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STATOR WINDING HIGH POTENTIAL TESTING

Vishnu Prasad Nishad[*1], Mr. Sunil Kumar[2]
[*1] Department of Electrical & Electronics Dronacharya group of institutions Gr. Noida.
[2]Department of Electrical & Electronics Dronacharya group of institutions Gr. Noida.

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ABSTRACT
Over-potential or high Potential tests are frequently applied to machine stator windings to assure that the electrical insulation in windings is fit for service. However, several questions are frequently raised: When should a high Potential test be applied? Which high Potential test should be applied? What should be the high Potential test levels? Does high Potential test damage a good high potential winding? To answer these questions, a comprehensive review of literature was done and industry experts were surveyed for their views and experience under an EPRI sponsored project. The results are summarized in this paper. The questions are answered using the information from the literature review and the survey responses.

INTRODUCTION
High Potential or over-potential tests are generally performed to assure that the winding insulation has a minimum level of electrical strength to survive electrical stresses in normal service. High Potential tests may be performed with any of three types of voltages: AC at the power frequency, DC, and very low frequency (VLF) at 0.1 Hz. Several questions have been frequently raised by test users. When should a high Potential test be applied? Which high Potential test should be applied? What should be the high Potential test levels? Does high Potential test damage a good winding? To answer these questions, a comprehensive review of literature was done and industry experts were surveyed for their views and experience under an EPRI sponsored project. The work was done first in 2000 and then updated again in 2007 to assess any change in industry attitudes. The findings from 2000 work were published in a report [1] and summarized in a 2001 paper [2]. The detailed results from the work in 2007 are given in a report [3]. This paper summarizes the important findings from the later work and may be considered an update to the 2001 paper [2].

VARIOUS HIGH POTENTIAL TESTS
High Potential tests are performed with three different types of voltages. The AC high Potential tests at the line frequency are described in ANSI/IEEE standard C50.10-1990 and other standards [4-6]. The VLF (very low frequency) high Potential test is performed at 0.1 Hz in accordance with IEEE Std. 433 [7]. In both cases the voltage is increased slowly (in about 1 minute or less) to the specified high Potential test level, and then maintained at that level for one minute.

DC high Potential tests described in IEEE Std. 95 [8] may be either a conventional high Potential test or a controlled high Potential test. In the conventional test the DC voltage is increased slowly from zero or some other low value to the specified high Potential voltage and then maintained at that level for one to ten minutes. In a controlled DC high Potential test the voltage is either increased in a series of steps or ramped up to the maximum test level. There are two variations of the stepped DC high Potential test: uniform-time voltage step method, the graded-time voltage step method [8]. The measured current is plotted against the applied voltage as the test progresses. Abnormalities or deviations in the current vs voltage plot may indicate insulation problems. The test also serves as a proof test (similar to AC test), if the insulation system withstands the prescribed high Potential test voltage.

The high Potential test level is (2E+1) kV for the power frequency AC test [4], 1.63 (2E+1) kV for 0.1 Hz test [7], and 1.7 (2E+1) kV for DC test [8] for new stator windings with rated line-to-line voltage E.

Use/specify high Potential for	**2000**	**2007**

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Acceptance - new coils and windings	100 %	100 % *(windings)* 100 % *(coils)*
Acceptance - rewinds	100 %	100 %
Maintenance (as one of many tests)	100 %	76 %
Maintenance (as only test)	0 %	0 %

Table 2. Which High Potential Test Used?

Test	2000	*2007 new machine*	*2007 Maintenance*
AC line	59%	90%	41%
VLF 0.1 Hz	5%	3%	0
DC (all)	93%	76% (*both*)	
- conventional	64%	38%	41%
- step	59%	31% *(u)* 7% *(g)*	45% *(u)* 21% *(g)*
- ramp	14%	10%	17%

All Table should be last in Apendix

Reasons to Prefer AC High Potential Test: The main reasons to prefer the AC test are the similarity of the test stress to that in service, the belief that AC tests are better in detecting defects, and availability of AC supply (Table 3). Other reasons are short time for test and between successive tests (no need to drain residual charge), OEM/insurance requirements, no need for a thorough dry out, and convenient application with other diagnostic tests (dissipation factor, PD etc). Only the DC test is used by 10 % respondents.

Table 3. Reasons to Prefer AC High Potential Test

Reason	**2000**	**2007**
Stress similar	52%	62%
AC supply available	11%	24%
AC high Potential better	25%	45%
Short test time	na	10%

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Other*	23%	31%
Use DC test		10%

*OEM, insurance, no thorough dry out required

Reasons to Prefer DC High Potential Test: The main reasons are the availability of cheap and small DC power supplies, possibility of aborting test on warning before a damaging failure, and diagnostic information in controlled tests (Table 4). Note that 24 % of the respondents use only AC tests.

