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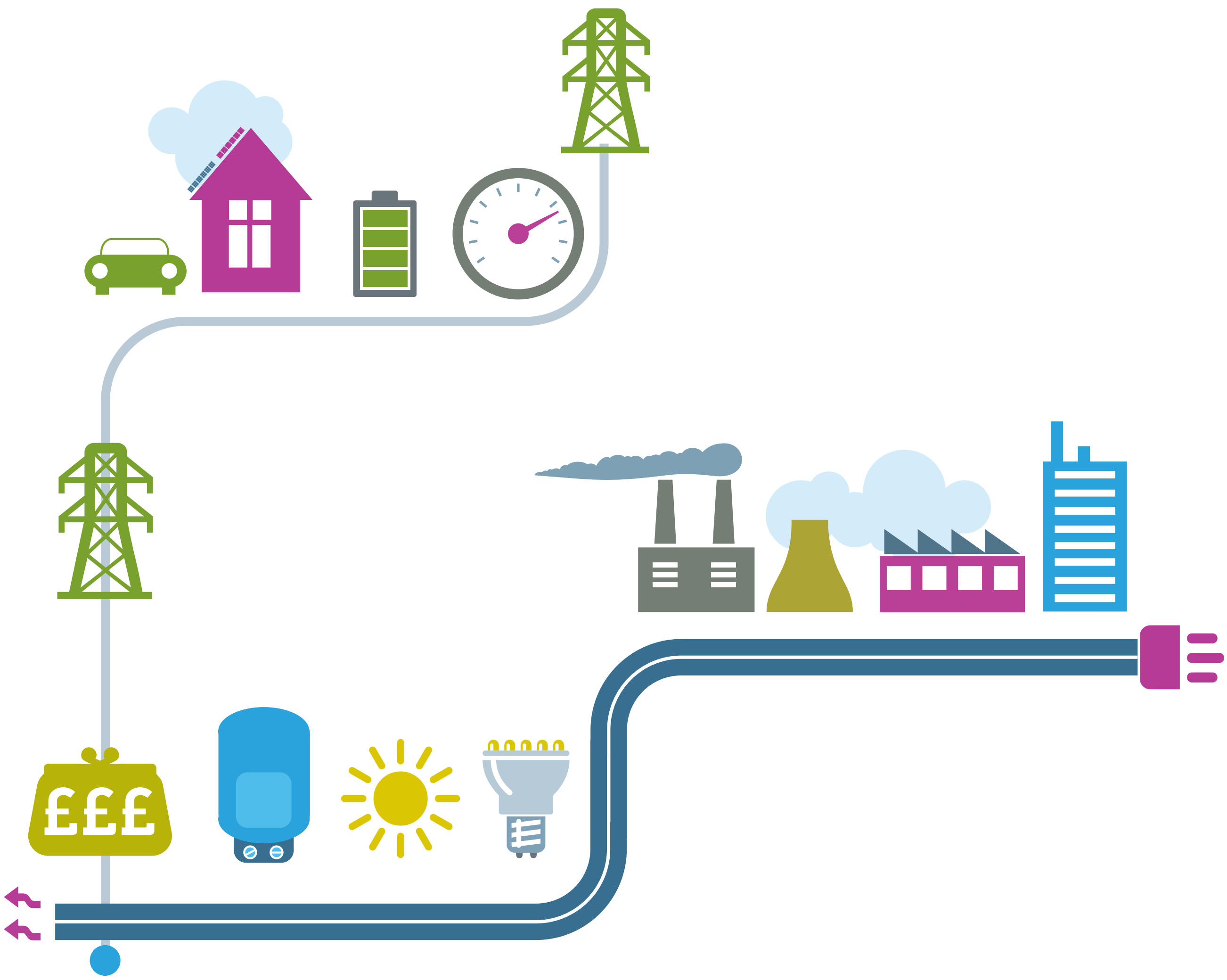
GUIDE TO POWER FACTOR CORRECTION



COMPANIES INVOLVED IN THE PREPARATION OF THIS GUIDE

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INTRODUCTION

BEAMA is the leading trade association that represents manufacturers of electrical infrastructure products and systems from transmission through distribution to the environmental systems and services in the built environment.

We work with our members to ensure their interests are well represented in the relevant political, regulatory and standardisation issues at UK, EU & international levels and our Vision is that member products provide a sustainable, safe, efficient and secure UK electrical system.

