An Introduction to Electrical Power for the Non-Power Professional

Like it or not many IT and other professionals are thrust into a facility management role without the background in some core areas such as the electrical systems. If words such as volts, amps, watts, demand and energy are foreign, or you just need a refresher this article is for you. A basic understanding of the pertinent terminology can go a long way in helping you understand the issues surrounding your facility ranging from maintenance to energy management.

Introduction

Since you can't see electricity it can be difficult to understand the basic concepts. We'll use the classic water system analogy to help visualize the basic concepts. First some basic parameters: Volts and Amps. Volts or Voltage is a measurement of potential in an electrical circuit. Voltage is measured as the difference between two points which are usually a phase conductor (wiring) and a reference such as neutral, ground or another phase. As a result, any voltage measurement has two connections plus and minus (reference). In a water pipe voltage is like the pressure of the water. Amps or Amperage is the unit of measure for electric current or how much water is flowing through the pipe. Amperage is directly related to consumption. When putting this all together think of your shower in the morning. A shower with low water pressure (voltage) requires more water to flow (current) to rinse you off. One with higher pressure requires less water and has a higher potential to get the job done and get you to that morning coffee faster!

The last basic parameter is resistance which is the opposition to the flow of current. Resistance, which is sometimes referred to as Impedance is measured in ohms and is analogous to the size or diameter of the pipe. The larger the pipe the lower the resistance which allows more water (current) to flow. When considering wires, the goal is to have no resistance but practically speaking there's always at least a little. Each item (servers, lights, etc) connected to the circuit has a certain resistance that's placed into the circuit.

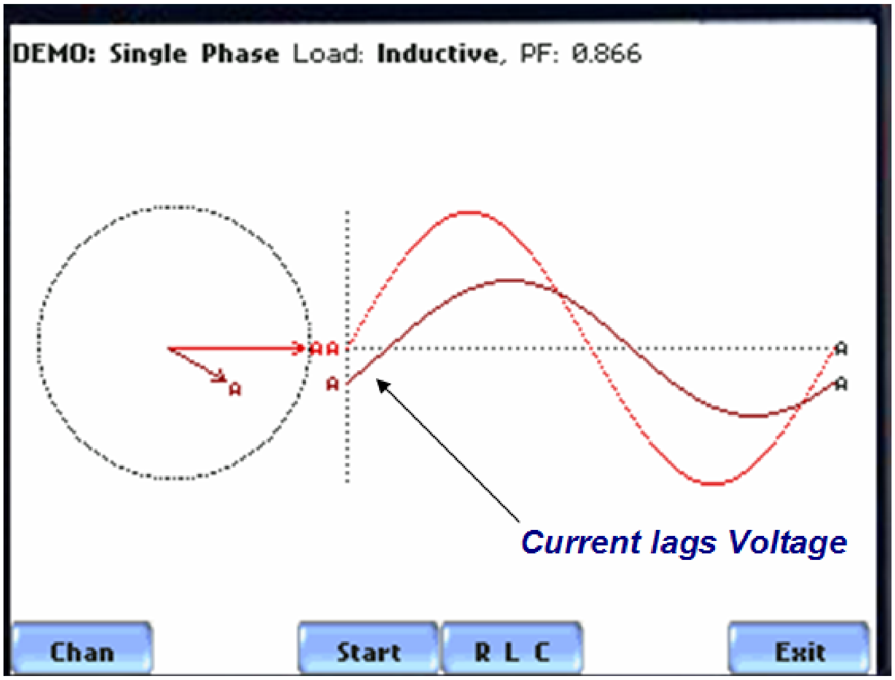
Ohms Law

Voltage (V), current (I) and resistance (R) are mathematically related by Ohms law which is the theorem that ties this all together. Ohms law is: $V = I \times R$. Consider a simple circuit with your computer plugged into a 120V wall outlet. The computer power supply completes the circuit allowing current to flow through the wires and through the power supply. Like all loads on a power system, the computers power supply has a certain resistance or load that's placed into the circuit when turned on. Following ohms law, if the resistance is 120ohms then the current flowing through the circuit is 1amp (120V/120ohms=1amp). As you can see voltage and current are inversely proportional. Assuming the resistance is constant, the higher the voltage, less current is needed to get the job done. Lower voltage requires more current to get that same job done. This is why utilities and large facilities like to distribute power at a (relatively) high voltage. The higher voltage means lower current which can allow you to use a smaller wire. Of course this is simplified but you get the picture.

