

Advanced Domestic Power Saving Power Factor Improvement

Abhinandana M, Madukesh B V, Naveen kumar B V, David Living ston, Dayananda B R

Abstract --Power factor is defined as the ratio of real power to apparent power. Where real power is the time integral of the instantaneous power measured over a full period and the apparent power is simply the product of the RMS voltage and RMS current measured over the entire period.

Keywords— Apparent power, capacitor bank, power factor, real power and relay

1 INTRODUCTION

Unlike Director Current Circuits, where only resistance restricts the current flow, in Alternating Current Circuits, there are other circuits aspects which determines the current flow; though these are akin to resistance, they do not consume power, but loads the system with reactive currents; like D.C. circuits where the current multiplied by voltage gives watts, here the same gives only VA.

Like resistance, these are called "Reactance". Reactance is caused by either inductance or by capacitance. The current drawn by inductance lags the voltage while the one by capacitance leads the voltage. Almost all industrial loads are inductive in nature and hence draw lagging wattless current, which unnecessarily load the system, performing no work. Since the capacitive currents is leading in nature, loading the system with capacitors wipes out them.

2 CAPACITORS FOR POWER-FACTOR IMPROVEMENT

A. Altrnating current circuits

Whatever the power factor is, however, the generating authority must install machines capable of delivering a particular voltage and current even though, in a particular case, not all the voltage and current products is being put to good use. The generators must be able to withstand the rated voltage and current regardless of the power delivered. For example, if an alternator is rated to deliver 1000A at 11000 volts, the machine coils must be capable of carrying rated current.

The apparent power of such a machine is 11 M V A and if the load power factor is unit this 11 MVA will be delivered and used as 11 MW of active power i.e. the alternator is being used to the best of its ability. If, however, the load power factor is say, 0.8 lagging, then only 8.8 MW are taken and provide revenue, even though the generator still has to

• Department of EEE, Dr.T.Thimmaiah Institute of Technology, Kolar
Gold Fields,India Email: mail2abhighowda@gmail.com,

be rated at 1000A at 11 kV. The lower the power factor, the

worse the situation becomes from the supply authorities' viewpoint. Accordingly, consumers are encouraged to improve their load power factor and in many cases are penalized if they do not. Improving the power factor means reducing the angle of lag between supply voltage and supply current

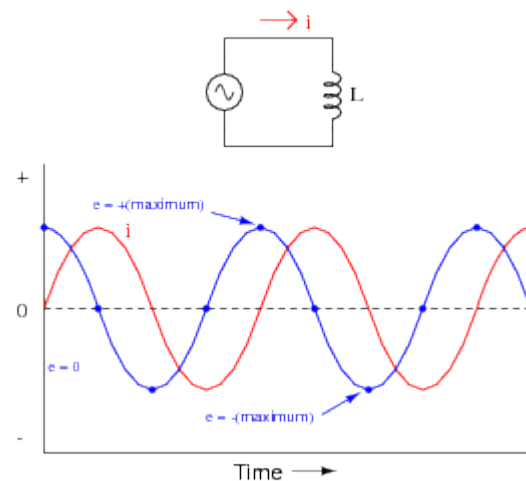


Figure I-1 Alternating circuit and waveform

B. Power factor in linear circuits

The template is used to format your paper and style the text. All margins, column widths, line spaces, and text fonts are prescribed; please do not alter them. You may note peculiarities. For example, the head margin in this template measures proportionately more than is customary. This measurement and others are deliberate, using specifications that anticipate your paper as one part of the entire proceedings, and not as an independent document. Please do not revise any of the current designations.

3 POWER FACTOR CORRECTION

The power factor of an AC electric power system is defined as the ratio of the real power flowing to the load to the apparent power in the circuit, and is a dimensionless number between 0 and 1 (frequently expressed as a percentage, e.g. 0.5 pf = 50% pf). Real power is the capacity of the circuit for performing work in a particular time. Apparent power is the product of the current and voltage of the circuit. Due to energy stored in the load and returned to the source, or due to a non-linear load that distorts the wave

shape of the current drawn from the source, the apparent power will be greater than the real power.

