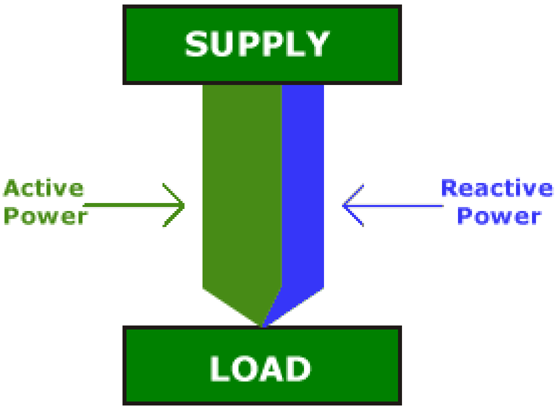
The Principles of Power Factor Correction

Under normal operating conditions certain electrical loads (e.g. induction motors, welding equipment, arc furnaces and fluorescent lighting (draw not only active power from the supply (kilowatts, kW) but also reactive power (reactive kVA, kVAr). This reactive power is necessary for the equipment to operate correctly but could be interpreted as an undesirable burden on the supply.

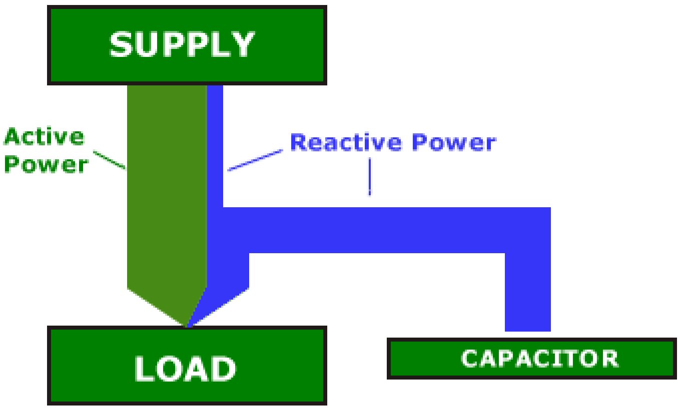
The demand made by such a load on the supply is outlined in the below.



A Typical Inductive Load

Opposing reactive power resulting from the correction of a correctly sized capacitor can compensate for the reactive power required by the load. This ensures a reduction in the reactive power drawn from the supply.

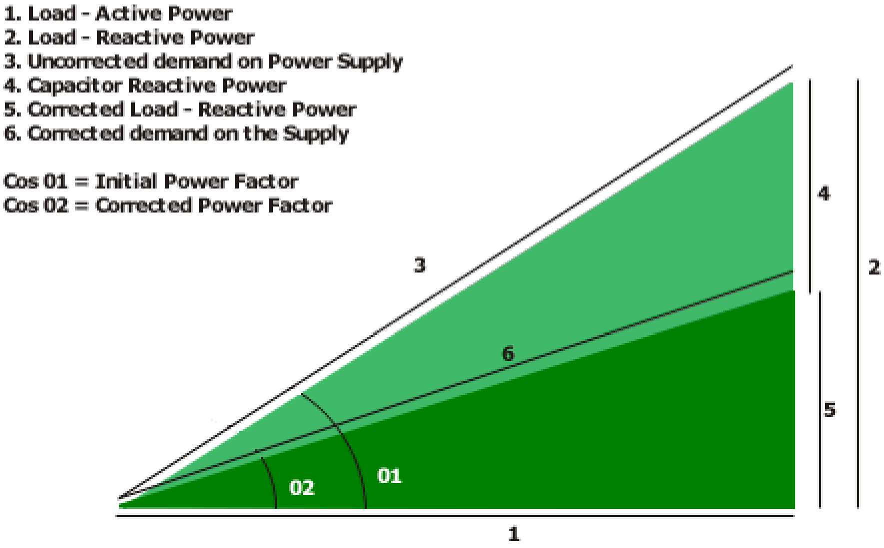
Power Factor Correction is the connection of a capacitor to an inductive load . This achieves a reduction in the total current drawn from the supply and is known as ‘PFC’ or ‘Correction’. A load with an associated capacitor is said to be ‘Corrected’.



