Power Factor Correction : The Changing Approaches

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In recent days, Power Factor Correction has gained importance with most countries across the world keen on reducing energy consumption owing to the rising pressure on resources.

What exactly is power factor? It is the ratio of the real power flowing on to the electrical load and the apparent power in the overall circuit, expressed as a dimensionless number between -1 and 1. A load having a power factor of 1.0 results in more efficient use of power, while having a -1 power factor indicates a much higher loss in the overall power supply system.

A poor power factor in the power supply can either be the result of significant phase difference between the voltage and current at the load terminals or result from high harmonic content or distorted or discontinuous current wave.

How to calculate power factor

Power factor (PF) can be defined as the cosine of the phase angle between voltage and current. So the mathematical formula can be expressed as:

PF=P/S (where PF= Power Factor, P= real power, S= apparent power)

Causes for lower Power Factor

Having a low power factor can be a result of multiple factors. Listed below are some of them:

» Transformers with low loads or without any load
» Induction motors running partially loaded or without load
» Oversized motors
» Induction or Arc furnaces
» Low power factor reactors on lighting system
» Above rated voltage level resulting in higher reactive power consumption
» Welding machines

Inductive loads require the current to create a magnetic field to perform the necessary work. As a result there is an increase in the reactive as well as apparent power and a decrease in the power factor or the efficiency of the system. The efficiency of the inductive equipment and how it affects the system's power factor depends on factors like the name of the manufacturer, the equipment's design, size and equipment itself. Inductive equipments generally have a nameplate containing its operating data, including the power factor at a rated load. International standards like IEC 61000-3-2 have been established in order to control current waveform distortion through the introduction of limits for amplitude of current harmonics.

Consequences of low Power Factor

The major consequences of low power factor are:

» Increased energy bill due to extra demand charge or Kilo-volt amperes (kVA) penalties
» Limited capability of power transformers
» Increasing electrical losses on the distribution line due to the Joule effect
» Dropping voltage and fluctuation on distribution channels
» Overload on protective and control devices, restricting the useful life
» Need for increasing conductor cross section
» Need to increase capacity of protective and control devices

Some of the worst scenarios can be losses of installation and voltage drops. The increasing flow of current due to excess of reactive power might cause interruption of energy supply and even

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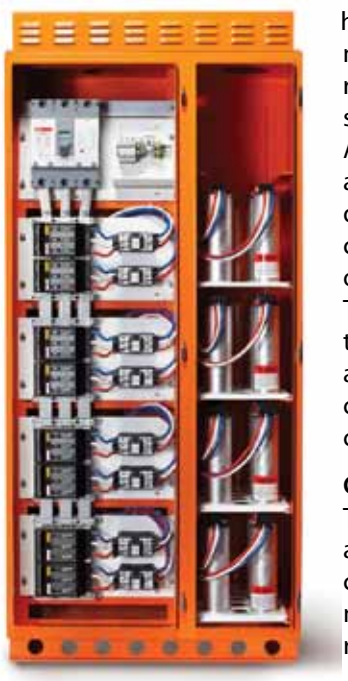
overload in some of the equipments. The risk is aggravated during periods when power supply is on the higher side. Voltage drops can also cause reduction in luminous intensity of lamps and increase current flow in electric motors.

The electrical losses mostly occur in the form of heat and are proportional to the square of the total current flow (I2 x R). As the reactive power increases, the current flow grows. This leads to a rise in power loss and low power factor is established, causing the heating up of cables and equipment.

Power Factor Correction

Power Factor Correction is a relatively new term which has been given to a technology that is widely used to restore power factor to as close to unity as is economically possible. Generally, this is done by adding capacitors to the electrical network which helps to compensate for the reactive power demand of the inductive load, helping to reduce the burden on the supply. The inductive loads draw power from supply made of resistive and inductive components. While the resistive components include load current and loss current, the inductive components comprise of leakage reactance and magnetizing current.

The power flow due to leakage reactance is dependant on the total current drawn by the motor. However, the magnetizing current is independent of the overall load on the motor. The magnetizing current usually remains between 20-60 percent of the rated full load current of the motor. Magnetizing current does not actually contribute to the actual working output of the motor. The leakage reactance and magnetizing current are regarded as the passenger components. Though they do not affect the power drawn by the motor, the passenger components can contribute to power loss within the electrical system. Power Factor Correction helps to neutralize a part of the magnetizing current of the motor.



The value of power supply reduces, as a result bringing the power factor to 1, minimizing energy wastage and improving the efficiency of the plant.

The benefits of Power Factor Correction include:

» Reduction of power consumption
» Reduced electricity bills
» Improved electrical energy efficiency
» Availability of extra kVA from the existing supply

Structure of Power Factor Correction unit

The Power Factor Correction unit consists of capacitors which serve to be reactive current generators. They reduce the total amount of power that is being drawn from the network by providing reactive power.

The structure of the Power Factor Correction unit consists of three main components, namely, smart meter, consumption profiler and scheduler.

