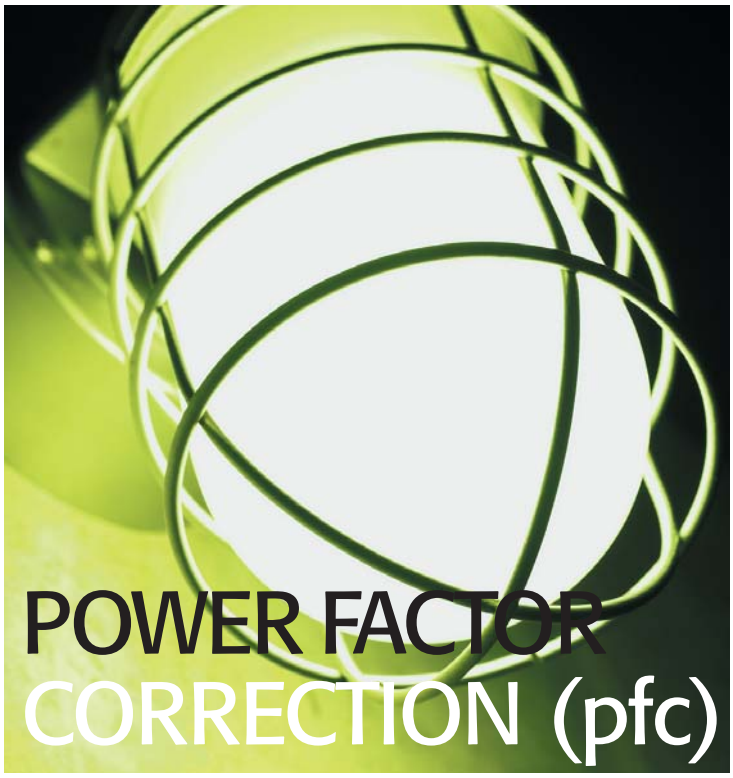


POWER FACTOR CORRECTION (pfc)

By John Ware

POWER FACTOR is the ratio between the useful (true) power (kW) to the total (apparent) power (kVA) consumed by an item of a.c. electrical equipment or a complete electrical installation. It is a measure of how efficiently electrical power is converted into useful work output. The ideal power factor is unity, or one. Anything less than one means that extra power is required to achieve the actual task at hand.

All current flow causes losses both in the supply and distribution system. A load with a power factor of 1.0 results in the most efficient loading of the supply. A load with a power factor of, say, 0.8, results in much higher losses in the supply system and a higher bill for the consumer. A comparatively small improvement in power factor can bring about a significant reduction in losses since losses are proportional to the square of the current.

When the power factor is less than one the 'missing' power is known as reactive power which unfortunately is necessary to provide a magnetising field required by motors and other inductive loads to perform their desired functions. Reactive power can also be interpreted as wattless, magnetising or wasted power and it represents an extra burden on the electricity supply system and on the consumer's bill.

A poor power factor is usually the result of a significant phase difference between the voltage and current at the load terminals, or it can be due to a high harmonic content or a distorted current waveform. A poor power factor is generally the result of an inductive load such as an induction motor, a power transformer, a ballast in a luminaire, a welding set or an induction furnace. A distorted current waveform can be the result of a rectifier, an inverter, a variable speed drive, a switched mode power supply, discharge lighting or other electronic loads.

A poor power factor due to inductive loads can be improved by the addition of power factor correction equipment, but a poor power factor due to a distorted current waveform requires a change in equipment design or the addition of harmonic filters. Some inverters are quoted as having a power factor of better than 0.95 when, in reality, the true power factor is between 0.5 and 0.75. The figure of 0.95 is based on the cosine of the angle between the voltage and current but does not take into account that the current waveform is discontinuous and therefore contributes to increased losses.

An inductive load requires a magnetic field to operate and in creating such a magnetic field causes the current to be out of phase with the voltage (the current lags the voltage). Power factor correction is the process of compensating for the lagging current by creating a leading current by connecting capacitors to the supply. A sufficient capacitance is connected so that the power factor is adjusted to be as close to unity as possible.

