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colour inside

Thyristor valves for high voltage direct current (HVDC) power transmission – Part 1: Electrical testing

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THYRISTOR VALVES FOR HIGH VOLTAGE DIRECT CURRENT (HVDC) POWER TRANSMISSION –

Part 1: Electrical testing

FOREWORD

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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

International Standard IEC 60700-1 has been prepared by subcommittee 22F: Power electronics for electrical transmission and distribution systems, of IEC technical committee 22: Power electronic systems and equipment.

This second edition cancels and replaces the first edition published in 1998, its Amendment 1:2003 and its Amendment 2: 2008. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition.

a) Definitions of terms “redundant thyristor levels”, “thyristor level”, “valve section” have been changed for clarification.
b) The notes were added to test requirements of dielectric d.c. voltage tests for valve support, MVU, valve, specifying that before repeating the test with opposite polarity, the tested object may be short-circuited and earthed for several hours. The same procedure may be followed at the end of the d.c. voltage test.
c) Table 1 on thyristor level faults permitted during type tests was supplemented.
d) The alternative MVU dielectric test method was added.
e) It was specified that production tests may include routine tests as well as sample tests.
f) It was added into test requirements for periodic firing and extinction tests that a scaling factor for tests shall be applied when testing with valve sections.

The text of this standard is based on the following documents:

CDV	Report on voting
22F/341/CDV	22F/351A/RVC

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

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

A list of all parts in the IEC 60700 series, published under the general title *Thyristor valves for high voltage direct current (HVDC) power transmission*, can be found on the IEC website.

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

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

The contents of the corrigendum of January 2017 have been included in this copy.

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 publication using a colour printer.

THYRISTOR VALVES FOR HIGH VOLTAGE DIRECT CURRENT (HVDC) POWER TRANSMISSION –

Part 1: Electrical testing

1 Scope

This part of IEC 60700 applies to thyristor valves with metal oxide surge arresters directly connected between the valve terminals, for use in a line commutated converter for high voltage d.c. power transmission or as part of a back-to-back link. It is restricted to electrical type and production tests.

The tests specified in this standard are based on air insulated valves. For other types of valves, the test requirements and acceptance criteria ~~must~~ can be agreed.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60060, *High-voltage test techniques*

IEC 60060-1~~:1989~~, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60071-1~~:1993~~, *Insulation co-ordination – Part 1: Definitions, principles and rules*

IEC 60099 (all parts), *Surge arresters*

IEC 60270~~:1981~~, *High-voltage test techniques – Partial discharge measurements*

IEC 61803:1999, *Determination of power losses in high-voltage direct current (HVDC) converter stations*
IEC 61803:1999/AMD1:2010[1]

ISO/IEC Guide 25~~:1990~~, *General requirements for the technical competence of ~~calibration and~~ testing laboratories*[2]

3 Terms and definitions

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

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1 There exists a consolidated edition 1.1 (2011) that comprises IEC 61803:1999 and its Amendment 1:2010.

