Pump ED 101

Two Steps To Increased Pump Life – (Part Two) Voltage Unbalance

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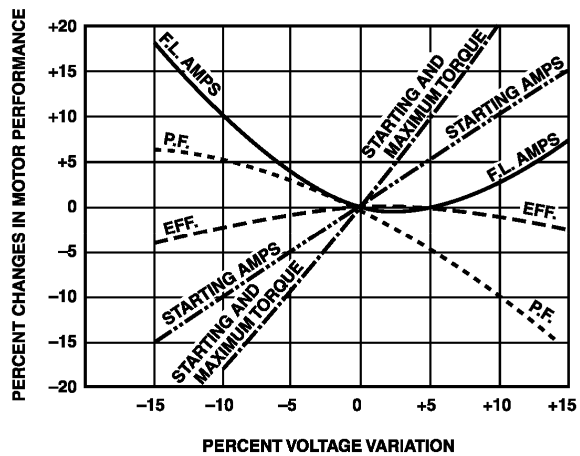
Last month we investigated the importance of identifying the actual operating point of a pump in an "as built" system or one that has changed over time. This month we will look at the electrical side of the system and its effect upon motor life.

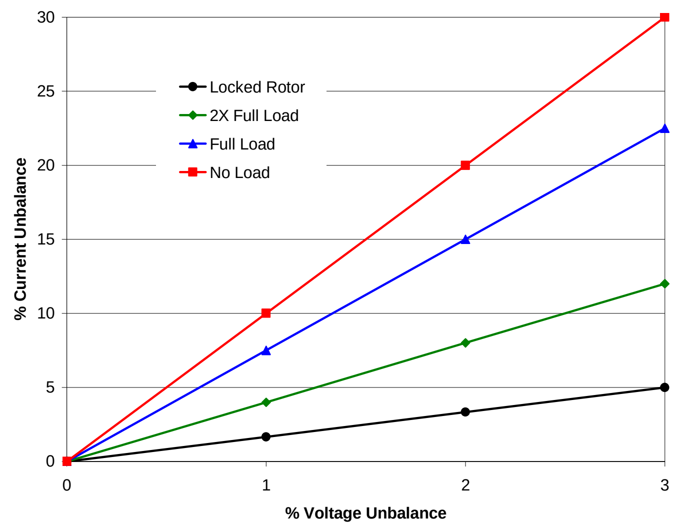


Most of us have seen the graph shown in Figure 1. It shows how a motor's various operating characteristics change with a corresponding increase or decrease in supply voltage. NEMA motors are designed to accommodate a voltage variation of +/-10% of their nameplate voltage. Will a variation of this magnitude affect motor life? Well, it depends upon the motor loading. For example, the graph shows that a 10% decrease in supply voltage will result in a 10% increase in current draw. As long as this increase does not exceed the nameplate current no damage will occur. In fact, on lightly loaded motors a small voltage drop can actually improve efficiency (the Nola effect). If, however, the motor is already loaded to its nameplate amperage, a 10% voltage drop will definitely have an adverse effect on motor life due to the additional heat that will be generated.

Figure 1 shows a similar increase in starting current when voltage increases by 10%. Also, some stator designs undergo a much larger increase in full load amps than shown on the right side of the graph. This increase is due to magnetic saturation and can be even greater on lightly loaded (<50%) motors. In the end, it is a motor's service factor (SF) that defines its ability to handle the additional current due to voltage variation (or varying loads). SF is intended to provide protection against short periods of rises and sags that occur in many circuits. If low or high supply voltage is continuous it should be corrected at the source. The closer to nameplate voltage a motor is operated, the longer its life.

Voltage Unbalance

A rise or sag in supply voltage may or may not have an adverse effect but, there is another type of voltage variation that will almost always shorten the life of a fully loaded motor. That variation is known as voltage unbalance and it is a condition where the individual phase voltages in a three phase circuit are not equal. The major effect of this unbalance is an increase in stator and rotor I2R losses which results in an even larger phase current unbalance. A voltage unbalance among the phases of just 1% can result in a current unbalance of 6 to 10% (even higher when a VFD is involved). Figure 2 is a close approximation of the % current unbalance generated by unbalanced phase voltage at various motor loads. The ratio of current to voltage unbalance increases dramatically as motor loading decreases. In the case of a fully loaded motor, a 2% voltage unbalance will typically result in a current unbalance of about 15%. NEMA motors are designed to accommodate a maximum phase voltage unbalance of 1%.



The net effect of voltage and current unbalance is a substantial increase in motor operating temperature. This increase can be estimated by the following equation: % Increase = 2(% Voltage Unbalance)^2. For example, if unbalance is 2%, the expected temperature increase would be 8%. If a motor normally operates at 130 deg C, a 2% unbalance would raise the operating temperature to 140 deg C. This may not seem like a huge increase but, insulation life is reduced by 50% for each 10 deg rise in operating temperature. A worst case scenario can occur when there is a combination of significant supply voltage variation and voltage unbalance.

