

INTERNATIONAL STANDARD

NORME INTERNATIONALE



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

**Valves à thyristors pour le transport d'énergie en courant continu à haute
tension (CCHT) –**

Partie 1: Essais électriques

[IEC 60700-1:2015](#)

[standards/sist/f3574230-2944-4f25-af2e-90ab476ab414/iec-60700-1-2015](#)



THIS PUBLICATION IS COPYRIGHT PROTECTED
Copyright © 2021 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de l'IEC ou du Comité national de l'IEC du pays du demandeur. Si vous avez des questions sur le copyright de l'IEC ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de l'IEC de votre pays de résidence.

IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, ...). It also gives information on projects, replaced and withdrawn publications.

IEC online collection - oc.iec.ch

Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

Electropedia - www.electropedia.org

The world's leading online dictionary on electrotechnology, containing more than 22 000 terminological entries in English and French, with equivalent terms in 18 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

A propos de l'IEC

La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications IEC

Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Recherche de publications IEC - webstore.iec.ch/advsearchform

La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études, ...). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

IEC online collection - oc.iec.ch

Découvrez notre puissant moteur de recherche et consultez gratuitement tous les aperçus des publications. Avec un abonnement, vous aurez toujours accès à un contenu à jour adapté à vos besoins.

IEC Just Published - webstore.iec.ch/justpublished

Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et une fois par mois par email.

Electropedia - www.electropedia.org

Le premier dictionnaire d'électrotechnologie en ligne au monde, avec plus de 22 000 articles terminologiques en anglais et en français, ainsi que les termes équivalents dans 16 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

Service Clients - webstore.iec.ch/csc

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: sales@iec.ch.



IEC 60700-1

Edition 2.1 2021-09
CONSOLIDATED VERSION

INTERNATIONAL STANDARD

NORME INTERNATIONALE



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

**Valves à thyristors pour le transport d'énergie en courant continu à haute
tension (CCHT) –**

Partie 1: Essais électriques

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 29.200

ISBN 978-2-8322-4450-0

**Warning! Make sure that you obtained this publication from an authorized distributor.
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.**

REDLINE VERSION

VERSION REDLINE



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

**Valves à thyristors pour le transport d'énergie en courant continu à haute
tension (CCHT) –**

Partie 1: Essais électriques

[IEC 60700-1:2015](#)

[standards/sist/f3574230-2944-4f25-af2e-90ab476ab414/iec-60700-1-2015](#)

CONTENTS

FOREWORD.....	5
1 Scope.....	7
2 Normative references.....	7
3 Terms and definitions	7
3.1 Insulation co-ordination terms.....	8
 3.2 Valve construction terms.....	8
3.3 Terms related to type tests.....	9
3.4 Terms related to production tests.....	10
4 General requirements	10
4.1 Guidelines for the performance of type tests.....	10
4.1.1 Evidence in lieu	10
4.1.2 Test object.....	10
4.1.3 Sequence of tests	10
4.1.4 Test procedures	10
4.1.5 Ambient temperature for testing.....	11
4.1.6 Frequency for testing	11
4.1.7 Test reports	11
4.2 Atmospheric correction.....	11
4.3 Treatment of redundancy.....	11
4.3.1 Dielectric tests	11
4.3.2 Operational tests.....	11
4.4 Criteria for successful type testing.....	12
4.4.1 General.....	12
4.4.2 Criteria applicable to thyristor levels.....	12
4.4.3 Criteria applicable to the valve as a whole	13
5 List of type tests	13
6 Dielectric tests on valve support.....	14
6.1 Purpose of tests	14
6.2 Test object.....	14
6.3 Test requirements	15
6.3.1 General	15
6.3.2 Valve support d.c. voltage test	15
6.3.3 Valve support a.c. voltage test	15
6.3.4 Valve support switching impulse test	16
6.3.5 Valve support lightning impulse test	16
7 Dielectric tests for multiple valve units (MVU).....	16
7.1 Purpose of tests	16
7.2 Test object.....	16
7.3 Test requirements	17
7.3.1 MVU d.c. voltage test to earth	17
7.3.2 MVU a.c. voltage test.....	18
7.3.3 MVU switching impulse test.....	18
7.3.4 MVU lightning impulse test.....	19
8 Dielectric tests between valve terminals.....	20
8.1 Purpose of tests	20

