Energy and cost savings with power factor correction

Power factor correction (PFC) is generally applied to save on maximum demand charges or power factor penalties levied by electricity distributors. If properly applied, PFC can also reduce energy consumption in many types of installation.

There are two potential cost savings areas associated with power factor correction.

- Additional connection charges paid to the suppliers in terms of maximum demand charges or power factor penalties
- Increased losses in the installation wiring and damage to switchgear and other components

Low power factor increases losses in the distribution network and hence the size of cables, switchgear and transformers required to maintain voltage regulation, and increases the cost of delivering power to consumers. Most distributors levy a penalty on customers with a power factor of below 0.95, either directly or via maximum demand charges.

Additional cost savings can be achieved by reducing the impact of low power factor within the customers installation, and this article focusses on this often overlooked opportunity.

Where should PFC be applied?

PF correction may be applied at two different points in the network, either the point of connection to the grid, or the load point. This depends on the nature of the load and the cost savings required. See Fig. 1.

Centralised PFC

This application is the one most often used to avoid penalties by correcting the overall power factor presented to the grid connection, and compensates for the combined power factor of all loads in the installation. For sites with many different loads which may be switched in and out of service, automatic PFC equipment is required. This consists of banks of capacitors which are switched in and out under control of equipment which constantly monitors the power factor at the point of connection to the grid and attempts to maintain the power factor within required limits. In applications where there is a constant steady load with a constant power factor it may be easier to install fixed power factor correction equipment. Savings in this application will result from a reduction in maximum demand charges or power factor penalties.

Distributed PFC

At installations where there are many loads and long cable runs it may be worthwhile considering installing PFC at each load. Low PF results in losses within the installation which can result in significant costs, as well as affecting the performance and life time of components. Applying PFC at the load point also gives the same penalty reduction benefits to the overall PFC as a centralised system. If a centralised system is being considered, there is a clear indication that there are power factor problems, and there may be a case for distributed PFC instead.

Effects of low power factor in installations

Increased losses

Low power factor will result in an increase in the current flowing in the circuit compared to unity power factor, and this will increase the voltage drop and resistive (I²R) losses in the cabling, and other components between the main distribution board and the load.

To illustrate this, consider a well-designed circuit that meets the SANS 10142 [1] wiring code requirements of a maximum voltage drop of 5% of the nominal supply voltage at unity power factor. Table 1 shows the effect of power factor on both voltage drop and circuit losses.

At unity power factor the reference current of 100% produces a voltage drop of 5% and this results in losses amounting to 5% of the total energy consumed.
At a power factor of 0.9 the current rises to 100/0.9 = 111.11\%

And the voltage drop will rise to 5 \times 111.11 = 5.56\%

This results in the losses increasing to 111.11 \times 5.56 = 6.17\%, an increase of 26.4%.

Table 1 shows that at a power factor of 0.6 the losses have risen to 13.89% of the total power drawn.

For example consider a load drawing 100 kW at unity power factor. The total power drawn will amount to 100/0.95 = 105.26 kW, and losses will amount to 5.26 kW.

Table 2 shows the losses for power factors ranging from 0.9 to 0.6.

To be completely accurate we need to add the fact that IR losses are dissipated as heat, and if the building is air-conditioned, this will add to the heat load. Assuming a COP of 2 for the air-conditioning plant, the total additional load requirement resulting from low power factor is shown in Table 3.

Overloading of switchgear

All switchgear used in installations, including circuit breakers and isolators, is rated on current carrying capacity, and is designed to work correctly when carry the rated current. Low power factor increases the current flowing in a circuit and can place stress on switchgear and even result in nuisance tripping or failure. If a circuit is designed from the outset to carry a maximum current at a high power factor and equipment is subsequently installed that causes a low power factor, the maximum current limits of switchgear can be exceeded if the circuit is fully loaded.

Case study

The installation consisted of three 24 kW rectifier units feeding telecommunications equipment. The unit efficiency at full load was 85% with a power factor of 0.85 giving a phase current at full load of approximately 144 A. When the units were installed they were running at well below full load, but the load increased with time until they were almost at full load. Reports had been received that the circuit breaker was overheating and showing signs of being overloaded, and plans had already been made to upgrade the distribution board.

Measurements revealed that the current drawn was well above that expected and the power factor was in fact around 0.6 instead of 0.85. At full load a power factor of 0.6 gives a phase current of 204 A, 60 A more than that expected. Further investigation revealed that power factor correction capacitors in the units had been disconnected. As previous incidents of capacitors overheating and catching fire had occurred. A modification had been developed to overcome this fault but had not been applied.

Restoring the power factor correction capacitors returned the current levels to that expected, obviating the need to upgrade the board and removing the stress on the circuit breakers. The modification was subsequently applied with no further problems. 60A represents a 40% overload on the components of the installation at 0.85 PF, and a 50% overload at unity power factor.

Other effects

From table one it can be seen that voltage drop increases with power factor. The effect of this will depend on the type of load.

- **Constant power loads**: reducing the voltage will result in further increase in current which will increase wiring losses even more.
- **Motor loads**: Generally a lower voltage will result in a higher current which will reduce the voltage even further. In addition, if the motor is heavily loaded, the higher current may exceed the safe limit of the motor.
- **Linear loads**: lowering voltage will lower the current drawn. However low power factor is not generally associated with linear loads, but these may be connected in same circuit as loads with low power factor.

Applying PFC at the load has the advantage of being self adjusting, as each load does its own correction and switching loads in and out should have no effect on the overall power factor.

Does power factor improvement increase energy consumption?

This may sound strange as most of the previous argument is based on savings in energy. However there is some evidence that in some cases power factor improvement may well increase energy consumption. This is based on the fact the improving PF will result in a higher voltage at the load. For linear loads this will increase power consumption, but the effect on other loads varies.

A study performed on the effects of lowering voltage on a typical mixture of commercial and industrial loads showed that energy decrease for every percentage point decrease in voltage was between 0.5 and 1.2% for commercial installations and between 0.6 and 1.2% for industrial installations [2]. This implies that for every percentage point increase in voltage the energy consumption will increase by similar amounts, which could reduce the energy savings achieved by applying PFC.

**Decision criteria**

The choice between centralised and distributed PFC will depend on the characteristics of the installation and each installation will require its own solution. If power factor problems are resulting in higher network connection charges then there could be probably high losses within the installation as well. The example given has been taken at the limits of voltage drop for installations, and the energy savings or reduction in losses for an installation will depend on the actual voltage drop existing and how well or how badly the installation is designed. Installations running at well below design capacity will have lower internal losses and may not benefit from distributed PFC. On the other hand a heavily loaded and badly configured installation could benefit more than the examples given here.

**References**


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