Power factor correction - factors influencing the return on investment in commercial and industrial applications

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ABSTRACT

Power factor correction can help industrial and commercial electricity users to not only significantly reduce their energy costs but also free up capacity on the electrical supply to their installations. There are a number of factors which influence the return on investment of this type of energy efficiency intervention, some of which have a significant impact on the viability of an investment in power factor correction equipment. The purpose of the paper is to educate the reader in the above factors and enable them to obtain the required knowledge when considering an investment in power factor correction equipment

1. INTRODUCTION

Up until fairly recently, the return on investment for power factor correction equipment, in commercial and industrial applications, was unacceptably long for most company executives.

The significant electricity tariff increases introduced in recent years, have made investments in power factor correction very attractive for most commercial and industrial consumers.

2. WHAT IS POWER FACTOR

Power factor is the ratio between the active power (KW) and the apparent power (KVA) drawn by an electrical installation. It is a measure of how effectively the current drawn by the load is being converted into a useful output.

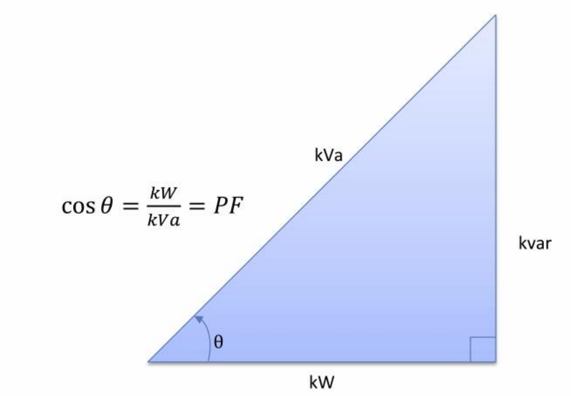

Figure 1: Power triangle

All current will cause losses in supply and distribution systems. A load with a power factor of 1.0 results in the most efficient loading of the supply and a load with a power factor of 0.5 will result in much higher losses in the supply system.

A poor power factor is the result of a significant phase difference between the voltage and current at the load terminals.

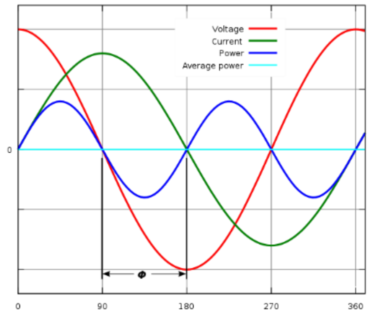

Figure 2: phase angle

A poor load current phase angle is generally the result of an inductive load such as an induction motor, power transformer, lighting ballasts, welder or induction furnace.

A poor power factor due to an inductive load can be improved by the addition of power factor correction equipment.

3. POWER FACTOR CORRECTION OF INDUCTIVE LOADS

An inductive load, such as a motor, draws current from the supply, which is made up of resistive components and inductive components.

The resistive components are:

- Loss current (small)
- Load current

The inductive components are:

- Leakage reactance current (small)
- Magnetizing current

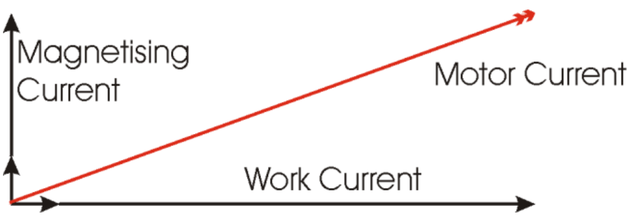

Figure 3: Current vectors

The current due to the leakage reactance is dependent on the total current drawn by the motor, but the magnetizing current is independent of the load on the motor. The magnetizing current will typically be between 10% and 30% of the rated full load current of the motor.

The magnetizing current is the current that establishes the flux in the iron and is essential if the motor is going to operate. The magnetizing current does not actually contribute to the actual work output of the motor. It is the catalyst that allows the motor to work properly. The magnetizing current and the leakage reactance can be considered passenger components of current that will not affect the power drawn by the motor, but will contribute to the power dissipated in the supply and distribution system.

