A basic guide to Power Factor Correction

Introduction

Most industrial installations take more current from the regional electricity supply than is actually needed. This is because currents are required to drive the magnetic fields of air-conditioning plant, cranes, motors and the like, even though these fields produce no direct outputs themselves. Power factor is the relationship between working (active) power and the total (apparent) power consumed. The better the power factor, the more effectively electrical power is being used.

A distribution system's operating power is composed of two parts, active (working) power and reactive (non-working) magnetising power. The active power performs useful work whilst the reactive power does not. Its only function is to develop the magnetic fields required by the inductive devices. Generally power factor decreases (i.e. it gets worse) with an increasing proportion of motor / transformer loads.

Power factor is the ratio of active power to apparent power.

$$\textbf{Power factor} = \frac{\textbf{kW}}{\textbf{kVA}}$$

Power factor values range from 0 to 1. The closer the power factor is to one, the lower the current that is required to provide the same real power output. An installation with a power factor of one (unity) is using 100% useful current with no inefficiency but an installation with a power factor of 0.5 uses twice as much current to provide the same real power output. The power factor of typical site locations are listed below:-

Carpentry Shop	0.5
Engineering Workshop	0.7
Quarry	0.7
Site Offices	0.8
Site Lighting	0.5 to 1.0 depending on light source and luminaire specification
Tower Crane	Check with supplier
Batching Plant	Check with supplier

Capacitive loads have an opposite effect on the electrical system to inductive loads, so introducing a capacitor to an inductive system can improve the power factor.

Why correct power factor

Low power factor means low efficiency and the lower the power factor, the higher the apparent power drawn from the electricity system. If a low power factor is not corrected, the electricity board must provide the non-working reactive power as well as the working active power. This results in larger generators, transformers, busbars, cables and switchgear than would otherwise be needed. As the utility's capital expenditures and operating costs are going to be higher, they are going to pass these costs down to the energy customer in the form of power factor penalties.

A poor power factor has a drastic effect on the current required for the same useful power output. A power factor of 0.9 requires a current that is 11% higher than would otherwise be required and a power factor of 0.5 would require the current to double. This increased current causes unnecessary losses throughout the electricity board's distribution system. This leads to a genuine need to improve the power factor by the fitment of power factor correction capacitors.

Benefits of power factor correction

- A reduction in electricity charges.
- Possible elimination of utility power factor penalties or peak demand penalties.
- Reduced I^2R losses of transformers and distribution equipment, with a correspondingly reduced carbon footprint.
- A reduction in the heat in cables, switchgear, transformers etc with a corresponding improvement in lifespan.
- Reduced voltage drop in cables, allowing smaller cables to be used for the same purpose.
- A return on investment for power factor correction equipment is typically between 12 and 24 months.

How power factor correction equipment can help

Power factor correction capacitors can be added to an installation to improve the power factor. The capacitors work as reactive current generators to provide the reactive element (kVAr) of the apparent power. By providing their own source of reactive power, the end user is no longer reliant on the utility to supply the necessary current, so the apparent power provided by the utility is less. For complex installations with varying loads, a power factor controller is often needed to switch capacitors in and out to provide exactly the correct level of reactive power.

Power factor correction in more detail

With purely resistive loads, the voltage and current waveforms are exactly in phase and the power factor is exactly 1 (unity). However a wide range of industrial equipment such as motors, transformers and even fluorescent lights draw some element of inductive current. This is the current needed to establish the magnetic field required for these items. All magnetic fields require inductive currents lagging their voltages by 90°so the resulting overall current is no longer in phase with its voltage. This is as shown in the attached diagrams.

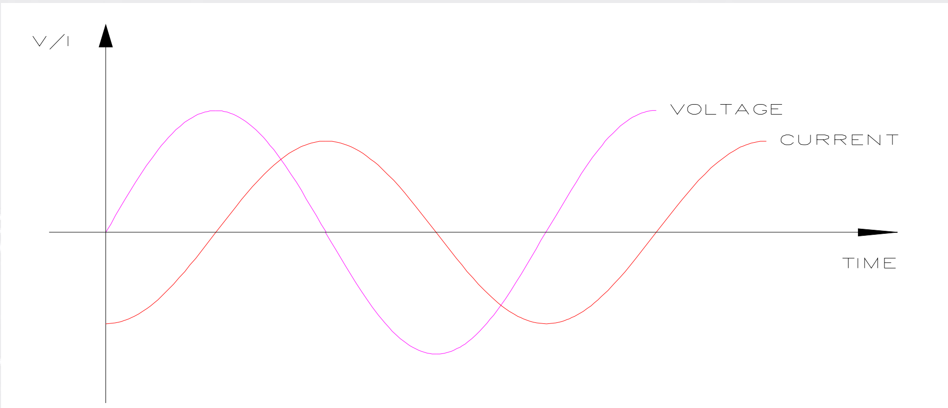


Diagram 1
The current lags the voltage for an inductive load.

