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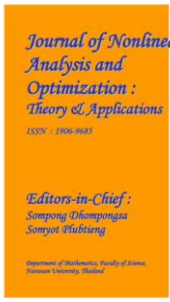

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AN OVERVIEW OF THE TECHNIQUES FOR IMPROVING THE POWER FACTOR

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ABSTRACT: Alternating current is the most common method for generating, distributing, and transmitting electricity. As a result, the power factor becomes apparent quite quickly. Many loads, such arc lamps and induction motors, are mostly inductive, resulting in a low trailing power factor. An negative power factor causes increased current, which leads to additional active power losses across the entire power system, including the generator at the power station and the utilization devices. To maximize the supply system's efficiency in both technical and economic terms, the power factor must be kept to an absolute minimum. This paper will look at various ways for boosting power factor.

Keywords: *energy, distributed, inductive, utilization, active.*

1. INTRODUCTION

Power factor is the cosine of the angle created by current and voltage in an alternating current circuit. In general, the voltage and current phases in an alternating current circuit are opposite. The symbol cosΦ represents the power factor of the circuit. A lagging power factor arises when the current in an inductive circuit lags behind the voltage. Voltage is followed by current, and power factor takes precedence in a capacitive circuit. Analyze an inductive circuit with a lag angle of and a supply voltage V to determine trailing current I. The circuit's phasor diagram is shown in the figure.

The circuit current consists of the perpendicular components indicated below:

- The active component, Icos1, is in phase with V.
- When isin is 90 degrees out of phase with V, it's called the reactive or wattless component.

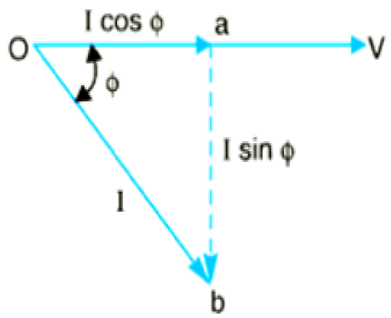

Figure 1 shows the phasor diagram for the lagging circuit.

The reactive component is determined by measuring the power factor. A tiny reactive component causes a transient phase angle Φ, resulting in a high power factor (cosΠ). A circuit with low IsinΦ reactive current will have a high power factor, while the opposite is true.

A. Power triangle

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The power factor can be calculated by measuring the quantity of energy consumed by the AC circuit. Figure 2 depicts the power triangle OAB, which is formed by multiplying each side of the triangle OAB in Figure 1 by voltage.

Where

OA = VICosΦ and represent the active power in watts or kW

AB = VISinΦ and represent the reactive power in VAR or KVAR

OB = VI and represent the apparent power in VA or KVA

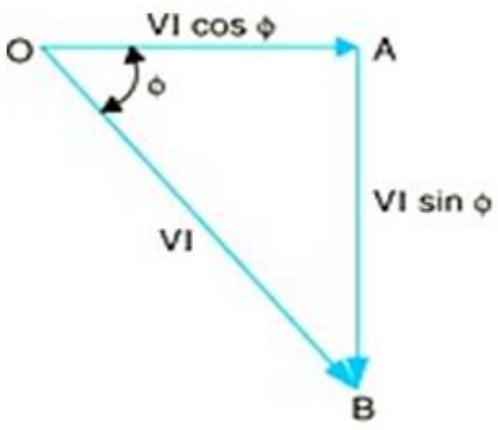

Fig2 The Triangle of Power

The power triangle emphasizes the following points: Active power and reactive power, which are perpendicularly aligned, make up the apparent power of an AC circuit.

$$OB^2 = AB^2 + AB^2$$

Or $(\text{apparent power})^2 = (\text{active power})^2 + (\text{reactive power})^2$

Or $(kVA)^2 = (kW)^2 + (kVAR)^2$

(ii) Power factor, $\cos\Phi = \frac{OA}{OB} = \frac{\text{active power}}{\text{apparent power}} = \frac{kW}{kVA}$

The power factor of a circuit is the proportion of active power to perceived power.