WITH COMPANIES ANXIOUS TO DEMONSTRATE THEIR GREEN CREDENTIALS TO CUSTOMERS, SHAREHOLDERS AND STAFF WILL WANT TO REVIEW THE POWER FACTOR OF THEIR BUILDING.

There's a lot going on in the electrical industry that involves the infrastructure of the electrical network from generation, transmission to the point of use.

The government is signed up to reductions in carbon emissions and needs solutions. We've seen the introduction of a host of new renewable energy sources, the roll out of smart meters, more sophisticated energy control and the move towards the connected homes environment.

With a host of new products and technologies introduced to meet the demand for energy management and control, it is important that the quality of energy supplied is maintained and for this reason BEAMA has set up a Power Quality Group which looks at product sectors like Power Factor Correction, Voltage Management, Harmonic Conditioning and Surge Suppression.

These product areas are also part of the solution for providing improved energy efficiency in domestic, commercial and industrial markets and, as the more sophisticated electrical infrastructure takes shape, will play an increasingly important role.

Take for example the area of Power Factor Correction.

Power Factor Correction is an important element of an electrical installation. Not only because of the year-on-year increase in energy costs, but also because it can reduce the burden on our generation and distribution infrastructure and the production of greenhouse gases. With Companies anxious to demonstrate their green credentials to customers, shareholders and staff will want to review the power factor of their building.

With the systematic use of Power Factor Correction,

- energy losses in the electrical transmission and distribution networks can be significantly reduced, with a corresponding reduction in the CO_2 emissions involved in generating that lost energy;
- energy transmission and distribution networks can be used more efficiently, for instance for the transmission of regenerative energy;
- the reliability of planning for future energy networks can be increased.

The green element of Power Factor Correction encourages improvement closer to unity than simple return on capital considerations.

Part L of the Building Regulations recognises the importance of Power Factor Correction in reducing the carbon footprint of an enterprise, important in the fight against global warming.

Power Factor Correction can:

i) **Provide financial savings with a typical return on investment of 2 years or less**

ii) **Reduce the demand (kVA) of an installation**

iii) **Reduce currents in cables and equipment: reducing voltage drop and copper losses and so improving performance and reducing energy consumption (kWh)**

iv) **Enable the existing infrastructure to accommodate additional loads without the need for expensive increases in utility supply**

Consumers affected by Ofgem P272 with CT metering will see kVA availability and potential Excess Reactive Power charges, which have not been previously applied.

Electrical installations operating on half hourly tariffs incorporate a kVA authorised supply capacity (ASC) charge and reactive penalty charge and would benefit from any improvement in Power Factor.

TERMS & DEFINITIONS

Power Factor is the ratio of the actual electrical power consumed by an AC circuit to the product of the r.m.s. values of current and voltage. The difference between the two is caused by reactance in the circuit and represents power that does no useful work.

Active Power (real or true power) is the power that is used to do work on the load. Active power is measured in watts (W) and is the power drawn by the electrical resistance of a system doing useful work. Active Power is symbolised by the capital letter P.

Reactive Power (kVArh) is the difference between working power (active power measured in kW) and total power consumed (apparent power measured in kVA). Some electrical equipment used in industrial and commercial buildings requires an amount of 'reactive power' in addition to 'active power' in order to work effectively. Reactive Power is symbolised by the capital letter Q.

Reactive power therefore generates the magnetic fields, which are essential for inductive electrical equipment to operate - especially transformers and motors. This load is measured via the reactive register on your half hourly meter.

Apparent Power is the combination of both reactive power and active power. It is the product of a circuit's voltage and current, without reference to phase angle. Apparent power is measured in the unit of Volt-Amps (VA) and is symbolised by the capital letter S.

Inductive Loads pull a large amount of current when first energised, then settle down to a normal running current after a few seconds or cycles.

When switched, inductive loads can cause excessive voltages. Some examples of inductive loads include transformers, motors and wound control gear.

Inductive loads resist changes in current and as such, when you measure the current, it lags (behind) the voltage.

Electromagnetic fields are the key to inductive loads, and as such all motors (fans, pumps, etc), solenoids, and relays are inductive in nature.