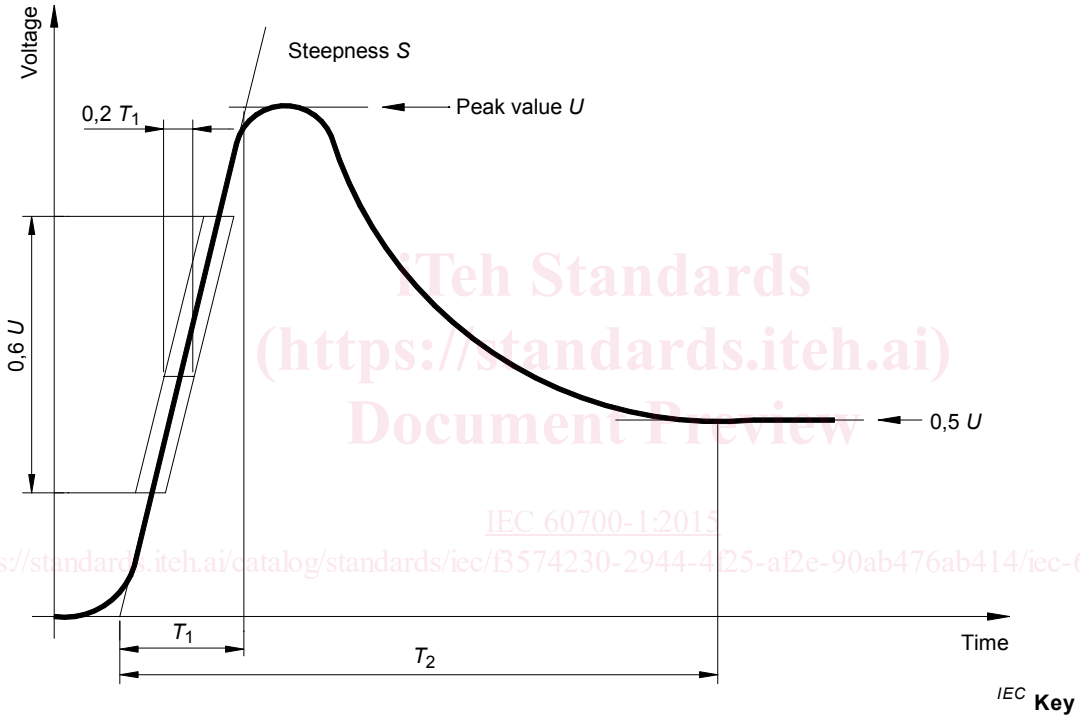
2 Withdrawn.

3.1 Insulation co-ordination terms

3.1.1
test withstand voltage
value of a test voltage of standard waveshape at which a new valve, with unimpaired integrity, does not show any disruptive discharge and meets all other acceptance criteria specified for the particular test, when subjected to a specified number of applications or a specified duration of the test voltage, under specified conditions

3.1.2
steep front impulse
fast-front voltage impulse whose time to peak is less than that of a standard lightning impulse but not less than that of a very-fast-front voltage as defined in IEC 60071-1.

Note 1 to entry: For this standard, the steep front impulse voltage for test purposes is as shown in Figure 1.



U specified peak value of steep front impulse test voltage (kV)

S specified steepness of steep front impulse test voltage (kV/μs)

T_1 virtual front time = $\frac{U}{S}$ (μs)

The following conditions shall be satisfied:

a) The peak value of the recorded test voltage shall be $U \pm 3$ %. This tolerance is the same as that in IEC 60060 for standard lightning impulse.

b) Over a voltage excursion of not less than 0,6 U, the rising portion of the recorded test voltage shall be entirely contained between two parallel lines of steepness S and separation 0,2 T_1.

c) The value of the test voltage at T_2 shall not be lower than 0,5 U. T_2 is defined as the time interval between the origin and the instant when the voltage has decreased to half the peak value of the waveform which is obtained from system study. However, it shall be assured that an unintentional du/dt switching of the thyristors can be adequately detected.

Figure 1 – Steep front impulse test voltage

3.1.3
internal and external insulation
air external to the components and insulating materials of the valve, but contained within the profile of the valve or multiple valve unit is considered as part of the internal insulation system of the valve

Note 1 to entry: The external insulation is the air between the external surface of the valve or multiple valve unit and its surroundings.

3.1.4
valve protective firing
means of protecting the thyristors from excessive voltage by firing them at a predetermined voltage

3.2 Valve construction terms

3.2.1
valve support
that part of the valve which mechanically supports and electrically insulates from earth the active part of the valve which houses the valve sections

Note 1 to entry: A part of a valve which is clearly identifiable in a discrete form to be a valve support may not exist in all designs of valves.

