Using Quality Acceptance Standards for Predicting Electric Motor Winding Failures

By Kevin R. Bergstrom, Mgr., Electrom Instruments

Electric motor manufacturers and rewind shops use high voltage methods to determine the quality of the insulation used in their windings. This paper will describe several standards used, and the increased likelihood of failure with a decrease in insulation integrity.

High voltage testing of the winding insulation system of rotating machinery is a well accepted and commonly used practice. The voltage withstand capability of the winding insulation system is the most useful measure of a winding's ability to withstand normal thermal, mechanical, and dielectric stresses.

Several IEEE, NEMA, and EASA standards deal with the safe and non-destructive procedure of using high voltage on electric motor windings for verifying the quality of the new windings before installation and service. These standards are primarily for the groundwall insulation, but also apply to interturn and phase insulation as well.

Most standards deal only with the "new motor" acceptance standard which is normally 1.7 (2E + 1000) for a test using Direct Current (NEMA MG 1). This formula has been used for many years as a "Quality Acceptance" standard. Although this test voltage does not simulate the thermal and mechanical stresses the windings will encounter, it does assure that the winding is capable of withstanding the dielectric stresses that would ultimately destroy the winding in the event of an insulation failure.

During routine inspections, some motors may have less than the new motor standard for dielectric integrity. Because of recent motor designs, however; winding temperatures are running higher with less back iron to act as a heat sink and pull the heat away from the windings. As a result, the used motors which do not meet the dielectric standard of a new motor may be much more susceptible to failure.

Many variations of the Factory AC Proof Test are used for acceptance testing of the ground and interturn insulation systems.

These include:

1. Factory AC Proof Test
   2E + 1000
2. Acceptance AC Test
   1.5E
3. Factory DC Proof Test
   1.7 (2E + 1000)
4. Installation DC Proof Test
   1.7 (2E + 1000) .80

These calculations represent the minimum acceptable withstand voltage of the groundwall insulation during a controlled DC step voltage test as described in IEEE Std 95.

The interturn and phase insulation is commonly tested using a Surge Comparison Tester. During operation, the first 10% of the motor winding can see voltage stresses much higher than the ground insulation. Proper testing of the interturn insulation at the same levels that the ground insulation is tested at is essential. It could also be the most important test for the "acceptability" of a motor before installation and service.

The lower multipliers for "installation" and "after service" are examples of the lower expectations of a used motor winding than a new motor winding. Indeed, the rotating apparatus may be capable of operating with the insulation strength well below test voltages.

How far below, and how long it will last, are not readily known because of different operating environments of the motor. Several factors can contribute to the rate of deterioration of an insulation fault, including high temperatures, extreme dirt and moisture, mechanical stresses and vibration, voltage variations and imbalances, and transient voltage surges.

Winding insulation must be capable of withstanding voltages at least 1.5 times the rated voltage (AC test) to be operated. The equivalent DC test voltage would be 2E or 3E depending on the nameplate voltage of the motor. A common guide for minimum voltages is the "2, 3,4, 5 Rule".

2300/4160/6900	460	230	110
2E	3E	4E	5E

Example for a 460 volt motor:

1.6 (1.2E + 400) = 1523 volts DC
3E = 1380 volts DC

Although the "2, 3,4, 5 Rule" establishes a test voltage below the EASA and NEMA recommended levels, they are consistent with the IEEE standard 95. Knowing that the "new motor" standards are well above these voltages, a window of "unknown" insulation stability exists between the withstand capability of sound insulation, and the reduced test voltage of the "used motor standard".

By lowering the test voltage on a used motor for the "suitable for service" standard, it does not prove the insulation strength if the insulation withstand strength is just above the test voltage.

If the test voltage is increased to a voltage above the "used motor" standard and found to be defective, the assumption that it is still acceptable is invalid. The detection of a flash-over, or trip-out with voltage equipment is an indication of a crack, void, weakness, or instability in the insulation which can only get worse. The acceptability of any winding showing a defect, even above the minimum test standard, cannot be proven by the research done for this paper.

Based on statistics and case studies of using high voltage for maintenance testing, the great majority of motors over three years old will meet or exceed the new motor test criterion (it is not advised to increase the test voltage higher than any recommended test voltage). The small percentage of motors not meeting the new motor standard should be tagged for repair, replacement, or further diagnosis, based on the critical nature of the equipment and the withstand voltage of the insulation.

Using the "used motor" standard reduces the percentage of motor problems that could be detected during routine maintenance testing. Developing a higher standard may reduce the "unexpected" failures by detecting a weakness that may otherwise go undetected by lowering the standard to just below the fault level.

When allowing a motor to operate to failure, the damage to the iron laminations by a short to ground should be considered. If rewinding the motor is more economical than replacing it with a new one, damaged iron can reduce the efficiency and shorten the life of a rewind.

For more information on electric motor analysis contact Kevin Bergstrom, Electrom Instruments, 843 N. Cleveland Ave., Loveland, CO 80537; (303) 669-6609.

Standards References

IEEE Standard 43-1974, Recommended Practice for Testing Insulation Resistance of Rotating Machinery.

IEEE Standard 56-1977, Guide for Insulation Maintenance of Large AC Rotating Machinery.

IEEE Standard 62-1958, Guide for Making Dielectric Measurements in the Field.

IEEE Standard 95-1977, IEEE Recom-mended Practice for Insulation Testing of Large AC Rotating Machinery with High Direct Voltage.

IEEE Standard 432, Insulation Maintenance for Rotating Electrical Machinery (5 hp to less than 10,000 hp).

IEEE Standard 522, Testing Turn-to-Turn Insulation of Form-Wound Stator Coils for Alternating Current Rotating Electric Machines.

NEMA MG1, Motors and Generators.

NETA MTS-1989, Maintenance Testing Specifications, Section 7.15 Rotating Machinery.

NETA ATS-1991, Acceptance Testing Specifications, Section 7.15 Rotating Machinery.