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# Technical guide of HVDC earth electrode system

高压直流接地极技术导则

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# Technical guide of HVDC earth electrode system

## 1 Scope

This Standard specifies the terminology terms and definitions of HVDC earth electrode system, and proposes technical conditions, test items and methods, and general technical principles of operation and maintenance.

This Standard applies to the earth electrode system at both ends of the monopolar and bipolar HVDC transmission system; it does not apply to the converter grounding grid.

## 2 Normative references

The following documents are indispensable for the application of this document. For dated references, only the dated version applies to this document. For undated references, the latest edition (including all amendments) applies to this document.

GB/T 17949.1, Guide for measuring earth resistivity, ground impedance and earth surface potentials of a ground system - Part 1: Normal measurements

GB/T 13498, Terminology for high-voltage direct current (HVDC) transmission

DL/T 5224, Technical Rule for the Design of HVDC Earth Return Operation System

DL/T 475, Guide for measurement of grounding connection parameters

## 3 Terms and definitions

Except for the terms which are specified in this Chapter, the rest shall be in compliance with the relevant provisions of national and industry standards.

**3.1**

**HVDC earth electrode system**

The general term for a group of devices that are specially designed and constructed to operate with earth or sea water as a current loop during normal operation or failure, in the high-voltage direct current transmission system. It is mainly composed of an electrode line, an earth electrode feeder line and an earth electrode.

When the earth electrode is in operation, if a person stands on the ground near the earth electrode and touches an earth conductor that is connected from a remote place, or if a person stands on the distant ground and touches an earth conductor that is drawn from a place near the electrode site grounding, the touch potential it bears is the transfer potential. The maximum value of the transfer potential is the earthing electrode potential rise.

# 4 Technical conditions

## 4.1 General technical guidelines

**4.1.1** The design of the DC earth electrode shall consider the three working conditions of rated current under monopolar mode, maximum overload current and maximum transient overcurrents.

**4.1.2** The design life of the DC earth electrode shall generally be no less than 30 years under the specified operation mode.

**4.1.3** The DC earth electrode is generally composed of 2 or more separated components.

**4.1.4** In order to prevent the earth current of the HVDC earth electrode system from corroding and interfering with the converter station, the straight-line distance between the earth electrode and the converter station in the HVDC transmission system should not be less than 10 km; it shall be ensured that the grounding grid of the converter station is completely separated from the earth electrode.

**4.1.5** The DC earth electrode generally has ring, star, linear, ray, grid shapes, which should be confirmed according to the conditions of the electrode site topography, geology, hydrology, traffic conditions, from the two aspects of convenient construction and reasonable technology and economy.

**4.1.6** The buried depth of the DC earth electrode shall be determined, according to the requirements for step potential in this Standard, by comprehensive techno-economic comparison in combination with the soil climate characteristics of the electrode site, the engineering excavation and the external force factors; it is generally not less than 1.5 m.

**4.1.7** The earth electrode design shall consider the changes of the groundwater level; water injection devices shall be installed when necessary.

## 4.2 Electrode site selection

**4.2.1** The DC earth electrode site should generally be far away from densely populated cities and towns, and areas with more public facilities underground.

**4.2.2** Geological and hydrological surveys must be carried out within 20 km of the pre-selected electrode site. The content of the survey at least includes:

a) Geological structure and thickness of each layer. The depth from the ground to the bedrock, the thickness of the bedrock.

b) Seawater erosion conditions, detailed geological map of pre-selected electrode sites with contours (land electrodes) or isobaths (ocean electrodes).

c) Surveys shall be conducted when the survey data is incomplete.

**4.2.3** Before designing the DC earth electrode, it is necessary to evaluate the influence of the earth electrode on the surrounding environment. Therefore, it is necessary to investigate the existing and planned transmission lines and important facilities around the electrode site. For the assessment of environmental impact, refer to the relevant standards and regulations for preventing corrosion of metal structures.