3.2.2
valve structure
physical structure holding the thyristor levels of a valve which is insulated to the appropriate voltage above earth potential

3.2.3
redundant thyristor levels
~~thyristor levels in the series string which may be shortcircuited, while the specified type test performance of the valve is still met~~
maximum number of thyristor levels in a thyristor valve that may be short-circuited externally or internally during service without affecting the safe operation of the thyristor valve as demonstrated by type tests, and which if and when exceeded, would require shutdown of the converter to replace the failed thyristors or acceptance of increased risk of failures

3.2.4
valve base electronics
electronic unit, at earth potential, which is the interface between the control system for the converter and the thyristor valves

3.2.5
thyristor level
part of a thyristor valve comprising a thyristor, or thyristors connected in parallel, together with their immediate auxiliaries, and reactor, if any

3.2.6
valve section
electrical assembly, comprising a number of thyristors and other components, which exhibits pro-rated electrical properties of a complete valve

3.2.7
multiple valve unit
MVU
single physical structure comprising more than one valve with a common mechanical support structure

3.3 Terms related to type tests

NOTE Those tests which are carried out to verify that the valve design will meet the requirements specified. In this standard, type tests are classified under two major categories: dielectric tests and operational tests.

3.3.1
dielectric tests
tests which are carried out to verify the high voltage characteristics of the valve

3.3.2
operational tests
tests which are carried out to verify the turn-on, turn-off and current related characteristics of the valve

3.4 Terms related to production tests

NOTE Those tests which are carried out to verify proper manufacture, so that the properties of a valve correspond to those specified.

3.4.1
routine tests
production tests which are carried out on all valves, valve sections or components

3.4.2
sample tests
production tests which are carried out on a small number of valves, valve sections or components taken at random from a batch

4 General requirements

4.1 Guidelines for the performance of type tests

4.1.1 Evidence in lieu

Each design of valve shall be subjected to the type tests specified in this standard. If the valve is demonstrably similar to one previously tested, the supplier may, in lieu of performing a type test, submit a test report of a previous type test for consideration by the purchaser. This should be accompanied by a separate report detailing the differences in the design and demonstrating how the referenced type test satisfies the test objectives for the proposed design.

4.1.2 Test object

Test object should meet the following requirements:

a) Certain type tests may be performed either on a complete valve or on valve sections, as indicated in Table 2. For those type tests on valve sections, the total number of valve sections tested shall be at least as many as the number in a complete valve.

b) The same valve sections shall be used for all type tests unless otherwise stated.

c) Prior to commencement of type tests, the valve, valve sections and/or the components of them should be demonstrated to have withstood the production tests to ensure proper manufacture.

4.1.3 Sequence of tests

The type tests specified can be carried out in any order.

NOTE Tests involving partial discharge measurement ~~may~~ can provide added confidence if performed at the end of the dielectric type test programme.

4.1.4 Test procedures

The tests shall be performed in accordance with IEC 60060, where applicable. The competence of testing and calibration laboratories should correspond to the ISO/IEC Guide 17025.

4.1.5 Ambient temperature for testing

The tests shall be performed at the prevailing ambient temperature of the test facility, unless otherwise specified.

4.1.6 Frequency for testing

AC dielectric tests can be performed at either 50 Hz or 60 Hz. For operational tests, specific requirements regarding the frequency for testing are given in the relevant clauses.

4.1.7 Test reports

At the completion of the type tests, the supplier shall provide type test reports in accordance with Clause 16.

4.2 Atmospheric correction

When specified in the relevant clause, atmospheric correction shall be applied to the test voltages in accordance with IEC 60060-1. The reference conditions to which correction shall be made are the following.