The cause for the low power factor is the lag in reactive power. The power triangle predicts that a circuit with a lower reactive power component will have a higher power factor.

$$kVAR = kVASin\Phi = \frac{kWSin\Phi}{Cos\Phi}$$

$$kVAR = kWtan\Phi$$

For leading currents, the power triangle is reversed. Recognizing this fact is crucial for increasing the power factor. A leading reactive power-consuming component, such as a capacitor, is connected in parallel to improve the load's power factor. This somewhat counteracts the burden's trailing reactive power.

The power factor of a circuit can be determined using three different methods.

The power factor is the cosine of the angle created by voltage (V) and current (I).

(b) Power factor = $\frac{R}{Z} = \frac{Resistance}{Impedance}$

(c) Power factor = $\frac{VICos\Phi}{VI} = \frac{Active\ power}{Apparent\ Power}$

Reactive power is wasted and rendered ineffective within the circuit. Within the circuit, it moves bidirectional and alternates. A wattmeter is ineffective for measuring reactive power.

2. PROBLEM FORMULATION

Disadvantages of Low Power Factor

Power factor is important in alternating current circuits because it controls the amount of power utilized.

$$P = VICos\Phi \quad \text{(For single phase supply)}$$

$$\text{therefore} \quad I = \frac{P}{VCos\Phi}$$

$$P = \sqrt{3}VICos\Phi \quad \text{(for 3phase supply)}$$

$$I = \frac{P}{\sqrt{3VCos\Phi}}$$

It is clear from above that for fixed power and voltage, the load current is inversely proportional to the For constant voltage and power, it is clear that load current varies inversely with power factor. In the other way, a drop in power factor causes an increase in discharge current. When the power factor falls below 1,

it leads to higher capacity (KVA). Assessment of equipment: Kilovolt-amperes (KVA) are the standard unit of measurement for electrical equipment, including alternators, switchgear, and transformers.

As

$$kVA = \frac{kW}{Cos\Phi}$$

- ➢ The power factor and KVA rating of the apparatus are inversely proportional. A lower power factor leads in a higher KVA rating. As a result, in order for the equipment to perform with a low power factor, its KVA rating must be increased, which results in larger dimensions and a higher cost.
- ➢ To transmit a certain amount of power and carry a higher current at a constant voltage and

a low power factor, the conductor must be larger. This requires big conductor diameters.

- The large current flow with a low power factor causes elevated copper losses, which add to I2R losses throughout the supply system. This leads to low efficacy.
- Poor voltage control is caused by high current at a low lagging power factor; as a result, voltage drops in alternators, transformers, transmission lines, and distributors increase. As a result, the supplied voltage is reduced, preventing the gadget from operating properly.
- Additional hardware, such as a voltage regulator, is needed to keep the receiving end voltage within acceptable limits.
- The trailing power factor reduces the handling capacity of all system components. The reactive component of current prevents the full use of installed capacity.

Causes of Low Power Factor

In economics, a low power factor is unnecessary. The power factor of the whole load on the supply system frequently goes below 0.8. The reasons for an insufficient power factor are as follows:

- The majority of AC motors, including three-phase and single-phase induction motors, have a low trailing power factor. When operating under moderate load, these motors have a power factor of 0.2 to 0.3.
- However, when operating at full load, the power factor rises to 0.8 or 0.9.Arc lamps, electric discharge lamps, and industrial heating furnaces commonly have a low trailing power factor.
- The electrical system has changing loads, with peak demand in the morning and evening, followed by periods of low demand. When the load is minimal, the supply voltage rises, increasing the magnetization current. Containing this reduces the power factor.

3. IMPORTANCE OF POWER FACTOR IMPROVEMENT

As previously stated, improving power factor is critical for both generators and consumers.

For consumers:

Electricity usage is billed to the client based on the units utilized and the maximum demand stated in KVA. Consumers can improve their power factor and generate annual cost savings by lowering their maximum KVA demand, avoiding the need to pay more for maximum demand. The annual cost of power factor correction equipment rises as the power factor improves. Despite this, the client saves money on an annual basis by meeting the power factor criterion.

For generating stations:

Consumers place equal attention on improving power factors as they do on generating stations. Although a power plant's generators are rated in KVA, the actual output is measured in KW.

This is the station's output.

$$kw = kVACos\Phi$$

Its ability to deliver units is therefore determined by the power factor. Increasing power factor producing stations add more kilowatt-hours to the system. An enhanced power factor increases the power plant's potential revenue.

