

# A NEW IEEE STANDARD FOR VOLTAGE ENDURANCE TESTING of HYDROGENERATOR STATOR COILS

G.C. Stone	S. Cherukupalli
Iris Power Engineering	B.C. Hydro

## INTRODUCTION

In the 1950's various manufacturers and users developed procedures that evaluated the ability of the electrical insulation of form-wound stator coils and bars to withstand electrical stress and high temperature operation. The test was referred to as a voltage endurance test. The original purpose was to find those designs and manufacturing processes that could perform the test under combined electrical and thermal stresses. Over the years some utilities started to apply the test to full size coils and bars, and use the results to either qualify a coil or bar design from a vendor, or as a quality control tool on a new winding [1-4].

In 1989, the IEEE issued Standard 1043-1989, "Recommended Practice for Voltage Endurance Testing of Form Wound Bars and Coils". This guide defined the procedure for performing such tests on full-size bars and coils. The guide was successful in that most organizations that performed such testing adopted the procedure, making the testing procedures more uniform. Consequently, the test results from different organizations could be realistically compared. Several utilities required winding manufacturers to perform the test on 2 or more coils per winding. The test is most often required for hydrogenerators windings.

In 1996, the IEEE Standards Board approved a revision to IEEE 1043, which was published in 2000 as IEEE 43-2000. In addition, in late 2002, IEEE 1553 was published that defined the test conditions and pass/fail criteria when the voltage endurance test is applied to hydrogenerator stator windings. This new standard is reviewed, after a brief description of the test.

## TEST METHOD

In a voltage endurance test on coils, usually two or more coils or 4 or more stator bars are randomly drawn from a production batch. The coils are placed in a special stand where the slot portions of the coils are encased in metal heater plates, which raise the surface to a specified temperature ("the test temperature") -Figure 1. At the same time, a 50 or 60 Hz ac voltage ("the test voltage") is applied between the heater plates and the coil copper conductors. The coil is subjected to this high voltage and temperature for a minimum time. If the coil or bar does not puncture in the specified time, then the insulation is considered "good", i.e. suitable for service. The test is sensitive to the following design or manufacturing problems:

- misalignment of the copper conductors, leading to high electric stress, usually at the corners
- inadequate groundwall insulation thickness
- wrinkles in the insulating mica tapes
- poor impregnation by epoxy or polyester
- insufficient or poor quality partly conductive slot coatings
- insufficient or poor quality stress relief (silicon carbide) coatings

The test is destructive in nature, and coils subject to the voltage endurance test cannot be placed into service.

The voltage endurance test is expensive to perform, because spare bars or coils must be made, and the test itself requires time and expensive test apparatus to do. Thus it should only be required when the hydrogenerator is critical to utility operation.

The specific details of the test procedure are in IEEE 1043-2000.