In the interest of reducing the losses in the distribution system, power factor correction is added to neutralize a portion of the magnetizing current of the motor. Typically, the corrected power factor will be above 0.95

Some municipalities penalize consumers with a poor power factor by charging them for excessive reactive power consumption (kVArh > 30% of kWh consumed during the same period) and by doing so, encourage them to reduce wasted energy by applying power factor correction.

Power factor correction is achieved through the addition of capacitors in parallel with the connected inductive load and can be applied directly to the load (static power factor correction), or applied at the distribution panel (bulk power factor correction).

The resulting capacitive current is a leading current and is used to cancel the lagging inductive current flowing from the supply to the inductive load.

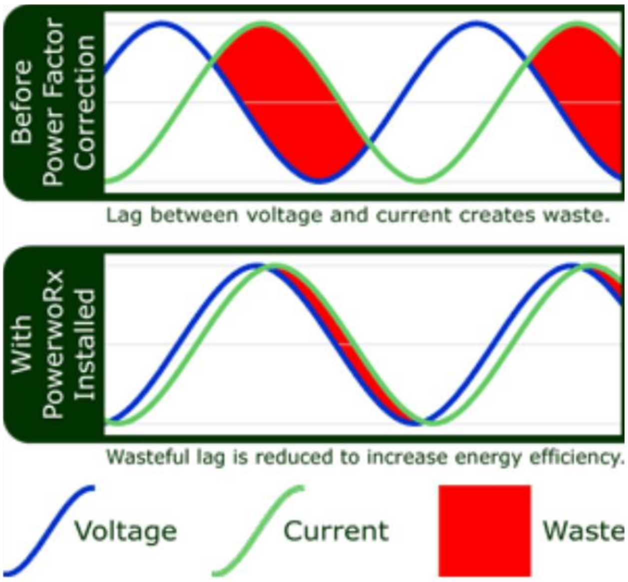

Figure 4: current and voltage wave forms

4. BENEFITS OF POWER FACTOR CORRECTION

4.1 Reduced electricity costs

Eskom provides working (kW) and reactive power (kvar) in the form of apparent power (kVA) and its transmission and distribution system must be large enough to provide the total power drawn by the users.

Eskom and the municipalities have various ways of passing along the expense of larger generators, transformers, cables, switches, etc. to the consumer.

A reduction in apparent power or maximum demand (kVA), as well as a reduction in reactive power consumption (kVArh) results in a reduction in electricity costs.

4.2 Reduced losses

Losses caused by poor power factor are due to reactive current flowing in the system. These are watt-related losses and can be reduced through power factor correction.

Power loss (watts) in a distribution system is calculated by squaring the current and multiplying it by the circuit resistance (I^2R)

4.3 Increased system capacity

Power factor correction capacitors increase system current-carrying capacity. Raising the power factor of an electrical load, reduces the apparent power drawn by the load. Therefore, by adding capacitors, additional kW load can be added to a system without altering the kVA load.

5. FACTORS INFLUENCING THE RETURN ON INVESTMENT OF POWER FACTOR CORRECTION EQUIPMENT

In order to identify the right power factor correction solution, it is imperative that the load profile of the installation be known. Sophisticated high speed data logging equipment is typically installed for a period of +/- 7 days on the main supply to the installation, in order to obtain all the required data needed to determine the correct power factor correction solution.

5.1. Equipment and installation cost

5.1.1. Quality of key components

The reliability and life expectancy of power factor correction equipment is primarily determined by 2 factors: the identifications of the correct **specifications** of the power factor correction equipment for the environment in which it will be operating as well as the **quality of the key components** of power factor correction equipment, being the capacitors, harmonic blocking reactors, contactors or thyristor switches and the controller. High quality components will increase the investment value but will ultimately result in lower life cycle costs.

5.1.2. Enclosure

The IP rating of a power factor correction panel can have a significant impact on the cost of the equipment. Since good ventilation is required to ensure the longevity of the capacitors, the higher the IP rating of the panel, the more it will interfere with standard ventilation methods. In some instances, dedicated closed loop air conditioning systems have to be installed on the panels in order to keep the operating temperature inside the panels within acceptable limits.

Enclosures which have non-standard dimensions due to available space constraints or special material requirements such as stainless steel for corrosive environments, can also have a significant impact on the equipment cost.