Power factor explained

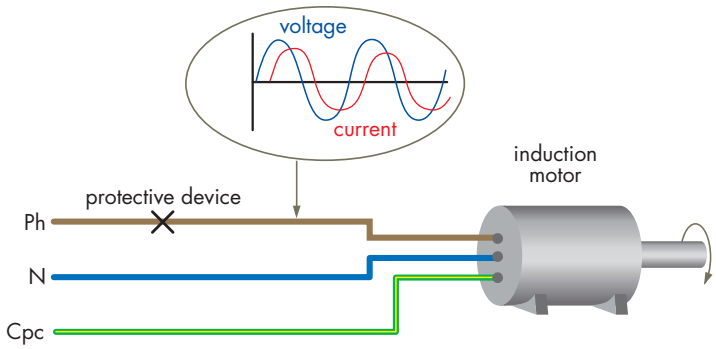
Consider a single-phase induction motor. If the motor presented a purely resistive load to the supply, the current flowing would be in-phase with the voltage. This is not the case. The motor has a magnet and the magnetizing current is not in phase with the voltage. The magnetizing current is the current that establishes the flux in the iron and, being out of phase, causes the shaft of the motor to rotate. The magnetizing current is independent of the load on the motor and will typically be between 20% and 60% of the rated full load current of the motor. The magnetizing current does not contribute to the work output of the motor.

Consider a motor with a current draw of 10 Amps and a power factor of 0.75. The useful current is 7.5 A. The useful power from the motor is 230 × 7.5 = 1.725kW but the total power that has to be supplied is 230 × 10 =

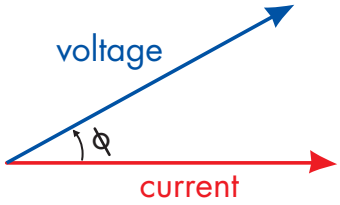
2.3 kVA. Without power factor correction, to achieve the required output of 1.725 kW (7.5 A) a power of 2.3 kVA (10 A) has to be supplied. A current of 10 A is flowing but only 7.5 A of that current is producing useful output.

The power factor can be expressed in two ways:
Power factor (pf) = Useful power (kW) divided by the total power (kVA), or

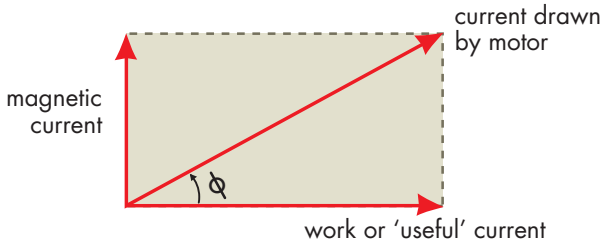
Power factor (pf) = The cosine of the angle between useful power and total power
= cos ø.



