

Power electronics for electrical transmission and distribution systems — Testing of thyristor valves for static VAR compensators

The European Standard EN 61954:1999, with the incorporation of amendment A1:2003, has the status of a British Standard

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National foreword

This British Standard is the official English language version of EN 61954:1999, including amendment A1:2003. It is identical with IEC 61954 Ed. 1.0:1999, including amendment 1:2003.

The start and finish of text introduced or altered by amendment is indicated in the text by tags **A1** **A1**. Tags indicating changes to CENELEC text carry the number of the CENELEC amendment. For example, text altered by CENELEC amendment A1 is indicated by **A1** **A1**.

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Power electronics for electrical transmission and distribution systems — Testing of thyristor valves for static VAR compensators

(includes amendment A1:2003)

(IEC 61954:1999 + A1:2003)

Electronique de puissance pour les réseaux électriques de transport et de distribution —
Essais des valves à thyristors pour les compensateurs statiques d'énergie réactive
(inclut l'amendement A1:2003)
(CEI 61954:1999 + A1:2003)

Leistungselektronik für Übertragungs- und Verteilungsnetze —
Prüfung von Thyristorventilen für statische Blindleistungskompensatoren
(enthält Änderung A1:2003)
(IEC 61954:1999 + A1:2003)

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

The text of document 22F/57/FDIS, future edition 1 of IEC 61954, prepared by SC 22F, Power electronics for electrical transmission and distribution systems, of IEC TC 22, Power electronics, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 61954 on 1999-10-01.

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Annexes designated normative are part of the body of the standard.

In this standard, Annex ZA is normative.

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 61954:1999 was approved by CENELEC as a European Standard without any modification.

Foreword to amendment A1

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Endorsement notice

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POWER ELECTRONICS FOR ELECTRICAL TRANSMISSION AND DISTRIBUTION SYSTEMS – TESTING OF THYRISTOR VALVES FOR STATIC VAR COMPENSATORS

1 Scope

This International Standard defines type, production and optional tests on thyristor valves used in thyristor controlled reactors (TCR), thyristor switched reactors (TSR) and thyristor switched capacitors (TSC) forming part of static VAR compensators (SVC) for power system applications. The requirements of the standard apply both to single valve units (one phase) and to multiple valve units (several phases).

Clauses 4 to 7 detail the type tests, i.e. tests which are carried out to verify that the valve design meets the requirements specified. Clause 8 covers the production tests, i.e. tests which are carried out to verify proper manufacturing. Clauses 9 and 10 detail optional tests, i.e. tests additional to the type and production tests.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of IEC 61954. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on IEC 61954 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60060 (all parts), *High-voltage test techniques*

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

IEC 60060-2, *High-voltage test techniques – Part 2: Measuring systems*

IEC 60071 (all parts), *Insulation co-ordination*

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

IEC 60270, *Partial discharge measurements*

IEC 60700-1:1998, *Thyristor valves for high-voltage direct current (HVDC) power transmission – Part 1: Electrical testing*

3 Definitions

For the purpose of this International Standard, the following definitions apply:

3.1

thyristor level

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

3.2

thyristor (series) string

series connected thyristors forming one direction of a thyristor valve

3.3

valve reactor

reactor incorporated within some valves for limitation of stresses. For testing purposes it is considered an integral part of the valve

3.4

valve section

electrical assembly, comprising a number of thyristors and other components, which exhibits pro-rated electrical properties of a complete thyristor valve but only a portion of the full voltage blocking capability of the thyristor valve, and that can be used for tests 

3.5

thyristor valve

electrically and mechanically combined assembly of thyristor levels, complete with all connections, auxiliary components and mechanical structures, which can be connected in series with each phase of the reactor or capacitor of a SVC

3.6

valve structure

physical structure which insulates the valves to the appropriate level above earth potential and from each other

3.7

valve base electronics (VBE)

electronic unit, at earth potential, which is the interface between the control system of the SVC and the thyristor valves 

3.8

multiple valve unit (MVU)

assembly of several valves in the same physical structure which cannot be separated for test purposes (e.g. three-phase valves)