4. POWER FACTOR CORRECTION CALCULATION

In power factor calculations, the source voltage is measured with a voltmeter, while the current drawn is measured with an ammeter. Wattmeters are used to measure active power.

As $\quad P = VICos\Phi \text{ watt}$

Or $Cos\Phi = \frac{P}{VI} = \frac{\text{Wattmeter reading}}{\text{voltmeter reading X Ammeter reading}}$

At this point, calculate the reactive power.

$$Q = VI\ Sin\Phi\ VAR.$$

By connecting the capacitor in parallel with the local demand, the reactive power can now be provided. The formula used to determine the capacitor value is as follows:

$$Q = \frac{V^2}{Xc}$$

$$C = \frac{Q}{2\pi f V^2} \text{ farad}$$

5. POWER FACTOR IMPROVEMENT METHODS

The total discharge power factor for a big generating station typically ranges between 0.8 and 0.9. There are times when the power factor falls; in such scenarios, it is often beneficial to take certain actions to increase it. Static capacitors, phase advancers, and synchronous condensers are all suitable for this application.

Fixed Capacitor:

To improve the power factor of equipment with a trailing power factor, connect capacitors in parallel. To partially or completely eliminate the load current's following reactive component, a leading current is drawn through the capacitor, also known as a static capacitor. This increases the load's power factor. The capacitor for three-phase loads can be connected in either a delta or star configuration, as shown in Figure 3. Static capacitors are commonly used in industrial applications to improve power factor. Table 1 details the pros and downsides of using static capacitors.

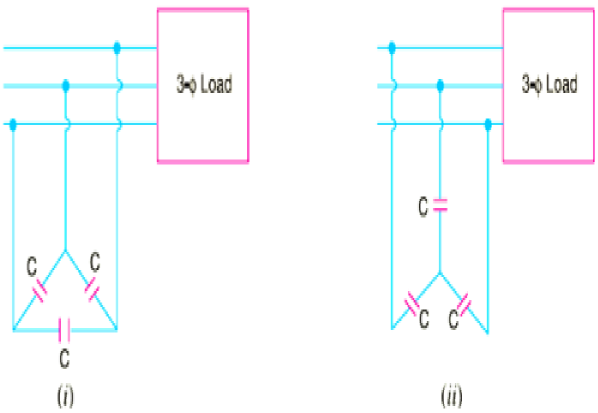

Figure 3 illustrates the parallel connection of a static capacitor to the load. Table 1: The benefits and drawbacks of using static capacitors

Advantages	Disadvantages
low losses.	Have short service life ranging from 8 to 10 years.
require little maintenance as there are no rotating parts.	Easily damaged if the voltage exceeds the rated value.
Can be easily installed as they are light and require no foundation.	Once the capacitors are damaged, their repair is uneconomical.
Can work under normal atmospheric conditions	

Synchronous Condensers:

A synchronous motor, like a capacitor, draws a leading current when overexcited. Conversely, synchronous condensers act as overexcited synchronous motors with no mechanical load. A machine linked in parallel with the power source uses leading current, which helps to compensate for the load's lagging reactive component. As a result, the disadvantaged variable has been strengthened. Figure 4 demonstrates the increase in power factor due to the synchronous condenser technology. The three-phase load draws current IL and has a low trailing power factor (CosL). The synchronous condenser draws a phase-leading current (Im) with regard to the voltage. To compute the resulting current I, which is phase-shifted by an angle Φ from the voltage, use the vector sum of Im and IL. CosΠ is larger than CosΠL when Φ is less than ΦL. The difference between CosΠL and CosΠ indicates an increase in power factor. This method is commonly used by large bulk supply substations to improve power factor. Table 2 discusses the benefits and drawbacks of synchronous condenser technology.

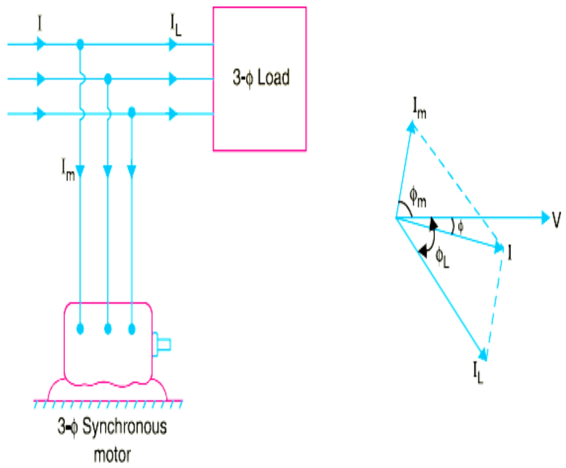

Figure 4 illustrates the Synchronous Condenser process.

