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**Common Specifications of High-voltage Direct Current
Circuit-breakers for High-voltage Direct Current
Transmission Using Voltage Sourced Converters (VSC-
HVDC)**

柔性直流系统用高压直流断路器的共用技术要求

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Common Specifications of High-voltage Direct Current Circuit-breakers for High-voltage Direct Current Transmission Using Voltage Sourced Converters

1 Scope

This Standard specifies the operating environmental conditions, terms and definitions, ratings, design and structure, type test, exit-factory test and selection guidelines, etc. of high-voltage DC circuit-breakers for the VSC-HVDC.

This Standard is applicable to mechanical high-voltage DC circuit-breakers, power electronic DC circuit-breakers and hybrid DC circuit-breakers installed indoors and outdoors for the VSC-HVDC with a voltage level of DC 6 kV and above.

This Standard does not apply to specific types of DC circuit-breakers that are otherwise specified in product standards related to DC circuit-breakers.

2 Normative References

The following documents are indispensable to the application of this document. In terms of references with a specified date, only versions with a specified date are applicable to this document. In terms of references without a specified date, the latest version (including all the modifications) is applicable to this document.

GB/T 311.1-2012 Insulation Co-ordination - Part 1: Definitions, Principles and Rules

GB/T 1984-2014 High-voltage Alternating-current Circuit-breakers

GB/T 2900.20-2016 Electrotechnical Terminology - High-voltage Switchgear and Controlgear

GB/T 7354-2018 High-voltage Test Techniques - Partial Discharge Measurements

GB/T 11022-2011 Common Specifications for High-voltage Switchgear and Controlgear Standards

GB/T 13498-2017 Terminology for High-voltage Direct Current (HVDC) Transmission

GB/T 13540-2009 Seismic Qualification for High-voltage Switchgear and Controlgear

GB/T 16927.1-2011 High-voltage Test Techniques - Part 1: General Definitions and Test Requirements

GB/T 20990.1-2007 Thyristor Valves for High Voltage Direct Current (HVDC) Power

Transmission - Part 1: Electrical Testing

GB/T 25091-2010 High-voltage Direct-current Disconnectors and Earthing Switches

GB/T 30425-2013 Water Cooling Equipment for Converter Valves for High Voltage Direct Current (HVDC) Power Transmission

GB/T 34139-2017 Technical Specification of Converters for High-voltage Direct Current (HVDC) Transmission Using Voltage Sourced Converters (VSC)

IEC 61850-10:2012 Communication Networks and Systems in Substations - Part 10: Conformance Testing

3 Terms and Definitions

The terms and definitions defined in GB/T 2900.20-2016, GB/T 1984-2014 and GB/T 13498-2017, and the following are applicable to this document.

3.1 General

3.1.1 high-voltage direct current circuit-breaker

A switching device that can make, carry and interrupt DC operating current, and can make, carry and interrupt current under abnormal circuit conditions (for example, short-circuit conditions) within a specified time.

NOTE 1: DC circuit-breakers generally include: main conduct branch, current transfer branch and energy absorption branch. The main conduct branch is used to carry the DC operating current, and with the cooperation of the transfer branch, it has the capability to interrupt the main conduct branch current; the current transfer branch is used to transfer the current of the main conduct branch to the energy absorption branch; the energy absorption branch is used to absorb the energy stored in the system.

NOTE 2: in accordance with the type of interrupting components, DC circuit-breakers can be divided into mechanical DC circuit-breakers, power electronic DC circuit-breakers and hybrid DC circuit-breakers. In accordance with the direction of operating current, DC circuit-breakers can be divided into unidirectional DC circuit-breakers and bidirectional DC circuit-breakers.

3.1.2 mechanical DC circuit-breaker

A DC circuit-breaker that provides artificial zero-crossing oscillating current for mechanical switching devices to realize the interruption of DC current.

NOTE: the typical structure is that the main conduct branch is a mechanical switching device, the current transfer branch is an inductor and a capacitor (active or passive), and the energy absorption branch is a lightning arrester. See Figure 1.

NOTE: this voltage depends on the characteristics of the circuit and the DC circuit-breaker.

3.2.5 peak transient interruption voltage

When a DC circuit-breaker interrupts the current, the maximum voltage value generated between the terminals of the DC circuit-breaker.

3.2.6 maximum continuous direct current in operation

The DC current value flowing through the DC circuit-breaker when the DC system continues to be overloaded. The maximum continuous direct current in operation is determined by the continuous overload capability of the DC system.