The important thing to remember about inductive loads is that they have two types of power; active power and reactive power. The active power is based on the work done by the device (such as when a motor is spinning). The reactive power is that which is drawn from the source to produce magnetic fields. The total power consumed is real and reactive power combined, which is measured in VAR (volts-amps-reactive).

Capacitive loads are for many purposes, the opposite of inductive loads. They resist changes in voltage, and as you'd expect, the voltage lags the current (or more commonly said "current leads voltage"). A capacitor is two conductive surfaces separated by an insulator, which store charge. When power is first applied, current is very high, but drops as the voltage of the charge reaches that of the applied voltage. Capacitance is measured in farads. Like inductive loads, capacitive loads also have reactive power, but it's opposite the polarity of an inductive load. Therefore, a capacitive load has a negative VAR. Capacitive loads are not very common, but things like some modern IT servers and UPS systems may operate at a leading power factor.

1
WHAT IS POWER FACTOR

Power factor is the ratio between the kW and the kVA drawn by an electrical load where the kW is the actual load power and the kVA is the apparent load power.

Quite simply Power Factor is a measure of how efficiently the load current is being converted into useful work output and, more particularly, is a good indicator of the effect of the load current on the efficiency of the supply system current

Consider this:

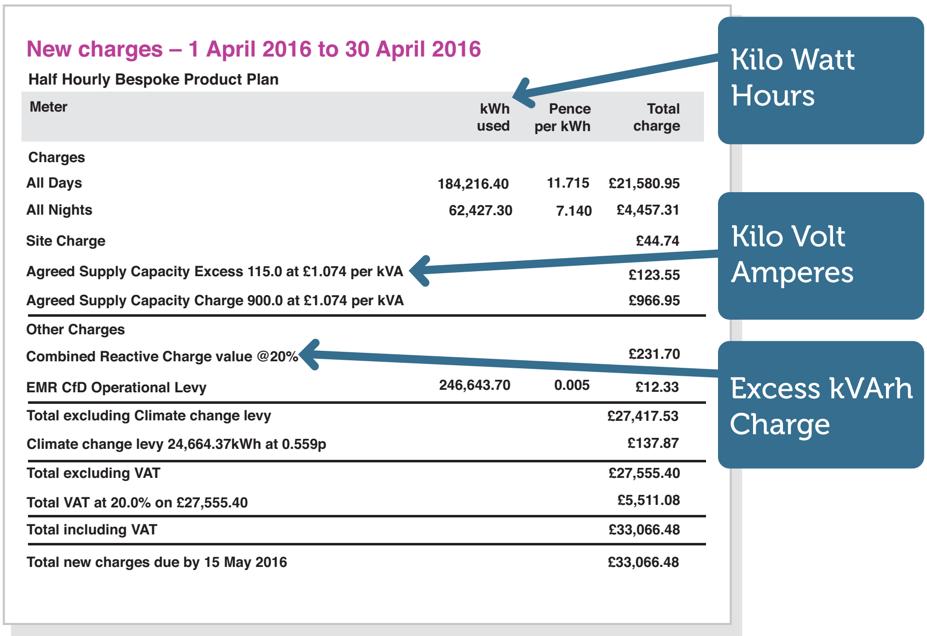
When you buy fuel for a vehicle, the manufacturer makes it in litres, the pump dispenses it in litres and you pay for it in litres. £/litre – simple!

And incidentally individuals often buy their vehicle based on its fuel efficiency.

When you buy potatoes, the supplier bags them in kilos, the shop sells the them in kilos and you pay for them in Kilos. £/kg – simple!

For electricity it is not so simple.

Electricity Invoice



New charges – 1 April 2016 to 30 April 2016

Half Hourly Bespoke Product Plan

Meter	kWh used	Pence per kWh	Total charge
Charges			
All Days	184,216.40	11.715	£21,580.95
All Nights	62,427.30	7.140	£4,457.31
Site Charge			£44.74
Agreed Supply Capacity Excess 115.0 at £1.074 per kVA			£123.55
Agreed Supply Capacity Charge 900.0 at £1.074 per kVA			£966.95
Other Charges			
Combined Reactive Charge value @20%			£231.70
EMR CfD Operational Levy	246,643.70	0.005	£12.33
Total excluding Climate change levy			£27,417.53
Climate change levy 24,664.37kWh at 0.559p			£137.87
Total excluding VAT			£27,555.40
Total VAT at 20.0% on £27,555.40			£5,511.08
Total including VAT			£33,066.48
Total new charges due by 15 May 2016			£33,066.48

FIGURE 1: TYPICAL COMMERCIAL ELECTRICITY BILL

Not so simple is it?