In an electric power system, a load with a low power factor draws more current than a load with a high power factor for the same amount of useful power transferred. The higher currents increase the energy lost in the distribution system, and require larger wires and other equipment. Because of the costs of larger equipment and wasted energy, electrical utilities will usually charge a higher cost to industrial or commercial customers where there is a low power factor.

Linear loads with low power factor (such as induction motors) can be corrected with a passive network of capacitors or inductors. Non-linear loads, such as rectifiers, distort the current drawn from the system. In such cases, active or passive power factor correction may be used to counteract the distortion and raise the power factor. The devices for correction of the power factor may be at a central substation, spread out over a distribution system, or built into power-consuming equipment.

4 DEFINITION AND CALCULATION

AC power flow has the three components: real power (also known as active power) (P), measured in watts (W); apparent power (S), measured in volt-amperes (VA); and reactive power (Q), measured in reactive volt-amperes

The power factor is defined as:

In the case of a perfectly sinusoidal waveform, P, Q and S can be expressed as vectors that form a vector triangle such that:

If θ is the phase angle between the current and voltage, then the power factor is equal to the cosine of the angle, and:

Since the units are consistent, the power factor is by definition a dimensionless number between 0 and 1. When power factor is equal to 0, the energy flow is entirely reactive, and stored energy in the load returns to the source on each cycle. When the power factor is 1, all the energy supplied by the source is consumed by the load. Power factors are usually stated as "leading" or "lagging" to show the sign of the phase angle.

If a purely resistive load is connected to a power supply, current and voltage will change polarity in step, the power factor will be unity (1), and the electrical energy flows in a single direction across the network in each cycle. Inductive loads such as transformers and motors (any type of wound coil) consume reactive power with current waveform lagging the voltage.

Capacitive loads such as capacitor banks or buried cable generate reactive power with current phase leading the voltage. Both types of loads will absorb energy during part of the AC cycle, which is stored in the device's magnetic or electric field, only to return this energy back to the source during the rest of the cycle.

For example, to get 1 kW of real power, if the power factor is unity, 1 kVA of apparent power needs to be

transferred ($1 \text{ kW} \div 1 = 1 \text{ kVA}$). At low values of power factor, more apparent power needs to be transferred to get the same real power. To get 1 kW of real power at 0.2 power factor, 5 kVA of apparent power needs to be transferred ($1 \text{ kW} \div 0.2 = 5 \text{ kVA}$). This apparent power must be produced and transmitted to the load in the conventional fashion, and is subject to the usual distributed losses in the production and transmission processes.

Electrical loads consuming alternating current power consume both real power and reactive power. The vector sum of real and reactive power is the apparent power. The presence of reactive power causes the real power to be less than the apparent power, and so, the electric load has a power factor of less than 1.

5 DISTORTION POWER FACTOR

The distortion power factor' describes how the harmonic distortion of a load current decreases the average power transferred to the load.

$$\text{Distortion power factor} = \frac{1}{\sqrt{1 + THD_i^2}} = \frac{I_{1,rms}}{I_{rms}}$$

THDi is the total harmonic distortion of the load current. This definition assumes that the voltage stays undistorted (sinusoidal, without harmonics). This simplification is often a good approximation in practice. $I_{1,rms}$ is the fundamental component of the current and I_{rms} is the total current - both are root mean square-values.

The result when multiplied with the displacement power factor (DPF) is the overall, true power factor or just power factor (PF)

A. Location of power-factor improvement capacitor banks:

Any installation including the following types of machinery or equipment is likely to have low power factor which can be corrected, with a consequent saving in charges, by way of reduced demand charges, lesser low power factor penalties:

1. Induction motors of all types (which from by far the greatest industrial load on a. c. mains).
2. Power thyristor installation (for D.C. motor control and electro-chemical processes).
3. Power transformers and voltage regulators.
4. Welding machines
5. Electric-arc and induction furnaces.
6. Choke coils and magnetic system.
7. Neon signs and fluorescent lighting.

Apart from penalties like maximum demand charges, penalty for low power factor, the factory cabling and supply equipment can be relieved of a considerable wattles or reactive load, which will enable additional machinery to be connected to the supply without enlarging these services. Additionally, the voltage drop in the system is reduced.

