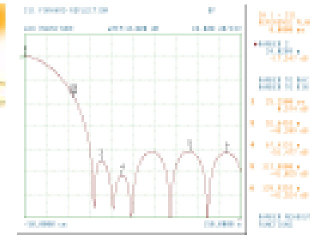

Power Factor and Harmonic Suppression:

A Technical Paper:

Scope: The scope of this document is to explain the fundamental principles and the science of power in an alternating current power delivery system, the effects of some components. The impact this can regulate the charges on a typical electric bill. There are terms, formulas and definitions at the end of the document.

POWER FACTOR OPTIMIZATION

Real Power vs. Apparent Power

Real Power is the amount of power that is dissipated in a circuit from the AC source. For resistive loads, like an incandescent light bulb, Apparent Power and Real Power are the same. In practical application, most loads are either resistive, or they are inductive. Inductive loads are loads that have coils of wire in them. This includes but is not limited to transformers, and motors. Motors are the way that electrical energy is transformed into mechanical energy, thereby making it by far the most likely consumer of reactive power in your facilities. As an example, an Air Conditioner unit has a blower motor in the inside unit or air handler, along with a compressor and a fan in the outside unit. These devices are frequently your biggest source of reactive power in your facilities. The presence of Reactive power is measurable with an amp meter and Power Factor Meter. There are two loads that create reactive power: coils of wire called inductors (the windings in a motor) and capacitors.

Coils of wire cause a delay or change in current while it charges up a magnetic field in the coil. The coil stores the charge until the current rotates through its cycle at 60 Hertz. At that time there is a delay in the current going collapsing as the coil dumps current into the circuit from the collapsing magnetic field (also known as a back EMF). In AC circuits in the USA, we operate on 60 Hertz. That means the power goes from zero to positive to zero to negative to zero, 60 times every second. That means the coils are constantly storing and discharging these currents. In theory, the charging and discharging should all equal out resulting in a net change in power of zero. The Real Power is what the load would draw if there were no reactance. Many engineers know that there should be a theoretical cancellation from the charge and discharge. The problem is that things in this Real World do not behave the same as in a theoretical world. Wire does have resistance, and therefore losses. The magnetic fields expanding and collapsing in the motor are not as perfect as the theoretical world either. When the current is demanded to charge the coil, it travels down the length of wire from the supply to the motor. All that loss adds into the system. When the coil is discharging, it is doing so all the way back to the transformer that is supplying the power. That is typically a lot of wire. If we could keep the wire length a relatively short distance, we would only be paying for the loss of a short wire, have you ever noticed the effect of long extension cords on power tools?

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Now, let's enter the other Reactive load, capacitance. Capacitors work on Volts like coils work on Amps. The capacitor charges with the voltage and the coil charges the flow of amps, and if they are properly matched, the will "fill in" delays for each other, making a power factor of 1.0. At that point, the amps on the power line (not between the capacitor and the coil, but from where they tie together to the breaker panel, through the meter to the transformer) is matched in mathematic vector phase by the amount of amps that was caused by reactive power.

Here is an example:
If a motor draws 5.5Amps, but when the power factor is optimized, the amps drop down to 1.5 amps, we will see a lower total power draw in kVA in the system. On a calibrated Watt meter, the only difference you would read is the reduction from the lower amps on the wire. In practice this has shown to be as high as, for example 18% in tests performed by Honeywell engineers when testing their chiller motors.

Minimal Benefits
There are many factors to consider in regard to power factor optimization. Some of these factors include being responsible to minimize waste, other factors may pay the user a financial dividend for taking responsible action, in the form of reduced electric bills. Reducing the I2R losses in the wiring through your facilities will reduce the wasted power lost in the cables from your power meter to the transformer that delivers power to your facility in addition to reducing the losses from your power panel through your facility to your load. Fixing the Power factor will reduce the losses in the whole system. The losses in the wiring from the transformers to your power panel end up getting paid by someone. This is power that goes away in unwanted heat. Part of the power company's overhead costs in your rate is to pay for those losses. If everyone optimized power factor, there are miles of wire that would have less wasted power going through them. On an individual basis, power factor optimization benefits may be very significant. It would depend on the amount of reactive load demanding amps in your facility.