For electricity you pay for kWh and any Excess Reactive kVArh and possibly the Power Factor. Calculated by:

Excess Reactive kVArh
= Total kVArh – (kWh x 0.33)

What is the kilowatt hour (or unit) we get on our bills? This is the useful Active Power and is simply 1000 watts of electricity being used for 1 hour.

Now here comes the problem: In an alternating current (AC) electrical supply, in many case there will also be non-useful Reactive Power consumed which still has to supplied. The combination of this Reactive Power and the Active Power produces the Apparent Power.

The ratio between the Active Power and the Apparent Power is known as the "Power Factor". Power Factor is simply the measure of the efficiency of how power is being used, so, a power factor of 1 would mean 100% of the supplied power is being used to do productive work. A power factor of 0.7 means that only 70% of the supplied power is being used productively.

REACTIVE power is consumed by inductive or capacitive loads and is measured in kVAr (kilo Volt Amperes reactive).

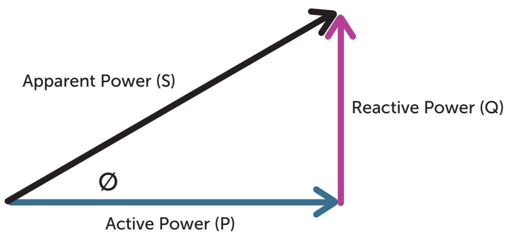


FIGURE 2: ACTIVE POWER IS THE BASE LINE AND IS THE "REAL" USABLE POWER MEASURED AND CHARGED IN KWH'S.

APPARENT Power is the vectorial sum of the active and reactive elements of the power being consumed and dictates the size of the generation and distribution systems.

Mathematically the power can be calculated by Pythagoras or trigonometry whereby Power Factor is expressed as COS Ø (The Cosine of the angle between Apparent Power and Active Power).

2
WHAT CAUSES POWER FACTOR TO CHANGE?

In actuality a natural power factor of 1 (unity) is rarely achieved with loads such as motors, transformers, welding plant etc., being installed These ‘inductive’ loads cause the current drawn from the supply to lag behind the voltage. See Figure 3.

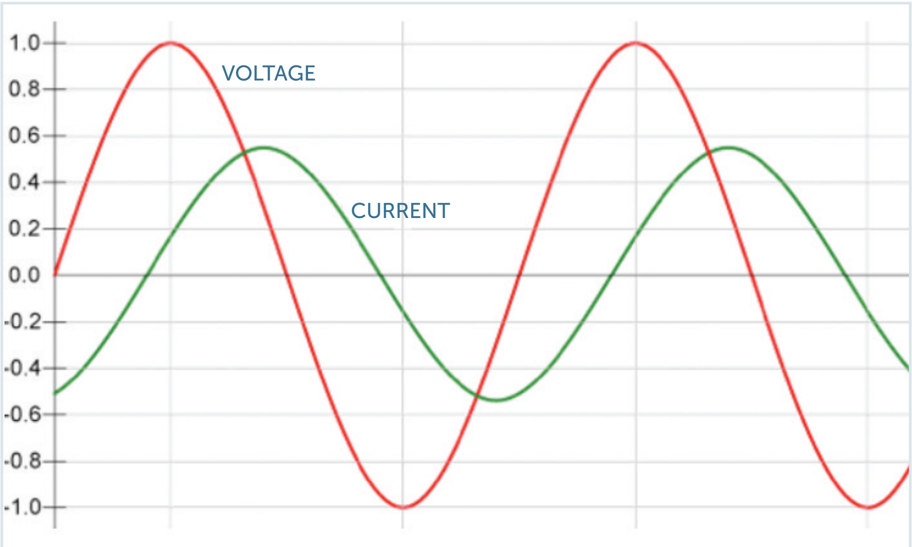


FIGURE 3: VOLTAGE SINE WAVE WITH A LAGGING (INDUCTIVE) CURRENT

The current taken by most electrical installations, and much electrical equipment, lags the voltage. Figure 3 shows a voltage sine wave, with a lagging or inductive current.

