

# INTERNATIONAL STANDARD

# NORME INTERNATIONALE

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Static var compensators (SVC) – Testing of thyristor valves

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

[IEC 61954:2011](#)

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## INTERNATIONAL ELECTROTECHNICAL COMMISSION

**STATIC VAR COMPENSATORS (SVC) –  
TESTING OF THYRISTOR VALVES**

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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 electronics.

This second edition cancels and replaces the first edition published in 1999, amendment 1 (2003) and constitutes a technical revision.

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

- a) Definitions of terms "thyristor level", "valve section", "valve base electronics" and "redundant thyristor levels" have been changed for clarification.
- b) Conditions of testing thyristor valve sections instead of a complete thyristor valve have been defined.
- c) The requirement has been added that if, following a type test, one thyristor level has become short-circuited, then the failed level shall be restored and this type test repeated.
- d) The time period of increasing the initial test voltage from 50 % to 100 % during type a.c. dielectric tests on TSC, TCR or TSR valves has been set equal to approximately 10 s.

- e) The duration of test voltage  $U_{ts2}$  during type a.c.-d.c. dielectric tests between TSC valve terminals and earth as well as the duration of test voltage  $U_{tvv2}$  during dielectric tests between TSC valves (for MVU only) has been changed from 30 min to 3 h.
- f) The reference on the number of pulses per minute of the periodic partial discharge recorded during a.c.-d.c. dielectric tests on TSC valves and exceeding the permissible level has been deleted.

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

CDV	Report on voting
22F/217/CDV	22F/231A/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.

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

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# STATIC VAR COMPENSATORS (SVC) – TESTING OF THYRISTOR VALVES

## 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 referenced documents are indispensable for the application 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, *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 60071-1:2006, *Insulation co-ordination – Part 1: Definitions, principles and rules*

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

IEC 60700-1:2008, *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:

### 3.1

#### **thyristor level**

part of a thyristor valve comprising a thyristor, or thyristors connected in parallel or antiparallel, 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 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 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

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### 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 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	Clause or subclause		Test object
	TCR/TSR	TSC	
<b>Dielectric tests between valve terminals and earth (type tests)</b>			
AC test	5.1.2		Valve
AC-DC test		6.1.2	Valve
Lightning impulse test	5.1.3	6.1.3	Valve
<b>Dielectric tests between valves (MVU only) (type tests)</b>			
AC test	5.2.2		MVU
AC-DC test		6.2.2	MVU
Lightning impulse test	5.2.3	6.2.3	MVU
<b>Dielectric tests between valve terminals (type tests)</b>			
AC test	5.3.2		Valve
AC-DC test		6.3.2	Valve
Switching impulse test	5.3.3	6.3.3	Valve
<b>Operational tests (type tests)</b>			
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
<b>Electromagnetic interference tests (type tests)</b>			
Switching impulse test	7.2.2	7.2.2	Valve
Non-periodic firing test	7.2.3	7.2.3	Valve
<b>Production tests</b>			
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	
<b>Optional tests</b>			
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

### 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:

- 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.

#### 4.2.2.2 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 a.c. and d.c. 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 a.c. and d.c. 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 4.2.2. 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. Tests that may be performed on valve sections are identified in 4.1.

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.

#### 4.4.1.2 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:

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

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 ( $\text{g/m}^3$ ).

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

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:

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

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).

Correction factors should not be applied either 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.

#### 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. Antifreezing 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.

##### 4.4.3.2 Operational tests

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  $k_n$ .