 1994)

### III. METHODOLOGY

The problem of low pf can be solved by connecting power factor correction capacitors to the industrial electrical system. The capacitors can be of low rating for lower rated loads, and rating of capacitors will increase for loads with high rating.

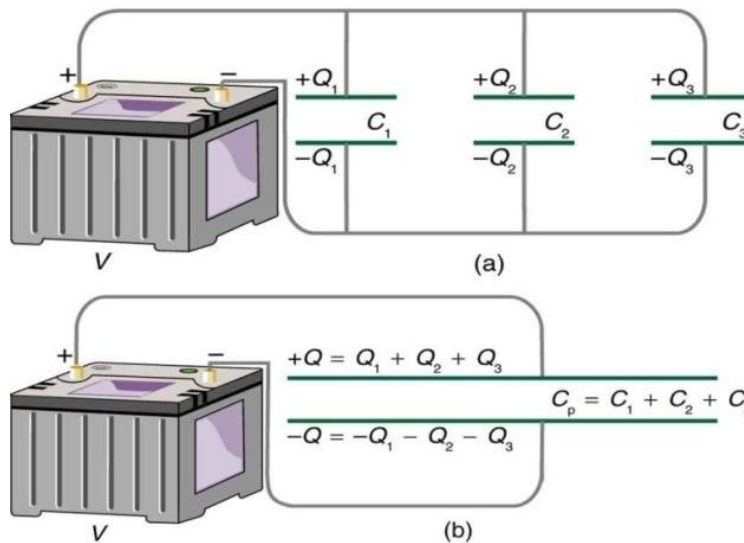


Fig. 3 Capacitors Connected Parallel To The Load.

The capacitors are made as a combination according to the respective loads and then they are connected parallel to the load as shown in figure 3. Capacitors give needed reactive power (KVAR) to the given industrial power supply. By providing the reactive power, it decreases the total amount of apparent power supplied.

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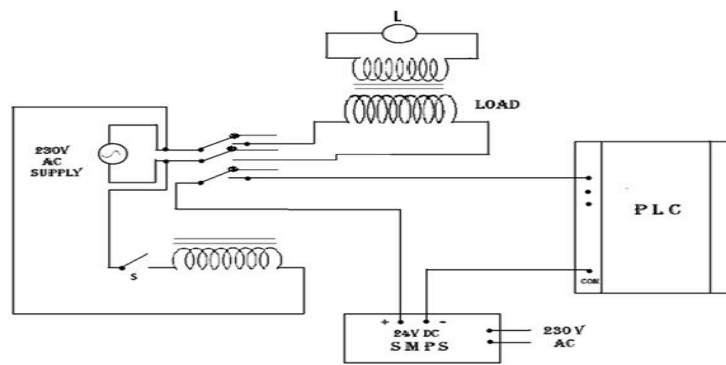
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## IV. EXPERIMENTAL SETUP

Following are the experimental setup made for the experiment:

- a) **Input Design:** The main components of the input side are the transformer (i.e. the inductive load) and the 4 pole relay. The 4 pole relay has 14 terminals. The terminals 1,2,3,4 are normally closed and 5,6,7,8 are



normally open. Terminals 9,10,11,12 are common terminals 13 and 14 are meant for excitation of relay. In Fig. 4 Input design

the figure 4 the excitation coil and the switch S (toggle switch) are shown. When S is closed, the coil gets energized by the 230 V supply. Hence the terminals of relay switch gets attracted towards the normally open terminals. The transformer is connected across the terminals 7 and 8. So the circuit is completed and the load gets active by 230 V supply. Here the 24 V supply is provided by the SMPS. Whenever the load gets ON, +24 V is given to the PLC through the 5th terminal.

- b) **Output Design:** The output side mainly consists of the capacitor banks and the 2 pole relay as shown in fig. 5. The 2 pole relay is energized by the 24 V dc supply. This supply is fed from the PLC i.e. once the transformer load is ON, a 24 V dc supply comes across the PLC. As a result, PLC energizes the relay coils and the corresponding capacitor bank will be switched ON. Hence the power factor is corrected to a value nearly equal to 1.

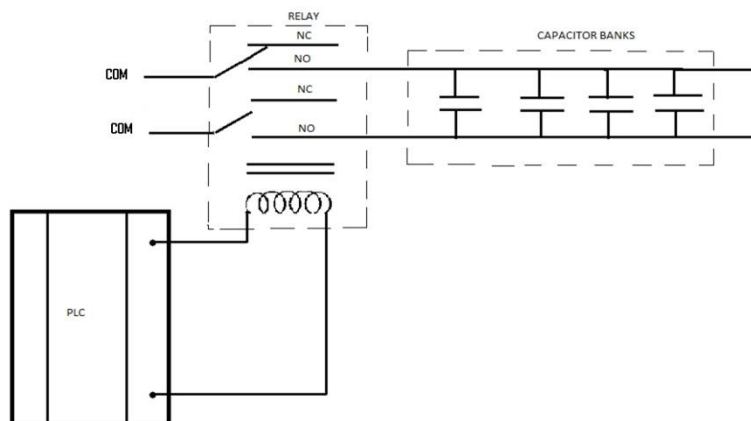


Fig. 5 Output design

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c) **Power Meter Wiring:** The most important component in the hardware is the power meter. The