Sources

Unbalanced voltage can originate with the utility or within your own distribution system. In the “Fixes” section we will identify a number of the potential causes. Another source of current unbalance is voltage distortion. This condition is due to the harmonics produced by non-linear loads and is characteristic of solid state devices. These harmonics may not lead to measurable voltage unbalance but can cause a significant current unbalance. Current unbalance can also be due to problems on the motor side of the circuit that usually do not result in voltage unbalance. Since current unbalance can exist without an accompanying voltage unbalance, an accurate system analysis will require measurement of both voltage and current in the circuit.

Measurement & Analysis

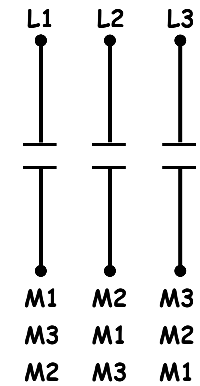
For a stand alone pump station, you can perform all of the voltage and current measurements at the control panel. If the pump is installed in a treatment plant or other multi load / motor facility, measurement should also be performed at the supply's point of entry, major circuit branches, and each pump installation.

Perform the following steps with the pump off. On the line side of the contactor, measure and record each phase to phase voltage (L1/L2, L2/L3, L3/L1). Calculate the average and identify the voltage with the largest deviation from that average. Then calculate the voltage unbalance. For example, if the measured voltages are 468, 458, and 469 the average is 465 and the largest deviation is 7 (465 – 458). The % voltage unbalance = 100 X (deviation / average) = 1.5 %. Repeat these same steps with the pump running at its maximum load (typically the pump on level in a pump down application). Also measure and record each phase to phase current while the pump is running. Use the same method to calculate the % current unbalance. Once you have all of this information you can begin your analysis.

If the voltage unbalance in a stand alone pump station is greater than 1% with the pump off, you should contact the utility as their system is probably the source of that unbalance. If it is 1% or less with the pump off but increases to more than 1% with the pump running, you will need to evaluate your current measurements. Even if it remains at 1% or less, you should still evaluate the current readings because current unbalance may exist even if voltage unbalance does not.

If the calculated current unbalance is 2% or less, you should see a normal stator life. Current unbalance between 2 and 5% can be acceptable as long as the highest current leg does not exceed the nameplate current. In this situation it will be worthwhile to roll the leads as described below as there are instances when a different lead connection sequence will reduce current unbalance. A current unbalance greater than 5% will shorten the life of a fully loaded motor.

If current unbalance is greater than 5% or one or more of the legs are above nameplate amperage you will need to locate the source of the unbalance. This can be accomplished via a technique known as rolling the motor leads. Figure 3 shows a magnetic contactor with incoming power connected at the top (L1, L2, L3) and the pump motor leads connected at the bottom. In a three phase installation there are always three possible motor lead connection sequences that will allow rotation in the same direction. Motor lead sequence M1, M2, M3 is the "as installed" connection that was used for your original measurements. Lead sequences M3, M1, M2 and M2, M3, M1 are the new connections that need to be measured. In each case, all three leads are "rolled" to the next terminal so that proper motor rotation is maintained. Record the voltage and current for each of the two new connections while the motor is running. If one of these connections reduces current unbalance to 2% or less, use that connection. If one does not, use the deviation data to determine the source of the unbalance. If, on the three lead sequences, the leg with the greatest deviation from average remains with the same incoming power lead the unbalance is a product of the distribution system. If it moves with the same motor lead, the unbalance is on the motor side of the contactor.



Fixes

If the utility is the suspected source of voltage unbalance, there can be many causes. Faulty power factor correction banks, open wye or delta transformers, harmonic distortion, and uneven distribution of single phase customers are just a few. If voltage unbalance is greater than 1% with the pump off, get them involved.

If the voltage unbalance is traced to your distribution system, check all of the system connections as vibration and corrosion can reduce their connectivity over time. A very common control panel problem is magnetic contactor wear or corrosion. If there are a number of single phase loads (fans, welders, heaters, etc) connected to the system, make sure that they are evenly distributed across all three phases. Also check for runs of unsymmetrical phase wiring. If your facility has a capacitor bank for power factor correction, check the fuses. If harmonic distortion is present, locate its source and install harmonic filters. Existing variable frequency drives may require line reactors.

If the current unbalance is on the motor side check for poor splices or J-Box connections. If none are found the problem is probably due to a faulty winding or internal motor connection and is usually not correctable.

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44805. He can be reached at *joe.evans@pentairwater.com*, or via his website at *www.pumped101.com*. If there are topics that you would like to see discussed in future columns, drop him an email.