

IEEE Recommended Practice for Test Procedures for High-Voltage Direct-Current Thyristor Valves

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Abstract: Information and recommendations for the type testing of thyristor valves for high-voltage direct current (HVDC) power transmission systems are provided. These tests cover only the principal tests on the valves and do not include tests of auxiliary equipment associated with the valves.

Keywords: HVDC thyristor valves, HVDC power transmission systems, multiple-valve unit (MVU), thyristor levels

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Introduction

(This introduction is not part of IEEE Std 857-1996, IEEE Recommended Practice for Test Procedures for High-Voltage Direct-Current Thyristor Valves.)

This recommended practice was prepared by the Working Group I1, Power Electronic Equipment of the IEEE High-Voltage Power Electronics Stations Subcommittee. Working Group I1 was established in 1994 with the goal of reaffirming or revising IEEE Std 857-1990 to conform with the five-year review cycle mandated by Article 1.4 of the IEEE Standards Board Bylaws. To keep up with the advance of technology in the high-voltage direct-current (HVDC) industry and to attempt harmonization with an IEC standard (IEC700-1) that was under preparation, Working Group I1 decided that IEEE Std 857-1990 , should be revised from a guide to a recommended practice.

This revised document achieved the goal of keeping up with the technology but only partially succeeded in the harmonization effort. While there were close communications and cooperation with the Chair of the IEC 22-F Working Group 06, IEC procedures prevent any IEEE input to or discussion of the revision of IEC 700-1 . To the extent supported by technical justifications, this revised IEEE standard incorporated many changes proposed by IEC members. At the time this document was reviewed and approved, the IEC revision was still under preparation. Further harmonization with the IEC 700-1 will be attempted by several Working Group I1 members through their respective representatives on the IEC National Committee.

As stated in the original IEEE Std 857-1990 , the purpose of this document is to complement other IEEE standards on HVDC power transmission systems and give guidance to the industry on how to treat the important subject of testing a thyristor valve that is a complex device. The tests recommended in this document cover only the principal electrical tests on the thyristor valves. This is not intended to be a comprehensive guide on valve testing because it does not have within its scope other valve tests, i.e., development tests, production sample tests, routine tests, loss determination tests, commissioning tests, site tests. Further, material flammability tests were not included.

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Gene Wolf

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CLAUSE	PAGE
1. Scope	1
2. References	1
3. Definitions	2
4. Classification of tests	3
4.1 Dielectric tests	3
4.2 Operational tests	4
5. Test requirements	4
5.1 General	4
5.2 Valve temperature at testing	5
5.3 Treatment of redundancy for type tests	5
5.4 Selection of impulse test withstand voltage levels	6
5.5 Wet type tests	7
5.6 Criteria for successful type testing	7
5.7 Suitability of valve for type test	9
5.8 Partial discharge measurements	9
5.9 Valve insensitivity to electromagnetic interference	10
5.10 Test sequence	11
6. Test program	11
6.1 Dielectric tests on valve base	11
6.2 Dielectric tests on an MVU	14
6.3 Dielectric tests on a valve	15
6.4 Operational tests on modules	19
7. Presentation of test results	22
Annex A (informative) Bibliography	23

IEEE Recommended Practice for Test Procedures for High-Voltage Direct-Current Thyristor Valves

1. Scope

This recommended practice contains information and recommendations for the type testing of thyristor valves for high-voltage direct-current (HVDC) power transmission systems. Other equipment tests, such as development tests, production sample tests, routine tests, tests for the determination of losses, commissioning tests, and site tests are not within the scope of this recommended practice. Furthermore, the tests given here cover the principal tests on the valves only and do not include tests of auxiliary equipment associated with the valves, such as cooling system components.

This recommended practice applies to any type of line-commutated indoor thyristor valve, with metal-oxide surge arresters connected between the valve terminals, used in converters for HVDC power transmission systems. Any modifications to these tests and/or additional tests required for outdoor valves are to be considered separately.

