132-400 kV AC substation

Outdoor AC substations
Earthing systems

ETS-50-08-01, Rev. 0
## REVISION VIEW

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</table>

This standard supersedes the Danish version.
Table of contents

1. Introduction 4
2. References 4
3. Functional requirements 4
4. Technical requirements 4
   4.1 Earthing network 4
   4.2 Earthing of steel supports/high-voltage apparatus 5
   4.3 Earthing of voltage transformer 5
   4.4 Earth electrodes 5
   4.5 Outer substation fence and gates 6
   4.6 Expansion of the earthing system 6
   4.7 Documentation 6
5. Appendix 1: Example of an earthing network 7
6. Appendix 2. Installation of cable connection on steel support 8
1. Introduction
This standard specifies the minimum requirements for earthing systems designed for outdoor substations in the 132-400 kV nominal voltage range.

All high-voltage grids in Denmark in the 132-400 kV voltage range are effectively earthed.

The requirements stated in the technical specification for any specific unit take precedence over the requirements stated in this standard.

2. References
- ETS-50-00 Outdoor AC substations. General
- The Danish Heavy Current Regulation, part 2 Design of electricity supply systems

3. Functional requirements
The purpose of the earthing network on a high-voltage substation is to protect personnel against injury and eliminate the risk of extensive damage to the system caused by earth faults.

The risk of injury to personnel outside the outer substation perimeter caused by high-voltage faults must also be dealt with. This in particular applies if electrically conductive connections are routed from the substation area to the surrounding areas.

4. Technical requirements
Energinet.dk states the maximum future earth current as well as the maximum duration of a high-voltage fault. The earthing network of the given substation must as a minimum be dimensioned for this earth current during this period of time.

The earthing resistance for the complete system must not exceed 0.1 ohm for large-scale substations. For small-scale substations (eg GIS substations and cable stations), a detailed analysis of the earthing network design is required.

For new substations, the specific earth resistance must be measured in collaboration with Energinet.dk. Based on such measurement, Energinet.dk will conduct an analysis of the preliminary design and recommend improvements, if any.

The earthing network must be constructed to comply with the requirements of the Danish Heavy Current Regulation, part 2, section 9, as well as appendices A to S, excluding appendix H.

4.1 Earthing network
The earthing network must be a meshed network connected with compression tap connectors (H-shaped) at all crossings. The typical mesh size is approximately 10 x 10 m, but is otherwise adjusted to the position of the individual foundations and apparatus.
The mesh size should be smaller under special conditions, for example for transformers and reactors. Earthing conductors must always be laid in and along cable ducts.

See the example of an earthing system in appendix 1.

The earthing network must be installed at a depth of 1.0-1.1 m below the final ground level.

Endeavours should be made to ensure that the individual earthing conductor goes uninterrupted from earth electrode to earth electrode. If the earthing conductor has to be elongated, two H-shaped compression tap connectors must be used to safeguard the connection.

The conductors in the earthing network must be made from hard-drawn, non-insulated copper wire and be dimensioned according to the size and duration of the earth current. For an earth current of, for example, max 30 kA for 1 sec., the earthing network must be laid out with 95 mm² copper. For 40 kA for 1 sec., 120 mm² copper must be used.

4.2 Earthing of steel supports/high-voltage apparatus
Double upward wire routing must always be used for the individual support/apparatus

The two upward wire routings are established by routing the earthing conductors uninterrupted and directly to the support after which an H-shaped compression tap connector is installed in the ground between the two upward routings. The connector ensures a galvanic connection in the actual earthing network, also if the connection to the support fails or must be removed.

The two earth connections are routed up through the foundation in a plastic pipe. If such a plastic pipe is not available (eg in old substations), the earth connections must be routed in a plastic pipe on the outside of the foundation.

The connections must be terminated on the support/apparatus in two tinned cable lugs. Each cable lug must be fixed to the support/apparatus with a hot-dip galvanised M12 bolt and nut, see appendix 2.

In special cases, underground electrical connections between two different metals (eg steel/copper – reinforcing steel/earthing network) can be performed by means of CADWELD welding.

4.3 Earthing of voltage transformer
Voltage transformers must be earthed as specified in section 4.2. In addition, the support must have two additional connections to two separate earth electrodes. See appendix 1.

4.4 Earth electrodes
In the periphery of the earthing system, an earth electrode must be driven down in every second mesh on the outside.

An earth electrode is constructed as a steel pipe for routing down the copper wire to the correct depth. The copper wire constitutes the actual earthing.
The earth electrodes are normally driven down to a depth of approx 6 m; however, depending, on the given ground conditions, it may be required that the earth electrodes are driven down deeper to achieve a satisfactory earthing resistance.

4.5 Outer substation fence and gates
It must be ensured that dangerous touch voltages can never occur outside the outer substation fence.

The outer substation fence and gates are not connected to the earthing system of a high-voltage substation unless the distance between the earthing network and the fence/gate is less than 2 m. If the distance is less than 2 m, potential rings must be laid out in the relevant area to prevent dangerous touch voltages. In such cases, it must be agreed with Energinet.dk how to earth fences/gates.

If standard gates or sliding gates are used for access to the substation, a suitable bonding conductor must be established between the parts that are galvanically connected to the fence on both sides of the gate.

Electrically conductive connections leading out from the substation area (e.g., 380 VAC supply) must be ensured to avoid dangerous touch voltages.

4.6 Expansion of the earthing system
If an existing earthing system has to be expanded, the expansion must be made using the same technology and approach as previously used for the substation, if possible. Any deviations must be agreed with Energinet.dk.

The Danish Heavy Current Regulation, part 2, must always be observed, and the expansion must be documented according to the same rules that apply to documentation for a new system.

4.7 Documentation
The complete earthing network must be documented on a drawing showing earthing conductors, earth electrodes, connections to the individual apparatus, all joints as well as the connections leading into the control building of the substation.

The depth for earthing conductors and for the individual earth electrodes must be documented.

The earthing resistance of the individual earth electrodes as well as the substation's total earthing resistance must be measured and documented.

By means of a representative selection of measurements, it must be documented that dangerous touch voltages cannot occur in the event of an earth fault. This must be documented for both the inside and outside areas of the substation.
5. Appendix 1: Example of an earthing network
(The full-size drawing can be ordered from Energinet.dk.)
6. Appendix 2. Installation of cable connection on steel support