Does ABB "LEAP" Produce Realistic Estimates of Stator Winding Remaining Life?

In the past year, ABB Service has heavily promoted a new service it calls the "Life Expectancy Analysis Program" or LEAP, which claims to be able to predict the remaining life of a motor or generator stator winding, with a high degree of confidence (up to 90%). If the claim is valid, it would be an important tool for planning stator winding maintenance. The following are my comments and opinions on what this service does and the chances of its effectiveness.

When one reviews the list of data, tests and inspections that ABB uses to estimate remaining life, all but one of the tests is well known and widely used by many organizations. Even the polarization/depolarization test is well known to researchers (for example, see the many papers on this subject that were presented in the rotating machines session at the 2009 IEEE Electrical Insulation Conference.) What is new is combining all this information into a specific estimate of remaining life.

In three analyses, two recommend that the owner purchase a spare winding very soon, and the third suggests that the complete set of comprehensive tests be repeated during a few day outage within the next year. Based on my over 30 years reviewing of insulation resistance/polarization index, dissipation factor, capacitance and partial discharge data, I would have concluded 2 of the machines, although showing some signs of deterioration, would in fact operate for many more years rather than the few thousand hours predicted. The third machine was is in good condition, and expensive off-line tests would not have been needed again for at least 5 years. Thus I do not agree with the specific ABB conclusions in those cases. Since I have reviewed many papers and attended many conferences where advanced DC test methods such as used by ABB were discussed by a variety of researchers, I do not think the polarization/depolarization results that are shown in the ABB report would have raised any more concern than what is raised by the standard insulation resistance and polarization index tests that were also done. Thus I can not see that the polarization/depolarization results would have contributed to the alarms raised over the health of the stator windings.

Some of the DC tests in the LEAP report are controversial amongst researchers, The session on such diagnostics at the June 2009 IEEE Electrical Insulation Conference clearly showed this. Furthermore, with the exception of the PD tests, all of the diagnostic quantities they use represent the average condition of the insulation. They do not provide information about the condition of the insulation at the most aged location, which is where the winding will most likely fail. Thus one does not know from these diagnostics if the winding has one very aged area (and thus more at risk from early failure), or widespread minor aging (with little risk to the winding). This limitation of all DC diagnostics, capacitance and dissipation factor tests is well known and well understood. This is one of the reasons why past research has shown why diagnostic tests can not predict the remaining life [1].

The reports and ABB promotional material do not explain in any meaningful way how they calculate the remaining life, or how they obtain the confidence factors (80%, 90% etc). However they show a curve of percent life used up vs. equivalent operating hours. This is a straight line curve vs. linear hours. The fundamental assumption is that that each winding has well-known design life that is an accurate reflection of the true life. In the examples they have assumed that this "life" is either 200,000 hours (22 years) or 400,000 hours (44 years). How ABB decided what the design life was for each machine is not explained. Based on the 3 examples I have seen, I conclude ABB has assumed a 200,000 hour design life if the motor has less than 200,000 hour actual life, and if it exceeds this life, they assume a 400,000 hour design life. With the exception of the thermal aging process, I am not aware that any manufacturer designs the winding for such a precise lifetime, after which the winding should be discarded. In fact with appropriate operation and maintenance, many would agree that stator windings can easily achieve >50 year life. Thus ABB setting a design life as the expected actual life is the main uncertainty of LEAP. The estimated remaining life seems to be calculated by subtracting the equivalent operating hours from their assumptions of the design life, with what appears to be minor adjustments due to the diagnostic results. Clearly the remaining life is completely dependent on a highly subjective estimate of the design life.

There are other problems with this apparent method, in addition to the huge assumption that there is a realistic design life:

- As Dr. Simoni (one the researchers referenced in the LEAP reports) has pointed out, and insulation aging research has found, deterioration is not a linear process. So in my opinion, the simple subtraction of equivalent operating hours from assumed life is not likely to be valid.
- The concept of "equivalent operating hours" calculated from the actual hours plus 20 hours or so for each switching event has been useful and been widely used, but it is at best an approximation and has not been proven to be valid. In any case the correction for switching events will depend entirely on the machine design and the operating environment.
- I was somewhat surprised that LEAP does not appear to include a much more valid correction for the operating temperature that has been widely used over the years. That is, if the motors are operating below their design operating temperature, the winding life (due to thermal aging) will be increased from its "design" life.

The only way to prove the validity of LEAP is to use the LEAP method to estimate a remaining life for a number of stators, and then let the machines continue to operate until failure, without any maintenance. If the machines fail close to the predicted time, then the method is proven. If they fail at substantially different times, then the method is not valid. Regrettably, I am not aware that ABB has provided any data of this type. In the absence of any experimental proof, then based both on what I believe to be incorrect diagnoses in three case studies, as well as the serious flaws in how they apparently apply aging theory, I think the estimates of remaining life provided by LEAP are without validity.

In fact there is a long history of machine manufacturers offering services to predict the remaining life of stator windings which have turned out to be ineffective. In the early 1980s, several Japanese manufacturers claimed they could predict remaining life, and published some IEEE papers to support the claim [2,3]. In the late 1980s, ACEC, a Belgian machine manufacturer promoted TestACEC, which also claimed to predict remaining life [4]. The Japanese relied on insulation resistance, capacitance, dissipation factor and PD tests for their calculation. TestACEC also used these tests, as well as the DC polarization and depolarization and similar measurements. The TestACEC method appears to be very close to the ABB method. As a researcher at Ontario Hydro, I lead a project sponsored by EPRI to investigate the accuracy of the Japanese and TestACEC claims. Ontario Hydro did all the measurements for the Japanese method, and in the case of TestACEC, we hired ACEC to do the tests (since like ABB, some of the tests were proprietary and could not be independently performed by a third party). The tests were done on a variety of stators. The Japanese method did not allow us to correctly predict breakdown voltage (an indicator of remaining life) [1]. Although TestACEC predicted that several stators would fail soon, the windings were in good condition as determined by a visual inspection, and in fact continued to operate for over a decade at least [4]! I understand that that the test was no longer offered shortly after we presented our data at the 1988 CIGRE meeting

Diagnostic tests are very useful. They warn of a developing problem, and allow an objective way to determine the severity of any insulation deterioration. However it is my belief that the diagnostic tests that are currently available, including the many variations of DC testing such as used by ABB, can not be used to predict winding life. Instead, by using a selection of off-line tests and a visual inspection, at best one may be able to determine the risk of failure.

I believe the best organizations to evaluate the condition of the winding are the owners of the machine, or independent test organizations whose main business is to test and evaluate, rather than perform rewinds or repairs. The machine owner and independent third parties will not have the inherent conflict of interest that a repair/rewind shop may have.

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References:

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2. H. Yoshida and Y. Inoue, “Insulation Diagnosis for Rotating machines”, IEEE Trans EI, Dec 1986, pp1021-1025

3. K.T. Kadotani et al, “An Approach for Insulation Diagnosis of Mica-Resin Coils”, IEEE Trans PAS, Sept 1981, pp 4136-4141.

4. M. Krecke, R. Goffaux, “Attempt at Estimating the Residual Life of HV Insulation of AC Rotating Machines”, CIGRE, Paper 11-12, Sept 1988. Also see the formal discussion of the same paper by B. Gupta, G.C. Stone