AC vs. DC

Now's a good time to talk about AC (alternating current) vs. DC (direct current) systems. Direct current means that current always flows in one direction and is the simplest type of circuit to grasp for reasons we'll cover soon. Alternating current means the voltage and current are sine waves that change direction (flow) or oscillate continuously. In North America this typically happens 60 times per second or 60Hz (Hertz). Europe and other parts of the world use 50Hz systems but the concepts are the same. This oscillation makes things more complicated than in a DC circuit. Since the voltage and current continually change direction you now must also consider if they are "in phase" with one another and if not, what's the angle or time difference between them. Many people lose it here so stay tuned…The resistance or now using the more appropriate term Impedance of the load(s) make AC systems more complicated. Impedance takes into account the angle between the voltage and current and requires using complex arithmetic that includes both magnitude and angle. It turns out that not all types of loads react the same to voltage and current. Voltage and current react the same through resistive loads like a light bulb. In other words, the voltage and current remain in phase with each other. If you superimpose them on a graph they are on top of each other. However, there are other basic circuit elements called inductors and capacitors that force us to consider these as "complex circuits". We won't get into the details here but voltage and current react differently when such elements are placed into a circuit. Most real world power systems are inductive (motors, transformers, etc) meaning all of the loads look like inductors when connected together in the circuit. The electrical properties of inductors are such that the voltage can change instantaneously but not the current. The result is the current is delayed in time or "lags" the voltage. If you superimposed voltage and current on a graph you'll see the current does not line up with the voltage and is shifted in time which is usually measured in angular degrees (see the Inductive Load picture below). The opposite is true for capacitive circuits. This lag results in inefficiencies and losses in the power system. In summary AC circuits are complex and the angle between V and I must be taken into account

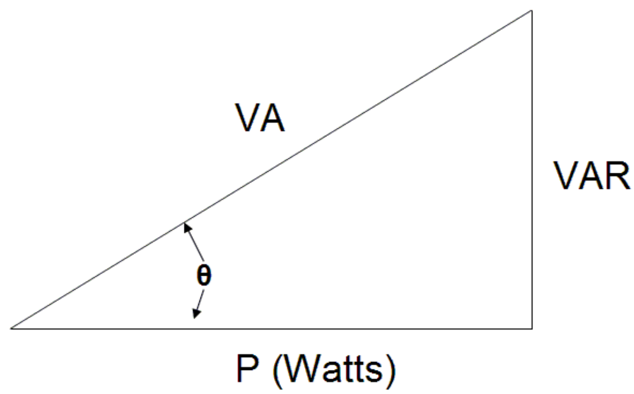
Inductive Load



Current lags Voltage. Out of phase
Power Factor < 1 (positive, opposite of capacitive)

<u>Power</u>
Kicking it up a notch, along comes power which is measured in Watts (W). Power is the ability to perform work. W = V x I x PF. Again, DC circuits are simple but most AC systems are more complicated so the angle between voltage and current must be taken into account. As a result, other terms come into play such as Power Factor (PF), Volt-Amperes (VA) and Reactive Power (VAR), see the power triangle diagram below. Power Factor is a unit-less measurement and ranges from 0 to 1 with a PF of 1 being a resistive circuit. Anything less than one means there is an angle between V & I and a typical PF may be something like 0.86. In a DC or resistive AC circuit the PF is 1 so many times it's not referenced. The power triangle below ties all of this together. W is the actual power consumed. VA represents the heating effect of the circuit while VAR represents wasted energy. Anytime VA is not equal to W there is a PF less than 1 and utilities bill consumers for such situations in the form of PF and other penalties.