Table 4. Reasons to Prefer DC High Potential Test

Reason	**2000**	**2007**
DC supply small/cheap	52%	45%
DC high Potential better	5%	7%
DC • failure warning	61%	48%
DC• diagnostic info	na	*31%*
*other	36%	0
Use AC		24%

*Supply available, trending, less damaging

AC High Potential Test Level: Most respondents use 2E+1 kV AC for new machines and coils. Many OEMs often use AC voltages 5 - 15 % higher than 2E+1 kV for new machines and 10 to 90 % higher than 2E+1 kV for new coils. Most respondents use 60 to 80 % of 2E+1 kV voltage for maintenance tests. However, four *{two}* respondents used voltage as low as 1.0 to 1.1 E kV for old machines.

DC High potential Test Level: DC voltages from √2 (2E+1) kV to 1.7(2E+1) kV are used for new machines and coils in almost all cases, and 57 to 80 % of 1.7(2E+1) kV for maintenance tests in most cases. However, voltages 1.25 E, 1.7E, 1.13E, and 25□A leakage current limit are also reported for maintenance tests by individual respondents.

Type of DC High potential test Used: About half of the respondents use conventional DC high potential test with highest voltage held for 1 minute in most cases, and 5 - 10 minutes in few cases (Table 5). Step tests (with uniform and graded steps) are also used by almost 50 % of the respondents as described in IEEE Std 95 [8]. Only 21 % *{14%}* respondents use ramp test at 1 to 3 kV/min rate. Many respondents use more than one type of DC high potential tests.

Table 5. Type of DC High potential Test Used

DC high potential type	**2000**	**2007**
Conventional -1 min	45 %	41 %
5 -10min	5 %	10 %
Ramp 1-3 kV/min	14 %	21 %
Step test	50 %	*U 48%* *G 21%*

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Which High potential at What Level Used for Green coils? To this new question posed in the 2007 survey, 86 % of respondents left it to the vendor or gave no response. Few other responses were unrealistic, indicating either poor understanding of the question or the poor language of the question.

High potential Test for Water-Cooled Machines: This new question in the 2007 survey got no response from 34 % respondents. AC high potential tests at E to 1.5E is used by 27%, DC high potential tests at 1.25 E to 1.7(2E+1) by 27%, and 'either of AC or DC test' by 10%. 10% of respondents specify dry and/ or drained condition and one specifies wet/dry. 10% use AC high potential with other (PD, C, dissipation factor) tests. Also three respondents specifically mention 'as recommended by manufacturer', which in our opinion is extremely important.

Comments from High potential Test Experience: Many different comments, as detailed in [2], were received including these important ones: (a) High potential tests fail marginal, not good windings; (b) High potential failures near the neutral end do occur; (c) Managers are often reluctant to approve a high potential test; (d) AC tests better detect defects, and used for water cooled machines;

(e) DC tests give prior warning of failure, may fail windings without warning, are time consuming, give questionable trending, are not good for epoxy-mica system; (f) A high potential test is more useful when performed with IR, PD, DF tests.

Suggestions for Further R &D: Many divergent suggestions directly or indirectly repeated questions asked earlier. Few respondents saw need for further R&D. Many respondents asked: how to convince managers when seeking approval for a high potential test?

ANSWERS TO IMPORTANT QUESTIONS

The project's objective was to answer some important questions on the use of high potential tests frequently raised by utility engineers. Answers to these questions are given using the findings from the survey and a comprehensive review of existing literature.

Do High potential Tests Damage a Good Winding?

The answer is NO to this question raised often by managers, who have to approve the high potential tests. Maintenance high potential tests do not introduce any significant degradation in a machine with good insulation system. Machines, which failed a high potential test, have always been found to have a poor insulation system in an examination following the failure.

Theoretically, the insulation in a good machine should not suffer any detectable degradation during a high potential test [9, 10]. Coils and bars used in machines should have the capability to pass a voltage endurance test [IEEE Std 1043]. For example, a 13.8 kV winding coil passes the endurance test for 400 hours at 30 kV at about 100 C without failure. If a 400-hour test at 30 kV and 100 C represents 25 years or more life in service, then an AC high potential test for 1 minute at 29 kV (2E+1 kV) at room temperature 30 C ages the insulation by nine (9) hours using IEEE Standard 930 for the relationship between voltage stress level and insulation life In experiments on 90 coil groups, Sedding et al [11] found that the AC breakdown voltages for sets of coil groups, which had been subjected to 5 AC or 5 DC high potential tests, were no different than those for the set of coil groups not subjected to any high potential tests. This shows empirically that the high potential tests do not damage an otherwise good insulation system.

When to Apply (or not Apply) High potential Tests?