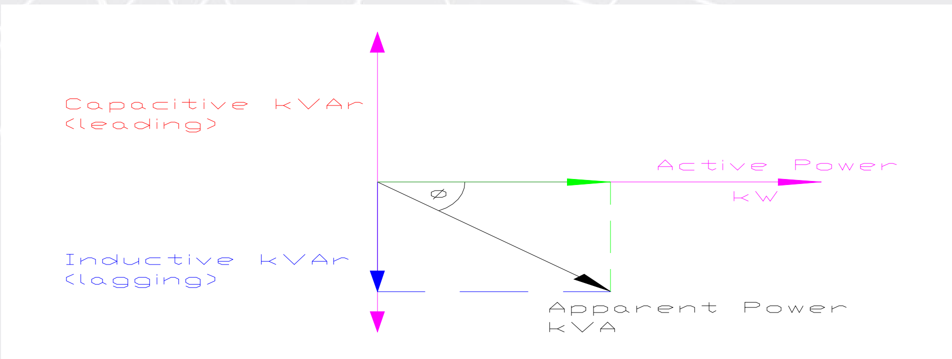
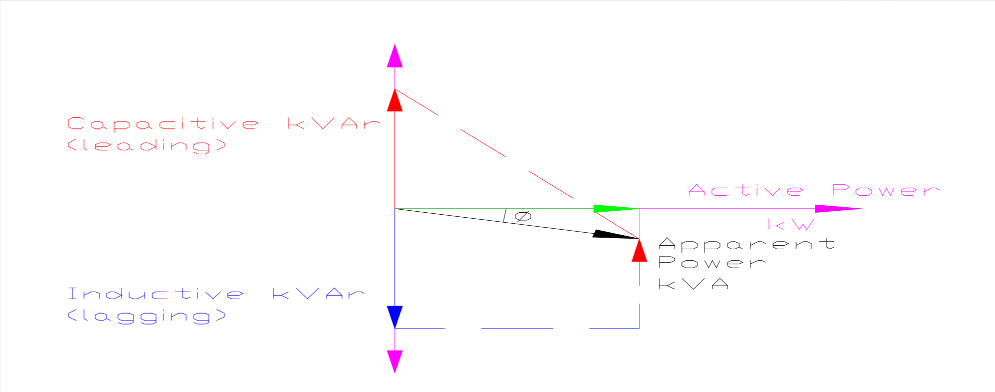


Diagram 2
Phasor diagram showing active and apparent power vectors.

The active power (expressed in kW) is therefore less than the apparent power (expressed in kVA). The apparent power is the vectorial sum of the active power and the reactive power (expressed in kVAr).

In order to correct for the inductive load, capacitors can be added to the system. With a capacitor, the current leads the voltage instead of lagging behind it. Therefore, the effect of the capacitive load can be used to compensate for the effect of the inductive load, reducing the overall reactive load. This is shown below.

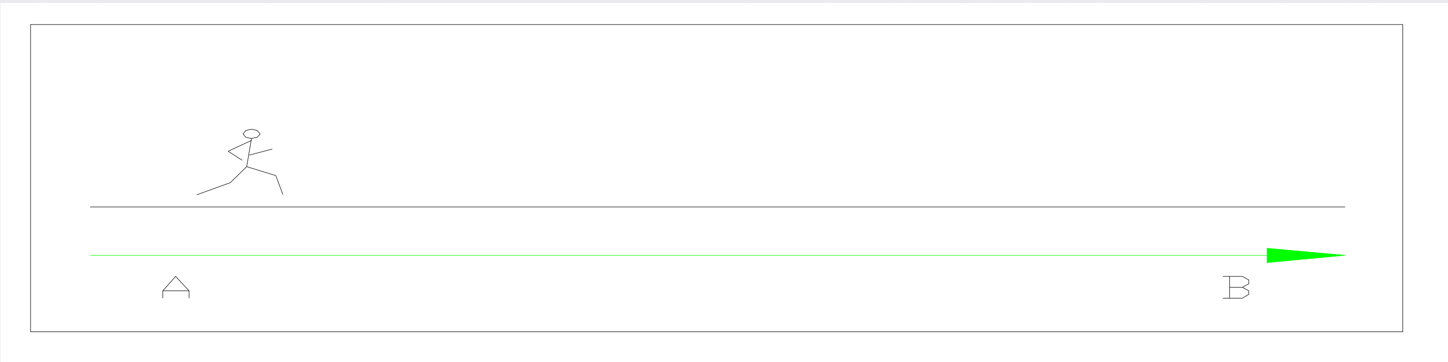
Diagram 3 – The effect of introducing power factor correction.