8.2	Test object.....	20
8.3	Test requirements	21
8.3.1	Valve d.c. voltage test.....	21
8.3.2	Valve a.c. voltage test.....	21
8.3.3	Valve impulse tests (general)	22
8.3.4	Valve switching impulse test.....	23
8.3.5	Valve lightning impulse test.....	23
8.3.6	Valve steep front impulse test	24
8.4	Valve non-periodic firing test	24
8.4.1	Purpose of test	24
8.4.2	Test object.....	24
8.4.3	Test requirements	25
9	Periodic firing and extinction tests.....	26
9.1	Purpose of tests	26
9.2	Test object.....	26
9.3	Test requirements	26
9.3.1	General	26
9.3.2	Maximum continuous operating duty tests.....	27
9.3.3	Maximum temporary operating duty test ($\alpha = 90^\circ$).....	29
9.3.4	Minimum a.c. voltage tests.....	29
9.3.5	Temporary undervoltage test.....	30
9.3.6	Intermittent direct current tests.....	31
10	Tests with transient forward voltage during the recovery period	32
10.1	Purpose of tests	32
10.2	Test object.....	32
10.3	Test requirements	32
11	Valve fault current tests	33
11.1	Purpose of tests	33
11.2	Test object.....	33
11.3	Test requirements	33
11.3.1	General	33
11.3.2	One-loop fault current test with re-applied forward voltage.....	34
11.3.3	Multiple-loop fault current test without re-applied forward voltage.....	35
12	Tests for valve insensitivity to electromagnetic disturbance	36
12.1	Purpose of tests	36
12.2	Test object.....	36
12.3	Test requirements	36
12.3.1	General	36
12.3.2	Approach one	36
12.3.3	Approach two.....	37
12.3.4	Acceptance criteria	37
13	Testing of special features and fault tolerance.....	37
13.1	Purpose of tests	37
13.1.1	General	37
13.1.2	Circuits to facilitate the proper control, protection and monitoring of the valve.....	37
13.1.3	Features included in the valve to provide fault tolerance	37
13.2	Test object.....	38

13.3	Test requirements	38
14	Production tests.....	38
14.1	General.....	38
14.2	Purpose of tests	38
14.3	Test object.....	39
14.4	Test requirements	39
14.5	Routine test – minimum requirements	39
14.5.1	Visual inspection.....	39
14.5.2	Connection check	39
14.5.3	Voltage-grading circuit check	39
14.5.4	Voltage withstand check.....	39
14.5.5	Partial discharge tests.....	39
14.5.6	Check of auxiliaries.....	39
14.5.7	Firing check	39
14.5.8	Pressure test	39
15	Method for loss determination	40
16	Presentation of type test results	40
Annex A	(normative) Test safety factors	41
A.1	General.....	41
A.2	Test safety factors for dielectric tests.....	41
A.2.1	Impulse tests	41
A.2.2	AC and d.c. temporary and long-term voltage tests	44
A.3	Test safety factors for operational tests	44
Annex B	(normative) Partial discharge measurements	45
B.1	Measurement of partial discharge	45
B.2	Partial discharge during a.c. tests.....	45
B.3	Partial discharge during d.c. tests.....	45
B.4	Composite a.c. plus d.c. voltage stress	46
Bibliography	47
Figure 1	– Steep front impulse test voltage.....	8
Table 1	– Thyristor level faults permitted during type tests.....	13
Table 2	– List of type tests	14

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

Part 1: Electrical testing

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

This consolidated version of the official IEC Standard and its amendment has been prepared for user convenience.

IEC 60700-1 edition 2.1 contains the second edition (2015-07) [documents 22F/341/CDV and 22F/351A/RVC], its corrigendum 1 (2017-01) and its amendment 1 (2021-09) [documents 22F/604/CDV and 22F/628/RVC].

