No Advanced Instrumentation? No Problem. Part 4.

Electric Motor Insulation To Ground Testing

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Introduction

So far, in this series, we have covered Volt meters, Ammeters and Resistance testing. This month, we are going to discuss insulation to ground testing using an insulation tester commonly called a 'Megger®.'

The insulation to ground tester, or Meg-Ohm meter, is also one of the earliest instruments used by technicians in evaluating and troubleshooting insulation systems, including electric motor insulation systems. In this article, we will concentrate on the testing method as outlined in IEEE Standard 43-2000 (R2006), "The Recommended Practice for Testing Insulation Resistance of Rotating Machinery," (IEEE 43) and a few additional methods for evaluating findings, we will also refer to the testing method as Insulation Resistance (IR) testing.

The standard that we generally reference within industry is the IEEE 43, which went through a major revision in May, 2000. It was updated because post 1970 insulation systems went through a series of changes in their chemical makeup. The insulation systems of newer insulation systems are very different from the older systems, including how they react through testing methodologies. The revised standard drastically changed a number of traditional testing programs for insulation resistance that had been in place for over 50 years, including the Polarization Index (PI), insulation to ground tests and AC vs DC testing of insulation systems.

The purpose of the IR reading is to evaluate the condition of the insulation between the conductors in the stator slots and ground. This is done by applying a direct voltage between the conductors (windings) and the casing of the electric motor (machine) and measuring current leakage across the insulation system. The measurement of current and voltage, applied, provide a finding measured as resistance (Ohm's Law: $R = V/I$). In the case of an insulation system, the leakage current may be measured in milli- or micro-Amps, with the lower the current reading, the higher the insulation resistance value. These IR readings change over time because of 'insulation polarization.' In effect, the insulation system consists of polarized atoms that 'line up,' or polarize, with the applied DC voltage. As they polarize, the insulation resistance will increase.

The Basic Insulation Resistance Test

Straight insulation resistance testing has been used to troubleshoot and evaluate the condition of machines for over a century, often with disastrous results, in the hands of an inexperienced user. There are very clear limitations on the ability of insulation resistance testing, alone, to evaluate the condition of an electric motor for operation. For one thing, there has to be a clear path between the insulation system and the casing of the machine. Air, mica, or any other non-conducting material between the winding and ground will provide a high insulation resistance. Faults on the end-turns of motor windings will also not provide a clear path to ground, with most winding faults starting as internal winding shorts that might graduate to insulation faults. So, care must be taken when using IR as a troubleshooting tool.

In performing IR, the proper method is to connect all leads together, test with the IR meter for a period of one minute, ensuring that the red test lead (negative) is on the leads and the black lead is on the housing. Once the IR measurement is obtained, it is then adjusted for temperature while the leads are grounded for four, or more, minutes. The values for IR applied voltage and minimum test values can be found in Tables 1 and 2.

Table 1: Insulation Resistance Test Voltage

Winding Voltage	**IR DC Voltage Applied**
<1000	500
1001 – 2500	500-1000
2501 – 5000	1000-2500
5001 – 12000	2500-5000
>12001	5000-10000

Table 2: Insulation Resistance Minimum Values

Min Insulation Resistance at 1 Min	**Winding Being Tested**
kV + 1MegOhms	Most windings made before 1970
100 MegOhms	Form wound stators after 1970
5 MegOhms	Random wound stators under 1,000 Volts after 1970

