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colour inside

Superconducting ac power cables and their accessories for rated voltages from 6 kV to 500 kV – Test methods and requirements

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INTERNATIONAL
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CONTENTS

FOREWORD ... 6
INTRODUCTION ... 8
1 Scope ... 9
2 Normative references ... 9
3 Terms and definitions ... 10
3.1 Definitions of dimensional values (thicknesses, cross-sections, etc.) ... 10
3.2 Definitions concerning tests ... 10
3.3 Other definitions (general design and cryogenic system) ... 11
4 Voltage and current designations ... 13
4.1 Rated voltages ... 13
4.2 Rated operating current ... 13
5 Cable materials ... 14
5.1 Cable conductor materials ... 14
5.2 Cable insulating materials (dielectric insulation) ... 14
5.3 Cable screen materials ... 14
5.4 Cable cryostat materials (thermal insulation) ... 14
5.5 Cable oversheathing materials (outside cryostat) ... 14
6 Cable characteristics ... 14
7 Accessory characteristics ... 15
8 Test conditions ... 16
8.1 Ambient temperature ... 16
8.2 Frequency and waveform of power frequency test voltages ... 16
8.3 Wave form of impulse test voltages ... 16
8.3.1 Lightning impulse voltage ... 16
8.3.2 Switching impulse voltage ... 16
8.4 Relationship of test voltages to rated voltages ... 16
8.5 Cryogen temperature and pressure ... 17
9 Routine tests on cables and on prefabricated accessories ... 17
9.1 General ... 17
9.1.1 Tests on cable core samples ... 17
9.1.2 Tests on cable cryostat ... 17
9.1.3 Tests on prefabricated accessories ... 17
9.2 AC voltage test for cable followed by partial discharge test ... 18
9.2.1 General ... 18
9.2.2 Procedure ... 18
9.2.3 Requirement ... 18
9.3 Critical current measurement ... 18
9.3.1 General ... 18
9.3.2 Procedure ... 18
9.3.3 Requirement ... 19
9.4 Pressure test ... 19
9.4.1 General ... 19
9.4.2 Procedure ... 19
9.4.3 Requirement ... 19
9.5 Vacuum leak test ... 19
9.5.1 General ... 19

9.5.2 Procedure 19
9.5.3 Requirement 19
9.6 Electrical test on oversheath of the cable 19
9.7 Tests on prefabricated accessories 19
9.7.1 Voltage test followed by partial discharge test 19
9.7.2 Pressure test and vacuum leak test 20
10 Sample tests on cables 20
10.1 General 20
10.2 Frequency of tests 20
10.3 Repetition of tests 20
10.4 Conductor examination 20
10.5 Measurement of thickness of cable insulation 21
10.5.1 General 21
10.5.2 Procedure 21
10.5.3 Requirement 21
10.6 Measurement of thickness of oversheath 21
10.6.1 General 21
10.6.2 Requirement 21
10.7 Measurement of diameters 21
10.8 Measurement of capacitance 21
10.9 Lightning impulse voltage test 22
11 Sample tests on accessories 22
11.1 Tests on components 22
11.2 Tests on complete accessory 22
12 Type tests on cable systems 23
12.1 General 23
12.2 Range of type approval 23
12.3 Summary of type tests 24
12.4 Electrical type tests on complete cable systems 24
12.4.1 Test voltage values 24
12.4.2 Tests and sequence of tests 24
12.4.3 Bending test 25
12.4.4 Critical current measurement 25
12.4.5 Pressure test 25
12.4.6 Thermal cycle test 26
12.4.7 Partial discharge test 26
12.4.8 Tan δ measurement 26
12.4.9 Load cycle voltage test 26
12.4.10 Impulse voltage tests 26
12.4.11 Examination of cable and accessories 27
12.5 Non-electrical type tests on cable components and on complete cable 27
12.5.1 Overview on non-electrical type tests 27
12.5.2 Check of cable construction 28
12.5.3 Tests for determining the mechanical properties of oversheaths before and after ageing 28
12.5.4 Loss of mass test on PVC oversheaths of type ST_2 28
12.5.5 Test on PVC oversheaths (ST_1 and ST_2) at low temperature 28
12.5.6 Heat shock test for PVC oversheaths (ST_1 and ST_2) 29

