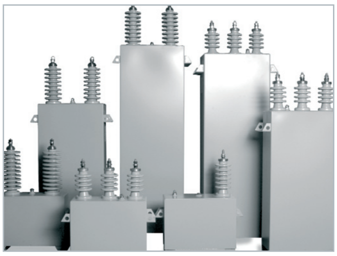
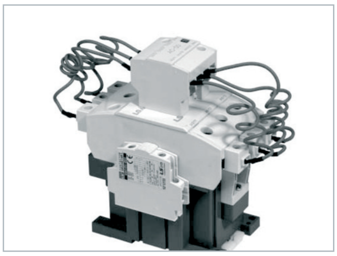
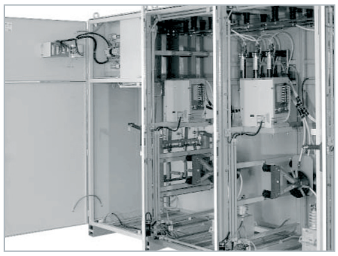
An Introduction to
Power Factor Correction (PFC)



Background

Most commercial and industrial operations use electric motors and additional plant such as florescent lighting, ventilation, refrigeration, air conditioning, welding equipment and arc furnaces, all of which are inductive loads.

Typically, these inductive loads operate at around 80% efficiency and at even lower efficiencies when they are not functioning at full load. An inductive load operating at 80% efficiency will waste 20% of the current it draws from the grid.

Power Factor Correction reduces the amount of power drawn from the grid by inductive loads, thus reducing the amount of power wasted by the loads on a circuit.

Power Factor Correction has been in use for decades by utilities and heavy industrial operations, but the recent rise in energy costs has rendered the technology cost effective for lower energy users including commercial installations.

Benefits of correcting your power factor

The benefits of PFC include:

Financial

- Reduces electricity consumption and fuel bills
- Reduces or eliminates utility penalties for low power factor (reactive power charges)
- Extends lifetime of machinery thus reducing equipment replacement costs

Emissions reduction

- Reduces carbon emissions (as power companies need to produce less electricity in fossil fuel fired power stations)

Electrical System and Power Quality

- Reduces power losses in cables and transformers
- Increases power transmission capacity in cables
- Increases available transformer capacity
- Improves voltage stabilisation in long cable runs

Motors and Appliances

- Reduces wear and tear on motors
- Provides a degree of surge protection

Electricity savings

Typically, a commercial installation that installs Power Factor Correction will reduce the electricity used by its inductive loads by between 5% and 25%. The precise amount of electricity saved depends upon a wide range of factors, including:

- The amount of electricity consumed by inductive loads in the circuits (PFC only works on inductive loads, not resistive loads)
- The current efficiency of your inductive loads
- How often these loads are in use
- How far away you are from the nearest power station
- Whether the power factor is corrected at the fuse board or at the load (appropriate for larger or more inefficient loads)

Return on investment

Return on investment depends upon the savings achieved and the costs of installation, but will vary between 6 months and 5 years, with 2- 3 years being typical. The design life of the equipment is 10-20 years.

Prices vary greatly as many installations require bespoke sizing, As a guide, here is an estimate for an installation at a University site awaiting Salix Funding:

Installation process

The installation process involves:

1. Listing the significant loads on a site or sub-circuit of a site
2. Sizing the loads at the fuseboards
3. Sizing significant loads at the load itself
4. Manufacture of bespoke PFC equipment where necessary
5. Installation (usually weekend or nighttime)

Issues

Some modern motor control gear, especially those with vari-speed drives or installations with a high harmonics level present in the electric loads will require de-tuned PFC.

Power Factor Correction: Example ROI

Annual electricity bill:	£51,350
Price paid per kWh:	£0.07
PFC Installation cost:	£15,000
Power Factor Correction percentage achieved:	15%
Annual kWh saved:	110,036
Estimated financial saving:	£7,703 per year
Estimated emissions reduction:	59 tonnes CO_2 per year
Payback time:	23 months

WHAT IS POWER FACTOR?

Power factor is the relationship between ACTIVE POWER (kW) and the total energy consumed of APPARENT POWER (kVA).

The ratio of active power (kW) to apparent power (kVA) in an inductive system is known as the power factor or COS. ∅ of the system.

$$\text{So COS. } \varnothing \text{ or PF} = \frac{\text{kW}}{\text{kVA}} = \text{Electrical Efficiency}$$

In short, power factor is a measure of how efficiently the electrical supply is being used.

All inductive electrical systems have 3 power components.

1. REACTIVE POWER (kVAr)

Required to maintain the electromagnetic field but contributes nothing to the useful output. All inductive apparatus uses this principle. The electromagnetic field power is called the REACTIVE POWER and is measured in volt-amperes.