The method employed to achieve the improvements outlined involves introducing reactive kVA (kvar) into the system in phase opposition to the wattles or reactive current mentioned above the effectively cancels its effect in the system. This is achieved either with rotary machines (synchronous condensers)

B. Hardware testing

In electronics, a continuity test is the checking of an electric circuit to see if current flows (that it is in fact a complete circuit). A continuity test is performed by placing a small voltage (wired in series with an LED or noise-producing component such as a piezoelectric speaker) across the chosen path. If electron flow is inhibited by broken conductors, damaged components, or excessive resistance, the circuit is "open".

Devices that can be used to perform continuity tests include multi meters which measure current and specialized continuity testers which are cheaper, more basic devices, generally with a simple light bulb that lights up when current flows.

An important application is the continuity test of a bundle of wires so as to find the two ends belonging to a particular one of these wires; there will be a negligible resistance between the "right" ends, and only between the "right" ends.

This test is the performed just after the hardware soldering and configuration has been completed. This test aims at finding any electrical open paths in the circuit after the soldering. Many a times, the electrical continuity in the circuit is lost due to improper soldering, wrong and rough handling of the PCB, improper usage of the soldering iron, component failures and presence of bugs in the circuit diagram. We use a multi meter to perform this test. We keep the multi meter in buzzer mode and connect the ground terminal of the multi meter to the ground. We connect both the terminals across the path that needs to be checked. If there is continuation then you will hear the beep sound.

6 POWER ON TEST:

This test is performed to check whether the voltage at different terminals is according to the requirement or not. We take a multi meter and put it in voltage mode. Remember that this test is performed without microcontroller. Firstly, we check the output of the transformer, whether we get the required 12 v AC voltage.

Then we apply this voltage to the power supply circuit. Note that we do this test without microcontroller because if there is any excessive voltage, this may lead to damaging the controller. We check for the input to the voltage regulator i.e., are we getting an input of 12v and an output of 5v. This 5v output is given to the microcontrollers' 40th pin. Hence we check for the voltage level at 40th pin. Similarly, we check for the other terminals for the required voltage. In this way we can assure that the voltage at all the terminals is as per the requirement.

A. Power Factor Test Layout:

An arrangement with supply source 230v, one lamp, 2 numbers low value resistors of 10R/10W for measuring current, a choke are all connected in series. Capacitors are required to be connected in parallel through relay contacts to improve power factor. While the SW2 switch is off, the choke acts as an inductor and same current will flow in R1 and R2. A CT is used the primary side of which is connected to the common point of R1 and R2. The other point of the CT goes to the common point of a SPDT S1 switch. While the SPDT switch is moved to right then the CT counts across R2 and the voltage drop proportional to the current is sensed by it to develop increased voltage at its primary. This voltage is given to the current sensing circuit. While the SPDT switch is moved to left then the CT counts across R1 and the voltage drop proportional to the current is sensed by it to develop increased voltage at its primary. While no capacitors are switched the voltage drop across R1 and R2 are same. This voltage drop is proportional to lagging current. Thus the primary voltage from the CT provides lagging current reference to the current sensing circuit. The microcontroller based control circuit thus receives zero current reference and compares with the zero voltage reference for calculating the power factor based on their time difference. Microcontroller output develops logic high for appropriate no. of port pins to feed to ULN2003 the relay driver to switch on capacitors to come in parallel to the inductive load that is the choke. So depending on the time difference required no. Of relays are switched on, there by switching additional capacitors till the power factor is near unity. Once the capacitors are switched on the R2 current becomes compensated while current flowing through R1 remains unchanged which is the lagging current.

Thus depending on the switch S1 position one can sense the lagging current or the compensated current and the display provides accordingly the time delay between voltage, current with power factor display. In case a linear load is required switch S2 is closed that by-passes the choke L2 and the CT in this case reads unity power factor.

B. Figures and Tables

This circuit consists of DC power supply unit, zero voltage crossing detectors, Micro-controller, LCD display, Relays and Capacitor bank and Load circuit. Let us see how it operates. The required DC power supply for Micro-controller and other peripherals is supplied by the DC power supply.

