TECHNICAL NOTES - Suggested reading for Installers and Trouble Shooting

THEORY OF OPERATION: GENERATOR

The generators used are standard 3-phase motors that can be connected to produce 240 or 440VAC.

The rotor maintains a small amount of residual magnetism, which when turned, creates a small pulse of electricity to each of the three phases. This can vary between 1V and 6V, depending on how long the motor has been standing or running slowly (below 20Hz or 500rpm). If each phase of the motor is connected to a capacitor, this small pulse will charge the capacitor as the magnet passes the field it is connected to. Once it is passed that point, the capacitor will then discharge into that phase and in so doing, induce magnetism into the rotor, causing the voltage to increase.

If the line is shorted or has a bad connection to the capacitor, the voltage cannot build up and the field will not energize or "excite''. This excitation happens best between 60Hz and 100Hz. Running the motor slower or faster than this will not work. The size of the capacitor will determine how much energy returns to the motor to provide magnetism or field. Too big a capacitor will result in too much field, running slowly, then overheating of the motor, less efficiency and blowing fuses at rated power. If they are too small, the motor will over speed, be less efficient and have a bad power factor. If you run over 100Hz, the power factor can be so far off to cause transformers to overheat. The right size caps are where the motor is most efficient, typically between 70 and 90Hz, depending on the site pressure.

Once a motor is excited, power can be drawn off one or all three phases. We have found it to be 5-10% more efficient to use all three phases rather than one, although sometimes, where efficiency is not a priority, single phase installations can be less expensive.

THREE PHASE:

Using all three phases allows for using the same size capacitor on all three legs and allows for use of the motor at full rated power plus service factor. For example, if a motor has a service factor of 15%, it can be run at 15% over the rated power continuously. Inverter rated motors are also better built and last longer. Totally enclosed, fan-cooled (TEFC) are made for wet and dusty environments. Wash down motors are one step better, as they have stainless shafts and double sealed bearings. The double seals take a while to wear in and can use 100W to begin with. If no load is connected to the motor, with just the caps, the open circuit voltage can be 2 to 4 times higher than the loaded voltage. If the voltage goes too high, the amount of current returning to the field can exceed the motor's rating, causing the motor to overheat or blow fuses.

When doing line testing and running the motor open circuit with the load removed, it is important to test at low power with only one nozzle to prevent over loading.

SINGLE PHASE:

When using only one of the three phases, the motor has to be double the rated output to prevent overheating. The motor will also produce more noise due to the uneven loading of the phases. The uneven loading can be mitigated to some degree by using different size capacitors on each field. On larger motors, the typical setup is called the C, 2C method. The normal size capacitor C is connected to the first phase. Twice that capacitance and the load are then connected to the second phase, and nothing connected to the third phase.

If properly balanced, there will be similar voltages and current on all three legs, in theory, allowing you to use 80% of the motors capacity, although we have found it to be more like 50%.

EXCITATION PROBLEMS:

Motors will not excite if the output is shorted or becomes disconnected form the capacitors. Motors can also loose their residual magnetism, if left running fast (disconnected from transformers) or slowly (below 30psi) for an extended period of time. To re-excite motors in this situation, it's easiest to remove the load, which will allow the voltage to recover easier. The easiest way to do this with our setup is to remove the same input wire from any two transformers. Transformers have two 12 or 14 gauge input wires connected to the small terminal block. Without the transformers connected, the motor voltage can be 2 to 4 times higher than normal and should not be run at full power. Once the machine has become excited, leave it running at low power and reconnect the transformers one at a time. If the system collapses, there may be a bad transformer or rectifier. If the system won't excite with the transformers disconnected, you may have a transmission line problem. The way to measure the transmission line is to remove the small AC fuses from the transformer box and with the hydro turned OFF, measure the resistance between the AC lines at the terminal blocks in the transformer box. You should get the resistance of the wire plus the resistance of the motor, in most cases less than 10 Ohms per leg. If it's less than 2 Ohms, it is probably shorted. If it shows high resistance or OL, check the motor and transmission line independently, to find out which one is open circuit. Motors measure less than 2 Ohms connected 240V, and about 4 Ohms connected 440V. Not all transmission problems can be measured with a multi meter. If there is a bad connection, it may not show up until current is passed through the wire. Some shorts only occur at high voltage, so the meter readings are helpful but not absolute. Another approach is to place the excitation capacitors at the motor site of the transmission line. Excite the motor and then hook up the transmission lines one at a time, until the motor collapses. If the motor does not collapse, leave the caps at the motor for testing and measure the voltage on the legs at the other end of the transmission line with the transformers connected. If there is more than a 10V difference across the legs, change the wires around at the transformer box and see if the discrepancy is in the transmission line or the transformer box, to isolate the problem. It is not advised to leave the capacitors at the hydro when running at full power, as a break in the line will result in dangerously high voltages, blowing fuses. Another approach to exciting a motor that has lost its excitement from running too fast or too slow for an extended period, is to excite on phase with a DC source of power, usually a rechargeable drill battery, with the motor running between 60 and 100Hz. This is done by opening the valve to the right place while measuring the speed of the motor and then flashing the contacts of the battery across any one phase, while it is running. This is usually only necessary on rare occasions and smaller motors.

