



Earth-termination system for onshore wind turbines

White Paper



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Standards for earth-termination systems

This document refers to international and German standards. Please note that country-specific standards can differ from German standards. The following standards form the basis for the installation of the earth-termination systems of onshore wind turbines with integrated mediumvoltage system:

- ➔ IEC 61400-24:2010 – International Standard – Wind Turbines Part 24: Lightning Protection
- ➔ IEC 60364-5-54:2012; – International Standard – Low-voltage electrical installations
- ➔ IEC 61936-1:2011 – International Standard – Power installations exceeding 1 kV a.c.
- ➔ IEC 62305-3:2010 – International Standard – Protection against lightning Part 3
- ➔ DIN 18014:03-2014 – Foundation earth electrode

DIN 18014: 03-2014: Foundation earth electrode

The fundamental design of a foundation earth electrode is defined in the German DIN 18014 standard, March 2014 edition. This DIN standard particularly describes the types of earth electrodes in case of tank seals, e.g. white tank, black tank and perimeter insulation.

If a building is equipped with a lightning protection system, the additional requirements in IEC 62305-3 must also be observed.

Foundation earth electrodes are an integral part of the electrical installation (DIN 18014, section 4) and fulfil essential safety functions. Therefore, they must be installed by or under supervision of electrically skilled persons (lightning protection specialists).

Foundation earth electrodes must be installed as a closed ring and arranged in the foundations of the exterior walls of the building or in the foundation slab according to DIN 18014, section 5.1

Earth-termination system

The earth-termination system of a wind turbine has the following tasks:

- ➔ Protective earthing with the task of safely connecting electrical equipment to the ground and protecting persons and property in the event of an electrical fault.
- ➔ Functional earthing with the task of ensuring safe and trouble-free operation of the electrical and electronic equipment.
- ➔ Lightning protection earthing with the task of safely conducting the lightning current from the down conductors to the ground.

From a lightning protection point of view, a single, common earth-termination system for all purposes is preferred for wind turbines (e.g. medium-voltage system, low-voltage supply, lightning protection, electromagnetic compatibility, telecommunication and control systems).

The foundations of reinforced concrete wind turbines should be preferably used as a foundation earth electrode. They provide a low earth resistance and represent an excellent basis for equipotential bonding.

Based on the fact that a medium-voltage transformer is also installed in the wind turbine, the earth-termination system must be designed according to IEC 61936-1.

Like the lightning protection standard, IEC 61936-1 describes all types of earth electrodes. Foundation earth electrodes are defined as the most effective earth electrodes.

The design of earth-termination systems according to IEC 61936-1 must fulfil four requirements:

- ➔ Mechanical strength and corrosion resistance must be ensured
- ➔ Maximum fault current (calculated) must be coped with from a thermal point of view
- ➔ Damage to objects and equipment must be avoided
- ➔ Persons must be protected from voltage at earth-termination systems that occurs in case of the maximum fault current

Consequently, the following parameters are important for dimensioning the earth-termination system:

- ➔ Composition of the surrounding ground
- ➔ Type of neutral point treatment and the resulting short-circuit currents in case of a fault

In a turbine with different nominal voltages, these requirements must be fulfilled for every high-voltage level. Simultaneous faults in galvanically isolated grids do not have to be considered.

The neutral or PEN conductor of the low-voltage system can be connected to the earthtermination system of the medium-voltage system if the following conditions are fulfilled in case of an earth fault in the medium-voltage system:

- ➔ No dangerous touch voltage will occur in the low-voltage system or in the consumer's installations connected to it
- ➔ The voltage load on the low-voltage devices in the consumer's installations will not exceed the values defined in IEC 60364-4-41 as a result of the potential rise at the low-voltage neutral point.

The medium-voltage earth-termination system should also be integrated in the lightning protection system.

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A layout plan that shows the material, position of the earth electrodes, their branching points and burial depth should be prepared for the earthtermination system.

Before commissioning, a test report that confirms that all requirements of the relevant standards are fulfilled should be created.

The IEC 62305-3 lightning protection standard requires an earth resistance $\leq 10 \Omega$.

Foundation earth electrodes

Foundation earth electrodes make technical and economic sense. In Germany, they must be designed and installed according to DIN 18014.

Foundation earth electrodes are required in the German technical connection conditions (TAB) published by German distribution network operators.

Foundation earth electrodes are a part of the electrical installation (DIN 18014-4, section 4) and fulfil essential safety functions. Therefore, they must be installed by or under the supervision of electrically skilled persons.

