Power Factor – A Tale of Two Currents - Part 2

Joe Evans, Ph.D http://www.PumpEd101.com

I hope that my September column provided a clearer definition of power factor and how it can be calculated. It can also be explained using a vector triangle but, I believe that comparing the voltage and current wave forms is more intuitive and leads to a clearer understanding of what is actually going on. In short, we learned that power factor is the percentage of the total current in the circuit that does work. From a power perspective it is the percentage of apparent power in kVA that actually performs work. It is also the ratio of the load power measured in kW to the apparent power measured in kVA.

Why is power factor important? After all, the current required to initiate a magnetic field in the stator is returned to the electrical grid when that field decays. There are a several reasons. Even though it is returned, the utility still has to supply it during each AC cycle and since it is not recorded by the kWH meter they do not get paid. Additionally, it is not available for sale to other customers since it must be available to meet the power factor requirement of the motor. Yet another reason is the increased wire and transformer size that is required to provide the additional current. This affects both the utility and the customer.

Let's take a look at a real example. A 30 HP, 460 volt motor has a nameplate efficiency of 94% and a power factor of 85 (0.85). The nameplate also shows a full load amperage (FLA) of 35 amps. Based upon the power factor, the current used to drive the motor load is 29.75 amps (35A X 0.85). The additional 5.25 amps are used to initiate the magnetic field in the stator and are returned to the electrical grid when the field collapses.

Now, a power factor of 0.85 is probably not a big deal when a single 30 HP motor is operating. It is unlikely that the power company would ever notice that extra 5.25 amps. If, however, it is in a plant and operating with a number of other motors, power factor becomes important. Suppose a plant operates twenty, 30 HP motors from a central motor control center (MCC). The load portion of the current increases to 595 amps and the magnetic portion increases to 105 amps (700A total). Chances are that the power company would get involved as the magnetizing current is now the equivalent of three additional 30 HP motors. Also the wiring providing power to the MCC has to be sized for 700 amps. As HP and the number of motors increase, magnetizing current becomes a costly item to both the power company and the plant.

If the power factor for these motors could be increased to 95 (0.95), the total current used by the MCC would be reduced to 626 amps. At first glance, a reduction of 74 amps may not seem like much but in a 460 volt, three phase circuit it equates to about 59 kW. That is the equivalent of removing about 74 HP from the utility's grid and allowing them to sell it to someone else. It would also increase the plant's transformer capacity and decrease wiring size on certain circuits. As a rule of thumb, conductor size doubles when power factor is reduced from 100 to 70. In addition, plant voltage will typically increase by one to two percent.

Motors can be designed for high power factor but, those design changes usually result in reduced efficiency. Today, most motors are designed for high efficiency because lower power factor can be corrected at the installation with the help of a very simple device – the capacitor. The capacitor is also a reactive device but it behaves very differently than the reactance caused by motors and other inductive loads. Fortunately, this behavior allows it to correct the problems associated with low power factor.

A capacitor can be compared to a battery since both can store and release energy. A major difference is that the capacitor can store and discharge all of its stored energy in a fraction of a second where as a battery will take far longer. A good example of a battery and capacitor working together is the electronic flash on a camera or smart phone. A battery charges the capacitor over several seconds and the capacitor dumps the full charge instantly causing the bulb to flash.

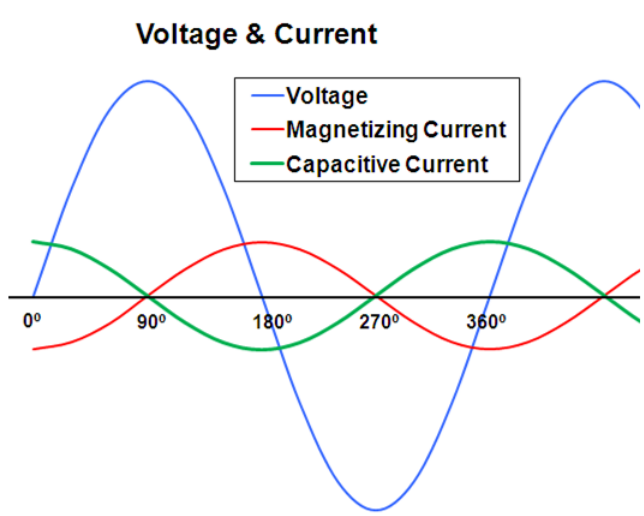

Figure 1 shows one complete AC cycle for a circuit that contains both a motor and a capacitor. The blue curve is voltage, the red one is the motor magnetizing current and the green one is the capacitive current. I left the load current out in order to keep it visually simple. The big difference in capacitive current is that it leads voltage by 90 degrees whereas magnetizing current lags voltage by 90 degrees. This puts them completely out of phase throughout the entire AC cycle. It turns out that this is a plus because the capacitor discharges current to the circuit as the magnetic field is building. When the field collapses, the capacitor stores it as a charge. In this example, the capacitor is sized to store and provide 100% the magnetizing current required by the motor so the improved power factor is 100 (1.0). Therefore the utility would be required to provide the load current only during motor operation.

Utility companies react differently to their customer's power factor. If the overall load is small, some will often ignore it. Others offer incentives to increase power factor. But, the majority charge customers an additional fee if power factor is below 0.90. Some require a minimum of 0.95.

There are several ways to install and control power factor correction capacitors. One is static or fixed correction and the other is central or bulk correction. Next month we will look at how they are installed and the impact of their location in the system. I will also provide some good references that provide detailed information on capacitor selection.

Joe Evans is responsible for customer and employee education at PumpTech Inc, a pump & packaged systems manufacturer & distributor with branches throughout the Pacific Northwest. He can be reached via his website www.PumpEd101.com. If there are topics that you would like to see discussed in future columns, drop him an email.