The Effect of a Capacitor on an Inductive Load

The Power Factor of a load is defined as the ratio of active power to apparent power i.e. kW : kVA and is referred to as $\cos \theta$. In the figure below the uncorrected power factor of the load is $\cos \theta 1$ and the corrected power factor is $\cos \theta 2$.

The closer $\cos \theta$ is to unity, the less reactive power is drawn from the supply.



Power Factor Correction - Vector Diagram

Common reasons for the provision of Power Factor Correction Capacitors include:

1. The reduction in the load on cables and switchgear

2. The ability of the supply to support additional load

3. The likely reduction in the charges levied by the Electricity Supply Company

Reducing the load on distribution network components can result in an extension of their useful life. This would improve the integrity of the system.

The ability to connect additional load is always of benefit to an expanding company.

Charges levied by the Electricity Supply Companies are calculated according to an agreed tariff. Some Tariffs penalise consumers for poor power factor. In these cases a reduction in the overall cost of electricity can be achieved by improving the power factor to a more economic level.

Example : A fully loaded 1000kVA transformer supplying a load with a power factor of 0.80 can only supply 800kW of “useful” load. By correcting the power factor to 0.95, an additional 150kW of load may be connected, increasing the “useful” load capacity to 950kW.

Alternatively, by correcting the power factor from 0.80 to 0.95, the demand on the supply would be reduced by 158kVA. The consumer would save over £230 per month based on a typical charge of £1.50 per kVA of supply.

Automatic Power Factor Correction

To automatically correct the power factor of a load, a number of capacitors are connected to the supply. The capacitors are controlled by a microprocessor based relay which continuously monitors the reactive power demand on the supply.

The relay connects and/or disconnects the capacitors to compensate for the reactive power of the total load. This reduces the overall demand on the supply.

Systems are manufactured utilising capacitors of either MKP, MKK or MPP/MKV technology. A typical power factor correction system would incorporate a number of capacitor sections (‘stages’) determined by the characteristics and the reactive power requirements of the installation under consideration.

Switching stages of 25kVAr are usually employed. Larger sections (eg. 50kVAr and above) are achieved by cascading a number of smaller sections. This has the beneficial effect of reducing the inrush currents to the capacitors and minimises supply disturbances. Where harmonic distortion is of concern, appropriate systems are supplied incorporating detuning reactors.

POWER CAPACITORS LIMITED is able to recommend, design, manufacture and supply automatic capacitor systems to suit any application.

1. Extendable Systems.

A consumer Whose load is likely to increase may require a capacitor system which is readily extendable. This would enable further capacitance to be installed cost effectively.

2. Factory-Built Assemblies.

A consumer with space available in a distribution board may require capacitors, contactors and fusegear to be supplied as a backplate assembly. This would avoid the unnecessary expense of installing further metalwork. This option is very popular with switchboard manufacturers - various styles and ratings are available.

3. Detuned Systems.

A consumer whose load includes a high proportion of variable speed motor drives and/or other harmonic generating loads may require a detuned capacitor system. This would perform the function of power factor improvement whilst preventing any amplification of harmonic currents and voltages caused by resonance.