Power Triangle



PF = $\cos(\theta)$

PF = W / VA

P = V * I* PF

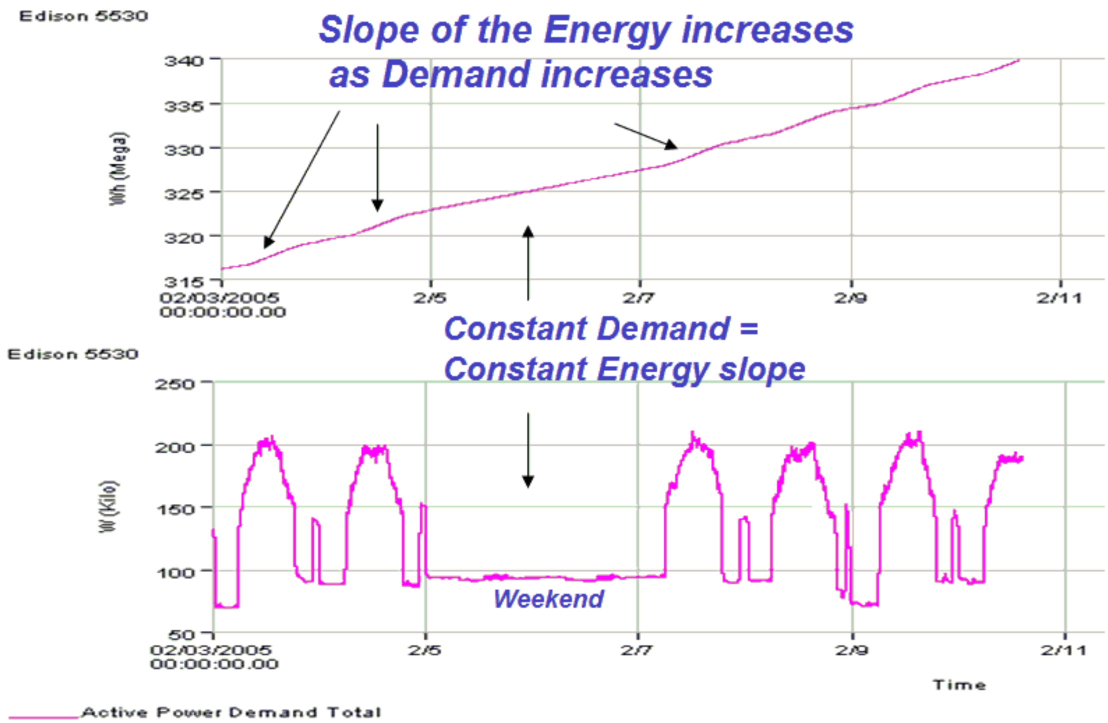
VA = V * I

VAR = VA $\sin(\theta)$

Ideally $\theta = 0$. W = VA. VAR = 0

<u>Demand and Energy</u>
Now we're into the meat and potatoes of the subject since you are billed for your energy consumption. Demand is measured in Watts (or KW) and is the amount of power consumed, averaged over a period of time called the Demand Interval. Demand interval is a basic utility billing parameter and is typically 10 or 15 minutes. Energy is an accumulation and is measured in Watt-Hours (KWh). As an example 1KW consumed over 1 hour equals 1KWh. The picture below shows plots of both demand and energy. You can see they are directly related.

Energy vs. Demand



There are many factors that go into your utility bill but demand and energy are the basic metrics used. Others can be PF penalties, ratcheting, stranded costs, fuel surcharges and more which are beyond the scope of this discussion. However, demand, energy and power factor are within your control and can be managed or reduced.

With the rising cost of energy, power monitoring systems put you in charge, allowing you to understand where and when you're consuming electricity and are the basis for an energy management/reduction program. Can your current power systems handle those new servers that pack a lot more computing power into a rack? Are you succeeding in reducing energy? Questions such these and many more can be answered by understanding your systems. Double checking that your utility bill is correct is also a good thing! Such errors are rarely in your favor.

In any high reliability environment power considerations go beyond consumption with the quality of supply being a major area of concern. Unreliable or intermittent power problems can result in costly downtime. This is a topic of another conversation but Power Quality should also be included in your power monitoring program.

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