Power Factor Correction

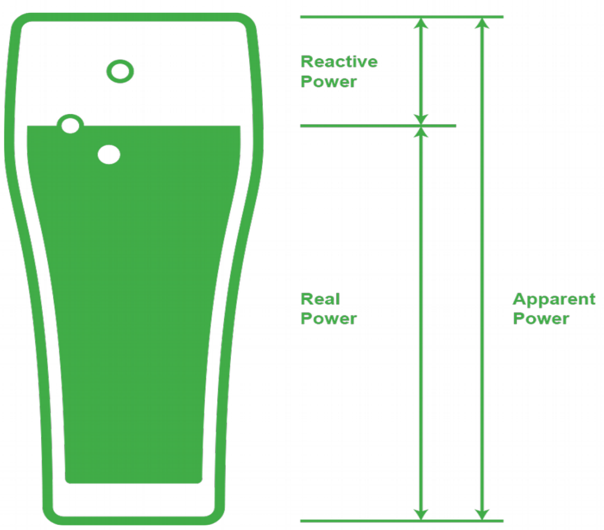
Power Factor Correction and Voltage Optimisation have been around since the turn of the 20th century and although in many cases their individual benefits and attributes make them a viable form of energy reduction in the right environment, in truth it is only recently that they have been considered as a powerful energy saving technology which when combined offer complimentary correction to improve energy efficiency and reduce consumption across a whole site.

There is now momentum towards a global low carbon economy with creation of the Paris Agreement, the impact around climate change, increase in energy costs, introduction of penalties for inefficient users and a need to reduce demand as electricity tariffs move towards time of day demand based billing.

Power Factor Correction improves the overall efficiency of an electrical supply by the controlled introduction of capacitors onto an electrical systems while Voltage Optimisation reduces energy consumption in voltage dependent loads by reducing and in some cases controlling voltage levels to within European Harmonised voltage levels to return an energy saving.

What Does 'Power Factor' Mean?

Power Factor is basically a degree of electrical efficiency and in an AC circuit, the ratio between the useful power kW (true power needed to perform a task) and apparent power kVA (a combination of true power and reactive power - power drawn in addition to useful power but does not contribute to the task).



Reactive power exists in an AC circuit when the current and voltage are not in phase, some electrical equipment like motors and machines used in industrial and commercial buildings require a degree of 'reactive power' in addition to real power in order to work effectively.

Reactive power generates the magnetic fields which are essential for inductive electrical equipment to operate, this leads to excessive energy consumption as the reactive load is recorded by the energy provider as an element on a half hourly meter.

Power Factor is displayed as a figure between 0.01pf to 1.00pf with a poor power factor generally understood to be less than 0.95pf and a perfect power factor as 1.00pf known as unity, in layman terms you could describe power factor as a % degree of electrical efficiency and a good power factor in excess of 95% is normally deemed as electrically efficient.

Power factor can also be termed as lagging or leading, a lagging power factor signifies that the load is inductive and in need of correction through the introduction of capacitors while a leading power factor signifies that there is too much capacitance in circuit. A general methodology exists between the network operators to apply penalties in the form of a Reactive Power Charge to users who's power factor falls below 0.95pf either lag or lead.

A Reactive Power Charge is sometimes termed as a Wattless Charge or Power Factor Surcharge and is normally applied in the Consumption or Distribution charges section of an electricity bill.

Poor power factor can create a number of negative effects in both billing and infrastructure, a European survey in 2007 discovered that poor Power Quality is seriously affecting business results in the industrial and service sectors which amount to an annual total loss of €150 billion across Europe.

Savings & Benefits of Power Factor Correction

In order to aid decision makers to form an opinion on whether power factor correction would be beneficial to their organization, the economic advantages of installing power factor correction are detailed below:

Removal of Reactive Power Charges

Targeting unity power factor and ensuring 0.95pf or better will in most cases remove the reactive power penalties on electricity bills completely.

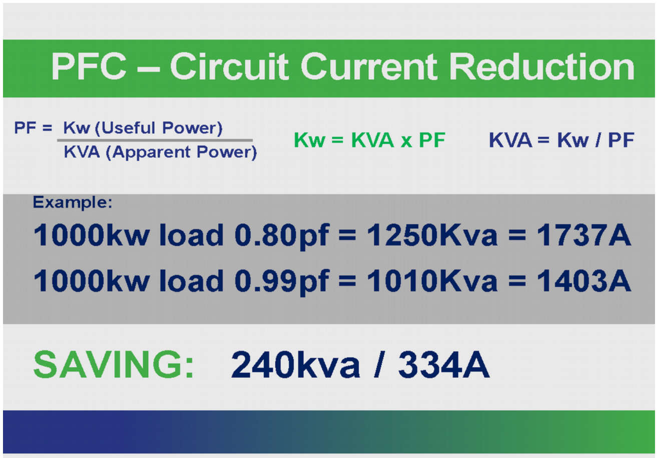
Reduction in Authorised Supply Capacity

Authorised Supply Capacity charges (Availability Charges) are normally charged in kVa at a typical rate of £1/kVA/month, the charge relates to the Maximum Demand or maximum power drawn from the network on a user's site and is generally in place to pay for the supply network infrastructure required to deliver the declared (or drawn) degree of energy at any time night or day.

Power factor in an AC power circuit is directly related to kVa and associated circuit currents, an improvement in power factor would normally allow the user to target the correct / lower capacity level to avoid exaggerated charges on monthly energy bills.