New windings: For new windings (also coils), the high potential tests are and should be used universally as acceptance and quality assurance tests. Generally AC high potential tests are used with other diagnostic tests such as insulation resistance (IR), polarization index (PI), dissipation factor (DF), and/or partial discharges (PD).

Windings in service: To reduce the risk of a costly forced outage, a regular maintenance program, including high potential tests, is necessary. The winding may be tested during maintenance outages often every 3 to 6 years and somewhat longer for large generators.

As stated above, a high potential test does not degrade an otherwise good winding. There is a finite risk that a marginal winding, which would have hopefully operated for some more time, may be punctured in the high

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potential test. For example, a winding with poor coils near the neutral end may operate for many years, but it may fail a high potential test. It will require immediate repairs or replacement. This risk can be minimized (but not eliminated) by using the DC ramp or step test and other diagnostic tests (IR, PI, PD, DF), which may detect insulation problems without a puncture during the test.

Maintenance high potential tests require a management decision. The choice is between the failure of a marginal winding during the off-line high potential test and an in-service failure sometime later with a costly forced outage. The decision depends on factors like the criticality of machine application (to production, safety, environment, or otherwise), the redundancy in the plant for operation with a failed machine, the availability of a spare machine for quick replacement, and the insurance implications.

Which (AC or DC) High potential is Better?

The stress distribution in the insulation in operating machines is more similar to that in AC high potential tests than in DC high potential tests. But DC supplies are smaller and cheaper than AC supplies required for high potential large machines.

The controversy about the relative efficacy of DC and AC high potential tests for detecting insulation weaknesses has continued for many years [12, 13]. Relative merits of AC and DC high potential tests applied to stator windings are discussed in detail in IEEE Std. 95 [8] and briefly in references [9, 10, 12].

REFERENCES

[1] Guide for Rotating Electrical Machine High potential Testing, Final Report #1000666, EPRI, Palo Alto, CA, December 2000
[2] B.K. Gupta, G.C. Stone, and J. Stein, Use of Machine High potential Testing in Electric Utilities, Proceedings of EIC/EMCW 2001, Cincinnati, Ohio, October 15-18, 2001, IEEE Publication 01CH37264, pp 323-326.
[3] Guide for Rotating Machine Stator Winding High potential Testing: 2007 Update, Final Report #1014908, EPRI, Palo Alto, CA: 2008.
[4] ANSI C50.10-1990, General Requirements for Synchronous Machines.
[5] IEC 60034-1 (2002), Rotating Electrical Machines – Part 1: Rating and Performance.
[6] NEMA MG 1-2006, Motors and Generators.
[7] IEEE Std. 433-1974, Recommended Practice for Insulation Testing of Large AC Rotating Machinery with High Voltage at Very Low Frequency.
[8] IEEE 95-2002, Recommended Practice for Insulation Testing of AC Electric Machinery with High Direct Voltage.
[9] J. Timperley, Power Frequency Over potential Tests on Installed Stator Windings of Rotating Electric Machines, Panel Session on "High Voltage Testing Of Rotating Machines", IEEE/PES Winter Meeting, New York, NY, February 1997, IEEE Publication 97TP119-0, pp 14-17.
[10] R.E. Draper and R.H. Rehder, Over potential Testing of Insulation in Hydro Generators, Panel Session on "High Voltage Testing Of Rotating Machines", IEEE/PES Winter Meeting, New York, NY, February 1997, IEEE Publication 97TP119-0, pp 10-13.
[11] H.G. Sedding, R. Schwabe, J. Stein, and B.K. Gupta, The Role of AC & DC High potential Testing in Stator Winding Ageing, Proceedings of EIC/EMCW 2003, Indianapolis, Indiana, September 23-25, 2003, IEEE Publication 03CH37480, pp 455-457.
[12] A. Audoli and J.L. Drommi, Advantages of High Voltage DC Dielectric Tests Compared with AC Tests, Proceedings, Electrical Electronics Insulation Conference, October 4 - 7, 1993, Chicago, Illinois, pp 661-665.
[13] B.K. Gupta, Use of AC And DC High potential Tests to Assess Condition of Stator Insulation, Proceedings, Electrical and Electronics Insulation Conference, September 18-21, 1995, Chicago, Illinois, pp 605-608.
[14] B.K. Gupta and I.M. Culbert, Assessment of Insulation Condition in Rotating Machine Stators, IEEE Trans. Energy Conversion, vol. 7 no. 3, Sept 1992, pp 500-508.
[15] L. Rux and S. Grzybowski, Evaluation of Delaminated High-Voltage Rotating Machine Stator Winding Groundwall Insulation, Conference Record of the IEEE International Symposium on Electrical Insulation, Apr 2000, pp 520-523.

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