In this Redline version, a vertical line in the margin shows where the technical content is modified by amendment 1. Additions are in green text, deletions are in strikethrough red text. A separate Final version with all changes accepted is available in this publication.

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 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.

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 the base publication and its amendment will remain unchanged until the stability date indicated on the IEC web site under 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.

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.

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 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, *High-voltage test techniques – Part 1: General definitions and test requirements*
[https://standards.iteh.ai/catalog/standards/sist/b574230-2944-4d25-af2e-90ab476ab414/iec-](https://standards.iteh.ai/catalog/standards/sist/b574230-2944-4d25-af2e-90ab476ab414/iec-60060-1-2016)

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

IEC 60099 (all parts), *Surge arresters*

IEC 60270, *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/AMD 1:2010¹~~

IEC 61803:2020, *Determination of power losses in high-voltage direct current (HVDC) converter stations with line-commutated converters*

~~ISO/IEC Guide 25, *General requirements for the technical competence of testing laboratories*²~~

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

3 Terms and definitions

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

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

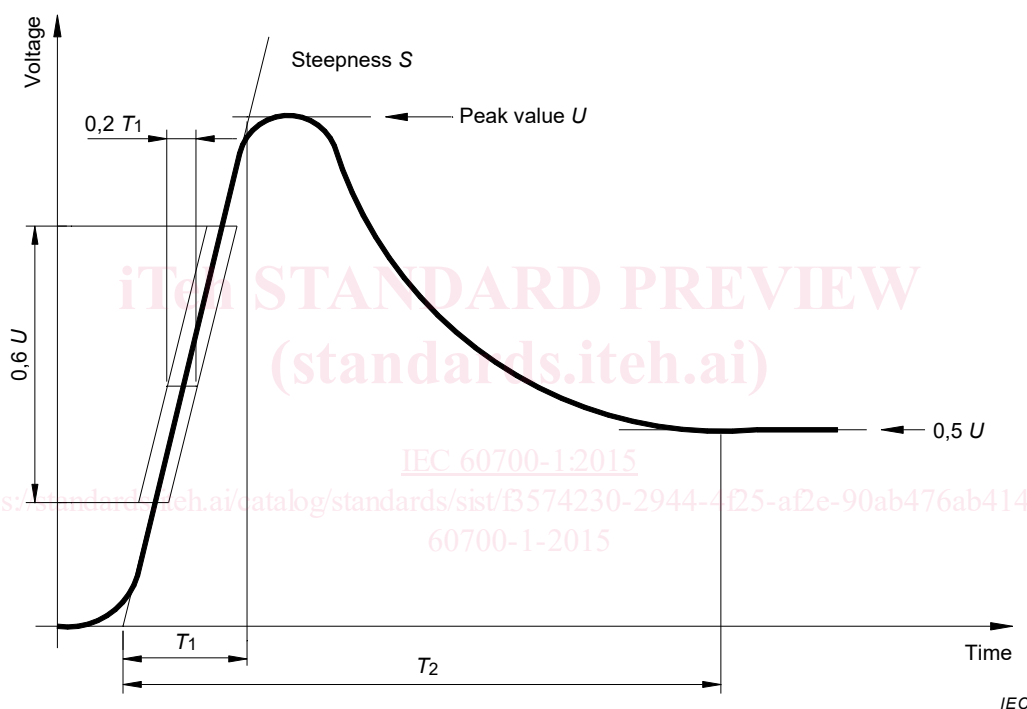
value of a test voltage of standard waveshape at which a new valve, with unimpaired integrity, does not show any disruptive discharge and meets all other acceptance criteria specified for the particular test, when subjected to a specified number of applications or a specified duration of the test voltage,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



Key

- U specified peak value of steep front impulse test voltage (kV)
- S specified steepness of steep front impulse test voltage (kV/ μ s)
- T_1 virtual front time = $\frac{U}{S}$ (μ s)

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~~

~~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 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:
 - 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 $\leq 1\ 000$ 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 ($^{\circ}\text{C}$);
- 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 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 :

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

where