12.5.7 Measurement of carbon black content of black PE oversheaths (ST_3 and ST_7) 29
12.5.8 Test under fire conditions 29
12.5.9 Pressure test of cable cryostat 29
12.5.10 Pressure test of components of accessories 30
13 Prequalification test of the cable system 30
14 Type test on cables 30
15 Type test on accessories 30
16 Tests after installation 30
16.1 General 30
16.2 Tests at ambient temperature 31
16.2.1 Vacuum test 31
16.2.2 Pressure test 31
16.3 Tests at operating temperature 32
16.3.1 General 32
16.3.2 DC current test 32
16.3.3 AC voltage test of the insulation 32
16.3.4 DC voltage test of the oversheath 33
Annex A (informative) Cooling system considerations 37
A.1 Introductory remarks 37
A.2 Cryogenic refrigeration 37
A.2.1 General process 37
A.2.2 General hardware components 38
A.3 Recommendations for tests after installation 39
A.3.1 General 39
A.3.2 Pressure test followed by vacuum leak test 39
A.3.3 Cooling capacity test and efficiency measurement 40
A.3.4 Circulation pump mass flow and pressure test 40
A.3.5 Temperature and pressure control test 40
A.3.6 Noise measurements 40
A.3.7 Other measurements 40
Annex B (normative) Critical current measurement 41
B.1 Critical current measurement test 41
B.1.1 General 41
B.1.2 Procedure 41
B.1.3 Test method 41
Annex C (informative) Tests for engineering information 43
C.1 Overview 43
C.2 AC loss 43
C.2.1 General 43
C.2.2 Electrical method 43
C.2.3 Calorimetric – vaporization method 43
C.2.4 Calorimetric – cryogen mass flow method 43
C.3 Heat invasion of cryostat 44
C.3.1 General 44
C.3.2 Calorimetric – vaporization of liquid cryogen 44
C.3.3 Calorimetric – liquid cryogen mass flow method 44
C.4 Electrical parameters 44

C.5 Short-circuit tests (fault current) 44
Annex D (informative) List of type tests on cable systems 45
Annex E (normative) Tests on outer protection for joints 46
E.1 General 46
E.2 Range of approval 46
E.3 Voltage tests 46
E.3.1 General 46
E.3.2 Assemblies embodying accessories without sheath sectionalizing insulation 46
E.3.3 Assemblies embodying sheath sectionalizing insulation 46
E.4 Examination of test assembly 47
Annex F (informative) Prequalification test of the cable system 48
Bibliography 49

Figure A.1 – General refrigeration process with indication of temperature and energy flows 37
Figure A.2 – General system components and process flow 39
Figure B.1 – Test setup for electrical four-probe method 41
Figure B.2 – Voltage-current characteristic for superconductor 42
Table 1 – Test voltages 34
Table 2 – Non-electrical type tests for oversheathing compounds for cables 35
Table 3 – Test requirements for mechanical characteristics of oversheathing compounds for cables (before and after ageing) 36
Table 4 – Test requirements for particular characteristics of PVC oversheathing for cables 36
Table D.1 – Type tests on cable systems 45
Table E.1 – Impulse voltage tests 47

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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SUPERCONDUCTING AC POWER CABLES AND THEIR ACCESSORIES FOR RATED VOLTAGES FROM 6 KV TO 500 KV – TEST METHODS AND REQUIREMENTS

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The text of this International Standard is based on the following documents:

FDIS	Report on voting
20/1858/FDIS	20/1865/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

As a result of major developments in superconducting cable systems with cold dielectric for medium- and high-voltage AC applications, CIGRE study committee B1 set up working group (WG) B1.31 in 2009 with the aim to prepare recommendations for testing superconducting AC cable systems for power transmission at a rated voltage of up to 150 kV.

The recommendations of CIGRE WG B1.31 were published in TB 538 in June 2013 [1][1]. At the time of preparation of the CIGRE recommendation, laboratory experience at voltages up to and including 275 kV was available, but operating experience was limited to 154 kV. At the time of preparation of this document, several projects up to 220 kV are in progress, and many others are planned for the near future. As the insulation system of high-temperature superconducting (HTS) cable systems considered in this document is comparable to oil-filled cable systems, it was agreed to extend the voltage range to 500 kV in order to be compatible with IEC 60141-1 [2].