2.1 HOW REACTIVE POWER ORIGINATES

Many electrical devices, such as AC single-phase and 3-phase motors, require both active power and reactive power. The active power is converted into useful mechanical power, while the reactive power is needed to maintain the device’s magnetic fields. This reactive power is transferred periodically in both directions between the generator and the load. See Fig 4.

FIGURE 4

Consider an 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 magnetising current is not in phase with the voltage. The magnetising 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 magnetising 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 magnetising current does not contribute to the work output of the motor.

The question is how do you provide for this reactive power. This can either be supplied by the energy supplier that you pay for, or you can provide for this reactive power via Power Factor Correction Equipment that reduces the reliance on the energy supplier. This provides the opportunity of making savings on your energy bill.

2.2 DETERMINING THE POWER FACTOR

Your Power Factor may be shown on your Energy Bill in the format of a number between 0 and 1. Excess reactive power charges are levied if your power factor is less than 0.95 and are applied for each half hourly consumption period.

Whether provided or not it is recommended that a site survey be conducted to determine the true Power Factor of the site over a period of time.

The relationship between the voltage and current can be shown using vectors and this approach allows easy calculation of the rating of Power Factor Correction equipment.

For a 3 phase power supply:

$$kVA = \frac{\text{Line Volts x Amps x 1.73}}{1000}$$

This is converted to kilowatts (kW) by the formula:

$$kW = \frac{\text{Line Volts x Amps x 1.73 x PF}}{1000}$$

This can instead be expressed as:

$$kW = kVA \text{ x } PF$$

(N.B. 1.73 is the square root of 3)

So as the power factor worsens from say 0.98 to 0.5, the generator has to supply more kVA for each kW you are using.

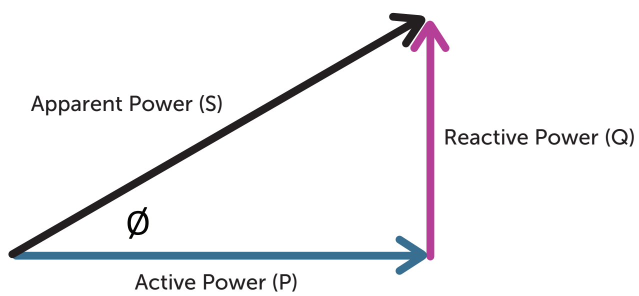
Take the example of an industrial site, which may typically have an uncorrected Power Factor of about 0.8.

If the site has a load of 1000kW, with an uncorrected power factor of 0.8 the electricity supplier would have to supply 1000 ÷ 0.8 = 1250kVA (1740A per phase), and you would require an authorised supply capacity of 1250kVA minimum.

However with the introduction of Power Factor Correction, applied to the same 1000kW, with a corrected power factor of 0.99 the electricity supplier would only have to supply 1000 ÷ 0.99 = 1010kVA (1414A per phase). With this improvement you could now set your authorised supply to 1010kVA.

A reduction of 240kVA (326A per phase).

How this power is wasted can be shown graphically since in 3phase power supplies "power" can be represented and measured as a triangle. The diagram in Figure 5 shows the relation between Active Power and Reactive Power and the resulting Apparent Power.



Active Power
P = S. CosØ

Apparent Power
S = P/CosØ

Reactive Power
Q = S.SinØ

Before applying PFC: Power Factor = 0.8

$$\text{Apparent Power S} \quad \frac{\text{Active Power P}}{\text{Cos}Ø}$$

$$= \frac{1000KW}{0.8}$$

$$= \mathbf{1250kVA}$$

After applying PFC: Power Factor = 0.99

$$\text{Apparent Power S} \quad \frac{\text{Active Power P}}{\text{Cos}Ø}$$

$$= \frac{1000KW}{0.99}$$

$$= \mathbf{1010kVA}$$

Although the motor’s mechanical power output only calls for 1000kW, the supply network loading is an apparent power of 1250kVA, i.e. it has to transmit 125% of the active power

FIGURE 5

3
WHAT IS 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 neutralise as much of the magnetising 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. If the lagging power factor is corrected, for example by installing a capacitor at the load, this totally or partially negates the inductive power consumed by the load and the overall reactive power drawn from the supply is minimised.

Power Factor Correction is at its most effective when it is installed as close as possible to the inductive load it is compensating. For example, as automatic centralised bulk correction on a main LV distribution board or individual motor correction with a medium of control to ensure over compensation does not occur. See Fig 6.