**4.2.4** The selection of the DC earth electrode site shall consider the impact on the surrounding environment. In principle, there should be no underground metal pipelines, railways or effective grounding transmission and transformation facilities within 10 km of the pre-selected electrode site.

**4.2.5** The electrode site selection of the DC earth electrode should be determined by the technical and economic comparison of no less than 3 different schemes.

### 4.3 Determination of earth parameters of the electrode site

#### 4.3.1 Groundwater level

The groundwater level of the electrode site can be obtained through hydrogeological maps or on-site detection.

#### 4.3.2 Earth resistivity

**4.3.2.1** The earth resistivity of the electrode site is generally measured by injecting current on the spot.

**4.3.2.2** The earth injection current that is used to measure the earth resistivity on site shall be a direct current.

**4.3.2.3** The test method can be any traditional earth resistivity test method, such as Wenner quadrupole method, Schlumberger-Palmer method, or the unequal-distance quadrupole method (see Appendix A) .

# 5 Test

## 5.1 General principles

**5.1.1** The purpose of testing the HVDC earth electrode system is:

a) The various parameters of the earth electrode shall meet the design standards.

b) Whether the step potential, touch potential and transfer potential, which are caused by the HVDC earth electrode system under the maximum operating voltage, meet the requirements of the guidelines.

c) Understand the interference and influence of the HVDC earth electrode system on the public utility system (such as water supply, electricity, gas, fishery administration) in the surrounding area; measure, if necessary, so as to check whether it meets the design requirements.

**5.1.2** The earth electrode shall complete the acceptance test before system debugging.

**5.1.3** The time sequence of the test items specified in this Standard can be carried out at the same time or in crossover if there is no special description.

**5.1.4** For the safety of test personnel, instruments and equipment, the earthing current in the test shall be in several grades from small to large.

**5.1.5** When repeating the same test item under different earthing currents, the same instrument shall be used in the same position and direction.

**5.1.6** All test items should be performed once at 70% ~ 80% and 100% rated current under monopolar mode.

**5.1.7** During the entire test process, measures must be taken to protect the safety of the testers and the people and animals moving in the test area according to the characteristics of the earth electrode site and its nearby electric field.

## 5.2 Appearance inspection

**5.2.1** The HVDC earth electrode system shall be visually inspected before the formal power-on test, so as to confirm that the ground part of the HVDC earth electrode system and its connection parts with the electrode line are intact, the assembly and installation are correct, and the size meets the design requirements, before the test.

**5.2.2** Remove the electrode site and its nearby items that affect normal operation and have nothing to do with the test; repair the natural damage (such as washing or sinking) of the soil on the electrode surface before the test.

**5.2.3** Check the detection device and the water seepage hole to prevent blockage.

**5.2.4** Check the safety signs and protective barriers to confirm that they are intact and clearly marked.

### 5.3 Earthing current

**5.3.1** After the earthing electrode is energized, the total current into the ground shall be measured. This work shall be carried out during the whole process of system debugging, so as to provide the most basic parameters for other various test tasks.

**5.3.2** In order to determine whether the current distribution of each segment of component of the earthing electrode is balanced, the current distribution of each segment of the feed component shall be measured. The measurement should be carried out at the beginning of the test. The balance of the current distribution of the earthing electrode components shall meet the design requirements.

**5.3.3** Various DC current measuring instruments and meters, such as DC transformers, DC clamp ammeters, and DC shunts, shall be used to measure the earthing current. The accuracy of the DC current measuring instrument is required to be grade 0.5 ~ 1.

### 5.4 Earthing resistance

**5.4.1** The earthing resistance value of the DC earth electrode shall meet the design requirements.

**5.4.2** For the earthing resistance test of the DC earth electrode, adopt the current injection method, that is, the ammeter-voltmeter method; do not adopt the portable earthing resistance tester.

**5.4.3** When measuring the DC earthing resistance, the injected earth current shall be a DC current; no alternating current shall be used. This kind of DC current can be provided by a DC power supply for separate test; the unbalance current flowing through the earthing electrode during system operation, or the earthing current during operation (or test) of the monopolar earth loop can also be used.