3.9

redundant thyristor levels

the maximum number of thyristor levels in the thyristor valve 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 either the shutdown of the thyristor valve to replace the failed thyristors, or the acceptance of increased risk of failures 

3.10

voltage breakover (VBO) protection

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

4 A1 General requirements for type, production and optional tests A1

4.1 Summary of tests

A1 The table below lists the tests given in the following clauses and subclauses. A1

A1 Table 1 – List of tests A1

Test	Clause or subclause		Test object
	TCR/TSR	TSC	
Dielectric tests between valve terminals and earth			
AC test	5.1.1		Valve
AC-DC test		6.1.1	Valve
Lightning impulse test	5.1.2	6.1.2	Valve
Dielectric tests between valves (MVU only)			
AC test	5.2.1		MVU
AC-DC test		6.2.1	MVU
Lightning impulse test	5.2.2	6.2.2	MVU
Dielectric tests between valve terminals			
AC test	5.3.1		Valve
AC-DC test		6.3.1	Valve
Switching impulse test	5.3.2	6.3.2	Valve
Operational tests			
Periodic firing and extinction test	5.4.1		Valve or valve section
Overcurrent test		6.4.1	Valve or valve section
Minimum a.c. voltage test	5.4.2	6.4.2	Valve or valve section
Temperature rise test	5.4.3	6.4.3	Valve or valve section
Electromagnetic interference tests			
Switching impulse test	7.2.1	7.2.1	Valve
Non-periodic firing test	7.2.2	7.2.2	Valve
Production tests			
Visual inspection	8.1	8.1	
Connection check	8.2	8.2	
Voltage dividing/damping circuit check	8.3	8.3	
Voltage withstand check	8.4	8.4	
Check of auxiliaries	8.5	8.5	
Firing check	8.6	8.6	
Cooling system pressure test	8.7	8.7	
Optional tests			
Overcurrent test	9.1		Valve or valve section
Positive voltage transient during recovery test	9.2	10.1	Valve or valve section
Non-periodic firing test	9.3	10.2	Valve

4.2 Objectives of tests

The tests described apply to the valve (or valve sections), the valve structure and those parts of the coolant distribution system and firing and monitoring circuits which are contained within the valve structure or connected between the valve structure and earth. Other equipment, such as valve control and protection and valve base electronics may be essential for demonstrating the correct function of the valve during the tests but are not in themselves the subject of the tests.

4.2.1 Dielectric tests

Tests for the following dielectric stresses are specified:

- a.c. voltage;
- combined a.c. and d.c. voltage (TSC only);
- impulse voltages.

In the interest of standardization with other equipment, lightning impulse tests between valve terminals and earth and between phases of an MVU are included. For tests between valve terminals, the only impulse test specified is a switching impulse.

4.2.1.1 Tests on valve structure

Tests are defined for the voltage withstand requirements between a valve (with its terminals short-circuited) and earth, and also between valves for MVU. The tests shall demonstrate that

- sufficient clearances have been provided to prevent flashovers;
- there is no disruptive discharge in the insulation of the valve structure, cooling ducts, light guides and other insulation parts of the pulse transmission and distribution systems;
- partial discharge inception and extinction voltages under a.c. and d.c. conditions are above the maximum steady-state operating voltage appearing on the valve structure.

4.2.1.2 Tests between valve terminals

The purpose of these tests is to verify the design of the valve with respect to its capability to withstand overvoltages between its terminals. The tests shall demonstrate that

- sufficient internal insulation has been provided to enable the valve to withstand specified voltages;
- partial discharge inception and extinction voltages under a.c. and d.c. conditions are above the maximum steady-state operating voltage appearing on the valve;
- the protective overvoltage firing system (if provided) works as intended;
- the thyristors have adequate du/dt capability for in-service conditions. (In most cases the specified tests are sufficient; however in some exceptional cases additional tests may be required).

4.2.2 Operational tests

The purpose of these tests is to verify the valve design for combined voltage and current stresses under normal and abnormal repetitive conditions as well as under transient fault conditions. They shall demonstrate that, under specified conditions:

- the valve functions properly;
- the turn-on and turn-off voltage and current stresses are within the capabilities of the thyristors and other internal circuits;
- the cooling provided is adequate and no component is overheated;
- the overcurrent withstand capability of the valve is adequate.