Smart Meter : These can be installed at device level and main level or both. As part of the smart grid initiative, this is being installed at many homes. These meters measure active and reactive power consumption of appliances. Appliance level of active and reactive power is determined from the cumulative signature of power consumption. The information is used to classify the appliances and monitor the customer behavior and comfort level.

Consumption profiler : This is used to measure and analyze the data collected from smart meters. It helps to reconstruct active and reactive power consumption of each appliance. The system makes use of either plug level or non-intrusive meters. Appliance Load Metering (NIALM) is used along with a database of device characteristics in order to reconstruct appliance consumption profiles.

Scheduler : A scheduler can be installed either at home or industry or even at commercial locations. It is able to store processed consumption history and appliance profiles and helps to compute schedules for appliances in order to improve power factor while respecting other external constraints. For example, user availability, comfort, etc.

Installing Power Factor Correction unit

Installation of capacitors can be done in four different ways which can help in conserving energy and saving cost.

Correction per load groups : Capacitors are installed to repair a specific area or a set of local machines. The installation is done along with distribution boards that are used to supply this equipment. The basic disadvantage of this process is that it does not reduce the current on the feeding circuits of the equipments.

Correction on low voltage energy input : This allows significant Power Factor Correction normally with automatic capacitor banks. Such corrections can be used on electrical installations with huge amount of loads having different power and utilization regimes with little uniformity. However this process also has some basic disadvantages which include absence of relief of the feeders of each product.

Local correction : This is done by installing the capacitors next to the equipment where the power factor increase is required. This kind of correction represents the best kind of solution from a technical point of view based on following advantages:

» Minimizing the load on the feeding circuits
» Reducing the energy losses
» Generating reactive power wherever necessary

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» Option of using single system for controlling and switching both the load and capacitors, saving one set of equipments

Mixed correction : It can be regarded as the best possible solution considering technical, financial and practical aspects. It is also good for energy conservation. While installing mixed correction, the following factors should be kept in mind:

» a fixed capacitor is installed next to the secondary of the transformer
» Lighting lines with discharge lamps having low power factor reactors are corrected on the line input
» Motors with 7.5 kW or higher are corrected locally
» Motors with less than 7.5 kW are corrected in groups

Difference between harmonics and Power Factor Correction

Harmonics are distortion of normal electrical current waveform which is generally transmitted by nonlinear loads. Harmonic frequencies in the electrical system or power grids are frequent causes of power quality related problems. Specifying the limits for each harmonics can control the pollution of input current, both from the aspect of minimizing the amount of current used and reducing the possibility of interference with other equipments. So, as far as the relation between harmonics and Power Factor Correction is concerned, the process of shaping the input current is commonly called 'Power Factor Correction' while its success in the case of international regulations is called harmonic content.

Several standards have been established to restrict the harmonic content of the input current of power supply. The most commonly known standard is EN61000-3-2 which has been set by the European Union. Usually passive Power Factor Correction units built from transformers, diode and passive circuit elements are unable to meet the standard criteria. There are also a few other disadvantages, such as:

» The bulkiness of the inductor can restrict its usability in many applications
» For world-wide operation a line-voltage switch is required. The switch, if not properly installed, makes the appliance prone to errors
» If the voltage rail is not regulated, it can lead to a cost and efficiency penalty on the dc to dc convertor that follows the Power Factor Correction stage

Moreover, passive PFC circuits require heavy and large magnetics. An active PFC circuit is therefore required in modern power supplies. Rectifier bridges and boost converters are commonly used in active PFC due to their easy implementation and good performance.

There are various ways or approaches to build a Power Factor Correction unit based on boost convertors. Among them are:

» Critical conduction mode
» Continuous conduction mode
» Frequency clamped critical conduction mode
» Discontinuous mode

There are two control objectives for the boost convertor in a Power Factor Correction unit, which are:

» Achieving a near constant output voltage V= Vref
» Keeping the (short-time) average value of the input current (ig) almost proportional to the input voltage, obtaining a close to unity power factor

There are several methods in which a Power Factor Correction boost convertor in continuous or discontinuous conduction modes can be built.

Cost Justification for Installing Power Factor Correction Equipment

Installing Power Factor Correction Unit is justified in cases like:

» During periods when 'peak demand' charge is imposed by the electricity network supply company
» To reduce greenhouse gas emissions. This is becoming increasingly important with close attention being given to environmental protection

Domestic electricity consumers won't usually feel the importance of Power Factor Correction because they are usually for real power (kilowatt hour). However, people having large generator or pumps are aware of it.

Power Factor Correction Unit Maintenance

Power Factor Correction Units do not need regular maintenance. Therefore, once installed they need to have only annual check-ups.

Conclusion

With energy resources being limited, every potential to save even the least bit of energy should be undertaken in order to protect the environment. Power Factor Correction is one such technique which can help to improve power factor by intelligent load scheduling. Alongside, it can also help to reduce the reactive power requirement from the grid, improving system efficiency in the process ■

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