Study of Insulation Resistance Profiling Use on Random and Form Wound Machines Under 6kV

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***Abstract*—The insulation resistance profile polarization index curve can be a powerful tool to understanding the condition of a ground wall insulation system when properly applied. The purpose of this paper is to review the success of several approaches including: all phases to ground; each phase to ground with other phases grounded; and, time applied. The conclusion will be a series of observations as to the effectiveness of this prognostic method for condition monitoring.**

Keywords-polarization index; insulation resistance; insulation resistance profile; ground wall insulation; prognostic testing

I. INTRODUCTION

The purpose of this paper is to review several concepts put forth in the draft proposals for IEEE Std P43-2000 Revision 9[1] in relation to polarization index on random wound machines and the application of Insulation Resistance Profile (IRP) as an effective method for machine prognostics and diagnostics. This study shall take the form of three distinct case histories of a small hydroelectric 4,160 Vac generator, a 4160 Vac form wound electric motor, and a small 480 Vac random wound electric motor.

The test equipment used for the analysis is a Megger® BM25 high voltage insulation resistance tester using Megger® Download Manager software. The software gathers data from the instrument every five seconds and places it in a table that can be used by the software to plot a graph or used by spreadsheet software, such as Microsoft® Excel®, to plot the data. Standard output from the instrument includes time, leakage current, capacitance, and insulation resistance readings. The duration of the test can be adjusted, as required, giving the ability to perform a test across a minute to 90 minutes.

Several key points were to be observed, including: would variations be captured during the 5 second period; is there a difference between reviewing all phases together or splitting the phases and testing one phase at a time with the others grounded; and, is the test valid for random wound electric machines. It is the purpose of this paper to address these issues and identify the strength of this testing for determining the condition of a machine. The concept is not a new one as this commercial tester, as well as many others, have the capability of performing IRP within the instruments or associated software.

II. GENERATOR CASE STUDY

The generator being reviewed is a 1935 era General Electric, 900kVA, 4800Vac, 120 RPM hydro generator located at a small dam shown in Fig. 1. IRP testing was performed on both the stator and rotating fields. The rotating fields were tested (Fig. 2) before and after cleaning and lead replacement and the stator was tested before and after a special weeping epoxy was applied then after the epoxy dried.

Figure 1. Generator Prior to Disassembly and Testing

Figure 2. Test Setup for IRP Testing on Rotor

The rotor test results at 500 Vdc were as found in Fig. 3, which compares before and after surface contaminants and failed conductors were replaced. It is important to note that the curve remains similar, but the post repair values are much higher. This would indicate improvements in the surface leakage and conduction currents. The absorption current appears to follow a similar path in both cases.

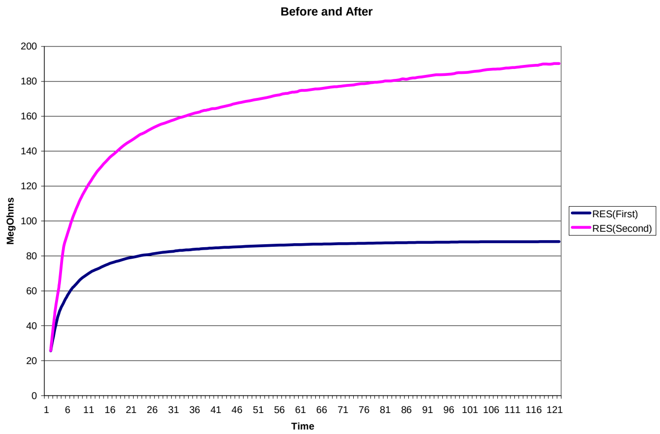

Figure 3. Rotor Test Results

The stator was tested at 2500 Vdc with the neutral broken and each phase tested with the other two grounded. This changes the overall surface area and evaluates the condition between the phases. Fig. 4 is of the test immediately after weeping epoxy was applied to the stator (Fig. 5) and Fig. 6 is of the tests after the weeping epoxy dried, which is similar to the original test prior to weeping epoxy application. Vertical axis are in MegOhms and horizontal relate to time.