Table 2 shows the advantages and downsides of using the synchronous condenser approach.

Phase advancers are us

Advantages	Disadvantages
Finer control can be achieved y varying the field excitation.	The cost is higher than static capacitors.
Possibility of overloading a synchronous condenser for short periods.	Higher maintenance and operating cost.
System stability is improved.	Lower efficiency due to losses in rotating parts and heat losses and noise.
The faults can be easily removed	Increase of short-circuit currents when the fault occurs near the synchronous condenser
	Except in sizes above 500kVA, the cost is greater than that of capacitor method.
	An additional equipment is required to start the synchronous motor, as they has no self-starting torque

ed to improve the power factor of induction motors. The stator winding of an induction motor receives an exciting current that is 90 degrees anti phase with the supply voltage. As a result, induction motors' power factors are reduced. When the exciting current comes from an external source, it is removed from the stator winding. It is possible to improve the power factor of an induction motor. Phase advancers give extra stimulation. It is referred to as the AC exciter. The auxiliary motor is installed on the motor shaft and connected to the primary motor's rotor circuit. The system stimulates the rotor circuit with ampere turns at the slip frequency.

It is feasible to run an induction motor with a leading power factor comparable to that of an overexcited synchronous motor by providing an excess of ampere cycles. Table 3 discusses the benefits and drawbacks of phase advancers.

Table 3: Advantages and Disadvantages of Using A Phase Advancer

Advantages	Disadvantages
Lagging KVAR drawn by the motor is drastically reduced due to supply of exciting ampere-turns at slip frequency	This method is conveniently used where the use of synchronous condensers are not possible
This method is conveniently used where the use of synchronous condensers are not possible	

5. BENEFITS OF POWER FACTOR CORRECTION

Power factor adjustment has various advantages. The advantages include reduced power system losses, increased load carrying capacity in current circuits, and lower demand charges on the power system. Implementing power factor modification delivers environmental and financial benefits.

Electric utility providers typically calculate demand charges using either the highest recorded demand in kilowatts (KW) or a percentage of the highest recorded demand in kilowatt-hours (KVA) (KVA meter). A poor power factor results in an increased proportion of measured KVA compared to KW consumption. Increasing the power factor and lowering the demand charge through power factor correction will eventually lower the cost of electricity.

Increased load capacity in current circuits:

Reactive current is a critical component in applications that demand reactive power. Power factor correction capacitors are placed near inductive loads at the termination points of current-carrying circuits to reduce the current flow in each. By boosting power factor, current flow can be lowered, allowing the circuit to accept larger loads without expanding the distribution network. This can result in significant cost savings over unnecessary changes. Reduced current passage in the circuit also lowers resistive losses.

Increased Voltage:

A lower power factor causes a higher current flow for a given capacity. A voltage drop may occur at the apparatus as the conductor's voltage loss increases in tandem with the line current. Improving the power factor causes an increase in the equipment's voltage by reducing conductor voltage loss

Lower power system losses:

While minimizing conductor losses does not typically result in enough cost savings to justify the installation of capacitors, it can be a useful extra benefit, especially in older facilities with lengthy feeder lines or when performing field pumping operations. In contrast to how the square of the power factor reduces conductor losses, a rise in current squared leads in an increase in losses.

The utility minimizes its carbon footprint by employing power factor adjustment, which relieves strain on the electrical grid by lowering the demand charge for the electricity system. Over time, power factor modification can reduce hundreds of tons of carbon emissions by boosting the electrical efficiency of the power system.

6. CONCLUSIONS

A careful investigation of the power factor reveals that both the utility provider and the user rely on it. Because of the low power factor, neither the utility provider nor the customers are required to pay penalties. Outages of power are eliminated. One technique to improve the efficiency of a plant is to raise the power factor of the circuit by adding appropriately sized power capacitors.

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