Power Factor and Billing
Power companies are typically regulated by the state in which they operate. Usually this is handled by the Utility Company filing a tariff with the government agency explaining how they will bill their customers. If there is a dispute in a customer's bill, the state uses the tariff to determine if the utility is billing according to the tariff (billing plan). These tariffs may be available from the utility company's web site or on your states web site. Examine the tariff and look for occurrences of the words "power factor". From reading several tariff's, there are frequently provisions that the customer is required to maintain a certain power factor range or there may be actions taken against them. Sometimes it may be penalty charges, or even that the utility company may come out and install equipment and bill the customer for it. This action depends on who the utility company is. There are some utilities that do not mention power factor at all.

If there is a penalty for power factor, the savings may be much greater than just the I2R losses in the system. One utility has a clause that if the power factor is less than 85%, they will bill as if it were 85%.

What these charges and tariff's translate to is if a motor is running at 65% Power Factor, for every 100KWatts consumed, the customer gets billed 130KWatts. If that is all that is on that bill, a savings of 30% would be realized by power factor optimization, without even considering the I2R losses.

Conclusion
Power factor optimization is something worth considering. A suggested course of action is to contact a competent company to check your facility, like Venergy Group. Check with them as to how your utility company charges for power factor. Have them provide you a link to the state or utility company's web site that shows the claims are correct. Have them explain what they would do and why, in addition to what to expect in reductions on your electric bill.

Terms, Formulas and Definitions
Basics: The electrical components of power include the following parts:
Electromotive force, measured in Volts and represented as V in mathematical formulas.

Current, measured in Amps or Amperes and represented as A or I in mathematical formulas.

Power, Power is broken into four (4) primary measurements in an alternating current circuit:

Real Power measured as Watts and represented as W in mathematical formulas.

Reactive Power, measured as Volt Amps Reactive and represented as VAR in formulas.

Apparent Power measured as Volt Amps and represented as VA (Volts times Amps) in formulas.

Power Factor, measured as a number between 0.0 and 1.0. This number is a ratio between Real Power and Apparent Power in the circuit. Often it is expressed as a percentage. If Real Power equals Apparent Power, the Power Factor is said to be at unity or 1.0 or 100%. Power factor is W/VA, and expressed as (PF) in this document.

Resistance, measured in Ohms and represented as R in mathematical formulas. Resistance determines the current in a circuit. The Amps is equal to the Volts divided by the Resistance (A=V/R).

Impedance is similar to resistance, however it compensates for power used by reactive components in an Alternating Current circuit. Impedance is represented as Z in mathematical formulas (In AC Circuits, A=V/Z). In AC, circuits that have Impedance equal to Resistance have a Power Factor at unity. If R=Z, then (PF)=1.0.

Reactance is similar to resistance, and is only present in an alternating current circuit. Reactive current will be present if the Power Factor is not 1.0. Reactive current will either "lead" or "lag" the Voltage in an AC circuit. The power from a Reactive load, in theory, is lossless, it isn't actually used because it is a result of charging and discharging energy in Reactive components, namely Inductors (coils of wire) and Capacitors.
In reality, there are measured losses related to the fact that, in theory calculations, losses in wire resistance is ignored. In empirical (measured real life applications), the losses in real wires, components, and connections can add up to significant losses.

I2R Losses (pronounced: I squared R losses) are the measured losses due to resistance in a power system. The loses are Amps times Amps times Resistance. A significant understanding is that a 10Amp circuit on 10 feet of wire will have two (2) times as much loss as a 10Amp circuit on 5 feet of wire. Half the resistance (or length of wire) results in half the losses. A 10 Amp circuit on 10 feet of wire will have five (5) times more loss than a 5 Amp circuit on 10 feet of wire.

Thank you,

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