

APPLICATION GUIDELINE #42

(Motor Insulation Turn-Turn Failures & Testing)

Brought to you by your Motor & Drive Specialists.....

Turn-to-turn Failures

Turn-to-turn failures are one of the most common Insulation type failures. In the case of random wound motors, placement of the conductors is not consistent. The first turn, for example, can be adjacent to the last turn and therefore, be subjected to maximum voltage stress. Magnet wire is allowed to have a certain number of pinholes for a given length and wire gauge. It is possible for two pinholes to line up. If a pinhole exists where the magnet wire is bent, such as in the end turn, the hole can be stretched bigger than it was at time of manufacture and further increase the opportunity for two pin holes to line up.

Mechanical rubbing can cause failures to occur as well. If the mechanical strength of the end turn bracing is not sufficient, movement can occur during starting. The magnetic forces exerted on a winding are proportional to the current squared. If there is any movement, individual turns can rub against each other and result in a turn to turn failure.

The mechanism of turn to turn failure is varied. Recently the most common cause of failure in low voltage motors is attributed to variable frequency drives that use devices with very fast rise times. Very similar stresses can occur on medium voltage motors though drives are usually designed with different topologies and/or slower devices, which reduce the problem. Large HP medium voltage motors that are switched by vacuum breakers can be subject to very fast rise time multiple pulses caused by pre-strike on breaker closing or stresses caused by re-strike on breaker opening. This is a separate topic unto its own but this issue can be very effectively dealt with by adding CR surge suppressors at the vacuum breaker that switches the motor or by adding a damping resistor to the surge capacitor at the motor.

When a turn to turn failure occurs, the shorted turn acts like the secondary of an autotransformer. If for example, a coil has 60 turns per phase and the shorted turn has one turn, the current in the short will be 60 times larger than the normal current. The heating effect is current squared times resistance (I^2R). This example would result in $(60)^2$ or 3600 times the normal heating effect. It doesn't take very long for this heat to start melting copper and insulation. The resulting loss of insulation manifests into a phase to ground fault, usually within seconds. Typically this type of fault is recognized by a lot of melted copper.

Fig. 1 shows an example of a turn to turn short on a 4 turn winding. (A 4 turn winding is not realistic but has been shown for simplicity.)

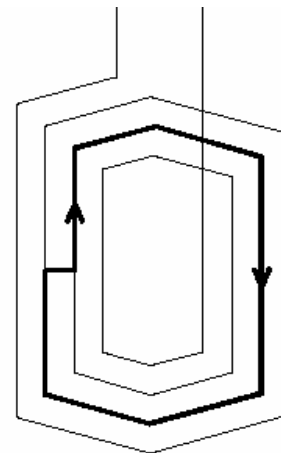


Fig 1: Turn to Turn Short

LVM Turn to Turn Test (Low-Ohmmeter test or Micro Ohmmeter test)

Use a 'LOW-OHM' resistance meter and check resistance between the phases. Check phases 1 to 2, record the reading, then 2 to 3, record the reading, and 3 to 1, record the reading. A regular Fluke meter or similar meter will not work. It has to be a 'LOW- OHM' resistance meter. Toshiba can provide typical Ohm readings for our motors by rating and voltage. This test can also be used to determine if nameplate voltage rating is correct, you can make comparisons with 460v typical values and 575v typical values. Also, this test can be performed to determine if the motor is the cause of an imbalance situation.

MVM 'Form Winding' Turn to Turn Test (Surge Test)

A **Surge Test** is a variation of a hipot test. This is a test designed for form wound motors and not random wound. This test is used to determine if the turn insulation in multi-turn coils is punctured. This is a go / no-go test. The voltage applied is similar to a possible surge that the motor might see. Typically, the voltage is 3.5 PU. (i.e. 10KV for a 4KV motor or the phase to ground voltage x 3.5) This test works on the principle that the oscillating frequency of an inductive capacitive circuit changes when the inductance or the capacitance changes. The test circuit utilizes fixed capacitance values and uses the coils of the motor as the inductors. By comparing the oscillation frequency of two coils, it can be determined if there is a turn to turn insulation breakdown.

$$f_o = \frac{1}{2p\sqrt{LC}}$$

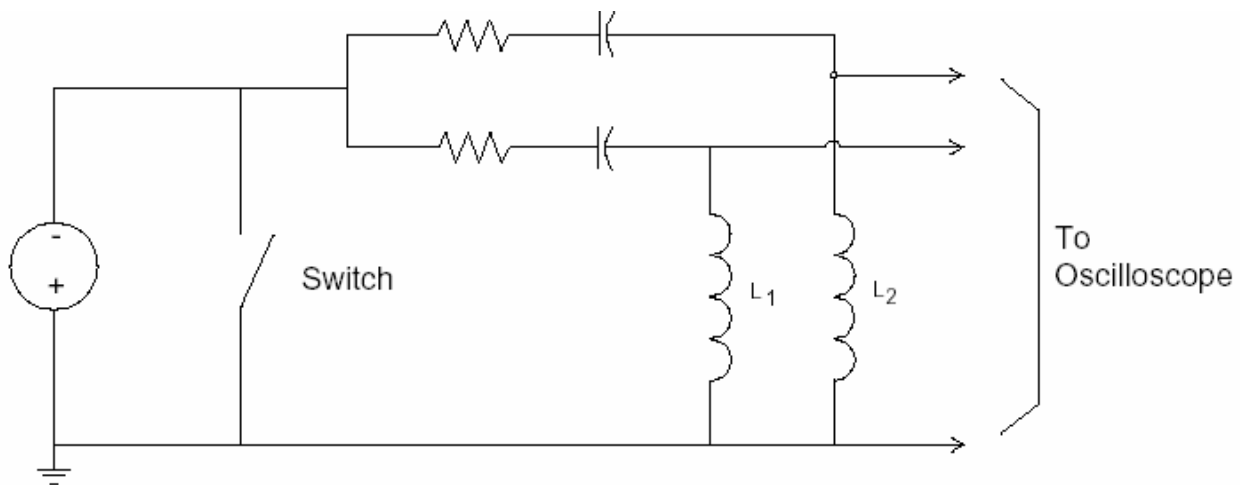
where,

f_o = Oscillation Frequency

L = Inductance of the motor winding

C = Capacitance of the tester

If each phase has 100 turns, and 1 turn is shorted on one of the phases, the current changes negligibly. L goes down 1% therefore f_o increases by 0.5%. This is a very small change and only becomes apparent when the two waveforms are superimposed on top of each other.



The switch above closes once the capacitors have charged up. This provides a fast rise time, high voltage pulse to the windings. L₁ and L₂ represent two windings that are being compared.