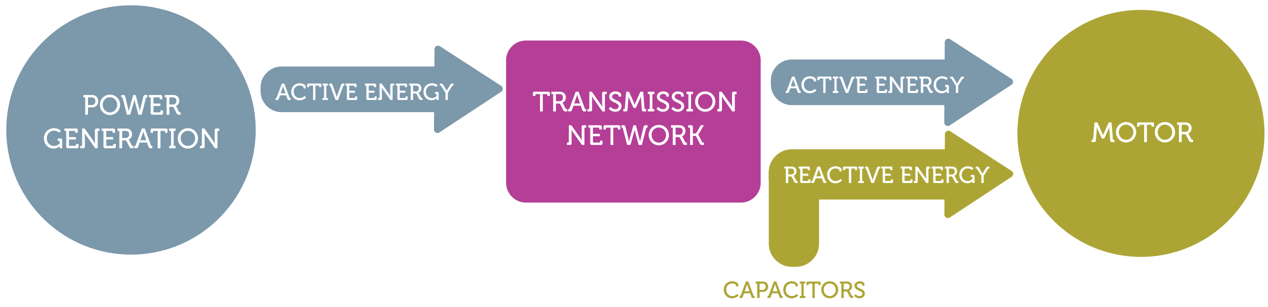


FIGURE 6

4
INCREASING ENERGY EFFICIENCY WITH POWER FACTOR CORRECTION

With Power Factor Correction, a situation can be achieved in which only the necessary active power is transported, both in the transmission & distribution networks and in the customers' networks. The current in the networks drops, and this has two advantages:

1. **Current-dependent network losses are reduced,** and require no compensation by increased power generation with corresponding CO_2 emissions. This applies both to customers' networks and public transmission and Distribution network networks.
2. **Additional transmission capacities are made available,** for instance for the transmission of renewable energy.

5
ECONOMIC ADVANTAGES OF POWER FACTOR CORRECTION

5.1 REDUCTION IN EXCESS REACTIVE POWER CHARGES

Excess kVArh charges apply when a half hourly (HH) metered LV or HV designated site's Reactive power consumption (measured in kVArh) exceeds 33% of the Active power (measured in kWh) consumption in each HH period. This threshold is equivalent to an average power factor of 0.95 during the period and applies to both leading and lagging kVArh consumption.

Ensuring that your site power factor is 0.95 or better will substantially reduce or eliminate excess kVArh charges.

5.2 REDUCTION IN AUTHORIZED SUPPLY CAPACITY (ASC)

ASC charges are based on the amount of power that is made available to you. Measured in kVA it is the level of Apparent (Total) Power that you "reserve" from the distribution network. The charge is made for each kVA of ASC made available in the month and is applied in £/kVA/month.

Ensuring that your site operates at a power factor close to unity could allow you to reduce your existing ASC.

5.3 REDUCTION OF EXCESS SUPPLY CAPACITY

If you exceed the agreed ASC for your site, Excess charges will be made which again are applied in £/kVA/month. The charges could be 70 – 300% higher than the charge for each kVA of Authorised Supply Capacity.

Ensuring that your site operates at a power factor close to unity will minimize or eliminate any Excess Supply Capacity charges.

5.4 REDUCTION CAPEX SPEND ON INFRASTRUCTURE (TRANSFORMERS, SWITCHGEAR, CABLES)

The cost of electrical infrastructure is inextricably linked to the rating of supply transformers, cables and distribution equipment etc.

Ensuring that your site will operate at a power factor close to unity will minimize the rating of electrical infrastructure and reduce capital expenditure.

5.5 AVOID COSTLY NETWORK UPGRADE

All electricity supplies have a maximum rating; if your existing supply is close to its maximum but you wish to install additional electrical plant the cost of a supply upgrade is likely to be significant and in some cases prohibitive.

If your site operates at a power factor of say 0.7, it will require a supply approximately 40% larger than if it operated at a unity power factor. This additional capacity could be used for additional plant.

Improving your site power factor to close to unity could "free up" capacity on your existing supply and may avoid costly network upgrade.