4.2.3 Electromagnetic interference tests

The principal objective of these tests is to demonstrate the immunity of the valve to electromagnetic interference from within the valve and from outside the valve. Generally, immunity to electromagnetic interference is demonstrated by monitoring of the valve during other tests.

4.2.4 Production tests

The objective of tests is to verify proper manufacture. The production tests shall demonstrate that

- all materials, components and sub-assemblies used in the valve have been correctly installed;
- the valve equipment functions as intended, and predefined parameters are within prescribed acceptance limits;
- thyristor levels and valve or valve sections have the necessary voltage withstand capability;
- consistency and uniformity in production is achieved.

4.2.5 Optional tests

Optional tests are additional tests which may be performed, subject to agreement between purchaser and supplier. The objectives are the same as for the operational tests specified in 4.2.2.

4.3 Guidelines for the performance of type and optional tests

The following principles shall apply:

- type tests shall be performed on at least one valve or on an appropriate number of valve sections, as specified, to verify that the valve design meets the specified requirements. All type tests shall be performed on the same valve(s) or valve section(s);
- provided that the valve is demonstrably similar to one previously tested, the supplier may submit a certified report of any previous type test, at least equal to the requirements specified in the contract, in lieu of the type test;
- certain type tests may be carried out either on a complete valve or on valve sections, as indicated in table 1 (see 4.1);
- for type tests performed on valve sections, the total number of thyristor levels subjected to such type tests shall be at least equal to the number of thyristor levels in a valve;
- the valve or valve sections used for type tests shall first pass all production tests. On completion of the type test programme, the valve or valve sections shall be checked again for compliance with the production test criteria;

- material for the type tests shall be selected at random;
- the dielectric tests shall be performed in accordance with IEC 60060-1 and IEC 60060-2 where applicable;
- individual tests may be performed in any order.

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

4.4 Test conditions

4.4.1 General

Dielectric tests shall be performed on completely assembled valves, whereas some operational tests may be performed on either complete valves or valve sections. Tests that may be performed on valve sections are identified in 4.1.

4.4.1.1 Dielectric tests

The valve shall be assembled with all auxiliary components except for the valve arrester, if used. Unless otherwise specified, the valve electronics shall be energized. The cooling and insulating fluids in particular shall be in a condition that represents service conditions such as conductivity, except for the flow rate and antifreezing media content, which can be reduced. If any object or device external to the structure is necessary for proper representation of the stresses during the test, it shall also be present or simulated in the test. Metallic parts of the valve structure (or other valves in a MVU) which are not part of the test shall be shorted together and connected to earth in a manner appropriate to the test in question.

Where standard values for a.c. power frequency and lightning impulse tests per IEC 60071 are being used, the normal procedures as per IEC 60060 apply. Where non-standard test levels are defined by this standard, a site air density correction factor k_d , defined below shall be applied where stated.

The value of k_d shall be determined from the following expression:

$$k_d = \frac{b_1}{b_2} \times \frac{273 + T_2}{273 + T_1}$$

where

- b_1 is the laboratory ambient air pressure, expressed in pascals (Pa);
- T_1 is the laboratory ambient air temperature, expressed in degrees Celsius (°C);
- b_2 is the standard reference atmosphere of 101,3 kPa (i.e. 1 013 mbar), corrected to the altitude of the site at which the equipment will be installed;
- T_2 is the design maximum valve hall air temperature, expressed in degrees Celsius (°C).

4.4.1.2 Operational tests

[A1] Where possible, a complete thyristor valve should be tested. Otherwise the tests may be performed on thyristor valve sections. The choice depends mainly upon the thyristor valve design and the test facilities available. Where tests on the thyristor valve sections are proposed, the tests specified in this standard are valid for thyristor valve sections containing five or more series-connected thyristor levels. If tests on thyristor valve sections with fewer than five thyristor levels are proposed, additional test safety factors shall be agreed upon. Under no circumstances shall the number of series-connected thyristor levels in a thyristor valve section be less than three. **[A1]**

Sometimes, operational tests may be performed at a power frequency different from the service frequency, e.g. 50 Hz instead of 60 Hz. Some operational stresses such as switching losses or I^2t of short-circuit current are affected by the actual power frequency during tests. When this situation occurs, the test conditions shall be reviewed and appropriate changes made to ensure that the valve stresses are at least as severe as they would be if the tests were performed at the service frequency.

