SUBMERSIBLE MOTOR ENGINEERING

9 Rye Lane Street
Maddington WA 6109
Western Australia
TEL: 61 8 9452 2922
FAX: 61 8 9452 2722

EMAIL: jayson@smeng.com.au
ABN: 27 098 297 539

Unbalanced Currents and Submersible Motors.

27/1/02

General

One of the most common causes of failure in Submersible Electric Motors is because of overheating due to unbalanced currents, usually caused by unbalanced voltages.

IEC Report 892:1987 (AS1359.31 1997) states: "The application of unbalanced voltages to a three phase induction motor introduces a "negative sequence voltage", and this produces in the airgap a flux rotating against the rotation of the rotor, thus tending to produce high currents. A small negative sequence voltage may produce currents in the windings that are considerably in excess of those present under balanced voltage conditions. Consequently the temperature rise of the motor operating on a particular load and percentage voltage imbalance will be greater than for the motor operating under the same conditions with balanced voltages."

This applies for all induction motors, but is especially critical for submersible motors because they operate at much higher current densities than standard air cooled motors and have a much lower tolerance to increased temperatures.

If voltages are unbalanced then currents will almost certainly be unbalanced. Even if the voltages are balanced it is possible to have large current unbalance – if this is the case it is usually caused by the way the drop cables are arranged in the well. For example, we recently helped a customer experiencing 20 amps current unbalance with a 150Hp 8 Inch motor on full load, when the voltages were balanced within 1 volt at the surface. The drop cables had been tied to the flexible column with 2 phases on one side and 1 phase and the earth cable on the other to give a better mechanical balance. When the cables were rearranged with the 3 phases tied together on one side and the earth on the other side the currents were balanced within 2 amps. This large variation in current was caused by magnetic field linkage and interaction between the 3 phases, which was amplified over 250 metres of cable down the hole.

We can expect increased, uneven, and localised heating in a motor because of unbalanced currents, so it is essential to ensure that the voltages and currents are balanced when motors are commissioned. If the voltage supply to the motor is solid and stable the currents will probably remain reasonably balanced, however, on some sites, such as mine sites, large variations can occur during the day as different parts of the plant are operated and alter the supply conditions. In this type of supply environment SME strongly recommend that voltage and current unbalance protection is included in the motor protection system. Voltage unbalance is more common in rural areas where there can be large single-phase loads, which unbalance the supply.

To get an idea of the effect of voltage and current unbalance; for 1% voltage unbalance we can expect about 8% current unbalance and 10% increase in temperature rise.

The correct way to calculate the percentage Current unbalance is to use the formula below:

Percentage Current Unbalance = (Maximum current difference from average current / average current) x 100

Procedure.

Measure the currents in all 3 phases.

Add the 3 measured currents and divide the total be 3, which gives the average current.

Calculate the amps unbalance for the worst phase by subtracting it from the average.

Divide the worst-case unbalance amps by the average and show as a percentage. This figure is know as the Percentage Current Unbalance and it should not be more that 5% for SME motors. (Most manufacturers do not allow more that 5% current unbalance).

Example:

Currents measured are 34, 36, and 40 amps.

The total of the 3 currents is 110, and the average is 36.67 amps.

Worst Case unbalance is 40 – 36.67 = 3.33.

Current Unbalance is 3.33 / 36.67 = 9%

A motor seldom has completely balanced currents even if the voltage supply is balanced so in some cases it is possible to balance the currents by rotating the motor connections. This should be done by moving all 3 connections in the same direction each time so that the direction of rotation of the motor is not changed. The currents should be recorded for each phase with reference to the supply and motor terminals. All 3 connection options should be tried and then the connection that gives the best result should be used.

If there is still significant current unbalance after the current unbalance has been reduced to a minimum by rotating the phases then it may mean considering de-rating the motor. This either means reducing the pump output by fitting a smaller pump or maybe by removing an impeller, or installing a larger motor. 5% current unbalance probably means that there is about 0.8% voltage unbalance.

As an alternative to derating it is possible to measure and monitor the actual temperatures in the motor using PT100s. SME fit 3 PT100s in the windings and in the slot as standard for all motors 8 Inch and above. In general SME will know where the winding hot spot is for different motors and they can then advise if it is safe to operate the motor when the actual temperatures are known, even if there is high current unbalance. In some cases the ambient water temperature may be low, or, the motor is not fully loaded by the pump, so the actual winding operating temperature will still be well within acceptable limits.

Current unbalance in an induction motor has a number of effects, which reduce the performance of the motor, but the most significant for submersible motors is the increase in temperature. Any installation with more than 5% voltage imbalance is not suitable for use with submersible motors or any type of induction motor. The supply authority needs to fix the problem.