NOTE: GB/T 34139-2017, definition 3.2, modified.

3.2.7 short-time overload direct current in operation

When the DC system operates in a mode exceeding the rated transmission power of the system for a short period of time (for example, 3 seconds), the DC current value flowing through the DC circuit breaker. The overload direct current in operation is determined by the overload capability of the DC system.

NOTE 1: GB/T 34139-2017, definition 3.3.

NOTE 2: the verification of the DC circuit-breaker's capability of short-time overload direct current in operation is included in the short-time withstand current type test.

NOTE 3: please refer to Appendix A for the overload current of a typical domestic flexible DC transmission project.

3.2.8 prospective short-circuit current

The current that may flow in a circuit when a circuit fault or incorrect wiring causes a short circuit and the DC circuit-breaker is replaced by a conductor with negligible impedance.

NOTE: GB/T 2900.20-2016, definition 3.7, modified.

3.2.9 cut-off current

The maximum instantaneous current value reached during the interruption by a DC circuit-breaker.

3.2.10 residual current

After the interruption by a DC circuit-breaker, the value of the current flowing through the DC circuit-breaker when the residual current interrupting device is closed.

3.2.11 rising rate of short-circuit current

5.2 Rated DC Voltage (U_{dN})

Under the specified operating conditions, the DC voltage of the DC circuit-breaker for normal and continuous operation, expressed in (kV).

The rated DC voltage can be selected from the following values:

6 kV, 10 kV, 25 kV, 35 kV, 50 kV, 100 kV, 160 kV, 200 kV, 320 kV, 400 kV, 535 kV, 800 kV.

NOTE 1: the above ratings are provided with reference to GB/T 34139-2017, combined with the voltage levels of existing flexible DC transmission projects.

NOTE 2: when there are special requirements for DC voltage, they shall be determined by the demand-side and the supply-side through negotiation.

5.3 Rated Insulation Level

The rated insulation level of the DC circuit-breakers is provided by actual projects.

The insulation level shall include DC withstand voltage (1 min DC withstand voltage U_{d1min} , 3 h DC withstand voltage U_{d3h} , and 1 h DC withstand voltage U_{d1h}), rated lightning impulse withstand voltage U_p and rated operating impulse withstand voltage U_s .

Among them, the withstand voltage applies to the standard reference atmosphere [temperature (20 °C), pressure (101.3 kPa) and humidity (11 g/m³)] specified in GB/T 311.1-2012. These withstand voltages include the altitude correct at the maximum altitude of 1,000 m specified under normal operating conditions (see 2.2 of GB/T 11022-2011). For special applicable conditions, the withstand voltage shall be corrected in accordance with 2.3 of GB/T 11022-2011.

NOTE 1: when there are special requirements for the rated insulation level, they shall be determined by the demand-side and the supply-side through negotiation.

NOTE 2: please refer to Appendix A for the rated insulation level of a certain domestic flexible DC transmission project.

5.4 Rated DC Current (I_{dN})

Under the specified operating conditions, the average DC current of a DC circuit-breaker that has been continuously operated for a long time, expressed in (A).

The rated DC current can be selected from the following values:

156 A, 250 A, 500 A, 625 A, 750 A, 1,000 A, 1,250 A, 1,560 A, 2,000 A, 2,500 A, 3,000 A.

NOTE 1: the above ratings are provided with reference to GB/T 34139-2017, combined with the current levels of existing flexible DC transmission projects.

NOTE 2: when there are special requirements for DC current, they shall be determined by the

demand-side and the supply-side through negotiation.

5.5 Rated Prospective Short-circuit Current

Under the specified conditions of use and performance and the specified voltage, the prospective steady-state value of the current in the event of a short circuit at the interruption terminal of the DC circuit-breakers, expressed in (kA).

The rated prospective short-circuit current of the DC circuit-breakers can be selected from the following values:

8 kA, 10 kA, 12.5 kA, 16 kA, 20 kA, 25 kA, 31.5 kA, 40 kA, 50 kA, 63 kA.

NOTE 1: the above currents are selected from the R10 series specified in GB/T 762-2002.

NOTE 2: when there are special requirements for the rated prospective short-circuit current, they shall be determined by the demand-side and the supply-side through negotiation.

5.6 Rated Cut-off Current

Under the specified conditions of use and performance and the specified voltage, the maximum instantaneous current value of a DC circuit-breaker when it interrupts at the rated prospective short-circuit current, expressed in (kA).