THEORY OF OPERATION: TRANSFORMER BOX

Three phase power is brought into the box and connected to the terminals marked AC. Each phase then goes through a fuse, the other side of which is connected to a capacitor and a transformer. The other side of the transformer can either be connected together, resulting in a Series or Y- connection for high voltage or to another phase, Parallel or Delta, for 240V. A slightly lower voltage can also be used, wiring the transformer for 120V and then connecting them Y. at low output, below 500W, it is often possible to obtain more efficiency running the 240V motor at 120V. We offer this option as a low power boost on systems with varying flow, where it is expected they will be producing less than 500W for much of the time. We do this by changing the transformers from Series Y to Parallel Delta with a 3-pole switch. As the size of the capacitor is affected by voltage, we use smaller capacitors on higher voltage systems. As the voltage drops from 240 to 120V, when using our low power switch, the capacitance of the capacitor will be less, resulting in the motor speeding up to a more efficient speed at low power. Once the power has been transformed to battery voltage, it is then rectified to produce DC, fused again and metered before exiting the box. The transformers can be wired to produce 12 or 24VDC, which we can connect in series or Y to produce 48V. The actual AC voltage will vary with the output, for example the 240V system will start working at 180V and then, depending on battery voltage, can go all the way to 260VAC. On high voltage models, connecting 240V in a Y configuration would result in 240V x root 3 or 1.7, which gives you 408V. However, the output on the low voltage side of the transformer is also connected Y, 24V times 1.7 = 41V. This means, the input voltage will rise above the expected 408V and run between 420V and 460V, depending on power level. The metered output will also vary with the line loss of the system. For example, a 2KW system with a 10% line loss will only produce 1800W.

THEORY OF OPERATION: TRANSFORMER/RECTIFICATION

Each transformer output is typically 24V with a center tap. For 12V systems, we are able to use a center tap on each transformer as the negative and feed the outside two lines into a diode to produce half-wave regulation, where only one side of the AC is going through a diode. Because of this, only one side going through the diode, it is slightly more efficient, with only half a volt drop across one leg, than full wave rectification, where there is a half a volt drop on both legs, resulting in one volt loss. Although half-wave is more efficient, it does produce more AC ripple and humm from the transformer. The total loss across the rectifier is the voltage drop on both legs times the amperage going through the rectifier. As small as half a volt is, when multiplied by the amperage of a 4KW, 24V system, it is 160A times three rectifiers (4KW / 25V = 160A x 1V) = 160W in heat. Schokkty diodes only have a third of a volt drop as opposed to regular diodes, which have a half a volt drop, but are seldom made in rectifier style modules. We only use them on 12V high amperage applications, where heat buildup is an issue due to higher amperages.

Two diodes in a module with a common positive or negative are called a rectifier, which allows for half-wave rectification. Putting two rectifiers together, results in a bridge diode, allowing for full-wave rectification. We typically use 35A or 60A bridge rectifiers that can take up to 600V. Despite this high voltage tolerance on the low voltage side of the transformers, which even on a 48V system will not exceed 60V, they are sometimes damaged by high voltage spikes caused by lightening and sometimes need replacement. They can also be damaged if the DC connections are hooked up backwards. Most multi meters have a diode test circuit indicated by a diode test symbol, the arrow with a line across its point. To test the bridge rectifier, you will need to disconnect it from the transformers and remove the fuse from the positive line to isolate it from the other rectifiers. With the multi meter on the diode position, first touch the test leads together to verify that the meter reads correctly. The meter should change from OL to zero. Place the positive meter terminal on the rectifier terminal marked negative and the negative lead of the meter on a terminal marked AC. The meter should read close to 0.5 connected this way, and zero continuity (OL) when hooked up the opposite way. The meter puts a small amount of current through the diode and determines that there is a 0.5 voltage drop across it, if it's good. If not, it will usually show a short in both directions. If you don't have a meter, the easiest way to test for a bad rectifier is to remove the AC leads between the transformers and the rectifiers, restart the hydro, and while running at low power reconnect the rectifiers one at a time until it quits. Do not try this at full power. If the hydro will not excite with the rectifiers disconnected, check the transformers.

Transformers usually have two sets of windings on both input and output. The resistance of these windings is very low and is difficult to measure with an Ohm meter. The high voltage side, which has small wires, should have a couple of Ohms resistance but must be disconnected from the others to be checked. It can also be connected to an external power source, either 120 or 240V, as it can be wired for either. If the low voltage side is left connected to the rectifier, connecting the high voltage side to an external power source will produce a reading on the output meter of the hydro box. If one or two transformers are bad, they can be removed from the system and the system will keep producing power on one phase, although the power level should be kept below 40% of the system's rated power.