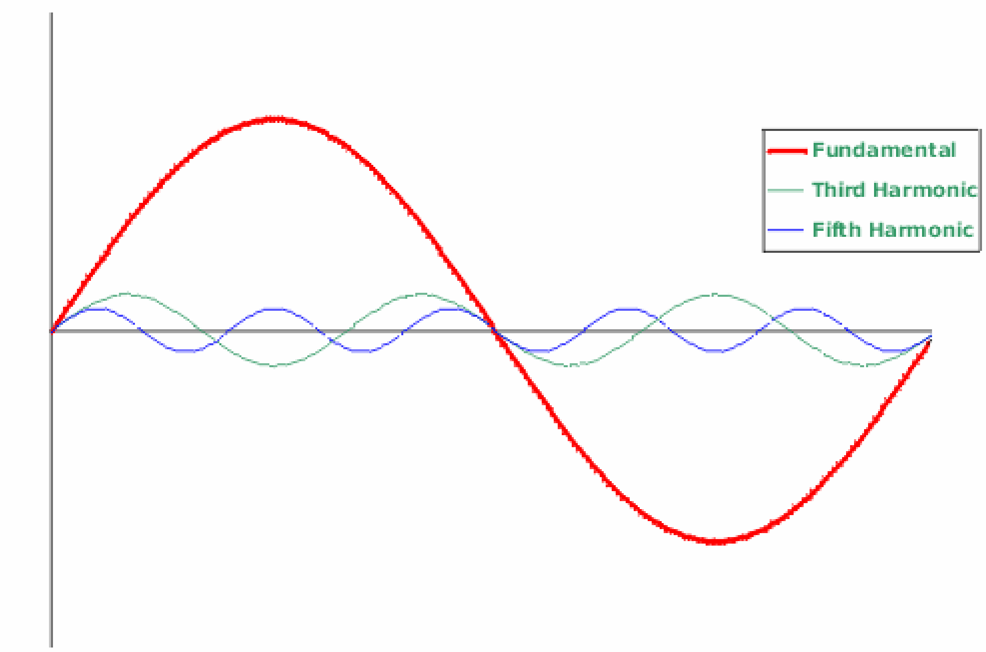
Harmonic Distortion and Filtering

Developments in modern semiconductor technology have led to a significant increase in the number of converter-fed-loads. Power converters such as rectifiers and inverters offer the consumer more effective control of the power requirements of a given load, maximising the potential for energy savings.

Unfortunately converters can also have undesirable effects on the incoming AC supply, drawing appreciable inductive reactive power and/or non-sine-wave current. The supply system needs to be kept free of this harmonic distortion to prevent equipment malfunction.

A typical converter current is composed of a mixture of sine-wave currents, a fundamental component at the supply frequency and a number of harmonics whose frequencies are integer multiples of the line frequency. The actual converter current waveform depends on both the type of converter and the load it supplies.

The diagram below demonstrates the theoretical 'optimum' waveform, and in may respects it is not dissimilar to converter currents met in practice.



However, when harmonic currents are superimposed on the AC supply, voltage distortion occurs which may result in system disturbances.

Harmonic distortion of an AC supply can result in any or all of the following:

1. Premature failure of capacitors.

2. Nuisance tripping of circuit breakers and other protective devices.

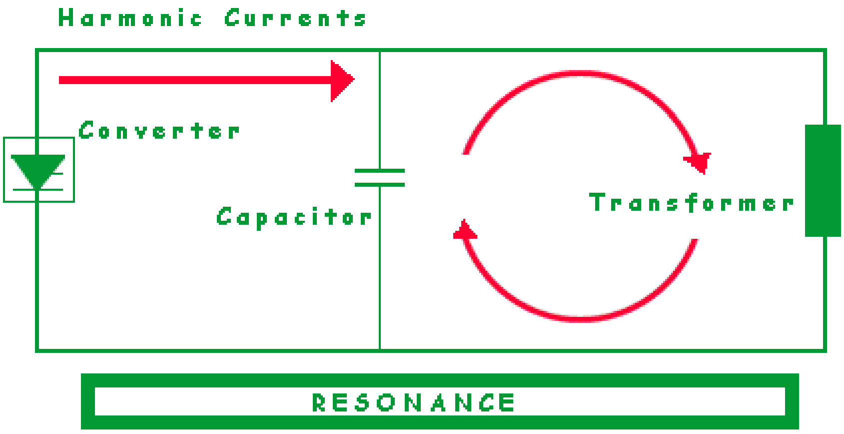
3. Failure or maloperation of plant such as computers, motor drives, lighting circuits and other sensitive loads.