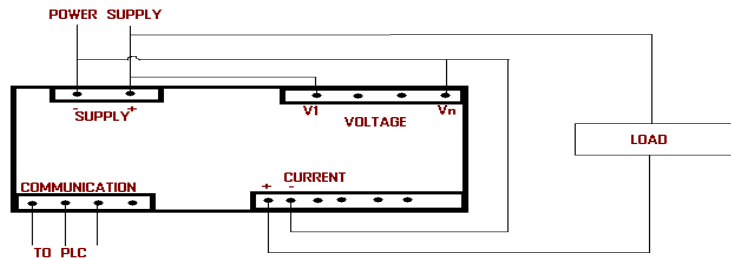


Fig. 6 Power meter wiring

main ports in a power meter are the supply port, voltage port, current port and communication port as in fig. 6. A 230V supply will be given to the supply port. Here voltage port is used to measure the voltage across the load and the current port is used to measure the current. So the voltage port is connected parallel to the supply and the current port is connected in Series with the supply. The communication port is connected to the serial adapter of the PLC, so it reads the power meter.

d) **Terminal Block Wiring:**

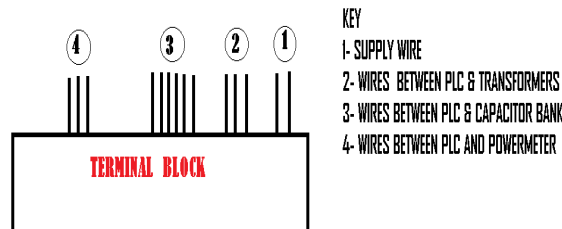


Fig. 7 Terminal block wiring

The first two wires are the supply wire through these wires the PLC feeds 24 V dc supply to the hardware as shown in fig. 7. 2 represents three wires which connects the three transformer loads to the PLC input port, so that the PLC gets indication about the status of input side. 3 represents the six wires which connects the output ports of the PLC to the six capacitor banks. 4 represents the three wires which connect the communication port of the power meter to the PLC.

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## e) PLC Wiring:

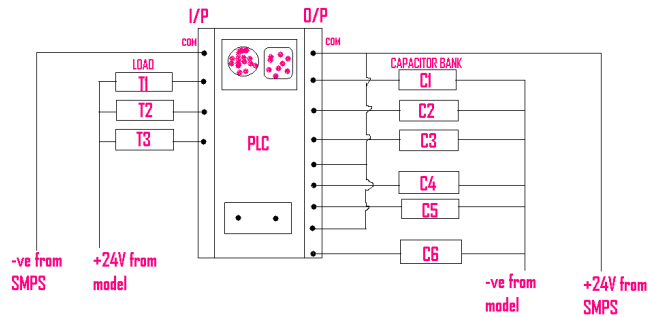


Fig. 8 PLC wiring

As shown in fig. 8, the three transformer loads are connected to the input ports of the PLC. The common terminal of the input side is connected to the negative terminal of SMPS. Connections from the capacitor banks are given to the output port of the PLC. The common terminal of the output side is connected to the positive terminal of SMPS. The communication port of the PLC is connected to the system via the communication cable and the serial adapter is connected to the powermeter. Through the supply ports, a 24 V dc supply is given to the PLC.