5.6 IMPROVED POWER QUALITY

Reliability and consistency of electricity supply is critical to many industrial and service activities. When the Power Quality is inadequate, business suffers. It is both surprising and alarming that companies often do not recognise that the causes of poor reliability are of their own making and that cost-efficient solutions are in their own hands. This was one of the main conclusions drawn from a European-wide survey as far back as 2007 and things are no better today. The survey shows that poor Power Quality is seriously affecting business results in the industrial and service sectors amounting to a total loss of €150 billion annually across Europe.

For a continuous manufacturing process, an unreliable power supply not only slows down or damages production; it also leads to equipment damage and additional maintenance. Moreover, the staff involved can be left idle until the line is running again. Revenues are postponed, if not lost entirely, cash flow is affected, and the organisation's reputation for product quality and supply reliability suffers.

Power interruptions in a service sector organisation affect the reliability of the service, a key deliver-able. The organisation loses credibility, usually followed by the loss of clients.

For an R&D organization, the cost of data loss due to power interruptions is usually much more than just the time wasted. It substantially affects intellectual property due to the loss of irreplaceable samples, experiment data, and any work not yet adequately backed-up.

Appropriately designed and applied PFC systems can improve the quality of your electricity supply and avoid costly down time due to supply or plant malfunction caused by voltage instability, harmonic pollution etc.

Power Factor Correction can improve the reliability of your supply

5.7 REDUCTION IN ENERGY LOSSES

The benefits of improving your sites operating power factor are not just limited to financial savings and reduced burden on your supply; the whole electrical system will benefit. The reduced load achieved on site will reflect all the way through the distribution & transmission grids back to the point of generation. This means increased capacity, reduced system losses and consequently reduced CO_2 emissions.

Improving your power factor saves Mr Polar Bear!

6
TECHNOLOGY OF POWER FACTOR CORRECTION SYSTEMS

There are a variety of Power Factor Correction technologies. Control is usually provided by an electronic device (Power Factor Controller), which monitors the actual power factor and orders the connection or disconnection of capacitors in order to obtain the targeted power factor. In addition, the Power Factor Controller provides information on the network characteristics (voltage, amplitude and distortion, power factor, actual active and reactive power etc.,) and equipment status.

6.1 STANDARD

This form of equipment is utilised when no significant non-linear loads are present. It will typically consist of main incoming device, individual stage protection, capacitor switching contactors and capacitors typically rated at 400-440V.

6.2 DE-RATED

This equipment is utilised when there is a nominal amount non-linear load connected (15-20%). It will typically consist of main incoming device, individual stage protection, capacitor switching contactors and higher strength dielectric capacitors typically rated at 480-525V.

6.3 DE-TUNED

Should there be a significant level of non-linear loads connected to the network (up to 25%) it is recommended to use De-tuned equipment. These units are similar in construction to the above De-rated equipment but have the addition of line reactors connected in series with the capacitors. This prevents the amplification of harmonic currents and protects the capacitors from potential overload.

6.4 THYRISTOR

This kind of compensation is required when rapidly fluctuating loads are present and voltage fluctuations have to be prevented. The equipment utilises Thyristors to switch the capacitors into circuit, the switching is typically done at the 'zero crossing' thus enabling the capacitors to be switched into and out of circuit multiple times over a short period to match the load, typical response would be 2-4 cycles. The specification can be De-tuned, De-rated or standard.

6.5 ACTIVE

Active correction can be utilised to correct for both leading and lagging power factor applications. Due to the use of DC capacitors and Insulated Gate Bipolar Transistors (IGBT's) it can also provide very fast response to load change, typical 2 cycles. This equipment can also be utilised to provide harmonic mitigation and load balancing along side PF correction.

6.6 DESIGN AND MANUFACTURE CONSIDERATIONS

One of the main issues affecting PFC in today's environment is the proliferation of non linear loads such as variable speed drives and power electronics. Hence careful consideration should be given to the type of PFC equipment to be used.

The duty and cycle of the load is also a significant consideration to ensure that the PFC equipment is capable of matching the load cycle. Incorrectly selected equipment could lead to a reduced life expectancy of equipment plus initiating unstable PFC equipment operation.

The availability of circuit protection is also a major factor and, as a 'rule of thumb' the upstream protective devices' current rating will need to be double the rated kVAr of the PFC i.e. 100kVAr = 200A.

Care should also be taken over the control relay fitted to any PFC. In today's connected age it is becoming increasingly important to be able to view the operational data and condition of the equipment.