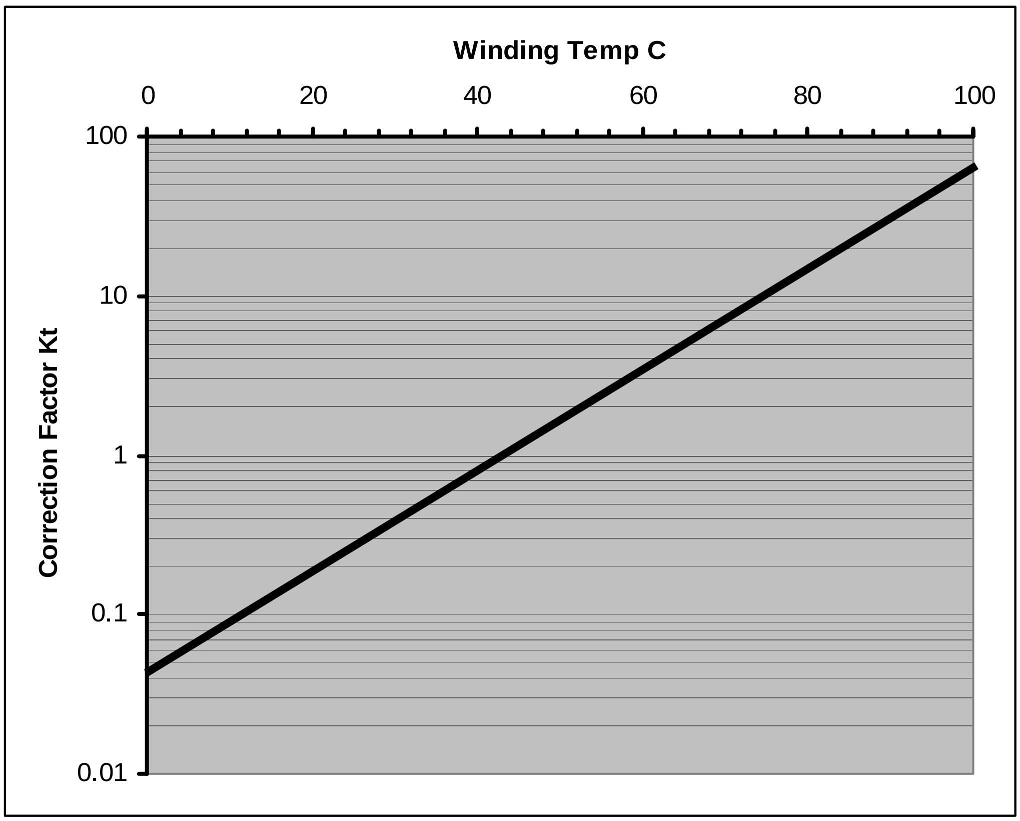
There are a few things that have to be considered when performing insulation resistance from a Motor Control Center (MCC) or disconnect a distance from the motor under test. For one thing, if you tie all of the cable leads together and test, because of the surface area under test, it is possible that the readings may be only a few MegOhms. This does not necessarily mean that the system is bad, and a few tricks can be used to evaluate the condition of the cable. Additionally, any capacitors or lightning arrestors should be disconnected from the circuit and variable frequency drives or amplifiers must be disconnected from the motor.

First, take each conductor and test between the conductor and ground. If the reading is greater by an order of magnitude then chances are that no problem exists. Next, disconnect the other end of the cable and separate the conductors from each other and ground. At the other end, perform the insulation resistance test between conductors. If the readings are above the minimum, then the insulation resistance of the cable is OK (however, it does not definitively clear the cable of any potential faults).

The same process can be used on some motors, with the exception of a phase to phase test, unless the internal connections of the motor can be broken, such as in a wye-delta motor or all twelve leads are brought out of the machine. If the phases can be separated, then an insulation resistance measurement can be taken between phases. The results should be above the minimum values shown above.

During these tests, if you are using an analog IR meter, if the needle is not steady, or the digits 'dance' around in a digital IR meter, then there is the strong possibility that moisture or contaminants have gotten into the windings. The bouncing is the result of 'capacitive discharge,' or the build up of the DC energy within the winding that suddenly discharges and then starts to re-charge.

Figure 1: Insulation Resistance Temperature Correction



R40 = Kt x Rt

Figure 1 represents the insulation resistance temperature correction chart for correcting to 40°C. Using this chart, if the winding temperature is 60°C and the insulation resistance was 200 MegOhms, the correction factor (Kt) would be '4,' and the result would be 4 times 200 MegOhms which would be a corrected insulation resistance of 800 MegOhms.

Dielectric Absorption

The dielectric absorption test, or 'DA,' is a ratio of the sixty second IR reading to the 30 second IR reading. As shown in Figure 2, the value at position A is divided by the value at position B. In a good insulation system, the IR will increase as a curve which will start fairly steep then will plateau, depending upon how fast the insulation system polarizes. Pass/Fail criteria can be found in Table 3. However, in insulation systems manufactured after 1970, it is not uncommon for insulation systems to polarize rapidly and insulation systems with a temperature corrected one minute reading greater than 5,000 MegOhms may show a low value. In these instances, the test results should be used for trending only, and in the new IEEE 43, the test results must be corrected for temperature.