5.1.3. Operating voltage

The cost per kVAr produced by an MV or HV capacitor is typically lower, when compared to an LV capacitor. MV and HV switchgear is however far more expensive than LV switchgear. Installations with a maximum electrical load of up to 2 MVA, typically require LV power factor correction equipment. Above 5 MVA, MV power factor correction equipment is usually more cost effective.

5.1.4. Harmonic blocking reactors

Although power factor correction equipment does not generate harmonics, the capacitors of a power factor correction system do amplify harmonic levels present in a distribution system. When the harmonic amplification results in unacceptably high levels, harmonic blocking reactors need to be fitted in series with the power factor correction capacitors banks, and this has significant cost implications.

5.1.5. Elevated ambient temperatures

In environments where the ambient temperature is elevated, additional ventilation and even cooling is required to ensure that the operating temperature of the capacitors is not excessive (typically below 55 degrees Celsius).

5.1.6. Installation constraints

The installation costs of power factor correction equipment can be as high as 25% of the total investment of a power factor correction solution. Cable length, protection requirements, access constraints and after-hour installation can have signification cost implications.

5.1.7. Thyristor switches

In environments where frequent and significant electrical load changes occur, standard capacitor switching contactors cannot be used to effectively correct the power factor of the electrical installation. Thyristor switches are required in these environments, which are far more expensive than contactors

5.2. Applicable electricity tariffs

Eskom and municipalities have different electricity tariffs that they apply to their various customer segments. They all use terminology which is difficult for non-technical people to understand and as a result, they do not appreciate the cost saving opportunities they have at their disposal. Some of the tariff sub-headings on which power factor correction can have a positive impact on, are detailed below.

5.2.1. Maximum Demand or Energy Demand

Maximum Demand, (sometimes also referred to as Energy Demand) is the highest 30 minute average power demand of an installation during a particular billing period and is expressed in kVA. The maximum demand charge is expressed in R/kVA and can be as low as R15.20/kVA (Eskom Nightsave Urban tariff, low season) or as high as R218.37/kVA (Eskom Nightsave Rural tariff, high season).

5.2.2. Reactive power consumption

Under certain tariff structures, the consumer is charged for his reactive power consumption (for example R0.1144/kVArh under Eskom Megaflex high season tariff)

5.2.3. Network access charge

The highest Maximum Demand of an installation during the previous 12 months is sometimes levied by Eskom and certain municipalities (over and above the monthly Maximum Demand charge), under the Network Access tariff heading (Ekurhuleni Tariff E: R38.09/kVA, for example). The affected customers are being billed for their Maximum Demand in the previous billing period (month) as well as the previous 12 months. As a result, the full benefit of an intervention in power factor correction is only seen 12 months after its implementation. This can have a significant impact on the return on investment of power factor correction equipment.

5.2.4. Distribution network capacity charge

Eskom levies under certain tariffs also for their distribution costs (over and above all other charges listed above). In the case of the Megaflex tariff, the charge can be as high as R14.15/kVA

As previously explained, power factor correction has a positive impact mainly on the apparent power and reactive power drawn by an electrical installation. It stands to reason that the higher the cost structure the user is subjected to, the higher the savings will be through power factor correction interventions.

5.3. Uncorrected and target power factor

The worse the power factor of an electrical installation is, the greater the opportunities for savings to be achieved through power factor correction. The smallest intervention in an installation with a power factor of 0.6, for example, has a significant impact on the apparent power drawn by the installation.

For example, an active load of 300kW at a power factor of 0.6, will have an associated apparent power of 500kVA and reactive power of 400kVAr. By installing a 175 kVAr power factor correction panel on this system, the power factor will improve to 0.8 and the apparent power will drop from 500 kVA to 375 kVA.

However, the law of diminishing returns is applicable, when it comes to power factor correction. As the power factor of an installation improves through a power factor correction intervention, the associated reduction in apparent power drops as the power factor approaches unity.

The figure below explains this: assume a load of 100 kW at a power factor of 0.7. It takes 67 kvar of reactive compensation to improve the power factor to 0.95 and reduce the apparent power to 105kVA – a saving of 37 kVA.

However, it takes an additional 33kVAr to improve the power factor to unity, which will only result in a marginal saving of 5kVA.