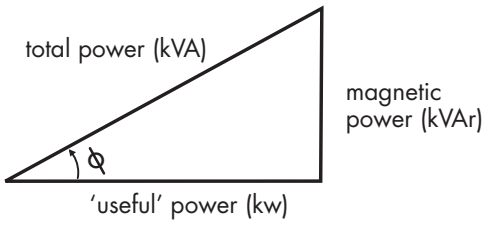
Power supply to induction motor



Phaser diagram of voltage and current



Phaser diagram of currents



Phaser diagram of KW, KVA, and KVAr

Power factor correction

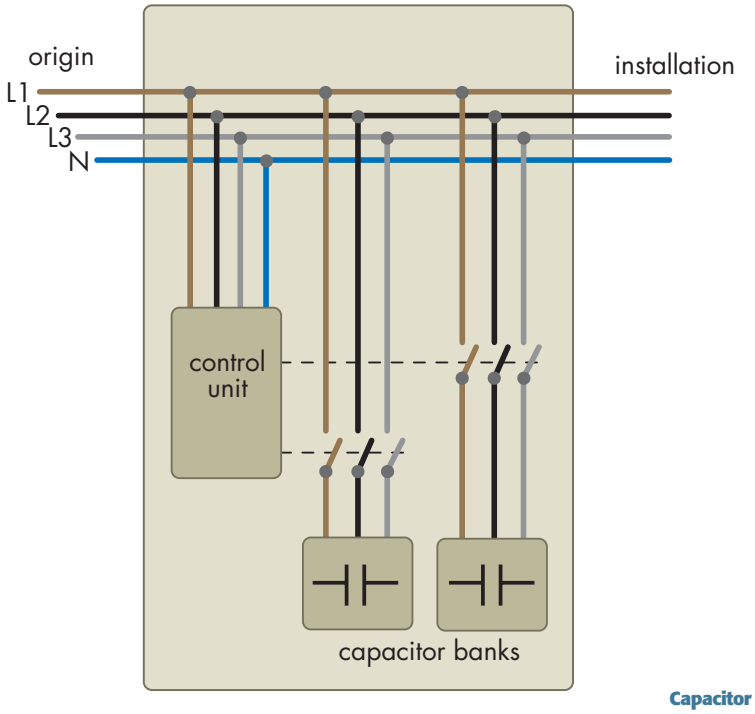
Power factor correction is the term given to a technology that has been used since the turn of the 20th century to restore the power factor to as close to unity as is economically viable. This is normally achieved by the addition of capacitors to the electrical network which compensate for the reactive 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.

To reduce losses in the distribution system, and to reduce the electricity bill, power factor correction, usually in the form of capacitors, is added to neutralize as much of the magnetizing current as possible. Capacitors contained in most power factor correction equipment draw current that leads the voltage, thus producing a leading power factor. If capacitors are connected to a circuit that operates at a nominally lagging power factor, the extent that the circuit lags is reduced proportionately. Typically the corrected power factor will be 0.92 to 0.95. Some power distributors offer incentives for operating with a power factor of better than 0.9, for example, and some penalize consumers with a poor power factor. There are many ways that this is metered but the net result is that in order to reduce wasted energy in the distribution system, the consumer is encouraged to apply power factor correction. Most Network Operating companies now penalize for power factors below 0.95 or 0.9.

Why improve power factor ?

The benefits that can be achieved by applying the correct power factor correction are:

- Environmental benefit. Reduction of power consumption due to improved energy efficiency. Reduced power consumption means less greenhouse gas emissions and fossil fuel depletion by power stations.
- Reduction of electricity bills
- Extra kVA available from the existing supply
- Reduction of I^2R losses in transformers and distribution equipment
- Reduction of voltage drop in long cables.
- Extended equipment life – Reduced electrical burden on cables and electrical components.



Power Factor Correction Unit

Capacitor module designed for local correction of individual loads such as single motors, starters or control gear incorporating an integral circuit breaker for independent isolation and overload protection.
[Illustration courtesy of PFC Engineering Ltd]

A 324 kVAr, automatic power factor correction unit.
[Illustration courtesy of PFC Engineering Ltd]

How to improve power factor

Power factor correction is achieved by the addition of capacitors in parallel with the connected motor or lighting circuits and can be applied at the equipment, distribution board or at the origin of the installation.

Static power factor correction can be applied at each individual motor by connecting the correction capacitors to the motor starter. A disadvantage can occur when the load on the motor changes and can result in under or over correction. Static power factor correction must not be applied at the output of a variable speed drive, solid state soft starter or inverter as the capacitors can cause serious damage to the electronic components.

Over-correction should not occur if the power factor correction is correctly sized. Typically the power factor correction for an individual motor is based on the non load (magnetizing) power since the reactive load of a motor is comparatively constant compared to actual kW load over compensation should be avoided.

Care should be taken when applying power factor correction star/delta type control so that the capacitors are not subjected to rapid on-off-on conditions. Typically the correction would be placed on either the Main or Delta contactor circuits.

Power factor correction applied at the origin of the installation consists of a controller monitoring the VAr's and this controller switches capacitors in or out to maintain the power factor better than a preset limit (typically 0.95).

Where 'bulk' power factor correction is installed, other loads can in theory be connected anywhere on the network. ■