For the calculation of the power factor by the Micro-controller we need digitized voltage and current signals. The voltage signal from the mains is taken and it is converted into pulsating DC by bridge rectifier and is given to a comparator which generates the digital voltage signal. Similarly the current signal is converted into the voltage signal by taking the voltage drop of the load current across a resistor of 10 ohms. This A.C signal is again converted into the digital signal as done for the voltage signal. Then these digitized voltage and current signals are sent to the micro-controller. The micro-controller calculates the time difference between the zero crossing points of current and voltage, which is directly proportional to the power factor

and it determines the range in which the power factor is. Micro-controller sends information regarding time difference between current and voltage and power factor to the LCD display to display them, Depending on the range it sends the signals to the relays through the relay driver. Then the required numbers of capacitors are connected in parallel to the load. By this the power factor will be improved.

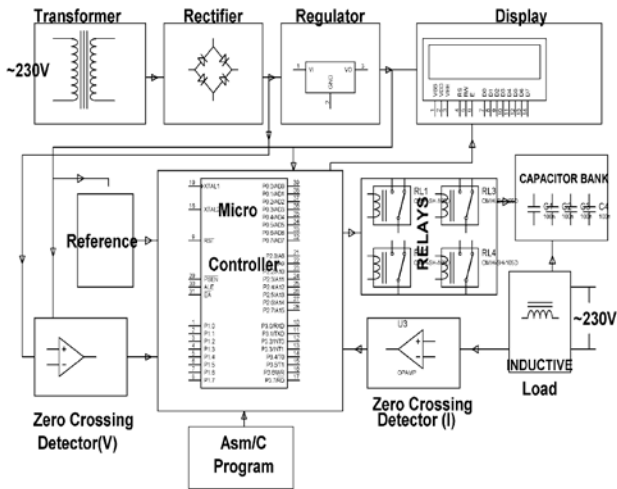


Figure V-1 Block diagram and circuit of power factor improvement

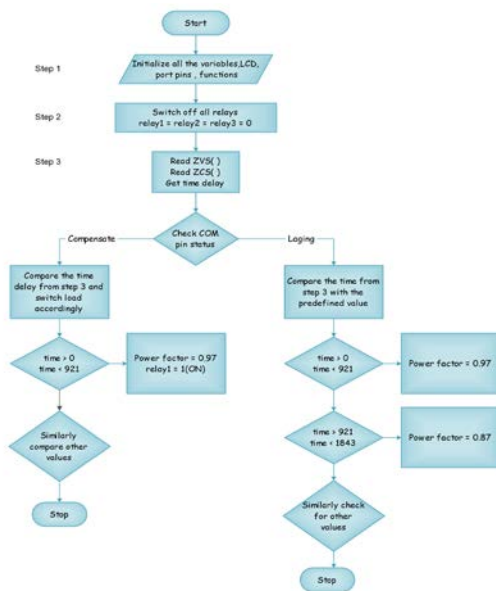


FIGURE V-2FLOW CHART



Figure V-3 Experimental set up

7 CONCLUSION

In a purely resistive AC circuit, voltage and current waveforms are in step (or in phase), changing polarity at the same instant in each cycle. All the power entering the loads is consumed. Where reactive loads are present, such as with capacitors or inductors, energy storage in the loads result in a time difference between the current and voltage waveforms. During each cycle of the AC voltage, extra energy, in addition to any energy consumed in the load, is temporarily stored in the load in electric or magnetic fields, and then returned to the power grid a fraction of a second later in the cycle. The "ebb and flow" of this nonproductive power increases the current in the line. Thus, a circuit with a low power factor will use higher currents to transfer a given quantity of real power than a circuit with a high power factor. A linear load does not change the shape of the waveform of the current, but may change the relative timing (phase) between voltage and current.

REFERENCES

- [1] B, Kim,S.Hong,Y.jeong and D,Eom, The study of Power saving to a Smart home,Powersystem computation conference (PSCC),Sevilla,2428 june 2002
- [2] K.R.Tremblay,Jr.(6/09),Energy conservation in the home
- [3] G8 summit agenda,Hokkaido toyako May2008
- [4] Lurita Doan Administrator Doan Issues GSA Telework Challenge 2007
- [5] A. Saedella,M. Devarasetty,J Eccli, D,Kharitonov "Effeicient scaling for Multiservice Networks"
- [6] "Achieving WAN opertational efficiency with the cisco ASR 100 Series",Cisco system 2008
- [7] Y,Rahal,H Pigot,and P,Mabilleau,Location Estimation in smart home:System Implementation and Evaluation using Experimental Data VOL,2008