**5.4.4** When using the DC power supply for testing, the minimum distance between the auxiliary current electrode and the earthing electrode shall be greater than 10 times the maximum distance between any two points of the

**5.7.5** Suitable temperature measuring instruments should be used to measure the temperature in the ground.

# 6 Assessment and protection of the impact on surrounding facilities

**6.1** When the selected electrode site cannot avoid underground metal pipes, underground cables, railways, and electrical equipment grounding devices and other underground metal components within 10 km, the extent of the corrosion and other adverse effects of the earthing electrode current on these components shall be evaluated. The soil potential (electrode potential relative to the copper-copper sulfate) of buried metals that have not been corroded or disturbed is generally between -0.85 V ~ -1.50 V. This value can be used as a control standard for the protected buried metals to the soil potential. If the evaluation result shows that the earth potential rise that is caused by the earthing electrode current and its corrosion to metal components will affect the safe operation of these facilities, relocation shall be considered, or appropriate protective measures shall be taken.

**6.2** The earth potential rise, which is caused by the DC earth electrode current, makes the neutral point of the AC power transformer that is effectively grounded around it to have a DC current; its value is related to the location of the transformer and its electrical parameters, system wiring, grid wiring. Analog computation shall be carried out when selecting the electrode site; field measurement shall be carried out after the earthing electrode is put into operation. When the DC current flowing through the neutral point of the transformer exceeds the allowable value, appropriate limiting measures can be adopted.

**6.3** The allowable DC current value of AC transformers (including power supply transformers for electrified railways and locomotive traction transformers) is related to their design, material, structure and manufacturing process. The manufacturer should provide relevant technical requirements. If the manufacturer cannot provide technical requirements, the allowable DC current of each phase winding of the transformer is tentatively set as: 0.3% of the rated current under monopolar mode for the single-phase transformer, 0.5% of the rated current under monopolar mode for the three-phase five-leg transformer, and 0.7% of the rated current under monopolar mode for the three-phase three-leg transformer.

# 7 Operation and maintenance of DC earth electrode

## 7.1 Appearance inspection

After the land earthing electrode is put into operation, the following items shall be inspected and disposed regularly. The cycle is once every 2 months in the initial stage of operation, and once every 6 months after 1 year.

**7.1.1** Subsidence of the backfill. If there is too much subsidence, continue backfilling, to ensure the height of the earth electrode components from the ground. However, the backfill soil shall not be higher than the ground nearby, so as not to affect the accumulation of rainwater on the soil on the surface of the earthing electrode.

**7.1.2** Check the gravel seepage area of the earthing electrode; remove debris such as sludge, if it is found to block the seepage hole, in time.

**7.1.3** Check whether the cables and joints entering the ground, the foundation of the tower and the safety warning signs are in good condition; abnormalities, if any, shall be dealt with in time.

### 7.2 Electrode line

After the HVDC transmission system is put into operation, the electrode line shall be regularly maintained and inspected. The maintenance and inspection items and cycles shall be the same as the system's direct current transmission line.

### 7.3 Current distribution

During operation, the current passing through the electrode line and the feeder cables of various components shall be periodically measured and inspected. The cycle shall not exceed once every 6 months. The length of the cycle shall be determined according to the system operation mode.

### 7.4 Earthing resistance

The HVDC earth electrode system should be tested and inspected for earthing resistance once a year.

### 7.5 Excavation

**7.5.1** Local excavation inspection can be carried out once, every 10 years within the design life of the earth electrode, every 5 years outside the design life, and every 1/3 ampere hour after the earth electrode operates the design life, so as to determine the operation of the underground parts (such as feeder components, connecting cables, connectors) of the earth electrode.

**7.5.2** Excavation inspection can be carried out when abnormal conditions are found during the detection of the earthing electrode.

### 7.6 Temperature

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