Foundation earth electrodes must be installed as a closed ring and arranged in the foundation of the exterior walls of the building or in the foundation slab according to DIN 18014. Foundation earth electrodes must be covered by 5 cm concrete from all sides.

Foundation earth electrodes must be made of galvanised or non-galvanised round or strip steel steel.

➔ Round steel must have a minimum diameter of 10 mm.

➔ Strip steel must have minimum dimensions of 30 mm x 3.5 mm.

The foundation earth electrode must be connected to the main equipotential bonding bar inside the wind turbine by means of a connection component (**Figure 1**).

According to the IEC 62305-3 lightning protection standard, a foundation earth electrode must feature terminal lugs for connecting the down conductors of the external lightning protection system to the earth-termination system (**Figures 1 and 2**).

Foundation earth electrode 1

- Round wire (\varnothing 10 mm) or strip (30 mm x 3.5 mm), St/tZn
- Concrete cover of at least 5 cm
- Closed ring
- Connection to the reinforcement at intervals of 2 m by means of a clamp 4

Terminal lug 2 to main earthing busbar 6 and

terminal lugs 3 for the earthing system of the tower

with SV clamp 5 at least 1.5 m long, easily identifiable

- Round wire, StSt, e.g. mat. No. AISI/ASTM 316 Ti (V4A), 10 mm
- Strip, StSt, e.g. mat. No. AISI/ASTM 316 Ti (V4A), 30 x 3.5 mm
- Round wire, StZn, \varnothing 10 mm, with plastic sheath
- Fixed earthing terminal

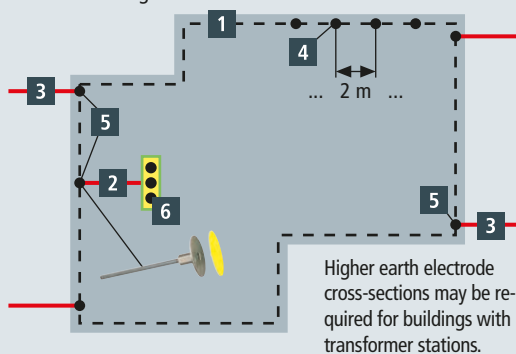


Figure 1 Foundation earth electrode with connection component for the lightning protection system and main equipotential bonding bar

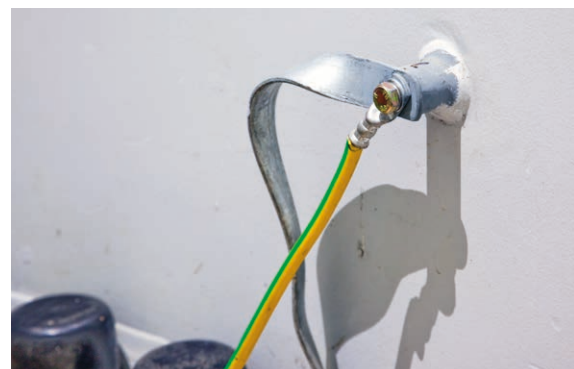


Figure 2 Terminal lug – Connects the earthing system of the tower to the earth-termination system



Figure 3 Reinforcement of a wind turbine with foundation earth electrode

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Figure 4 Reinforcement of a wind turbine with clamps



Figure 5 Reinforcement connected to the earth termination system at intervals of 2 m

In case of reinforced foundations which are commonly used for wind turbines, round or strip steel is placed on the lower reinforcement layer (**Figure 3 to 5**). It must be safely connected to the reinforcement at intervals of 2 m in such a way that it is electrically conductive. This is done by welding, clamping or pressing. No wedge connectors must be used if the concrete is compacted mechanically (e.g. by vibrators).

Welding connections

Welding connections must be made according to DIN ISO 857-1 and DIN 1910-11. Welding may only be performed by trained welders or companies that are certified according to DIN 4099. The reinforcing bars should be welded over a length of at least 30 mm. This is only allowed in agreement with the civil engineer.



Figure 6 Connection of the earth electrode to the reinforcement



Figure 7 Ring earth electrode connected to the foundation earth electrode

Lightning protection system

If the foundation earth electrode is used as part of the lightning protection system, connection components according to IEC 62561-1 must be used.

For equipotential bonding in case of lightning protection systems and for EMC purposes, round or strip steel must be in-

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Bild 8 Reinforcement of a wind turbine with buried ring earth electrode

stalled in the foundation and connected to reinforcement and the equipotential bonding bar.

