INSULATION RESISTANCE PROFILE (IRP) AND ITS USE FOR ASSESSING INSULATION SYSTEMS

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Abstract: After decades of research in insulation systems, little has been published in the area of analyzing the graph of resistance versus time. Plotting the Insulation Resistance versus Time, gives a graph which may be referred to as an "Insulation Resistance Profile" or IRP. In addition to the standard Insulation Resistance (IR) value and the Polarization Index (PI) value, an Insulation Resistance Profile (IRP) may provide useful information as to the condition of the insulation system. The condition of the insulation system will typically yield one of four profiles: Normal, Moisture, Contamination, or Embrittlement. Additionally, these profiles may yield useful information when the insulation resistance exceeds 5000 Megohm that may otherwise have been overlooked.

Key Words: Insulation Resistance, Polarization Index, Megger, Resistance-to-Ground, Polarization Index Profile (PIP)

I. INTRODUCTION

Industry has used Insulation Resistance (IR) and Polarization Index (PI) tests for many decades to aid in assessing the health of insulation systems. Insulation Resistance is a measure of the conductivity of the insulation system and is defined in IEEE Standard 43-2000 as: "The capability of the electrical insulation of a winding to resist direct current. The quotient of applied direct voltage of negative polarity divided by current across machine insulation, corrected to 40°C and taken at a specified time (t) from start of voltage application. The voltage application time is usually 1 min. (IR_1) or 10 min. (IR_{10}); however, other values can be used. Unit conventions: values of 1 through 10 are assumed to be in minutes, values of 15 and greater are assumed to be in seconds."

In conjunction with Insulation Resistance, the Polarization Index is a commonly used measurement to assess the health of the insulation system. Polarization Index is defined in IEEE Standard 43-2000 as: "The quotient of the insulation resistance at time (T_2) divided by the insulation resistance at time (T_1). If times t_2 and t_1 are not specified, they are assumed to be 10 min. and 1 min. respectively. Unit conventions: values of 1 through 10 are assumed to be in minutes, values of 15 and greater are assumed to be in seconds (e.g., $P.I._{60/15}$ refers to IR_{60s}/IR_{15s})." IEEE 43-2000 recommends a minimum PI value of 2.0 for most insulation systems. Lower readings may indicate moisture, contamination, embrittlement, or damage to the insulation system. Table 1 displays the minimum PI ratio values per IEEE 43-2000.

Table 1

Minimum PI values

Thermal Class	Minimum PI ratio
Class A	1.5
Class B, F and H	2.0

Presently, IEEE 43-2000 states, "When the IR_1 is higher than 5000 Megohm, the P.I. may or may not be an indication of the insulation condition and is therefore not recommended as an assessment tool." This has caused some confusion in industry "thinking" that if the insulation resistance is greater than 5000 Megohm, then nothing is wrong with the insulation system. These thought processes came about due to external influences affecting the test current during the insulation resistance test.

Although there are external influences that affect the test current during the insulation resistance test, the advent of higher technology has minimized these external influences during the 1-10 minute measurement period. Higher resolution metering capabilities using digital electronics and very low ripple power supplies have made accurate measurements at much higher values possible. Thus, the same phenomenon that affects and discounts the PI is found to be very beneficial as an additional assessment tool called the Insulation Resistance Profile (IRP), especially when the insulation resistance is greater than 5000 Megohm.

II. DISCUSSION

An Insulation Resistance Profile (IRP) is a graphical representation of the Insulation Resistance obtained by plotting resistance readings in discreet increments (such as 5 seconds) over a specified time period, typically 10 minutes. Insulation Resistance Profiles (IRP) have also been called Polarization Index Profiles (PIP) due to the fact they represent the IRP at the completion of a PI test. Figure 1 shows the IRP of a healthy insulation system.

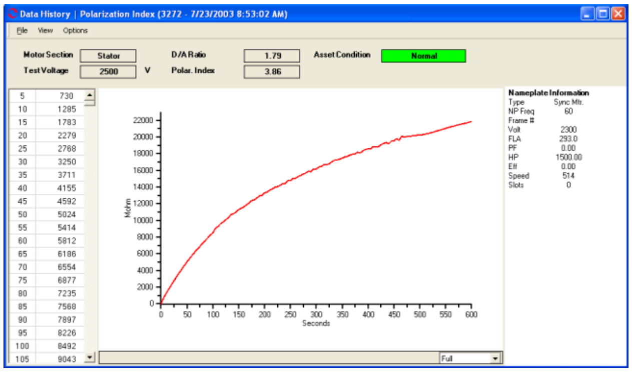

Figure 1. IRP of a Healthy Insulation System

Insulation Resistance Profiles of healthy insulation systems appear as an inverse exponential function in form because there are four primary components of the current, two of which decrease exponentially. These four components are: Surface Leakage (I_L), Geometric Capacitance (I_C), Conductance (I_G), and Absorption Current (I_A). These components are affected in different ways by the presence of moisture, contamination, embrittlement, temperature, and the insulation condition itself. See Figure 2.

