FIEA Management Seminar

“MAINTECH 2005”
Improving Machine & Maintenance Technologies in the Mill

Power Factor Correction for Improved Efficiency and Operating Costs

Andy Tuthill
Embedded Systems Engineer
Metalect Industries
108 Riri Street
Rotorua
New Zealand
Phone: +64 7 348-0286
Fax: +64 7 347-9707
Email: andy@metalect.co.nz
Electricity is the lifeblood of modern industry. Correct power factor can help get the most out of the site supply and allow for higher profitability through lower maintenance costs, improved system capability, or reduced line charges from the power provider. An uncorrected site could be experiencing many detrimental effects. Premature equipment failure and high supply premiums can be symptoms of bad power factor. Efforts to expand the system capability within a site could also be affected. Correcting the power factor will help make an industrial site work better. This presentation will define power factor, explain the main benefits of correcting a site’s power factor, and review the main methods of correction.

Power factor is defined as the cosine of phase angle between the voltage and current on an AC power supply. The phase angle is named based on the current in relation to the voltage. When the current is first the system is referred to as leading, and when the voltage is first the system is referred to as lagging (figure 1). When they are in phase it is referred to as unity and shown as 1.00. Power factor is normally shown as 0 to 1 lagging or 1 to 0 leading, with the figure falling away from 1.00 as the difference increases. It is generally accepted that a power factor of 0.95 lagging to unity is the desired range to operate the plant. It is not desirable to run the plant with a leading power factor.

Operating the plant in the optimal range of 0.95 lagging to unity will result in two main benefits. The first is a reduction of KVA on the main switch board and the supply transformer. This will reduce the plant’s power account if the supplier is charging on a maximum KVA basis. This reduction of KVA leads to the second benefit which is an increased plant capacity without changing the transformer or any cabling. Power line companies usually require large consumers to maintain a minimum power factor of 0.95 lagging. Customers who do not meet this requirement are usually billed a penalty charge based on the worst half hour power factor average for the given month.

Example Phase Difference in AC Supply

![Example Phase Difference in AC Supply](image)

Figure 1 – Phase Differences, leading and lagging currents
A more in depth understanding of power factor can be beneficial to understanding commonly used terms. When there is a difference in phase, it indicates that energy is being built up in the plant which is normally large inductive motors. These motors naturally create a magnetic field in their windings which opposes the normal flow of power on half of the AC sine wave. This power is commonly called 'reactive energy' or 'reactance' and is measured in VAR, or Volts-Amps-reactive. Higher reactance in a system requires more amperes to achieve the same watts (see figure 2). Reactance can be inductive or capacitive depending on the device storing it. The two types of reactance oppose each other and are used to minimize the total reactance in the system (see figure 3). In an uncorrected mill the power factor can easily be in the range of 0.6 to 0.75 lagging, showing that the amount of actual useable amps is significantly less than what is being supplied. The extra amps being drawn are used to maintain the reactance rather than perform work in the load. This is the fastest way to derate a mains supply and lower the total useable power, hence the extra KVA mentioned earlier. Simply by correcting this problem a site can recover all of this capability and maximize their power supply.

*The "Power Triangle"*

![The Power Triangle](image)

- Apparent Power measured in KVA
- Reactive Power measured in KVAR
- Power factor = cosine of the phase angle
- True Power measured in KiloWatts

Figure 2 – Power Triangle showing relationship of Power Factor to KiloWatts and KVA
Countering a low power factor is accomplished by installing a corrective control system with an automatic controller. A typical system is mounted in one or more standard industrial electrical cabinets depending on the amount of equipment needed. Capacitors are switched in and out of the system in parallel with the main load to reduce the reactance and maintain the power factor in the required range. A standard connection for a single phase controller is shown in figure 4. Three phase controllers require a current transformer (ct) on each phase. The switching has traditionally been done by contactor relays and continues to be the basic method. It has the advantage of being simple and cheaper compared to other methods. Metalect systems utilizing this method are referred to as MPE systems. A newer method detects the zero-volt crossing of the mains supply before turning on solid state components. These components are typically SCR’s, or silicon controlled rectifiers, and they handle the load while the contactor relay is switched on or off. Metalect systems utilizing this method are referred to as ZVX or Zero Volt Crossing systems. The advantage of ZVX switching is that the contactors do not experience any of the arcing of the MPE systems which increases the contactor life considerably. It also greatly reduces interference which can disrupt other control systems such as SCADA and PLC’s. While being slightly more complex ZVX is preferred by many industries where extra interference is intolerable. The lower maintenance costs appeal to everyone. The third method is similar to the ZVX but does not use contactor relays. All switching is done by the SCR’s which allows for a fast response time of one second between switches, hence Metalect systems using this method are referred to as Rapid Switch. A Rapid Switch system allows for the highest level of control available. They are used where a high power factor is essential for correct system operation or the load significantly changes in a short time.
Power factor can quickly become a complex topic. Understanding the concept does not require a very in-depth knowledge. Knowing what power factor is and the benefits it can provide to an industrial site allows for better planning and tighter control of operating costs. The different methods available to correct the power factor allow planners to have a system designed to meet their needs. Once installed, a power factor correction unit will typically pay for itself within the first twelve to eighteen months making it a very cost effective power solution for any large power consumer.
Power Factor Correction for the Timber Industry

- What is power factor?
- How will it benefit a site?
- How is correction performed?
- Case studies
What is Power Factor?

- Power factor is the cosine of the phase angle between the voltage and current.
- In plain English: values less than 1.00 (or Unity) show a phase difference.

More About Power Factor

- Power can be expressed as a triangle:
How Capacitors Correct Power Factor

- Capacitance and Inductance are opposites and cancel each other.

Benefits of Good Power Factor

- Minimizes the amount of amps used
- Prevents excess line charges by suppliers
Power Factor Line Charges?

• Power companies monitor the power factor average.

• Low power factor can result in a higher supply cost being charged.

Correcting Power Factor

• Capacitors are switched into the mains by a controller to cancel inductance.
Contactor Switching

- Contactor relays are frequently used to switch the capacitors in and out of the system.

Zero-Volt Crossing Switching (ZVX)

- Solid state components take the load while the contactor is switched on and off.
Rapid Switch

- All solid state switching.
- Fastest response time.

Case Study: Tachikawa

- Mill 2E uses 420 KVAR of capacitance
- Arranged in 9 steps with two being smaller to allowing for fine tuning.
Case Study: Tachikawa

- Uncorrected line currents average 720 amps per phase
- Corrected these averages are reduced to 460 amps per phase, over 36% less

Graphs Show Higher Amperage at Low Power Factor
Case Study: Ports of Napier

- Rapid Switch system used to handle continually changing load.

- Example system has 14 steps totaling 650 KVAR.

Case Study: Ports of Napier

- Maintaining 0.99L allows for maximum amount of load to be connected.

- Example Rapid Switch system maintains target of 0.99 with +/- 0.01 accuracy on a changing load.
Case Study: Ports of Napier

- A ZVX System is used to prevent problems with PLC's and a SCADA system

Case Study: Rotorua Water Treatment

- A ZVX System is used to prevent problems with PLC's and a SCADA system
- The ZVX System is installed in the control room and has not effected any other equipment
Case Study: Rotorua Water Treatment

- Load is primarily VSD’s and pumps, harmonics does not effect correction.

- Council has saved $734 dollars per month average on a 50 KVA load.
In Summary

• Power factor boards normally pay for themselves in 12 to 18 months

• Power factor correction is very beneficial in both performance and financial terms