Excess Authorised Supply Capacity

Charges drawn over and above the declared or agreed Supply Capacity,



Reduced kw/h consumption

Reduced kw/h losses in power cables, switchgear and supply transformers with benefits delivered to the whole electrical system

Reduced Emissions

Higher, inefficient energy consumption inevitably results in an increase in CO_2 emissions and associated penalties.

Reduced Investment in Infrastructure & Costly Network Upgrades

A site operating on a power factor close to unity would require less investment in associated power plant (Transformers, Switchgear & Cables) as the reduction in kVA will allow for the investment in associated plant to be minimized. Investments into costly network upgrades due to an overloaded electrical supply can be avoided by improving power factor and at a fraction of the cost of an upgrade

Improvement in Power Quality

The reliability and consistency of and electricity supply is critical to many energy users, a European survey discovered that poor Power Quality is seriously affecting business results in the industrial and service sectors which amount to an annual total loss of €150 billion across Europe

Types of Power Factor Correction

There are a number of different types of power factor correction although functionality wise, they can be separated into two main categories:

- Fixed & Semi-Automatic Power Factor Correction
- Automatic Power Factor Correction

Fixed Power Factor Correction

Fixed or DOL capacitors were once a relatively low cost alternative to automatic correction although recent changes in methodology to apply penalties for "leading" power factor have made fixed capacitor less attractive due to potential over compensation.

Semi-Automatic Power Factor Correction

A compromise between Fixed & Automatic where a capacitor is energized via the motor control circuitry. Semi-Automatic motor controlled capacitors do not however compensate for whole site power factor and will only correct the individual motor to approximately 0.95pf

Automatic Power Factor Correction

Automatic power factor correction is achieved through the controlled introduction of capacitor stages onto an inductive electrical system. Control is normally provided through the integration of an electronic device in the form of a Power Factor Control relay which monitors the actual uncorrected power factor and selects the appropriate capacitor stages to correct the inductive load to a pre programmed "target" power factor normally set to 1.00pf or unity.

As most industrial loads fluctuate, automatic control ensures the desired target power factor is maintained to avoid over compensation and target maximum savings.

Design of Power Factor Correction

Selection of the correct design of power factor correction is vital to long term trouble free operation. The main considerations in selection are based around the level of functionality required and installation environment.

Considerations include voltage levels, ambient temperature, degree of harmonic distortion present on the sites electrical system and the impact of imminent changes to infrastructure.

Functionality will depend mainly on load fluctuation and frequency of response required to correct the loads accordingly.

Standard Power Factor Correction

Standard power factor correction is designed as a relatively low cost automatic solution for the correction of a fluctuating inductive load when no significant non-linear loads are present. Typical construction consists of a main incoming device, individual stage protection (Stage Fuses), inrush limiting capacitor switching contactors, capacitors typically rated at 400-440v and a power factor control relay to automatically switch the capacitor in and out of circuit as required.

De-Rated Power Factor Correction

De-rated power factor correction is of a similar construction to standard and designed mainly as a low cost alternative to Detuned power factor correction where distortion levels are not problematic or the environment is harsh in respect of higher voltage levels or high ambient temperatures. Capacitors with a higher dielectric strength are employed, typically 525v – 690v although care should also be taken to ensure their output is also de-rated accordingly and the correct amount of correction applied in accordance with system voltage levels.

ie a 25kvar 525v capacitor operating on a system voltage of 415v will offer only 15.6kvar of correction

$$\text{De Rate} \; \frac{\text{System Voltage}^2}{\text{Capacitor Voltage}^2}$$

Detuned Power Factor Correction

Detuned power factor correction sometimes known as “future proof” is typically used on electrical systems containing a significant level of harmonic generating non-linear loads or where loads are expected to contain in excess of 25% of non-liner loads. Construction is similar to both the standard and de-rated designs although the capacitors are of a higher dielectric strength and typically around 525v while the main difference is in the inclusion of harmonic blocking detuning reactors or inductors connected in series with each capacitor stage to protect the capacitors from harmful harmonic frequencies and to avoid harmonic amplification or resonance.

Thyristor Switched Power Factor Correction

Thyristor switched power factor correction, sometimes known as “Real Time”, utilizes thyristors to switch capacitor stages instead of contactors and is best utilised on rapidly fluctuating high speed loads that require rapid correction that cannot be offered with contactor based systems. Contactor based systems require the capacitor to discharge for around 60 seconds before re-energisation, this is known as the discharge time and programmable through the power factor controller. Failure to observe the discharge time can result is serious damage to the power factor correction system and associated switchgear. Thyristors typically switch capacitors at the ‘zero crossing’ of a sinusoidal waveform, enabling the capacitors to be switched into and out of circuit multiple times over short periods of time (typically 2-4 cycles) without observing discharge protocol.

Designed as Standard, De-rated or De-tuned, cost implications of Thyristor switched usually encourages the user to invest in the more robust De-tuned systems to future proof their investment.

Active Power Factor Correction

Probably the most functional although also most costly, active power factor correction utilises IGBT’s to correct leading and lagging power factor with a very fast response to load changes of around 2 cycles and can also be used to provide harmonic mitigation and load balancing.

Power Factor Correction System Installation

Installation is carried out in parallel with the main supply via a suitably rated form of protective device although individual “local” power factor correction capacitors can also be installed on individual motor loads.

When installing on individual motor loads it is important to ensure over compensation cannot occur and that any associated controls will allow for the capacitor to discharge between energization periods.