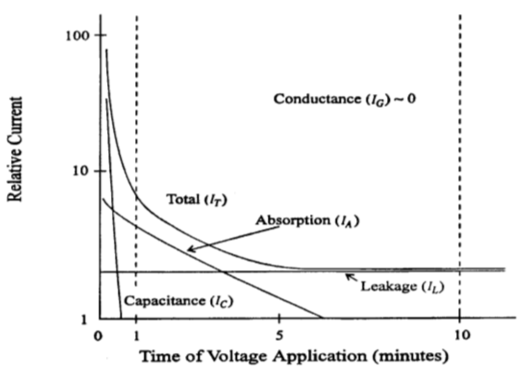

Figure 2. Four Primary Components of the Test Current

Moisture

When moisture is present on the surface of the insulation system, the surface leakage current (I_L) dominates the overall test current (I_T), and the absorption current (I_A) becomes negligible. This results in a lower overall insulation resistance, and a dramatic reduction in the time to reach the overall insulation resistance level. Figure 3 shows an example of an insulation system in the presence of moisture on the surface of the insulation system.

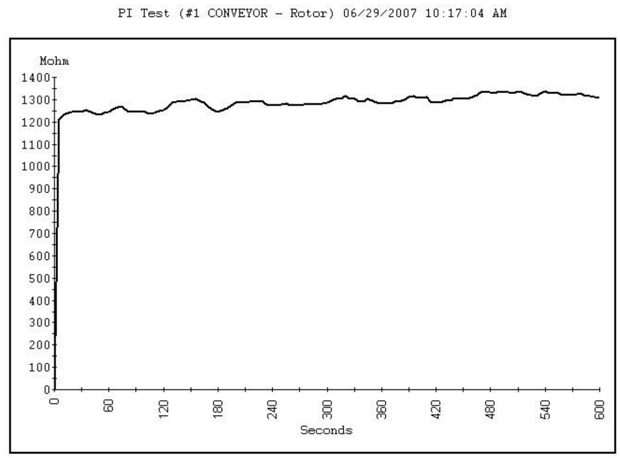

Figure 3. IRP of an Insulation System in the Presence of Surface Moisture

A similar situation exists when moisture is present within the insulation system itself, the Conduction Current (I_G) dominates, and absorption current (I_A) is negligible.

Presently, there is no methodology to differentiate surface moisture with moisture contained within the insulation system. Thus, when analyzing insulation systems in regards to moisture, the primary focus is the generality that moisture is present with a derogatory affect on the overall health of the insulation system.

Contamination

When contamination is present on the surface of the insulation system, the surface leakage current may become significantly higher than that of a clean insulation system. Surface contamination typically causes the surface leakage current to be somewhat erratic in nature as shown in Figure 4, which shows a severe form of spiking in the IRP with a Resistance-to- Ground measurement over 5000 Megohms. Notice the PI value is 2.16, which may be considered a good PI value without consideration of other test results.

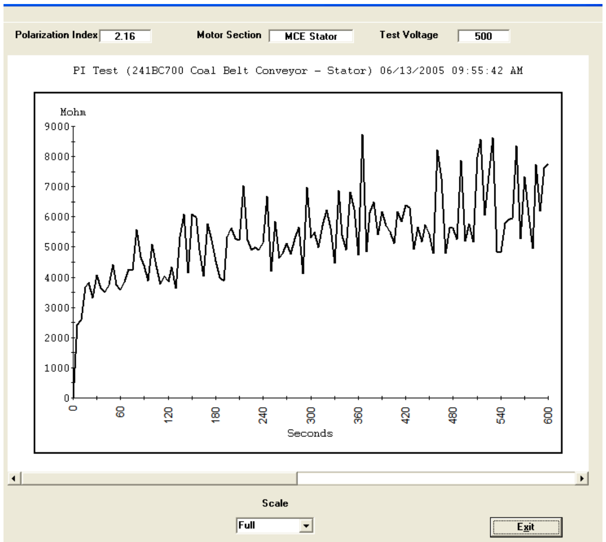

Figure 4. IRP of Contaminated Windings

Embrittlement

Insulation systems may become embrittled when the motor is running hot such as in overloaded conditions, high ambient conditions, and blocked cooling. When an insulation system becomes embrittled, the absorption component is primarily affected. As insulation becomes embrittled, its ability to polarize decreases, this phenomenon can be seen by a “flattening” of the exponential form of the IRP profile as shown in Figure 5.

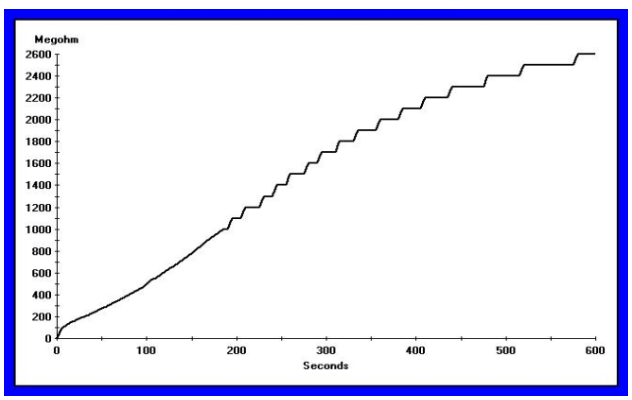

Figure 5. IRP of an Embrittled Insulation System

Although the overall Insulation Resistance and the PI ratio > 2.0 both meet IEEE 43-2000, without a thorough analysis using the IRP shown in Figure 5, the embrittlement of the insulation system may have never been properly diagnosed.