In reality, the inductive and capacitive currents both continue to flow, but the power flows from the inductive load to the capacitive load and back. Therefore the utility is no longer needed to supply the reactive current, so the current flowing in the utility's distribution system is reduced.

An alternative way of looking at this would be to image a person running from A to B in diagram 4. The energy required is dependent on the distance run, but also on the gradient.

Diagram 4

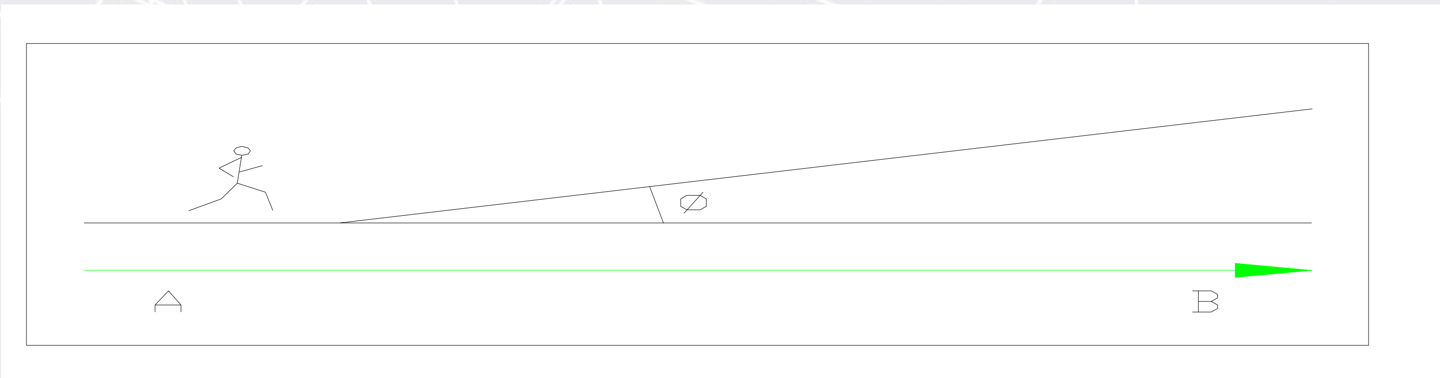


When the running surface is flat, the angle Φ is zero degrees (0°).
Cosine Φ (0°) = 1.00
or power factor = 1.00
or efficiency = 100%.

However of a gradient is introduced as shown in diagram 5, say at 30° to the horizontal, then more effort is needed for the same horizontal distance travelled.

Diagram 5

Cosine Φ (30°) = 0.87



or power factor = 0.87
or efficiency = 87%

In other words, only 87% of the energy expended by the runner is used to move the runner in a horizontal direction from A to B. In electrical terms, power factor correction is analogous to flattening the slope.

In practical terms power factor correction is simply a case of fitting a capacitor of an appropriate size into the installation, as close to the inductive load as possible. The closer the capacitor is, the smaller that part of the installation that carries the uncorrected current. This is straightforward when a single load such as a tower crane is concerned. A capacitor is simply installed adjacent to the crane's motor. However, it is often the case that power factor correction is required to cover a whole site or installation. The load drawn by the site might vary significantly over time, so the capacitor value required would keep changing. In this case, a more sophisticated unit is required comprising a number of capacitor banks and a control unit. The control unit measures the power factor of the whole site and connects the appropriate number of capacitors for as long as they are required. Typically the PFC unit will be fed from the main incoming site distribution assembly (an outgoing MCCB will be needed to feed the unit, as with any other load.) The voltage is measured on the incoming phase connections and a current transformer to measure the current will need to be fitted around the incoming L1 phase cable for the site.

Power factor correction units are sized according to their reactive power, expressed in kVAr. For example a site with an 800A supply with a power factor of 0.75 would need a 250kVAr PFC unit to correct it. This PFC unit would need to be fed from a 400A TP MCCB in the main incoming site distribution assembly.

A PFC worksheet is available in the electrical calculator on the Blakley website (www.blakley.co.uk).