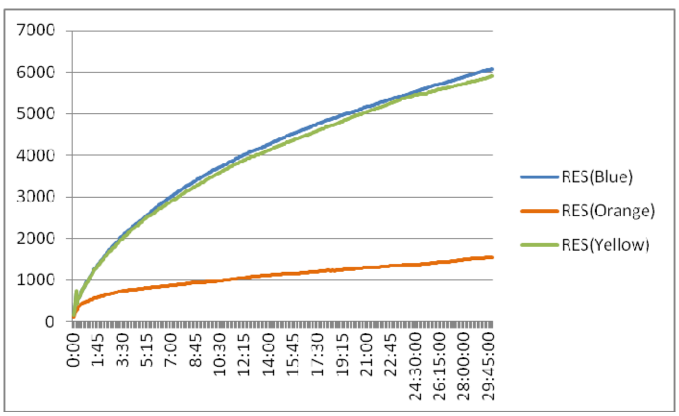

Figure 4. Stator after Weeping Epoxy Applied

For the initial tests a selection of 30 minutes was applied in order to try to capture the entire curve. After the application of the epoxy it was observed that there were discharges on all three phases that were not identified in the data that was captured by the software. This pattern would identify 'contamination' or 'moisture' in the insulation system when the discharges would occur towards the lower end of the time scale.

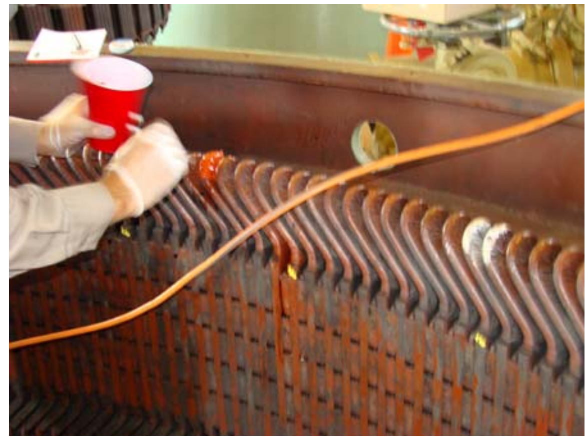

Figure 5. Application of the Weeping Epoxy

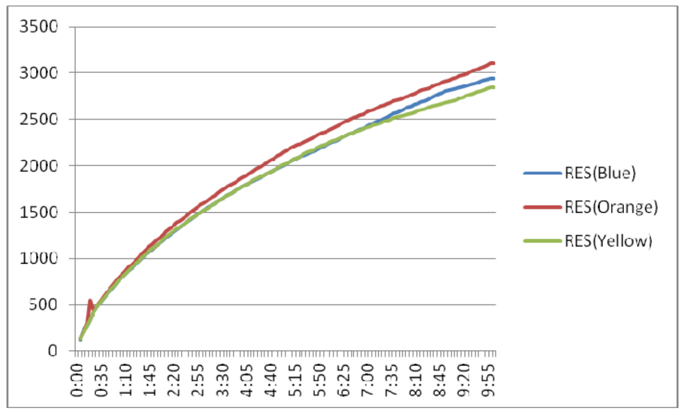

Figure 6. Insulation Resistance After Weeping Epoxy Dried

The final test was not performed to 30 minutes per phase due to time constraints. However, the data reflects that the trend of all three phases were following the Blue and Yellow phases from Fig. 4. The operator was instructed to watch the data progressing in order to detect any 'discharges,' of which there were none.

III. 3500 Horsepower 4160 Vac Motor

Prior to the installation of a 3500 horsepower, 4160 Vac, 1785 RPM electric motor that had been in storage for five years, it was to be test run only. It was included in this study originally to represent a good IRP through a test of all leads together and then all leads separate.

Fig. 7 represents the test result from all leads together while Fig. 8 represents all leads tested separately with the other leads grounded. It was immediately noted that there was a difference in the pattern when the phases were tested separately. The drive end cover was removed and a rodent nest was discovered (Fig. 9) that consisted of paper, candy wrappers, and rodent waste on the insulation system. Some chew-marks were discovered in the insulation system but were found to represent only surface marking allowing the stator to be cleaned, dipped in epoxy varnish and returned to service.