These considerations and other factors are reasons for ensuring that it is important to conduct a Site Survey during which an Action Plan can be developed as described in section 7.

7
INSTALLATION AND SITE TESTING & MAINTENANCE

In installations with inductive loads, the installation of power factor correction equipment can save energy and reduce electricity bills.

Whilst central automatically controlled equipment is likely to give the best payback, locally installed equipment has the potential to also save copper losses within the installation.

However, it should be noted that the individual method of correction does have its limitations, such that the overall power factor of 0.95 lag or better may not be achieved necessitating the installation of automatic correction at the main incomer position.
To determine the best solution it is important to undertake a Site Survey during which an Action Plan may be developed along the lines as follows:

- **Confirm installation maximum demand and power factor**
- **Identify loads having low power factor**
- **Determine scope for improvement of power factor**
- **Decide appropriate means of correction, in consultation with provider of power factor correction equipment.**
- **Determine size and specification of type of equipment required.**
- **Implement procurement/ installation of equipment**
- **Monitor demand and/or energy savings, from billing and half hourly consumption data**

7.1 INSTALLATION

In general terms there are no requirements outside those related to the current edition of the IET Wiring Regulations although a few specific points are worth noting:

Typically an installer of Power Factor Correction systems would be competent to work on electrical distribution systems.

The following minimum requirements for test equipment should also be observed to ensure good practice and compliance with the latest wiring regulations:

- Proving unit
- Multi Meter
- Insulation Resistance Tester
- Loop Impedance Tester
- Capacitance Meter
- Ammeter (Clip on)
- Phase Rotation Meter

Installation of Power Factor Correction is carried out in parallel with the supply to be “corrected” and is normally physically connected to the supply via a suitably rated protective device using the calculation below:

$$\text{Protected Device Rating in Amps} = \frac{\text{Var} \times 1.3}{\sqrt{3} \times \text{V}} = \text{Minimum Switch Rating in Amps}$$

$$\text{e.g. 100kVAr PFC System} = \frac{100{,}000 \times 1.3}{1.732 \times 400} = \text{188 Amps i.e. Minimum Switch Rating in Amps} = \text{200A}$$

IEC60831 requires that capacitors shall be suitable for continuous operation at 1.3 times the current at rated sinusoidal voltage and rated frequency.

Taking into account the capacitance tolerances of 1.15 times nominal capacitance (Cn), the maximum current can reach 1.5 times nominal Current (In).

As a general rule of thumb double the kvar provides the same result.

The manufacturer can provide more detailed installation instruction

7.2 COMMISSIONING

It is important to follow the Manufacturers instructions, which will include the Pre Energisation and Energisation phases of the commissioning process.

7.3 MAINTENANCE

Maintenance of Power Factor Correction products could be considered as somewhat specialised and can offer challenges to general maintenance staff and contractors.

Capacitor switching duty is extremely onerous and the correct operation of Power Factor Correction systems can be affected by changes in site loading. Therefore, in general, maintenance should be carried out on an annual basis.

An annual inspection and maintenance of the system is also recommended because generally Power Factor Correction equipment is non critical to site operations and a malfunction can go un-noticed resulting in unforeseen and irretrievable costs.

NORMATIVE REFERENCES

The following referenced documents are indispensable for the application of this document.

IEC 60831 – 1 & 2	Shunt power capacitors of the self-healing type for a.c. systems having a rated voltage up to and including 1kV. Part 1: General – Performance, Testing and Rating – Safety Requirements – Guide for installation and operation Part 2: Ageing Test, Self-Healing Test and Destruction Test
IEC 60871 – 1, 2, 3 & 4	Shunt Capacitors for a.c. power systems having a rated voltage above 1kV. Part 1: General Part 2: Endurance Testing Part 3: Protection of Shunt Capacitors and Shunt Capacitor Banks Part 4: Internal Fuses
IEC 61921	Power Capacitors – Low-voltage Power Factor Correction banks
EN50160	Voltage characteristics of electricity supplied by public distribution systems that provides the limits and tolerances of various phenomena that can occur on the mains
BS 7671 + A3	Requirements for Electrical Installations. IET Wiring Regulations. Seventeenth Edition
EN 61000-6 – 1 & 2	Electromagnetic compatibility (EMC). Generic standards. Part 1 Immunity for residential, commercial and light-industrial environments. Part 2 Immunity for industrial environments.

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