Temperature

Temperature inversely affects insulation resistance. As the temperature of the insulation system increases, the insulation resistance value decreases. In this case, the conduction current (I_G) is the primary component affected. A decrease in the overall insulation resistance value increases the conduction current I_G.

III. FIELD CASE

In March 2005, an Induced Draft (ID) fan motor tested in the field had the IRP shown in Figure 6. Notice the short rise time to the overall resistance value along with spikes in the IRP. Causal analysis determined that condensation around a cable entrance caused the IRP shown in Figure 6 the windings were passing through a cable entrance that had condensation all around it as seen in Figure 7.

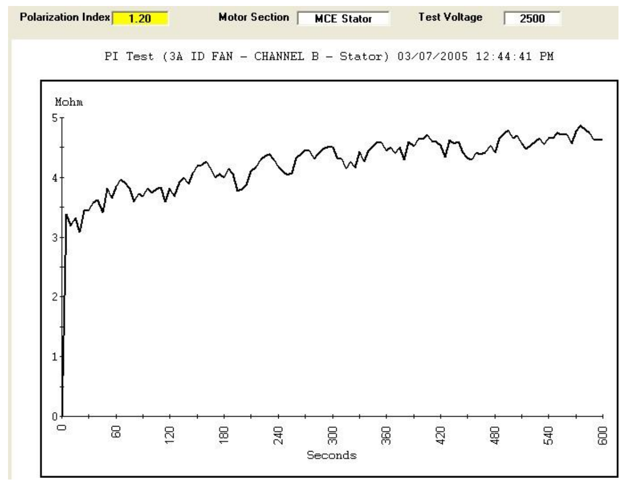

Figure 6. IRP of an Insulation System Containing Moisture

Figure 7. Condition that caused the unacceptable IRP

The area around the cable entrance was dried and resulted in the IRP shown in Figure 8.

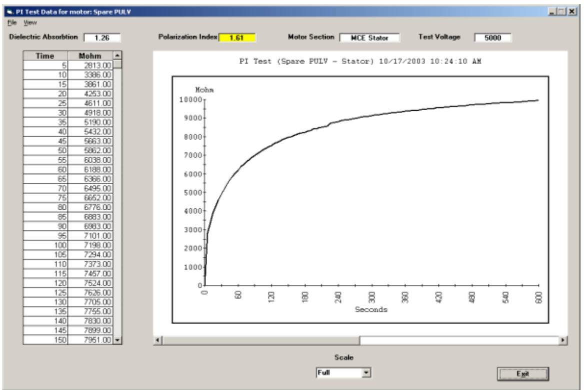

Figure 8. IRP After Drying and Cleaning

IV. SUMMARY

Although not deterministic in nature, the Insulation Resistance Profile (or Polarization Index Profile) may provide additional beneficial information in assessing the condition of the insulation system over the insulation resistance and polarization index values alone. The Insulation Resistance Profile may also provide additional information, which may otherwise be overlooked, when the insulation resistance is above 5000 Megohms.

V. REFERENCES

1. David, J. O., Jowett, J. R., Thomson, S. G., and Danner D. S. "A Guide to Diagnostic Insulation Testing Above 1 kV." *Megger*. 2002.

2. IEEE Std 43–2000. *Recommended Practice for Testing Insulation Resistance of Rotating Machinery*. IEEE Standards Association, March 2000.

3. IEEE Std 95–2002. *Recommended Practice for Insulation Testing (2300 V and Above) with High Direct Voltage*. IEEE Standards Association, April 2002.

4. Jeff, J., "*Diagnostic Insulation Testing*." AVO International, October 1999.

5. Swinskey, D., "*Fault Zone Analysis: Stator.*" PdMA Technical Conference, May 2006

6. McKinnon, D., "*Case Studies in Online and Offline Motor Analysis.*", EMCWA Conference, 2006

7. McKinnon, D., "*Using a Six Fault Zone Approach For Preventive Maintenance on Motors.*", EMCWA Conference, 2007

8. Brasher, J., "Thinking Outside of the BOX.", PdMA Technical Conference, May 2005

9. Brasher, J., "Wound Rotor Motor Assessments." PdMA Technical Conference, May 2008

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David L. McKinnon received his BS in Electrical Engineering from New Mexico State University in 1991 and a MBA from the University of Phoenix in 2002. He received his CQE certification in 2002. He has worked in the field of magnetics for over 17 years. During the past six years, he has worked for PdMA Corporation as a Project Manager for hardware and product development of motor test equipment. He actively participates in over a dozen standards working groups including the materials subcommittee, and is an active member of the strategic and general planning committees for the EMCWA.