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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Static VAR compensators (SVC) – Testing of thyristor valves

Compensateurs statiques de puissance réactive (SVC) – Essais des valves à thyristors

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STATIC VAR COMPENSATORS (SVC) – TESTING OF THYRISTOR VALVES

FOREWORD

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International Standard IEC 61954 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 third edition cancels and replaces the second edition published in 2011, Amendment 1:2013 and Amendment 2:2017. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition: important clarifications were made in 4.4.1.2, 5.1.2.2, 5.1.3.2, 5.2.3.2, 6.1.2.2, 6.1.2.4, 6.1.3.2, 6.2.2.2, 6.2.2.4, 6.3.2.2 and 9.3.2.

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

FDIS	Report on voting
22F/642/FDIS	22F/658/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.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

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- withdrawn,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.

STATIC VAR COMPENSATORS (SVC) – TESTING OF THYRISTOR VALVES

1 Scope

This document 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 document 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 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 (all parts), *High-voltage test techniques*

IEC 60060-1:2010, *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 60071-1:2019, *Insulation co-ordination – Part 1: Definitions, principles and rules*

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

IEC 60700-1:2015, *Thyristor valves for high-voltage direct current (HVDC) power transmission – Part 1: Electrical testing*

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
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

Note 1 to entry: 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 which 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 an 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
maximum number of thyristor levels in the 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 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 General requirements for type, production and optional tests

4.1 Summary of tests

Table 1 lists the tests given in the following clauses and subclauses.

Table 1 – List of tests

Test	Subclause		Test object
	TCR/TSR	TSC	
Dielectric tests between valve terminals and earth (type tests)			
AC test	5.1.2		Valve
AC-DC test		6.1.2	Valve
Lightning impulse test	5.1.3	6.1.3	Valve
Dielectric tests between valves (MVU only) (type tests)			
AC test	5.2.2		MVU
AC-DC test		6.2.2	MVU
Lightning impulse test	5.2.3	6.2.3	MVU
Dielectric tests between valve terminals (type tests)			
AC test	5.3.2		Valve
AC-DC test		6.3.2	Valve
Switching impulse test	5.3.3	6.3.3	Valve
Operational tests (type tests)			
Periodic firing and extinction test	5.4.1		Valve or valve section
Overcurrent test		6.4.1	Valve or valve section
Minimum AC 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 (type tests)			
Switching impulse test	7.2.2	7.2.2	Valve
Non-periodic firing test	7.2.3	7.2.3	Valve
Production tests			
Visual inspection	8.2	8.2	
Connection check	8.3	8.3	
Voltage dividing/damping circuit check	8.4	8.4	
Voltage withstand check	8.5	8.5	
Check of auxiliaries	8.6	8.6	
Firing check	8.7	8.7	
Cooling system pressure test	8.8	8.8	
Partial discharge tests	8.9	8.9	
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 or valve section

4.2 Objectives of tests

4.2.1 General

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.

4.2.2 Dielectric tests

4.2.2.1 General

Tests for the following dielectric stresses are specified:

– AC voltage;

– combined AC and DC 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.

4.2.2.2 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 AC and DC conditions are above the maximum steady-state operating voltage appearing on the valve structure.

4.2.2.3 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 AC and DC conditions are above the maximum steady-state operating voltage appearing between valve terminals;

– 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.)

4.2.3 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.

4.2.4 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.

4.2.5 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.

4.2.6 Optional tests

Optional tests are additional tests which may be performed, subject to agreement between the purchaser and the supplier. The objectives are the same as for the operational tests specified in 4.2.3. The test object is normally one valve or appropriate equivalent number of valve sections.

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 indicated in Table 1 (see 4.1), 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;

– 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

4.4.1.1 Dielectric test objects

Dielectric tests shall be performed on completely assembled valves, whereas some operational tests may be performed on either complete valves or valve sections.

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 anti-freezing 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 an 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.

4.4.1.2 Atmospheric correction

Atmospheric correction shall be applied to the test voltages in accordance with IEC 60060-1, except when specifically excluded. To calculate the test values applicable at standard reference atmosphere, the methods described in IEC 60060-1:2010,4.3.3.1 shall be used, considering the following conditions as input values for pressure p, temperature t and humidity h:

– pressure:

  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 less than 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 ($b_{1\ 000\ m}$).

  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.

  In any of the afore mentioned cases, the correction of test values from standard reference atmosphere to test conditions shall be as per IEC 60060-1:2010,4.3.3.2.

Where non-standard test levels are defined by this document, 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 formula:

$$k_d = \frac{b_1}{b_2} \times \frac{273 + T_2}{273 + T_1} \quad (1)$$

where

b_1 is the laboratory ambient air pressure, in pascals (Pa);

T_1 is the laboratory ambient air temperature, 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, in degrees Celsius (°C).

Correction factors shall not be applied to the dielectric tests between valve terminals or to the long duration dielectric tests whose primary purpose is to check for the internal insulation and partial discharges.

The atmospheric correction factors shall not be applied to operational tests or optional tests.

4.4.1.3 Operational tests

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.

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. Anti-freezing media content should, preferably, be equivalent to the service condition; however, where this is not practicable, a correction factor agreed between the supplier and the 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.