2. References

This recommended practice shall be used in conjunction with the following publications:

IEEE Std 4-1995, IEEE Standard Techniques for High-Voltage Testing (ANSI).¹

IEEE Std 100-1996, IEEE Standard Dictionary of Electrical and Electronics Terms.

IEC 60060-1 (1989-11), High-voltage test techniques—Part 1: General definitions and test requirements.²

IEC 60060-2 (1994-11), High-voltage test techniques—Part 2: Measuring systems.

IEC 60071-1 (1993-11), Insulation co-ordination—Part 1: Definitions, principles and rules.

¹IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

²IEC publications are available from IEC Sales Department, Case Postale 131, 3, rue de Varembe, CH-1211, Genève 20, Switzerland/Suisse. IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

IEC 60071-2 (1996-12), Insulation co-ordination—Part 2: Application guide.

IEC 60099-4 (1991-11), Surge arrestors—Part 1: Metal oxide surge arresters without gaps for a.c. systems.

IEC 60146-1-1 (1991-04), General requirements and line commutated convertors—Part 1-1: Specifications of basic requirements.

IEC 60146-1-2 (1991-04), General requirements and line commutated convertors—Part 1-2: Application guide.

IEC 60146-1-3 (1991-04), General requirements and line commutated convertors—Part 1-3: Transformers and reactors.

IEC 60146-2 (1974-01), Semiconductor convertors—Part 2: Semiconductor self-commutated convertors.

IEC 60146-3 (1977-01), Semiconductor convertors—Part 3: Semiconductor direct d.c. convertors (d.c. chopper convertors).

IEC 60146-4 (1986-09), Semiconductor convertors—Part 4: Method of specifying the performance and test requirements of uninterruptible power systems.

IEC 60146-5 (1988-11), Semiconductor convertors—Part 5: Switches for uninterruptible power systems (UPS switches).

IEC 60146-6 (1992-12), Semiconductor convertors—Part 6: Application guide for the protection of semiconductor convertors against overcurrent by fuses.

IEC 60633 (1978-01), Terminology for high-voltage direct current transmission.

IEC 60700 (1981-01), Testing of semiconductor valves for high-voltage d.c. power transmission.

IEC 60747-1 (1983-01), Semiconductor devices—Discrete devices—Part 1: General.

IEC 60747-5 (1992-05), Semiconductor devices—Discrete devices—Part 5: Optoelectronic devices.

IEC 60747-6 (1983-01), Semiconductor devices—Discrete devices—Part 6: Thyristors.

3. Definitions

Definitions given in this recommended practice apply specifically to the testing of HVDC thyristor valves.

3.1 failure of thyristor level: A thyristor level is deemed to have failed if it becomes short-circuited or in any other way has degraded to the extent to make it functionally inoperative.

3.2 multiple-valve unit (MVU): A single structure comprising more than one valve.

3.3 redundancy factor: The ratio of the total number of series thyristor levels in the valve, N_t , to the same number minus the total number of redundant series thyristor levels in the valve, N_r . The redundancy factor, f_r , is defined by

$$f_r = \frac{N_t}{(N_t - N_r)} \quad (1)$$

3.4 redundant thyristor levels: The maximum number of levels in the series string of thyristors in a valve that may be short-circuited externally or internally during service without affecting the safe operation of the valve as demonstrated by type tests, and which, if and when exceeded, would require shutdown of the valve to replace the failed thyristors or acceptance of increased risk of failure of the valve.

3.5 single-valve unit: A single structure comprising only one valve.

3.6 test withstand voltage: The maximum value of a test voltage at which a new valve, with unimpaired integrity, does not show any disruptive discharge, nor suffer component failures above permissible levels, when subjected to a specified number of applications of the test voltage, under specified conditions.

3.7 thyristor level: A single thyristor, or thyristors if the valve has parallel connected thyristors, and associated components for control, voltage grading, protection, and monitoring that constitute a single voltage level within the valve.

3.8 valve: A converter arm in a three-phase, 6-pulse bridge converter connection.

3.9 valve base: The assembly that mechanically supports and electrically insulates the valves from ground.