## f) Ladder Programming:

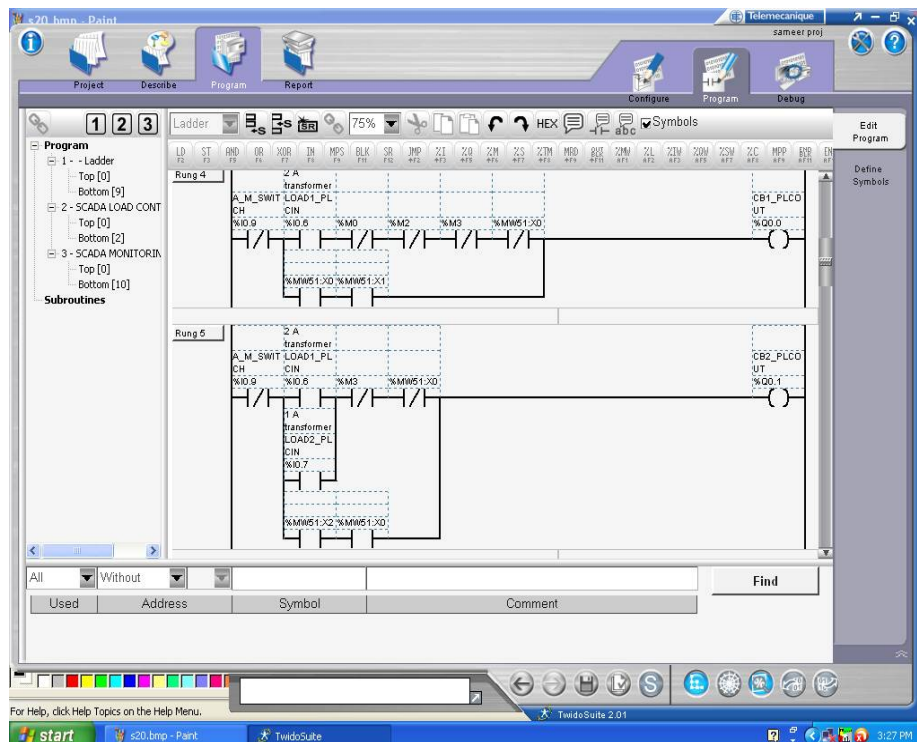


Fig. 9 Ladder programming

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Ladder logic is a programming language that represents a program by a graphical diagram based on the circuit diagrams of relay-based logic hardware. It is primarily used to develop software for Programmable Logic Controllers (PLCs) used in industrial control applications. These programmes are then downloaded to PLC using communication cable. Ladder program is shown in fig. 9.

### g) Final SCADA Model:

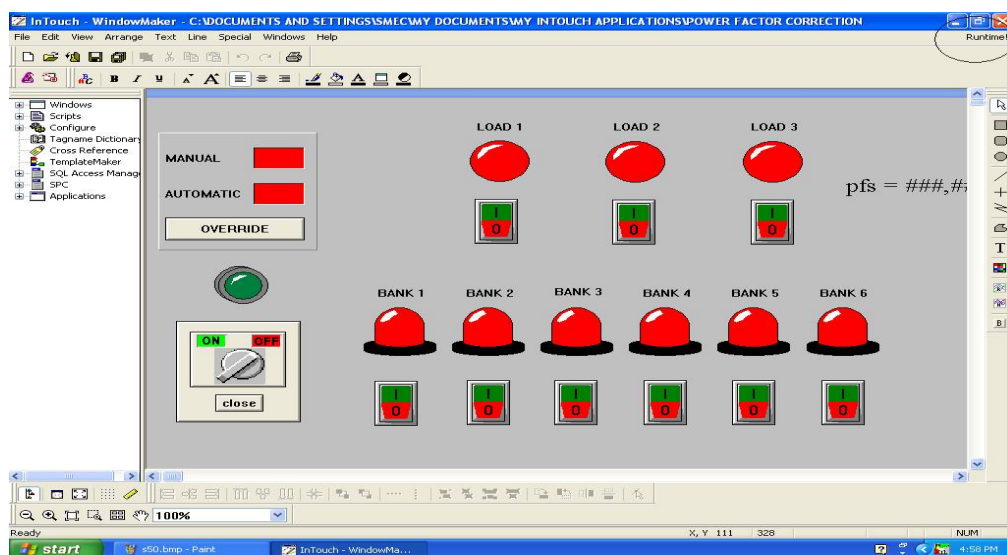


Fig. 10 SCADA model

SCADA model has been designed as per the requirements to show the different parameters like load, switches, capacitor banks etc. It also facilitates the user to select whether he wants to select automatic or manual triggering of capacitor banks. Even the powermeter has been synchronized to show the fluctuations in the power factor directly on the users screen as shown in fig. 10.

## V. EXPERIMENTAL RESULTS

A project on “Industrial Power Factor Correction” has been done. The aim of the project was to improve the power factor up to 0.9 and it was possible to improve the power factor till 0.71.

Load(s)	“ON”	Corresponding Capacitor Banks	Earlier PF	Corrected PF
L1		CB1+CB2+CB3	0.277	0.557
L2		CB2+CB6	0.502	0.710
L3		CB6	0.380	0.613
L1+L2		CB1+CB3+CB5+CB6	0.345	0.598
L2+L3		CB2+CB3+CB6	0.480	0.700
L1+L3		CB1+CB2+CB5+CB6	0.300	0.601
L1+L2+L3		CB3+CB4	0.342	0.626

Table 1 PFC details

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Table 1 shown above explains the final result of corrected power factor. There are total seven cases which has been considered. In case 1, load 1 is switched on and earlier pf was 0.277. After triggering of capacitor banks 1, 2 and 3, corrected pf was found to be 0.557. In second case load 2 is switched on. After triggering the corresponding capacitors the corrected pf was found to be 0.710. In third case the corrected pf was found to be 0.613. After this combination of loads were switched on. In case when load 1 and 2 was switched on, earlier pf was found to be 0.345. After triggering the required capacitor banks the corrected pf was found to be 0.598. Similarly in fifth and sixth case corrected pf was found to be 0.700 and 0.601 respectively. In last case all three loads were taken into account. After switching the required capacitors the corrected pf was noted as 0.626.

## VI. CONCLUSION

Power factor correction has got wide range of advantages in industrial sector. The most important one is reducing the electricity tariff. Usually capacitor banks used for power factor correction are placed in a scattered manner throughout the industry for better performance. Fixed shunt capacitors that we have used here are the least expensive way to achieve near unity power factor by providing a static source of leading reactive current. They can be installed either close to the highly reactive loads or at the service entrance.

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