Pump ED 101

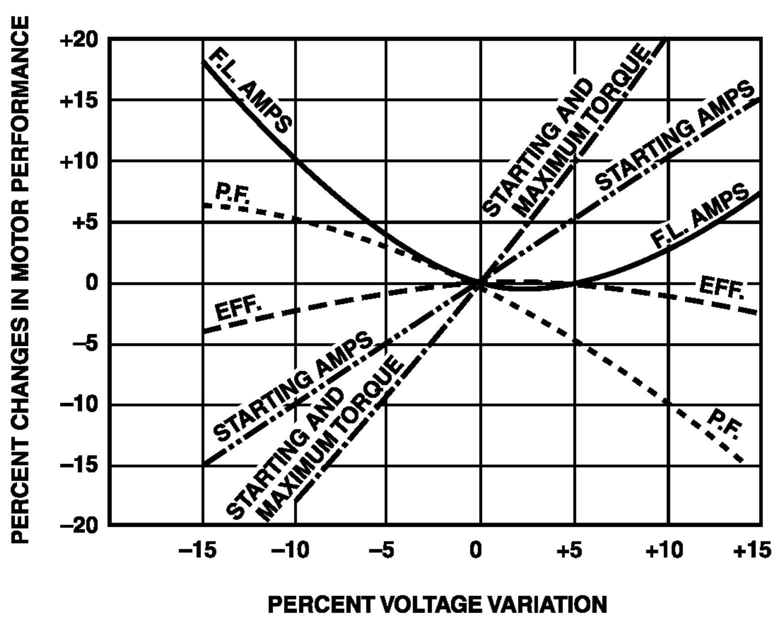
Three Phase Voltage Variation & Unbalance – Part 1

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

Three phase voltage variation and unbalance can have a significant effect upon motor insulation life. Voltage variation is defined as the difference between the motor nameplate voltage and the incoming source voltage. This assumes that the all three phases are the same voltage. Variation can be either negative or positive. Unlike variation, voltage unbalance refers to the differing voltages that can occur in each of the three phases. This month's article will review voltage variation. Next month we will cover voltage unbalance.

Prior to the introduction of the T-Frame motor in 1964, low voltage motors were designed to operate at 220 and 440 volts. Today, that standard is 230 and 460 volts and is referred to as the Utilization Voltage (ANSI C84.1). The reason that these voltages were selected is that they reside in the middle of the service range a utility is required to supply. They also allow for the voltage drop that can occur due to the distance between the motor and the service entrance. The National Electrical Manufacturers Association (NEMA) standards recommend that motors should be designed to operate satisfactorily at a voltage variation of plus or minus 10%. For 230 volts that range is 207 to 253 volts and for 460 volts it is 414 to 506 volts. The word "satisfactorily" is important because parts of this range can be less than optimal.

The graph seen in Figure 1 is commonly used to show the effect of voltage variation on several motor performance characteristics. It can be used to show the general effects but there will be variations based upon a particular motor design. The intersection of the zero (0) points on the x and y axes represent the motor nameplate voltage.



Effects of Low Voltage

The left side of the graph shows the effect of low voltage. A 10% reduction in nameplate voltage reduces motor efficiency by about 2%. In most cases this will convert that more costly, premium efficiency motor to the older, EPACT design. That same voltage reduction will increase power factor by 5%. This is a good thing but, there is a more efficient way to achieve improved power factor. Reduced voltage has its largest effect on motor torque. As shown, a voltage reduction of 10% will result in a torque reduction of about 19%. This is not usually a concern with variable torque machines such as centrifugal pumps and fans. It could, however, be a problem with constant torque loads.

The most important characteristic is full load current at lower voltages. As shown on the graph its increase is almost directly proportional to the reduction in voltage. A voltage reduction of 10% will increase full load current by 10%. This is not unexpected since the power in watts is proportional to the product of voltage and amps. This is not a problem if the measured amperage remains below the nameplate, full load amperage. If, however, the motor is loaded close to nameplate horsepower, amperage will exceed the nameplate maximum. This is not necessarily a problem if the 10% reduction is brief, as the motor's service factor is designed to handle intermittent voltage drops. If it is constant, the motor service factor is eliminated and any additional voltage drop will increase the operating temperature. The result will be a reduction in insulation life. When 230 volt motors are operated on 208 volt power systems, the normal 15% service factor disappears and additional voltage drops usually cannot be tolerated. Options include derating the motor horsepower, upgrading to the next higher horsepower or using a motor wound for 200 volts.

The final characteristic is starting amps. The opposite occurs when the motor starts and starting amps are reduced with a reduction in voltage. This is the basis for wye / delta and solid state, reduced voltage starters.

Effects of High Voltage

An increase in supply voltage above the motor nameplate rating has the opposite effect of low voltage for most motor characteristics. There are, however, two exceptions. The first is efficiency. It is also reduced at higher voltages but not as much as it is at lower voltages. The second is Full Load Amps. Full load amperage remains steady with small voltage increases but can increase rapidly above 5%. For many motors, the full load amp curve is much steeper than the one seen in Figure 1. Why do amps increase with a rise in voltage? Unfortunately, this is not a simple power issue but has to do with the magnetic field produced in the stator. At normal voltages, the motor windings create magnetic fields in the stator laminations. As voltage increases, these fields can become saturated. Once saturated, the field cannot increase in intensity so the motor draws more current in hopes of overcoming the saturation. The onset of saturation is not dependent on motor loading. It will occur in lightly loaded motors also. The higher current caused by saturation increases the operating temperature and reduces insulation life. Fortunately the newer, premium efficiency designs are somewhat more tolerant of high voltage than older designs.

Torque undergoes a major increase with an increase in voltage. So do the starting amps (inrush current) and we have to pay close attention to the number of starts per hour when operating at a higher voltages. Remember that inrush current can be five to seven times full load current. High voltage also causes a major reduction in power factor which will increase circuit loading and possibly anger your utility.

The plus and minus 10% voltage tolerance recommended by NEMA should not be used continuously. It is there to accommodate the normal ups and downs of plant and utility supply voltage. If high voltage variation (plus or minus) is continuous it is always best to correct it. Operating as close to nameplate voltage as possible will maximize insulation life.

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.