HV CABLE QUALIFICATIONS TO IEC 62067-2006 AND ICEA S-108-720-2004

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ABSTRACT

Manufacturers and users in the North American environment are faced with the dilemma of selecting the most appropriate qualification procedure for their cable or cable system: the cable system approach of IEC or the high temperature cable only method of ICEA. Parties are increasingly interested in performing a single test program which encompasses the most critical elements of each thereby providing a route to qualify a cable design to both IEC and ICEA requirements. This paper will review the differing test factors, considerations for laboratories when implementing serial or combined test programs, and issues for manufacturers and users when determining their test approach.

KEYWORDS

Cable qualifications, cable systems.

INTRODUCTION

As the use of XLPE cable systems increases in America, manufacturers and users are faced with the dilemma of selecting the most appropriate qualification procedure for their cable or cable system: the cable system approach of IEC or the high temperature cable only route of ICEA. Thus laboratories are increasingly being requested to perform a single test program which encompasses the most critical elements thereby providing a route to qualify a cable design to both IEC 62067 and ICEA S-108-720 requirements. NEETRAC has completed several combined tests on HV & EHV cable designs and these will be discussed in the paper.

Each of these two standards includes different test sequences as well as differing requirements for test voltages, conductor temperature range and setup, and impulse testing procedures. Users and manufacturers must determine if the test programs are to be combined or performed on a single sample in series with the cable dissection phase delayed. The differences in temperature and cable setup requirements are the main motivating factors for considering this approach. Figure 1 describes the required electrical type test programs and the NEETRAC combined approach utilized to meet the most onerous requirements of each standard on a single test sample.

This paper will review the differing test factors, considerations for laboratories when implementing either a combined or serial test program, and issues for manufacturers and users when determining their test approach.

COMPARISON OF TEST FACTORS

Sample requirements

IEC adopts a cable system test approach and requires a minimum of 10 m of cable and one sample of each accessory type to be included in the test. ICEA is a cable only test, but requires that the sample be installed within a pipe. Both qualification programs require that the cable portion of the sample be formed into a U bend with a diameter defined by the cable dimensions and materials.

Test Order

The most significant differences between the two qualification programs occur in the test order and the tests required. Figure 1 depicts the two programs (IEC and ICEA) from the bending procedure forward and the NEETRAC combined test program (right most). In the figure, dashed lines indicate equivalent tests. Bold lines show the source of the test in the combined test series (original clause numbers are retained).

IEC 62067 also requires an initial insulation thickness check (not listed in Fig. 1) to verify that the insulation thickness of the tested cable sample is not excessive compared with the nominal value. This check can be performed on the sample after the bending test, but should be completed prior to any voltage application.

Once the sample is installed, IEC requires an initial partial discharge test under ambient conditions and a hot dissipation factor measurement. At this point (identified as A in Fig.1), the manufacturer/end user must determine if a combined or a serial test program is to be performed. If a combined test program is selected, voltage and temperature levels can be set to the more stringent ICEA values.

Twenty thermal cycles with applied voltage are the next required test for both programs. As before, the more stringent ICEA voltage and temperature values should be applied if a combined test program is selected. IEC permits the two hour "at temperature" period to be anytime in the 8 hour current-on window for each thermal cycle. ICEA requires that the sample be in the "at temperature" period in the final two hours of the current-on window.

Once thermal cycling is complete, the test programs diverge into two paths. ICEA specifies that all tests can be performed on a single sample and in that situation the hot impulse test is moved to after the hot dissipation factor test. IEC permits the post thermal cycling ac tests to be moved to after the hot impulse tests completely. Another difference is in the impulse test procedures discussed in a later section of this article. The NEETRAC test program harmonizes the two standards by performing the ICEA ambient partial discharge and hot dissipation factor tests prior to performing the IEC required hot switching impulse test (if $U_m \geq 300$ kV) and the hot impulse test required by both standards. This test order also assumes that the manufacturer/end user does not wish to impulse the sample to failure.

Both standards require an ac withstand test after completing the impulse withstand test. The applied voltage and time length of the withstand test are dependent on the test approach selected. IEC also requires an ambient and hot partial dischage test to complete the testing.

A final difference in the test programs is the level of inspection. IEC utilizes only a visual inspection of the outer appearance of the cable system. ICEA removes a section of the cable at the center of the U-bend and performs an analysis comparing a new section of cable to the aged section. The analysis results are reported for engineering information only.