Figure 2: Dielectric Absorption

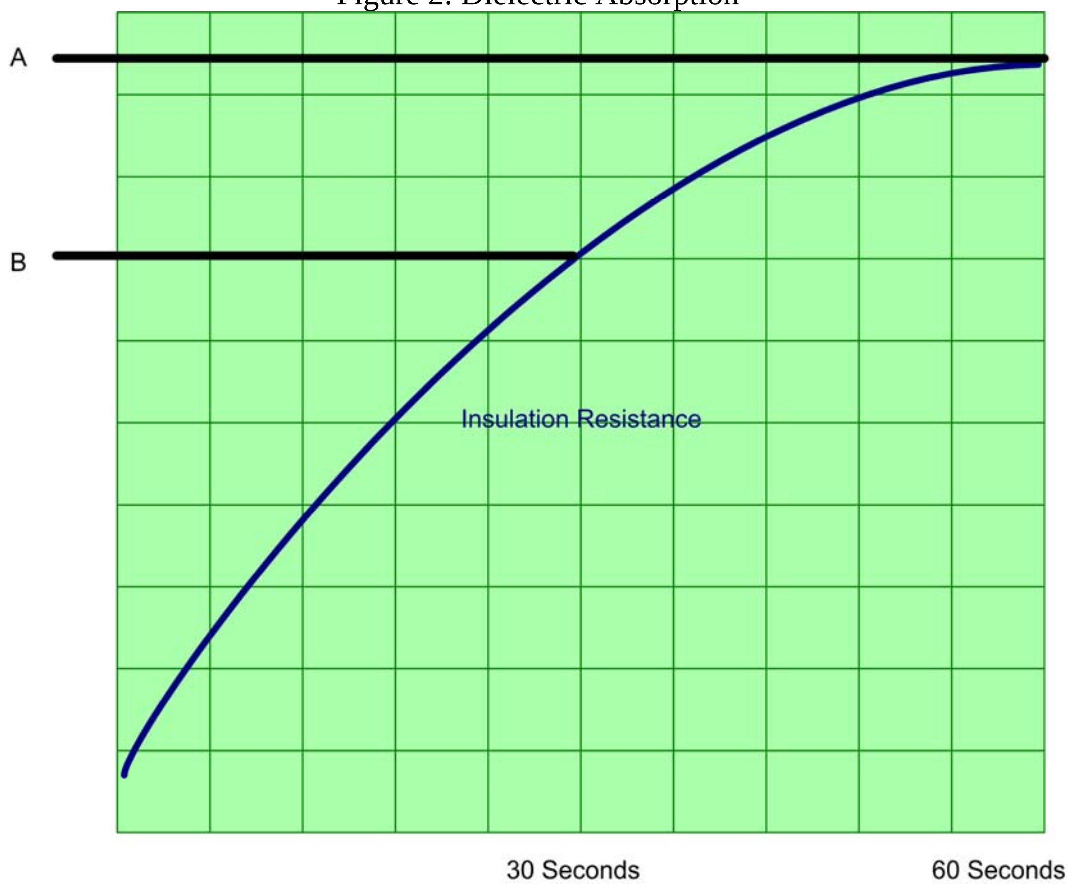


Table 3: Dielectric Absorption Chart

Insulation Condition	**Dielectric Absorption Ratio**
Dangerous	< 1
Questionable	1.0 – 1.4
Good	1.4 – 1.6
Excellent	> 1.6

Polarization Index

The Polarization Index, or PI, is the ratio of the 10 minute to 1 minute insulation resistance test. As shown in Figure 3, the result is the value at position A divided by position B. In a good insulation system, the IR will increase as a curve which will start fairly steep then will plateau, depending upon how fast the insulation system polarizes. Pass/Fail criteria can be found in Table 4. However, in insulation systems manufactured after 1970, it is not uncommon for insulation systems to polarize rapidly and insulation systems with a temperature corrected one minute reading greater than 5,000 MegOhms may show a low value. In these instances, the test results should be used for trending only, and in the new IEEE 43, the test results must be corrected for temperature.