In 2014, TC 20 decided to start the standardization work on testing of HTS AC cables based on the published CIGRE TB 538. Manufacturers of HTS cable systems, utilities as the main users, and independent test laboratories will benefit from this document.

A list of relevant references is given in the Bibliography (see [3], [4], [5], [6]).

[1] Numbers in square brackets refer to the Bibliography.

SUPERCONDUCTING AC POWER CABLES AND THEIR ACCESSORIES FOR RATED VOLTAGES FROM 6 KV TO 500 KV – TEST METHODS AND REQUIREMENTS

1 Scope

This document specifies test methods and requirements for high-temperature superconducting (HTS) AC power cable systems, cables and their accessories, for fixed installations, for rated voltages from 6 kV (U_m = 7,2 kV) up to and including 500 kV (U_m = 550 kV).

The requirements apply to single-core, three-core and three-phase concentric cables with cold dielectric and their accessories that are not intended for fault current limitation purposes.

This document does not cover special cables and their accessories, such as fault current limiting cables or submarine cables, for which modifications to the standard tests may be necessary or special test conditions may need to be devised.

This document does not cover test methods and requirements for the cooling system.

NOTE For considerations regarding cooling systems, refer to Annex A.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60060-1, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60229:2007, *Electric cables – Tests on extruded oversheaths with a special protective function*

IEC 60230, *Impulse tests on cables and their accessories*

IEC 60332-1-2, *Tests on electric and optical fibre cables under fire conditions – Part 1-2: Test for vertical flame propagation for a single insulated wire or cable – Procedure for 1 kW pre-mixed flame*

IEC 60811-202, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 202: General tests – Measurement of thickness of non-metallic sheath*

IEC 60811-203, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 203: General tests – Measurement of overall dimensions*

IEC 60811-401, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 401: Miscellaneous tests – Thermal ageing methods. Ageing in an air oven*

IEC 60811-409, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 409: Miscellaneous tests – Loss of mass test for thermoplastic insulations and sheaths*

IEC 60811-501, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 501: Mechanical tests – Tests for determining the mechanical properties of insulation and sheathing compounds*

IEC 60811-505, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 505: Mechanical tests – Elongation at low temperature for insulations and sheaths*

IEC 60811-506, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 506: Mechanical tests – Impact test at low temperature for PVC insulations and sheaths*

IEC 60811-508, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 508: Mechanical tests – Pressure test at high temperature for insulations and sheaths*

IEC 60811-509, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 509: Mechanical tests – Tests for resistance of insulations and sheaths to cracking (heat shock test)*

IEC 60811-605, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 605: Physical tests – Measurement of carbon black and/or mineral filler in polyethylene* compounds

IEC 60885-3, *Electrical test methods for electric cables – Part 3: Test methods for partial discharge measurements on lengths of extruded power cables*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1 Definitions of dimensional values (thicknesses, cross-sections, etc.)

3.1.1
nominal value
value by which a quantity is designated and which is often used in tables

Note 1 to entry: In this document, nominal values usually give rise to values to be checked by measurements, taking into account specified tolerances.

3.1.2
median value
middle value if the number of available values is odd, and mean of the two middle values if the number is even, when several test results have been obtained and ordered in an increasing (or decreasing) succession

3.2 Definitions concerning tests

3.2.1
routine test
test made by the manufacturer on each manufactured cable system component to check that the component meets the specified requirements

3.2.2
sample test
test made by the manufacturer on samples of complete cable, or components taken from a complete cable or accessory, at a specified frequency, so as to verify that the finished product meets the specified requirements

3.2.3
type test
test made before supplying, on a general commercial basis, a type of cable system covered by IEC 63075, in order to demonstrate satisfactory performance characteristics to meet the intended application

Note 1 to entry: Once successfully completed, these tests need not be repeated, unless changes are made in the cable or accessory with respect to materials, manufacturing process, design or design electrical stress levels, which might adversely change the performance characteristics.