In other words, as the corrected or target power factor approaches unity, it takes significant amounts of reactive compensation and associated investment, for a marginal reduction in apparent power.

The payback period for investments in power factor correction equipment for installations with a very poor power factor (below 0.7), is usually between 3 and 9 months.

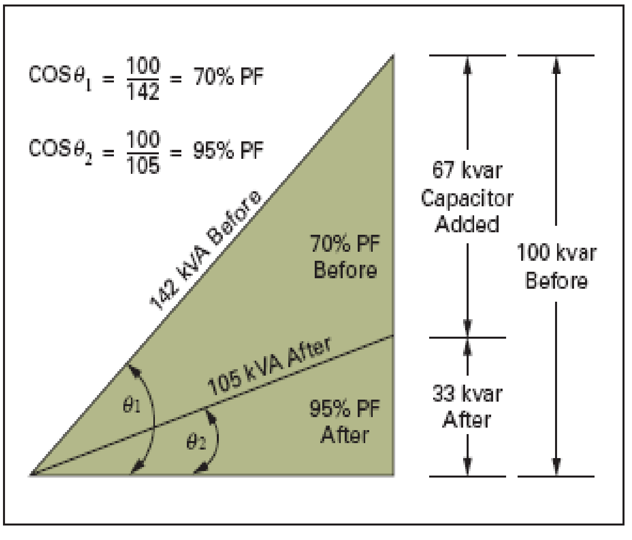

Figure 5: power vectors

5.4. Unbalanced loads

In situations where the phase loading of an installation is unbalanced and the loads cannot be shifted to improve this situation, the reactive compensation has to be done on each individual phase, rather than across all 3 phases simultaneously. This can have a significant impact on the investment required.

5.5. Static vs. bulk power factor correction

Automatic power factor correction equipment is usually installed by the main incomer, in order to correct the power factor of the complete electrical installation (bulk power factor correction) and it automatically adjusts the reactive compensation, as the load changes.

However, if there are only a few large inductive loads in the plant, it may be more economical to install a dedicated power factor correction capacitor on the individual inductive loads (static power factor correction).

5.6. Additional protection required

Poor electrical power quality conditions often result in additional protection devices having to be installed in power factor correction equipment, in order to ensure the longevity of the equipment. Protection devices such as surge arrestors, under- and over-voltage protection relays and constant voltage transformers for the control voltage of the power factor correction system, often have to be installed. This has significant cost implications.

6. TYPICAL INVESTMENT PAYBACK PERIODS FOR POWER FACTOR CORRECTION EQUIPMENT

The typical payback period of an investment in power factor correction is around 12 months, but it can be as low as 3 months and as high as 36 months, depending on the factors detailed above.

The minimum life expectancy of power factor correction equipment is at least 10 years, assuming minimal preventative maintenance is carried out at regular intervals, which consists mainly of keeping the equipment clean and well ventilated.

7. INDUSTRIES BENEFITTING MOST FROM POWER FACTOR CORRECTION

Typically, low power factor results when electric motors are operated at less than full load. This often occurs in cycle processes — such as those using circular saws, ball mills, conveyors, compressors, grinders, punch presses, etc. — where motors are sized for the heaviest load.

Examples of situations where low power factor (from 30% to 50%) occur include a surface grinder performing a light cut, an unloaded air compressor and a circular saw spinning without cutting.

The following industries typically exhibit low power factors:

Industry	Uncorrected Power Factor
Saw Mills	45% - 60%
Plastic (Esp. Extruders)	55% - 80%
Machine Tools, Stamping	60% - 70%
Plating, Textiles, Chemicals, Breweries	65% - 80%
Hospitals, Office buildings	80% - 90%

Table 1: typical industries with low power factor

8. CONCLUSION

Industrial and commercial organisations can no longer ignore the benefits of power factor correction.

Failure to do so will not only result in significant and unnecessary costs being incurred by these organisations but will also affect their opportunities for growth.

Indeed, Eskom and municipalities have started to cap the maximum apparent power organizations can draw from the power distribution network.

In order to add additional electrical equipment on their premises, organizations are now forced to improve their power factor and use more energy efficient electrical equipment.

The return on investment of power factor correction equipment will continue to improve, as the electrical energy costs continue to rise.

10. REFERENCES

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13. PRESENTER

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