The rated cut-off current can be selected from the following values:

4 kA, 5 kA, 6.3 kA, 8 kA, 10 kA, 12.5 kA, 16 kA, 20 kA, 25 kA, 31.5 kA.

NOTE 1: the above currents are selected from the R10 series specified in GB/T 762-2002.

NOTE 2: when there are special requirements for the rated cut-off current, they shall be determined by the demand-side and the supply-side through negotiation.

5.7 Rated Supply Voltage of Auxiliary and Control Circuits

4.9 of GB/T 11022-2011 is applicable.

5.8 Rated Supply Frequency of Auxiliary and Control Circuits

The standard value of rated supply frequency is AC 50 Hz or DC.

5.9 Rated Charging Levels for Insulation and / or Opening and Closing

4.12 of GB/T 11022-2011 is applicable.

5.10 Radio Interference Voltage Level (RIV)

When applying the highest test voltage, the radio interference voltage level does not exceed 2,000 μ V.

6.2.7.3 and 6.2.8.4 of GB/T 11022-2011 are applicable, with the following supplements: during the inter-terminal test, the lightning arrester of the energy absorption branch is only equipped with a lightning arrester jacket, or the lightning arrester is disconnected.

7.2.3 Operational impulse withstand voltage test

6.2.8.3 of GB/T 11022-2011 is applicable, with the following supplements: during the inter-terminal test, the lightning arrester of the energy absorption branch is only equipped with a lightning arrester jacket, or the lightning arrester is disconnected.

NOTE: it is advisable to carry out dry test, and wet test may also be carried out for outdoor DC circuit-breakers.

7.2.4 DC voltage withstand test

The DC circuit-breakers shall be subjected to DC voltage withstand test between terminals and terminals to ground. Chapter 5 of GB/T 16927.1-2011 and 8.3.1 of GB/T 20990.1-2007 are applicable, with the following modifications:

- a) Inter-terminal DC voltage withstand test: between the two main terminals of the test object, start to increase the voltage from not greater than 50% of 1 min test voltage U_{d1min} , within 10 seconds, increase the voltage to U_{d1min} , and maintain for 1 minute, then, drop to 1 h test voltage U_{d1h} , and maintain for 1 hour, then, drop to zero. Use voltage of opposite polarity to repeat the above-mentioned test. During the test, the lightning arrester of the energy absorption branch is only equipped with a lightning arrester jacket, or the lightning arrester is disconnected.
- b) Terminal-to-ground DC voltage withstand test: between the short-circuited main terminal of the test object and the ground, start to increase the voltage from not greater than 50% of 1 min test voltage U_{d1min} , within 10 seconds, increase the voltage to U_{d1min} , and maintain for 1 minute, then, drop to 3 h test voltage U_{d3h} , and maintain for 3 hours, then, drop to zero. Use voltage of opposite polarity to repeat the above-mentioned test.

NOTE: it is advisable to carry out dry test, and wet test may also be carried out for outdoor DC circuit-breakers.

7.2.5 Partial discharge test

8.3.1 of GB/T 20990.1-2007 is applicable, with the following supplements:

In the partial discharge test, the partial discharge is measured in accordance with GB/T 7354-2018 during the last 1 hour of the 3-h test specified in the ground DC voltage test. The number of partial discharges of 300 pC shall be recorded in accordance with the provisions of Appendix B of GB/T 20990.1-2007. Use voltage of opposite polarity to repeat the above-mentioned test.

Throughout the recording period, the average pulses above 300 pC shall not exceed 15 times per minute; among them, the pulses above 500 pC shall not exceed 7 times per minute, the

pulses above 1,000 pC shall not exceed 3 times per minute, and the pulses above 2,000 pC shall not exceed 1 time per minute.

NOTE: if an increasing trend in the number or level of partial discharge is observed, the test time may be extended by the demand-side and the supply-side through negotiation.

7.2.6 Status check test

If, after the making and interrupting tests, the insulation performance between the terminals of the DC circuit-breaker cannot be sufficiently and reliably verified by visual inspection, and there are no other provisions in the relevant product standards, an inter-terminal DC voltage withstand test may be carried out, and the test voltage is 80% of the 1 min DC withstand voltage U_{d1min} and is maintained for 1 minute. Or other test methods may be determined by the demand-side and the supply-side through negotiation.

7.3 Radio Interference Test

Applicable to DC circuit breakers with a rated DC voltage of 6 kV and above.