The coolant shall be in a condition representative of service conditions. Flow and temperature, in particular, shall be set to the most unfavourable values appropriate to the test in question. Antifreezing media content should, preferably, be equivalent to the service condition; however, where this is not practicable, a correction factor agreed between supplier and purchaser shall be applied.

4.4.2 Valve temperature at testing

4.4.2.1 Valve temperature for dielectric tests

Unless specified otherwise, tests shall be performed at room temperature.

4.4.2.2 Valve temperature for operational tests

Unless specified otherwise, tests shall be carried out under the conditions that produce the highest component temperature that may occur in real operation.

If several components are to be verified by a test, it may be necessary to carry out the same test under different conditions.

4.4.3 Redundant thyristor levels

4.4.3.1 Dielectric tests

All dielectric tests on a complete valve shall be carried out with redundant thyristor levels short-circuited, except where otherwise indicated.

4.4.3.2 Operational tests

A1 For operational tests, redundant thyristor levels should not be short-circuited. The test voltages and circuit impedances used shall be adjusted by means of a scaling factor k_n .

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

where

N_{tot} is the total 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.

NOTE – In thyristor valves with a small number of thyristor levels, where the redundancy is a significant portion of the total, this may cause certain valve components to be overstressed. As an alternative, it is therefore acceptable to perform the operational test with redundant thyristor levels short-circuited and without scaling the test voltages and impedances by k_n . **A1**

4.5 Permissible component failures during type testing

A limited number of thyristor and auxiliary component failures is permitted during the type tests.

The valves or valve sections shall be checked before each test, after any preliminary calibration tests, and again after each type test to determine whether or not any thyristors or auxiliary components have failed during the test. Failed thyristors or auxiliary components found at the end of a type test shall be remedied before further testing of a valve.

One thyristor level is permitted to fail due to short-circuiting in any type test. ^{A1} If, following a type test, one thyristor level has become short-circuited, then the failed level shall be restored and this type test repeated (see 4.4.1, b) in IEC 60700-1, Amendment 1). ^{A1} A total of two thyristor levels are permitted to fail due to short-circuiting in all type tests together.

In addition to short-circuited levels, the total number of thyristor levels exhibiting faults that do not result in thyristor level short circuit, which are discovered during the type test programme and the subsequent check, shall not exceed two.

The distribution of short-circuited levels and of other thyristor level faults at the end of all type tests shall be essentially random and it shall not show any pattern indicative of inadequate design.

4.6 Documentation of test results

4.6.1 Test reports to be issued

The supplier shall provide certified test reports of all type tests performed on the valves or valve sections.

Test records on the result of routine tests shall be provided by the supplier.

4.6.2 Contents of a type test report

A report on the type tests conducted on the thyristor valves shall be produced. The report shall include the following:

- a) general data such as:
 - identification of the equipment tested (e.g. type and ratings, drawing number, serial number, etc.);
 - identification of major parts of the test objects (e.g. thyristors, valve reactors, printed circuit cards, etc.);
 - name and location of the facility where the test was carried out;
 - relevant circumstances wherever necessary (e.g. temperature, humidity and barometric pressure during the dielectric tests, etc.);
 - reference to the test specification;
 - dates of the tests;
 - name(s) and signature(s) of the personnel responsible;
 - signature of the purchaser's inspector (if present) and the sign of his approval (if required);
- b) description of power sources (i.e. impulse voltage generator, d.c. voltage source, etc.) used for the particular test, such as the name of the manufacturer, ratings, characteristics, etc.;
- c) description of the measuring instrumentation, including information on guaranteed accuracy and date of the last calibration;
- d) detailed information on the arrangement for each test (e.g. circuit diagram);