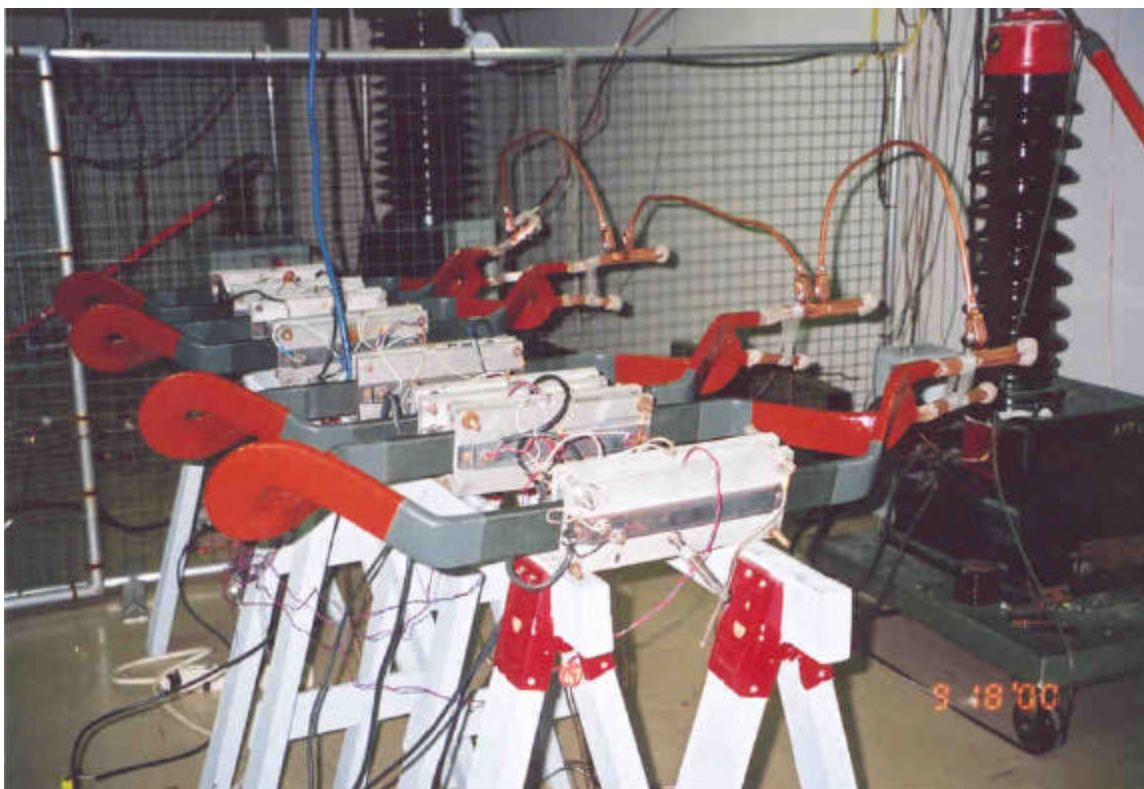


Figure 1: Typical voltage endurance test set-up.

## TEST CONDITIONS

The rationale for standardizing test conditions and pass/fail criteria is that some users were requiring coil manufacturers to perform the test at ever higher test voltages and temperatures, in the (sometimes mistaken) belief that more stringent conditions would lead to better windings. Publishing IEEE 1553 will likely halt this inflation in temperatures and voltages. (Making test conditions more difficult often leads to brand new failure mechanisms that are never likely to occur in service, and thus would render the voltage endurance test as a poor indicator of winding quality.) On the other hand, by making the test a Standard, the test would become more widely used, and increase the overall testing costs for the industry.

There are two main test parameters that must be defined: the voltage and the temperature. IEEE 1553 says the test temperature must be the expected normal maximum operating temperature of the winding. This is usually much lower than the 'class' temperature. For example, most hydrogenerators operate at a

maximum RTD temperature in the slot of 100C to 120C, whereas an epoxy mica insulation's thermal class is 155C (Class F).

Two 'schedules' of test voltage are embedded in the test standard. One schedule is easier to pass than the other. For a 13.8 kV rated stator, the test voltage is either 30 kVrms (schedule A) or 35 kVrms (schedule B), applied between the copper and ground. This represents a voltage that is 3.76 or 4.39 times the normal rated line to ground voltage of the coils. The test voltage for other rated voltages use the same multiplying factors. The test voltages that have been standardized are those that have been used for over 30 years.

## **DETERMINING IF THE TEST RESULTS ARE ACCEPTABLE**

In general, all coils or bars must survive 400 hours or 250 hours, for coils or bars tested according to schedule A or B, respectively. Experience shows that it is more difficult to pass the schedule B test criteria, i.e. 250 hours at 35 kV, for a 13.8 kV winding. All other considerations being equal, a schedule B winding will be more expensive.

The number of bars or coils used for the test represents a statistically very small sample size in comparison with the number of form-wound coils or bars normally manufactured for a machine. Therefore, conclusions reached about the insulation quality or manufacture may have some uncertainty, and if a 'failure' of one of the bars or coils occurs, this may just be a statistical aberration. IEEE 1553 recognizes this situation by allowing extra bars or coils to be tested in the event of one the initial bars or coils failing.

Specifically, if fewer than 26% of the specimens fail between 50% and 100% of the minimum time-to-failure, then 2 additional bars/coil legs can be tested. All these remaining specimens must pass the test. If six or more bars/coil legs are originally tested, testing of additional specimens is not required. If any failures occur during the re-testing, the complete production lot is considered to have failed, and any corrective action has to be determined after dissection and discussions between the manufacturer and user.

When one or more failures occur prior to 50% of the specified minimum time-to-failure, dissection of the failure and microscopic examination should be done. The corrective actions have to be determined after discussions between the manufacturer and user.

## **CONCLUSION**

A new IEEE standard has been published which specifies the test method, test condition and pass/fail criteria for voltage endurance tests on hydrogenerator stator windings. Use of such a test will enable utilities to qualify coil manufacturers for bidders lists, and ensure that coils and bars will provide a long service life, if the winding is properly installed and maintained.

## **ACKNOWLEDGEMENTS**

The 1553 working group that created this standard had many industrial and utility members and is a joint organization of the IEEE Dielectrics and Electrical Insulation Society, Voltage Endurance Technical Committee and the Power Engineering Society, Electrical Machines committee, Materials Subcommittee.

## REFERENCES

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