The test shall be carried out in accordance with the provisions of 6.9.1.1 in GB/T 11022-2011, and shall be carried out through the following procedures:

Apply a voltage of U_{dN} to the test object and maintain it for at least 5 minutes. Then, gradually reduce the voltage to $0.3U_{dN}$, then, gradually increase to the initial value, and finally, reduce to $0.3U_{dN}$ step by step. At each voltage level, radio interference measurements shall be carried out, and a curve of the radio interference level recorded in the last voltage drop series against the externally applied voltage shall be drawn. Thus, the obtained curve is the radio interference characteristic of the test equipment. The voltage level difference is approximately $0.1U_{dN}$.

If the radio interference level at $1.1U_{dN}$ does not exceed the value specified in 5.10, the test object shall be deemed to have passed the test.

7.4 Measurement of Main Circuit Resistance

Applicable to mechanical switches of the main conduct branch. 6.4 of GB/T 11022-2011 is applicable.

7.5 Test of Maximum Continuous Direct Current in Operation

6.5 of GB/T 11022-2011 is applicable, with the following supplements:

On the main conduct branch, carry out the test of maximum continuous direct current in operation. The test current is not less than the maximum continuous DC current that may occur in the DC circuit-breaker application system or the equivalent 50 Hz AC current. The test results shall satisfy the requirements of 4.5 in GB/T 11022-2011, and no component damage or failure shall occur after the test is completed.

Please refer to Appendix B for the test circuit schematic diagram and test current waveform diagram.

In any interrupting test, all parts of the DC circuit-breaker shall operate in accordance with the correct logic, and no malfunction or refusal to operate shall occur.

The test sample shall be able to withstand the transient interruption voltage after interrupting the test current and shall not suffer from heavy breakdown.

7.12.3.3 Status of the device after the test

After the test is completed, the test object shall ensure normal mechanical and electrical properties and be subjected to corresponding tests if necessary.

7.12.3.4 Recorded data

At least the following data shall be recorded during the test:

- cut-off current;
- peak transient interruption voltage;
- cut-off time;
- interruption time;
- make time;
- rising rate of short-circuit current;
- rising rate of transient interruption voltage.

7.13 X-ray Test Procedures for Vacuum Arc-extinguishing Chamber

6.11 of GB/T 11022-2011 is applicable (when applicable).

7.14 Seismic Resistance Test

The test shall be carried out in accordance with the provisions of GB/T 13540-2009 (when applicable).

7.15 Communication Conformance Test

For the communication conformance test of substation automation systems and DC circuit-breakers, IEC 61850-10:2012 is applicable (when applicable).

7.16 Cooling Equipment Test

The test shall be carried out in accordance with the provisions of GB/T 30425-2013 (when applicable).

8 Exit-factory Test

8.1 Overview

Exit-factory test is to find defects in materials and structures, as well as errors in the assembly process. They will not deteriorate the performance and reliability of the test object. Exit-factory test shall be carried out on each manufactured product at any suitable and feasible place in the manufacturer's factory, so as to ensure that the product is consistent with the equipment that has passed the type test. After consultation with the user, the exit-factory test can be carried out on site.

If the DC circuit-breaker is not fully assembled before transport, then, all transport units shall be individually tested. In this case, the manufacturer shall demonstrate the validity of these tests. Products exiting the factory shall be accompanied by an exit-factory test report.

Each component of the DC circuit-breaker shall comply with the requirements of the respective standards and be tested in accordance with these requirements.

8.2 Insulation Test of Main Circuit

8.2.1 Lightning impulse voltage test

6.2.7.3 and 6.2.8.4 of GB/T 11022-2011 are applicable, with the following modifications:

When the interrupting device is in the closed position, the lightning impulse withstand voltage to ground shall be applied between the terminal and the ground.

When the interrupting device is in the open position, the lightning impulse withstand voltage between fractures shall be applied between the terminals.

NOTE: during the test, disconnect the lightning arrester of the energy absorption branch.

8.2.2 DC withstand voltage test

Regarding the DC withstand voltage test, 7.2.4 is applicable.

8.3 Test of Auxiliary and Control Circuits

7.3 of GB/T 11022-2011 is applicable.

8.4 Measurement of Main Circuit Resistance

It is applicable to mechanical switches of the main conduct branch. 7.4 of GB/T 11022-2011 is applicable.

8.5 Sealing Test

7.5 of GB/T 11022-2011 is applicable.

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