– Pressure: ~~standard atmospheric air pressure (101,3 kPa), corrected to the altitude of the site at which the equipment will be installed;~~

  a) If the insulation coordination of the tested part of the thyristor valve is based on standard rated withstand voltages according to IEC 60071-1, correction factors are only applied for altitudes exceeding 1 000 m. Hence, if the altitude of the site a_s at which the equipment will be installed is ≤1 000 m, then the standard atmospheric air pressure (b_0 = 101,3 kPa) shall be used with no correction for altitude. If a_s >1 000 m, then the standard procedure according to IEC 60060-1 is used except that the reference atmospheric pressure b_0 is replaced by the atmospheric pressure corresponding to an altitude of 1 000 m ($b_{1\ 000\ m}$);

  b) If the insulation coordination of the tested part of the thyristor valve is not based on standard rated withstand voltages according to IEC 60071-1, then the standard procedure according to IEC 60060-1 is used with the reference atmospheric pressure b_0 (b_0=101,3 kPa);

– Temperature: design maximum valve hall air temperature (°C).;

– Humidity: design minimum valve hall absolute humidity (g/m^3).

The values to be used shall be specified by the supplier.

4.3 Treatment of redundancy

4.3.1 Dielectric tests

For all dielectric tests between valve terminals, the redundant thyristor levels shall be short circuited, with the possible exception of the valve non-periodic firing test (see 8.4). The location of thyristor levels to be short circuited shall be agreed by the purchaser and supplier.

NOTE Depending on the design, limitations ~~may~~ can be imposed upon the distribution of short-circuited thyristor levels. For example, there may be an upper limit to the number of short-circuited thyristor levels in one valve section.

4.3.2 Operational tests

For operational tests, redundant thyristor levels shall not be short circuited. The test voltages used shall be adjusted by means of a scaling factor k_n:

$$k_n = \frac{N_{tut}}{N_t - N_r}$$

where

N_{tut} is the number of series thyristor levels in the test object;

N_t is the total number of series thyristor levels in the valve;

N_r is the total number of redundant series thyristor levels in the valve.

4.4 Criteria for successful type testing

4.4.1 General

Experience in industry shows that, even with the most careful design of valves, it is not possible to avoid occasional random failures of thyristor level components during service operation. Even though these failures may be stress-related, they are considered random to the extent that the cause of failure or the relationship between failure rate and stress cannot be predicted or is not amenable to precise quantitative definition. Type tests subject valves or valve sections, within a short time, to multiple stresses that generally correspond to the worst stresses that can be experienced by the equipment not more than a few times during the life of the valve. Considering the above, the criteria for successful type testing set out below therefore permit a small number of thyristor levels to fail during type testing, providing that the failures are rare and do not show any pattern that is indicative of inadequate design.

4.4.2 Criteria applicable to thyristor levels

The following criteria are applicable to thyristor levels:

a) If, following a type test as listed in Clause 5, more than one thyristor level (alternatively more than 1 % of the series-connected thyristor levels in a complete valve, if greater) has become short circuited, then the valve shall be deemed to have failed the type tests.

b) If, following a type test, one thyristor level (or more if still within the 1 % limit) has become short circuited, then the failed level(s) shall be restored and this type test ~~continued~~ repeated.

c) If the cumulative number of short-circuited thyristor levels during all type tests is more than 3 % of the series-connected thyristor levels in a complete valve, then the valve shall be deemed to have failed the type test programme.

d) When type tests are performed on valve sections, the criteria for acceptance above also apply since the number of valve sections tested shall be not less than the number of sections in a complete valve (see 4.1.2 a)).

e) The valve or valve sections shall be checked after each type test to determine whether or not any thyristor levels have become short-circuited. Failed thyristors or auxiliary components found during or at the end of a type test may be replaced before further testing.

f) At the completion of the test programme, the valve or valve sections shall undergo a series of check tests, which shall include as a minimum:

- check for voltage withstand of thyristor levels in both forward and reverse direction;
- check of the gating circuits where applicable;
- check of the monitoring circuits;
- check of the thyristor level protection circuits by application of transient voltages above and below the protection setting(s) where applicable;
- check of the voltage grading circuits.