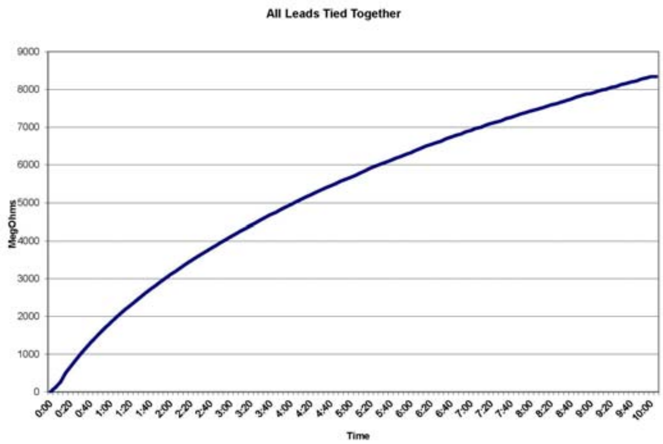

Figure 7. All Leads Tied Together for Testing

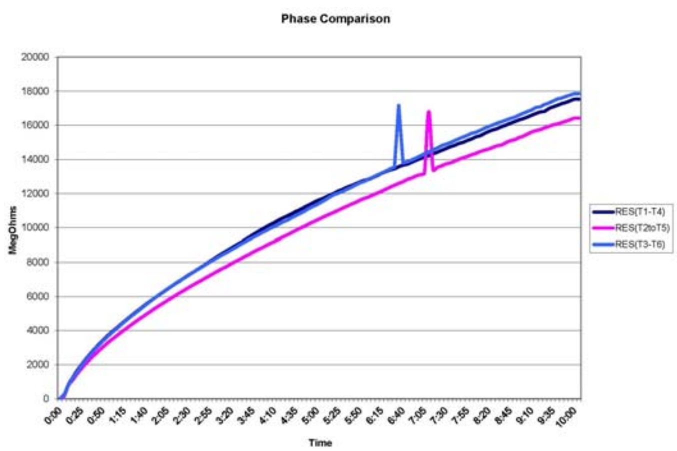

Figure 8. Each Lead Tested Separately

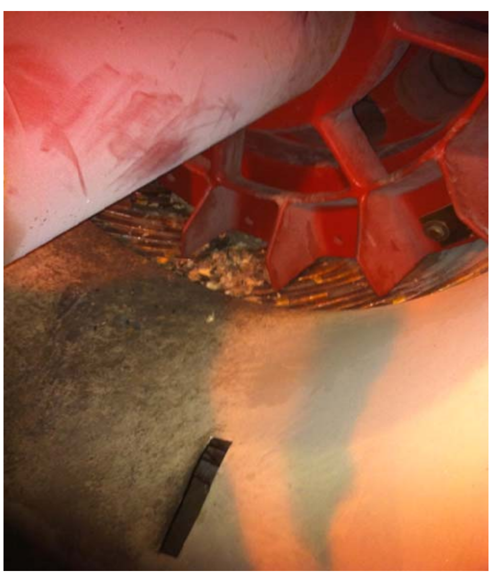

Figure 9. First View of Nest Materials

IV. Low Voltage Random Wound Machine

It was suggested in the newer revisions of IEEE Std. P43 that low voltage, random wound machines should be excluded from polarization index as the absorption current becomes negligible in seconds. While this is correct in some cases, it is not accurate for all cases leaving low voltage machines as candidates for polarization index. Fig. 10 is the IRP for a random wound, 125 horsepower, 1800 RPM electric motor.

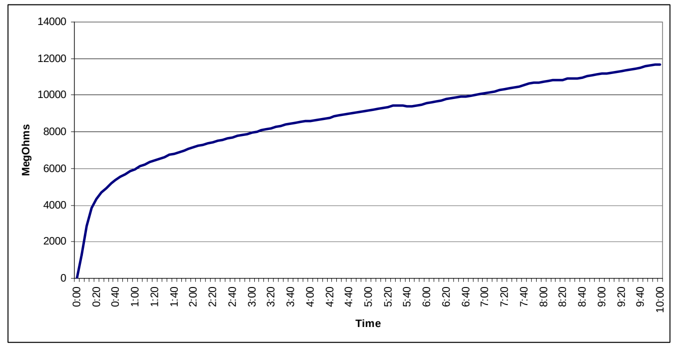

Figure 10. Random Wound Machine IRP

The challenge is that in most low voltage machines the neutral cannot be broken in order to test each phase with the others grounded. This limits the amount of information that can be used to evaluate a machine. The testing performed above was at 500 Vdc.

V. Conclusions

There is a great deal of information contained within an IRP test. With most insulation testers, even those that collect data, the operator must pay attention to the information that is being produced for signs of discharge. Wherever possible, the operator should open the neutral and test each phase to ground on a machine with the other phases grounded. This allows for increased accuracy in detecting insulation to ground and phase-to-phase issues.

In critical applications the ability to perform polarization index readings to a known standard is still important and should be continued by prognostic and diagnostic technicians. However, it should be noted that the results may have a very rapid insulation resistance rise resulting in a low polarization index value. The data contained in the IRP should still provide guidance as to the condition of the insulation system.

Note that at the time of the drafting of this paper that the final revisions to IEEE Std 43-2000 have not been completed.

References

[1] IEEE, IEEE Std P43-2000 R9: IEEE Recommended Practice for Testing Insulation Resistance of Electric Machinery, Electric Machinery Committee of the IEEE Power Engineering Society, May, 2011 (Draft)