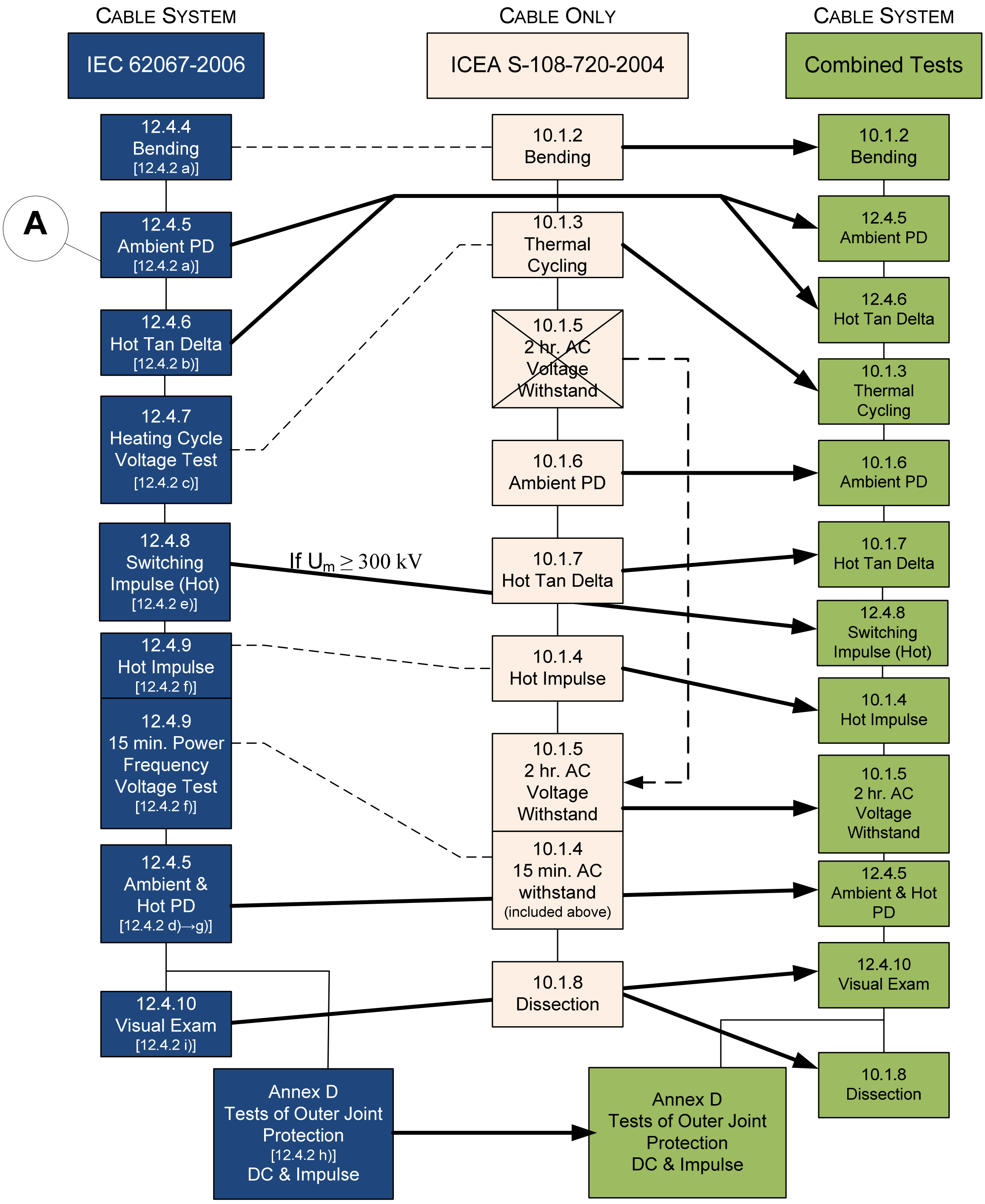

Fig. 1: Flowchart of IEC and ICEA Qualification test requirements and the combined test program implemented at NEETRAC. Dashed lines indicate equivalent tests. Bold lines show the source of the test (original clause numbers are retained.).

Temperature Requirements

ICEA S-108-720 Table 4-1 and IEC 62067 Table 1 agree that the maximum conductor temperature for normal operation is 90 °C for XLPE insulation. For the qualification program, IEC requires that the cable system be heated until the cable conductor is between 95 °C and 100 °C in air. ICEA requires that the cable be heated to 100 °C to 105 °C while enclosed in conduit.

For the thermal cycling/heating cycle tests, ICEA and IEC both define an eight hour current-on period and sixteen hours of natural cooling for each cycle. ICEA requires that the conductor be “at temperature” in the final two hours of the eight hour current-on window. The IEC requirement is simply that the conductor be “at temperature” for at least two hours of the current-on period.

The testing laboratory must develop a consistent heating cycle to maintain the conductor temperature in the thermal window during the final two hours. Temperature adjustments generally cannot be made in sufficient time during testing due to the large thermal time constants of HV/EHV cables. If a serial test program is selected, considerations must be made to permit altering the setup to add/remove the enclosed conduit to meet ICEA test requirements.

AC Voltage Requirements

ICEA utilizes test voltages based strictly on the rating of the cable unlike IEC which assigns a test value based on a voltage classification for the system. This difference results in the varying test voltages listed in Table 1 for a 230 kV rated system.