3.2.4
prequalification test
test made before supplying, on a general commercial basis, a type of cable system covered by IEC 63075, in order to demonstrate satisfactory long-term performance of the complete cable system

3.2.4
extension of prequalification test
test made before supplying, on a general commercial basis, a type of cable system covered by IEC 63075, in order to demonstrate satisfactory long-term performance of the complete cable system, taking into account an already prequalified cable system

3.2.5
test after installation
test made to demonstrate the integrity of the cable system as installed

3.3 Other definitions (general design and cryogenic system)

3.3.1
cable system
cable with installed terminations and/or joints

3.3.2
nominal electrical stress
electrical stress calculated at U_0 using nominal dimensions

3.3.3
high-temperature superconductor
HTS
class of superconductors with a critical temperature generally higher than about 25 K

[SOURCE: IEC 60050-815:2015, 815-11-11] [7]

3.3.4
HTS cable
cable comprising one or more phase conductors consisting of HTS material and a cryostat

Note 1 to entry: An HTS cable can be a single-core, a three-core and a three-phase concentric cable, all within a common cryostat.

3.3.5
cold dielectric
dielectric material which operates within a cryogenic environment

3.3.6
HTS cable core
either one or three concentrically arranged phase conductors consisting of HTS material with cold dielectric insulation and a screen

Note 1 to entry: A screen consists of metal or HTS material, or both.

3.3.7
single-core HTS cable
cable with HTS cable core comprising one phase conductor placed in a cryostat

3.3.8
three-core HTS cable
cable with three HTS cable cores, each comprising one phase conductor placed in a common cryostat

3.3.9
three-phase concentric HTS cable
cable with an HTS cable core comprising three concentric phase conductors placed in a cryostat

3.3.10
cryostat
container that provides the cryogenic environmental conditions to operate a superconducting device

[SOURCE: IEC 60050-815:2015, 815-15-51]

3.3.11
termination

device fitted to the end of a cable to ensure electrical connection with other parts of the system and to maintain the insulation up to the point of connection

Note 1 to entry: The termination is also an interface between cryogenic temperature and ambient temperature.

Note 2 to entry: The termination could also comprise an interface to the cooling system.

[SOURCE: IEC 60050-461:2008, 461-10-01, modified – The notes to entry have been added.]

3.3.12
joint
accessory making a connection between two HTS cables to form a continuous electrical circuit and a continuous thermal insulation

Note 1 to entry: The joint could also comprise an interface to the cooling system.

3.3.13
critical current
I_c
maximum direct current that can be regarded as flowing without resistance practically

Note 1 to entry: I_c is a function of magnetic field strength and temperature.

[SOURCE: IEC 60050-815:2015, 815-12-01, modified – "and strain" has been deleted from Note 1 to entry.]

3.3.14
fault current limiting cable
HTS cable that limits fault currents to acceptable values

3.3.15
AC loss
power dissipated in an HTS cable core owing to application of a time-varying magnetic field, electric current or voltage

Note 1 to entry: AC loss includes time average hysteresis loss of the HTS material, a coupling current loss and an eddy current loss of the conductor, an eddy current loss of the structural material, and a dielectric loss of the electric insulation.

Note 2 to entry: AC loss customarily also includes the power dissipated in the HTS material owing to application of transient changes in magnetic field or current.

3.3.16
cryogenics
study of the production and behaviour of materials at temperatures below 120 K

3.3.17
cryogen
liquid that boils at cryogenic temperatures below 120 K and is used to obtain very low temperatures

Note 1 to entry: The most common cryogen for HTS cables is liquid nitrogen due to its availability, cost and dielectric properties.

3.3.18
cryogenic refrigeration system
cryogenic cooling system
system that is capable of cooling cryogen at cryogenic temperatures

3.3.19
maximum allowable working pressure
maximum pressure (gauge) across the entire operating and testing temperature range to which the superconducting cable system may be exposed and operated

Note 1 to entry: The maximum allowable working pressure is referred to for pressure testing.

Note 2 to entry: The maximum allowable working pressure includes pressure variations within the normal operation.

Note 3 to entry: The maximum operating pressure shall be less or equal to the maximum allowable working pressure.

4 Voltage and current designations

4.1 Rated voltages

In this document, the symbols U_0, U and U_m are used to designate the rated voltages of cables and accessories, where these symbols have the meanings given in IEC 60183 [9].

4.2 Rated operating current

In this document, the symbol I_r is used to designate the rated operating current of the cable and accessories. The rated operating current is the RMS value of the current that the system shall be able to carry continuously under specified conditions of the cryogen. Preferably, current ratings in accordance with IEC 60059 [10] should be applied.