NOTE — A part of a valve that is clearly identifiable in a discrete form to be a valve base may not exist in all designs of valves. A valve base could be a separate platform insulated from ground by post-type insulators that carries a live-tank valve unit, or a steel framework insulated from ground by post-type insulators on which the various modules of an MVU are mounted, or a raised platform of insulating material that is integral to the valve structure and forms the base.

3.10 valve module: The smallest assembly, comprising a number of thyristors and their immediate auxiliaries for firing and protection, voltage-dividing components, and distributed or lumped valve reactors, from which the valve is built up and which exhibits the same electrical properties as the complete valve but can withstand only a portion of the full voltage-blocking capability of the valve.

3.11 valve section: An electrical assembly comprising a number of thyristor levels and other components that exhibits prorated electrical properties of a complete valve.

4. Classification of tests

The type tests described in this recommended practice are classified under two major categories: dielectric tests and operational tests.

4.1 Dielectric tests

These tests are intended to verify withstand and voltage-related characteristics of the valve under various overvoltage conditions. The following tests fall under this category:

- a) Dielectric tests on valve base
 - 1) DC voltage test
 - 2) AC voltage test
 - 3) Switching impulse test
 - 4) Lightning impulse test
 - 5) Steep-front impulse test
- b) Dielectric tests on an MVU
 - 1) DC voltage test
 - 2) Switching impulse test
 - 3) Lightning impulse test
 - 4) Steep-front impulse test
- c) Dielectric tests on a valve
 - 1) DC voltage test (dry and wet)
 - 2) AC voltage test

- 3) Switching impulse voltage test (dry and wet)
- 4) Lightning impulse voltage test
- 5) Steep-front impulse voltage test
- 6) Nonperiodic firing test
- 7) Turn-on stress test

4.2 Operational tests

These tests are intended to demonstrate the correct operation and capabilities of the valve under various operating conditions, including the worst-case fault condition. The following tests fall under this category:

- a) Load test, including periodic firing and extinction test
- b) Current-sharing test
- c) Minimum alternating voltage test
- d) Intermittent dc test
- e) Recovery period forward impulse withstand test
- f) Short-circuit current with subsequent blocking test
- g) Short-circuit current without subsequent blocking test

5. Test requirements

5.1 General

Thyristor valves are usually of modular construction with identical modules connected in series to obtain the required valve voltage rating. This type of construction lends itself to simplifying the tests and the test equipment required. Great economy can be obtained when valve sections instead of whole valves are used for type tests. However, certain dielectric tests must be performed on complete valves, as these tests relate to characteristics that are defined only after a valve is completely built. All operational tests are carried out on valve sections. Simultaneous full-scale voltage and current tests are not considered essential for thyristor valves.

If a type test is conducted on valve sections rather than the whole valve, the minimum number of valve sections so tested should be equal to those in one complete valve. The preferred approach is for the valve section to be made up of single or integer multiples of valve modules. If this is difficult because of limitations in the ratings of the available test circuit, valve sections made up of thyristor levels fewer than those in complete module(s) may be used. The test valve sections should have a minimum of five series-connected thyristor levels. This minimum number of thyristor levels is recommended to ensure that the performance of the valve section reasonably reflects the performance of the complete valve as affected by the design tolerances in the characteristics of different thyristors in a complete valve. If the valve section under test has less than the recommended number of levels, it may be necessary to include an additional safety factor. The need for and value of this additional test safety factor will be design-dependent and should be agreed upon, in advance, between the purchaser and the supplier.

The choice of valve section should also take into consideration the representation of the valve reactors within the valve. The number of series-connected levels in the test valve section should preferably avoid test arrangements that require fractional reactors, which may have to be specifically fabricated and which may not therefore be fully representative of the actual valve reactors.

Sometimes operational tests may have to be performed at a power frequency that is different from the service frequency (e.g., 50 Hz instead of 60 Hz). Thyristor switching losses, snubber circuit losses, and I^2t of short-circuit current are affected by the actual frequency during tests. When this situation occurs, the test conditions and valve characteristics should 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.