2. ACTIVE POWER (kW)

The useful work done by the motors on the systems and measured in kW.

3. APPARENT POWER (kVA)

This is the total energy consumed or total energy supplied by the local electricity authority. It is the vector addition of ACTIVE + REACTIVE POWER.

(i.e. kVA = kW + kVAr) (See Figure 1)

For economical power transmission, the reactive power component (kVAr) within the apparent power must be reduced or eliminated. This in turn improves the power factor of system and available capacity, **thus improving the electrical efficiency.**

CAPACITANCE

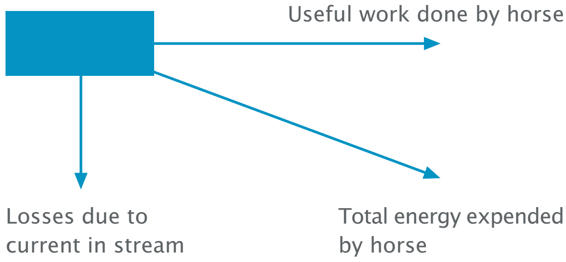
If we consider an electrical system the opposite component to an inductor is a capacitor (i.e. for a given magnitude inductive reactance is equal and opposite to capacitive reactance).

Therefore, if we add an amount of capacitance to an inductive electrical system we reduce the reactive power component (kVAr).

Therefore kVA is reduced and power factor is increased COS. ∅; (See Figure 2).

Consider a barge being pulled downstream by a horse:

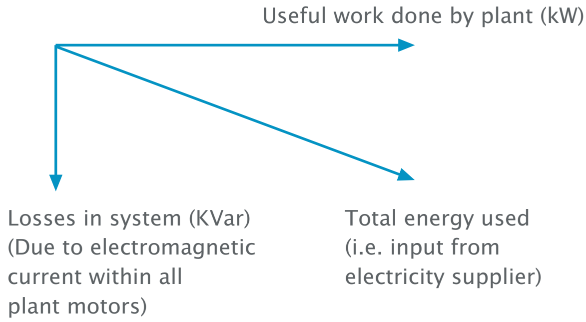
Figure 1.



$$\text{The efficiency of the system} = \frac{\text{Useful work done by horse}}{\text{Total energy expended by horse}}$$

Now consider an electrical system:

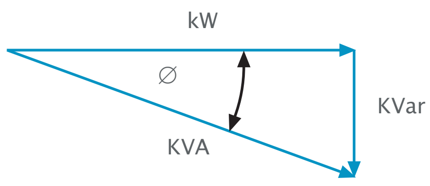
Figure 2.



$$\text{Therefore, the efficiency of the system (Efficiency)} = \frac{\text{Useful work done}}{\text{Total energy expended}}$$

$$\text{Efficiency} = \frac{\text{kW}}{\text{KVa}} = \text{COS. } \varnothing$$

Figure 3.



KVA = kW + KVar

(vectorially added)

Therefore Efficiency = COS. ∅

Also: COS. ∅ = power factor

Hence power factor is basically the efficiency of your electricity supply.

POWER FACTOR IMPROVEMENT BY CAPACITORS

Compensation by capacitors eliminates the need for the transmission of reactive power by the distribution network.

Therefore eliminating the need for large transformers and cables etc.

THE ADVANTAGES OF CAPACITORS

1. Capacitors are a relatively low cost item.
2. Capacitors are static equipment therefore low maintenance costs.
3. Capacitors are easily installed.
4. Capacitors have a fairly long life (10–20 years).

Therefore it pays to have a high power factor (i.e. increase the efficiency of the system) to reduce costs associated with poor power factor.

AN EXAMPLE

Consider "Power Factor" as the measure of the efficiency of the use of power:

- A Power Factor (PF) of 1 would mean 100% of the supply was being used efficiently
- A PF of 0.5 would mean that 50% of the supply is being wasted
- A power factor of 0.95 to 0.98 is usually acceptable without attracting reactive power charges on shore
- Power Factor Correction (PFC) does not save energy
- PFC capacitors liberate more kW from the available KVA supply
- Or for the same amount of kW, less KVA is required

Which leads us nicely into generators, or more correctly, alternators.

In the real world a power factor of 1 is not obtainable because equipment such as electric motors, welding sets, fluorescent and high bay lighting transformers create an "inductive load" which in turn causes the amps in the supply to lag the volts. The resulting lag is called Power Factor.

Typically a large electric motor will have a Power Factor of about 0.85 at full load. If our alternator is powering a hypothetical electric motor rated at 100kW, then ignoring the inherent inefficiency of the motor, when running at full load the alternator would have to supply 100/0.85 =115kVA to provide the 100kW to run the motor.

However, if the motor was operating off its duty point at say 50kW then the power factor may be as low as 0.6 in which case the alternator would have to supply 50/0.6 = 83kVA