Figure 3: Polarization Index

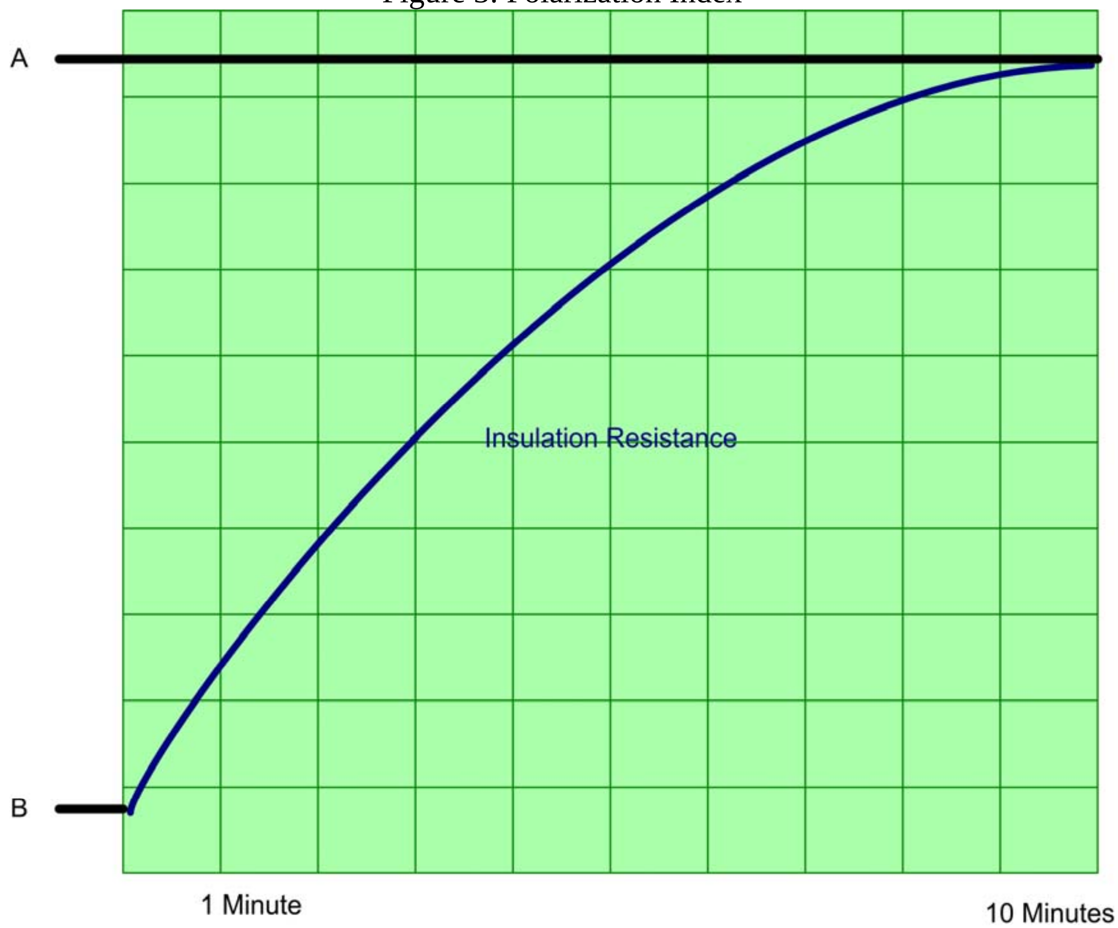


Table 4: Polarization Index

Insulation Condition	Polarization Index
Dangerous	< 1
Questionable	1.0 – 2.0
Good	2.0 – 4.0

Excellent	> 4

Using the PI, the user should watch the needle if the meter is analog. If the needle bounces as it increases, then it represents capacitive discharge and an impending insulation problem such as contamination. If the meter graphs the PI as a chart, the user should review the data to see if there are any downward spikes or the graph shows a decreasing value across the ten minutes. This would also indicate insulation resistance defects.

Conclusion

A common method for evaluating the condition of electric motors is insulation resistance testing. The most common methods of IR testing are outlined in the IEEE Standard 43-2000 (R2006) and include the 60 second test, the dielectric absorption and the polarization index test. Each of these tests are used to evaluate only the portion of the insulation system between the motor winding and the frame of the electric motor.

In post 1970 machines, insulation systems tend to polarize rapidly and systems with values over 5,000 MegOhms should only be trended when using DA and PI. However, the insulation charging can be viewed to see if capacitive discharges, which indicate winding contamination or insulation degradation, are occurring. However, the insulation resistance test is a powerful tool when used in conjunction with other testing methods.

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