In case of a lightning strike, no flashover may occur from the foundation through the insulation system to the earth-termination system. This is achieved by a maximum mesh size of 10 m x 10 m of the ring earth electrode according to IEC 62305-3.

The ring earth electrode and the terminal lugs must be corrosion-resistant (high-alloy stainless steel (V4A), material number AISI/ASTM 316 Ti).

Documentation

A layout plan is required to install the foundation earth electrode. Photos, plans and test reports can be used for documentation.

An example of the documentation for an earthtermination system can be found in Annex A of the German DIN 18014 standard or can be downloaded at: <http://www.dehn.de/de/pruefprotokolle>

Example: Earth-termination system of a wind turbine

The foundation of the wind turbine is designed as a circular ring with an outer diameter of 21.00 m and an inner diameter of 10.00 m. A foundation earth electrode made of 30 mm x 3.5 mm galvanised strip steel is installed inside the foundation and

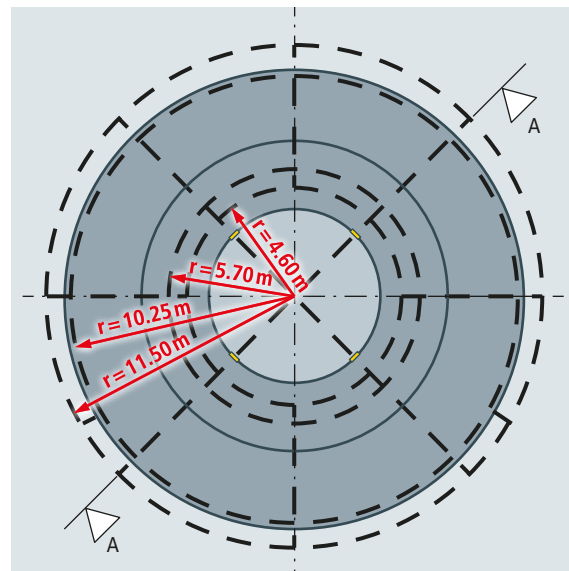


Figure 9 Top view of a foundation

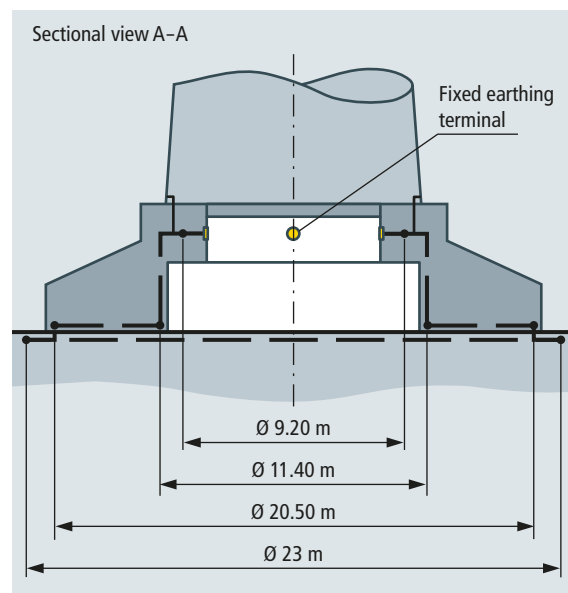


Figure 10 Sectional view of a foundation with earth-termination system

a ring earth electrode made of 10 mm round steel (stainless steel (V4A), material No. AISI/ASTM 316 Ti) is installed outside the foundation (Figure 7 to 10).

The following requirements apply to the earthtermination system used in the example:

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- ➔ A foundation earth electrode consisting of 30 mm x 3.5 mm galvanised strip steel is installed in the foundation with a radius of 10.25 m.
- ➔ The foundation earth electrode is covered by 25 cm concrete.
- ➔ An inner ring with a radius of 5.70 m and an additional ring with a radius of 4.60 m are also installed in the foundation.
- ➔ The galvanised strip steel is clamped to the reinforcement at intervals of 2 m (**Figure 5**).
- ➔ Three connecting conductors are routed from the foundation earth electrode with a radius of 10.25 m to the inner ring with a radius of 5.70 m and the inner ring with a radius of 4.60 m with an angle of 120° from each other.
- ➔ The connecting conductors are also clamped to the reinforcement.
- ➔ Two terminal lugs are connected from the inner ring with a radius of 4.60 m to a fixed earthing terminal (equipotential bonding).
- ➔ Four terminal lugs are connected from the inner ring with a radius of 4.60 m to the down conductors of the tower.
- ➔ A ring earth electrode made of round steel (10 mm, stainless steel (V4A), material No. AISI/ASTM 316 Ti) is installed at a distance of 1.0 m from the outer edge of the foundation.
- ➔ Eight stainless steel (V4A) connecting conductors are routed from the ring earth electrode with a radius of 11.50 m