Table 1: Comparison of Test Voltages for IEC/ICEA HV Qualification Programs at 230 kV rating

Test	IEC Voltage	ICEA Voltage
Value for Dermination of Test Voltages	U_0 = 127 kV	V_g = 133 kV
Partial Discharge	$1.5U_0$ = 190 kV	$2V_g$ = 265 kV
Dissipation Factor	U_0 = 127 kV	V_g = 133 kV
Thermal Cycling/Heating Cycle	$2U_0$ = 254 kV	$2V_g$ = 265 kV
Voltage after Impulse Voltage Test	$2U_0$ = 254 kV	$2.5V_g$ = 332 kV

IEC does require an adjustment of the test voltage based on the insulation thickness of the supplied sample. This adjustment is applied if the average value of the insulation thickness of the test sample exceeds the nominal by more than 5%. If the average value exceeds it by more than 15%, the qualification program cannot proceed. The adjustment is performed to permit equivalent electrical stresses at the conductor screen.

Impulse Test Requirements

Both IEC and ICEA require a hot impulse test at BIL with ten positive and ten negative impulses applied. As stated previously, the conductor temperature required for the test is at the upper limit of the IEC window and the lower limit of the ICEA window. ICEA then requires that the test sample be taken to failure. If the cable cannot be failed, ICEA requires a 15 minute AC withstand test. IEC simply requires a 15 minute AC withstand test after completing the BIL impulse requirements.

Unlike ICEA, IEC requires a hot switching impulse voltage test if $U_m \geq 300$ kV. The test order requires this test to be performed prior to the IEC impulse voltage test.

Pass/Fail Criteria

In addition to the voltage and temperature differences for the partial discharge and dissipation factor tests, ICEA and IEC have slightly different criteria for pass/fail of the partical discharge test. ICEA requires only an ambient partial discharge test with a pass/fail criterion of 5 pC or less. IEC requires both an ambient and hot partial discharge test with no detectable discharge permitted to pass.

LABORATORY CONSIDERATIONS

Before beginning a qualification test program, laboratories need to consider installation time, length of test periods, and reliability of thermal controls.

If a serial program is performed, the total test length will extend to approximately sixteen to eighteen weeks assuming minimal interruptions. The serial program would begin with the IEC 62067 tests followed by the ICEA test program. Advantages to this method include

- Allowing the design to be evaluated at the lower temperature and voltage stresses for an IEC 62067 qualification,
- Increased engineering information with data at two temperature ranges and voltage levels, and
- Full system evaluated under the stringent ICEA requirements.

Two temperature profiles will need to be created for the serial program: one for the IEC temperature range in air and one for the ICEA temperature range in conduit. Conduit must be selected that can be applied after the IEC program is complete.

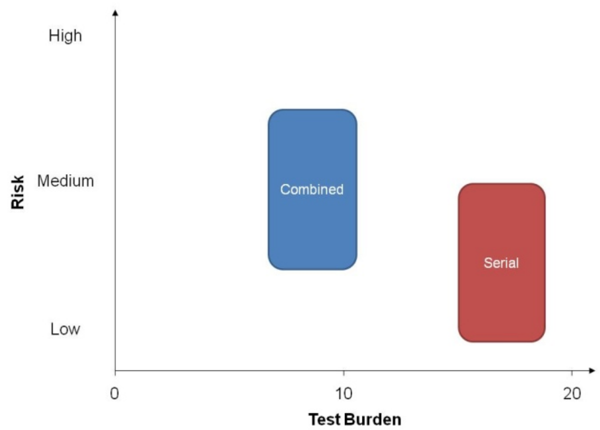

Fig. 2: Test Program Risk Vs. Test Burden

If the combined program is selected, the overall test length reduces to approximately eight to ten weeks and a single test installation and thermal profile will be necessary. While reducing the overall burden of the qualification test, there is increased risk due to the higher ICEA temperature window and test voltages. See Figure 2.

MANUFACTURER/END USER ISSUES

Manufacturers and end users have multiple issues to consider when developing a qualification test program to suit their needs.

- Have the system components being considered been previously qualified in a rigorous program?
- Is the emergency operating temperature 100 °C or 105 °C for the application?
- Is test information at both temperature ranges and voltage levels valuable for future applications?

The combined test program will provide the most efficient and possibly most cost effective evaluation of a design to both standards. However, by combining the test programs, there is increased risk of not completing either qualification.

TEST EXPERIENCE

Over six test programs have been completed using the combined format for 138 kV – 230 kV systems with conductor sizes from 1500 kcmil – 2500 kcmil. It is clear that the temperatures and voltages of the combined program are more rigorous for the cable system. This is shown by failures in the accessories and temperature excursions associated with the connectors. The NEETRAC combined program is a reasonable alternative method for compliance with the North American utility specification, AEIC CS9.

REFERENCES

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