Restrictions may be placed on the acceptable limits of harmonic distortion. These include the Electricity Councils recommendation G5/3 "limits on harmonic distortion in the UK supply network".

Where large converter loads are installed or certain supply conditions exist, more stringent limits may be imposed by the Regional Electricity Company (REC).

Where the harmonic component is low, power factor correction equipment should be fitted with reactor connected capacitors to prevent resonance phenomena.

Resonance is a condition resulting from the combination of power factor correction capacitors and the inductive nature of the supply network - usually in the form of the local supply transformer. The resulting circuit amplifies the harmonic currents imposed by the converter loads.



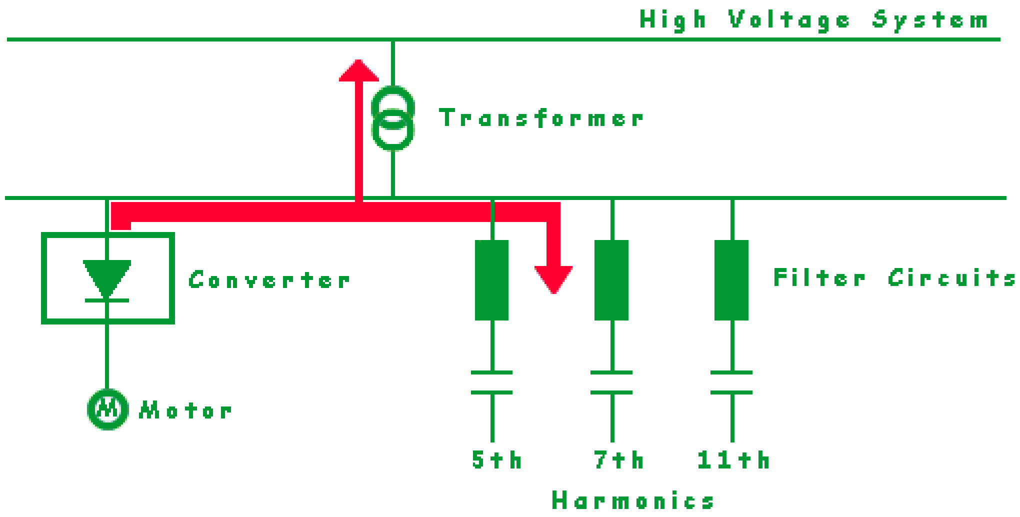
The extent of this current amplification depends on the specific network characteristics and in some cases may be of little consequence. However severe resonance can result in the failure of capacitors, the breakdown of transformer insulation, the tripping of main circuit breakers and the overloading of cables. Invariably this leads to loss of production and has significant cost implications.

The installation of detuned/reactor-connected capacitors forces the resonant frequency of the network below the frequency of the lowest harmonic present, ensuring that there is no resonant circuit and, by implication, no amplification of harmonic currents. Such an installation also has a partial filtering effect, reducing the level of voltage distortion on the supply.

Harmonic Distortion and Filtering

Where the level of harmonic distortion is unacceptable, a reduction in the level of harmonics is achieved by utilising filter circuits.

A filter circuit presents a very low impedance to the individual harmonic current, diverting the majority of the current into the filter bank rather than the supply.



FILTER CIRCUITS

Power Capacitors Limited designs and manufactures harmonic filters for many applications, often initiated by a comprehensive site survey utilising the latest in mains, load and harmonic analysis equipment.

Harmonic filters are designed on a 'one-off' basis to produce the optimum reduction in distortion for a specific installation. The filter system is manufactured to comply with local regulations and/or recommendations concerning the levels of harmonic distortion.

Reactive power compensation can be properly planned with the aid of the diagram below.