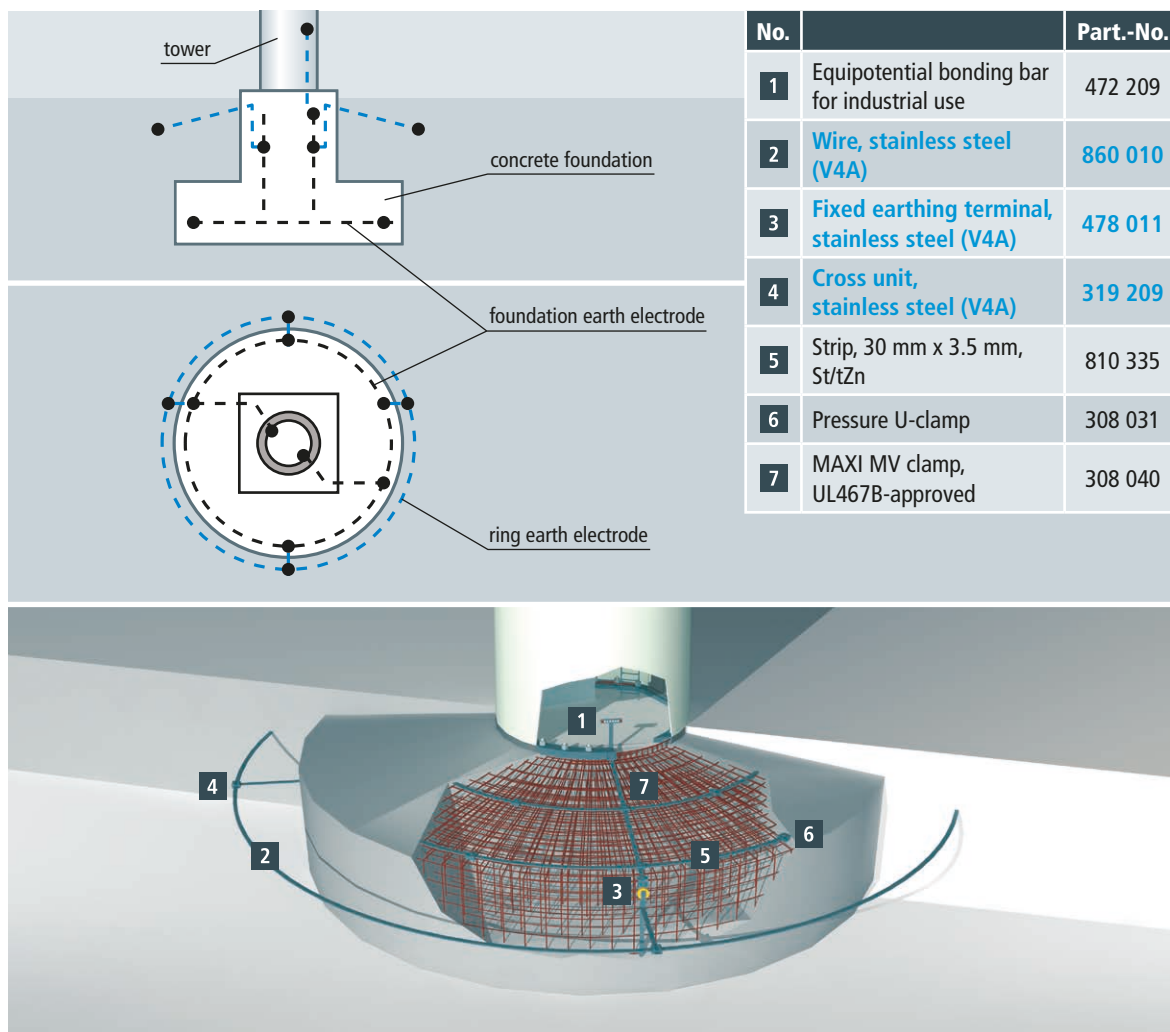


Figure 11 Recommended products for an earth-termination system

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