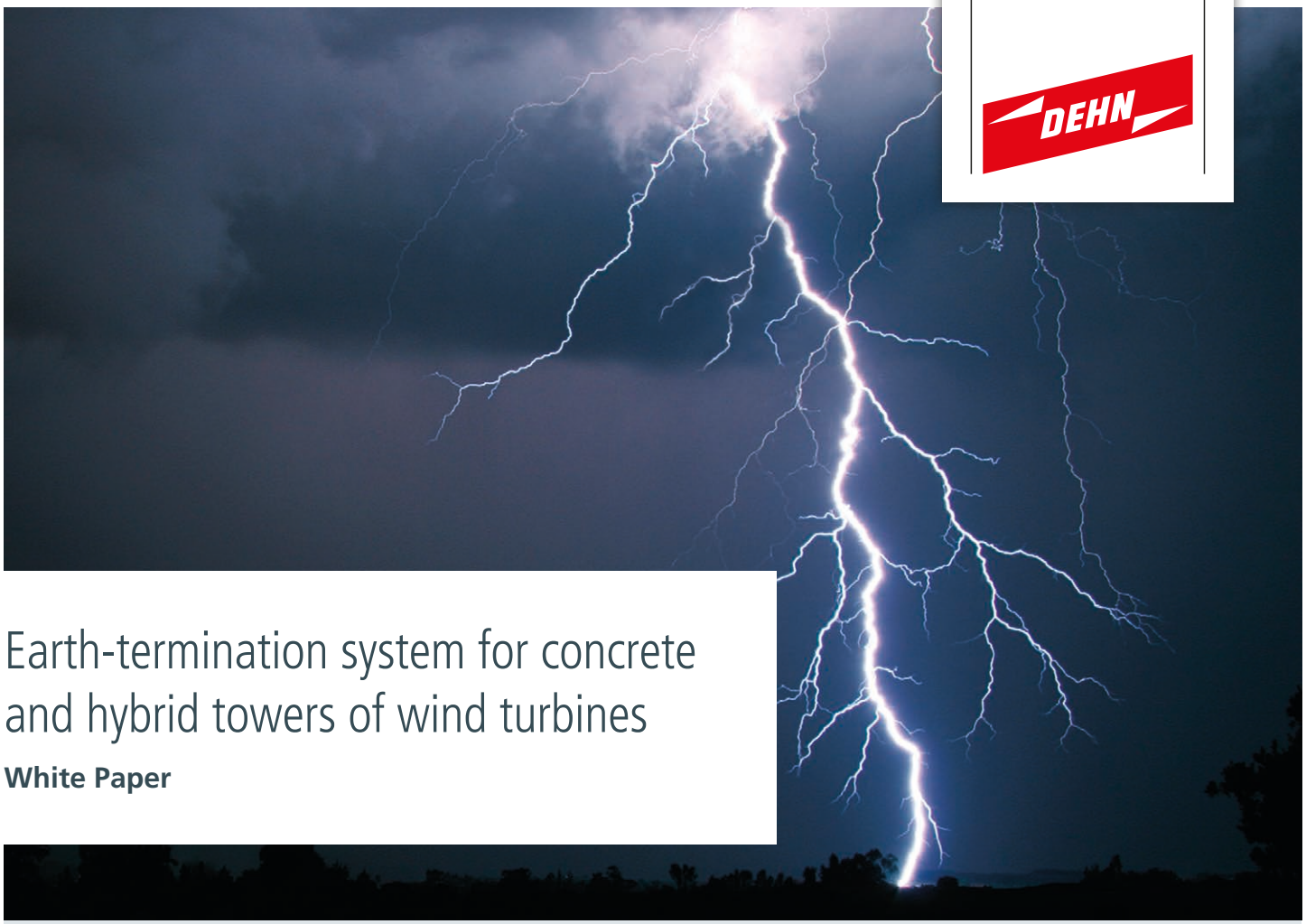

Earth-termination system for concrete and hybrid towers of wind turbines

White Paper

Contents

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White Paper

Standards for earth-termination systems

Due to the increasing hub heights of wind turbines, an increasing number of turbines will be equipped with concrete or hybrid towers. This hybrid towers consist of a concrete base part with a steel tubular tower on the top. As these towers are also part of the earth-termination system, these elements have to be considered as part of the electrical system. This requires compliance with the following standards:

- IEC 61400-24:2010: Wind turbines – Part 24: Lightning protection
- IEC 60364-5-54:2011: Low-voltage electrical installations – Part 5-54: Selection and erection of electrical equipment – Earthing arrangements and protective conductors
- IEC 61936-1:2010/COR1:2011: Corrigendum 1 – Power installations exceeding 1 kV a.c. – Part 1: Common rules
- IEC 62305-3:2010: Protection against lightning – Part 3: Physical damage to structures and life hazard

IEC 61400-24:2010; section 8.3.5:

"In steel reinforced concrete towers, the reinforcement can be used for lightning down conduction by ensuring 2 to 4 parallel vertical connections with sufficient cross section which connect horizontally at top, bottom and for every 20 m in between. The steel reinforcement will provide quite effective magnetic field attenuation and lightning current reduction inside the tower if bonded in this way."

IEC 61400-24:2010; section 9.3.3:

"The tower shall be considered as the primary protection earth conductor (PE) and equipotential bonding connection. Due to the height of the tower, direct lightning attachment to the tower structure must be expected and thus considered in the design of the tower (see IEC 62305-3, Subclause E.4.3).
External lightning protection systems can be considered for use with concrete towers, but should always be bonded to the steel reinforcement of the tower.
Equipotential bonding outlets connected to the steel reinforcement shall be placed at strategic termination points for bonding of equipment inside the tower. The reinforced concrete tower shall be designed according to 9.3.6."

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.

Figure 1 Hybrid tower made of pre-fabricated concrete elements

- Lightning protection earthing with the task of safely conducting the lightning current from the down conductors to the ground.

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 (especially when the transformer is located in the nacelle).
- 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.

Tubular steel towers fulfil these requirements due to their diameter and completely metallic body (Faraday cage).
In case of reinforced concrete towers that are usually built of pre-fabricated concrete elements these characteristics have to be ensured by an integrated earth-termination system.

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According IEC 61400-24, the earth-termination system of a concrete tower has to fulfill the following requirements:

- Lightning current carrying capacity according to LPL I for currents up to 200 kA
- 2 – 4 down conductors from top to bottom. Due to the use of pre-fabricated concrete elements, the connection between the elements can be external. The distance between the down conductors should not exceed 10 m.
- The functioning of the earth-termination system has to be ensured for the full lifetime of the wind turbine.
- Horizontal ring connection every 20 m
- Bonding of all metallic parts of the turbine to the equipotential bonding system

Concrete foundation: IEC 61400-24:2010; section 9.3.6: "Since the metal reinforcement of the wind turbine foundation will always be part of the lightning or fault current path to remote earth due to the mechanical and electrical connections to the tower, the metal reinforcement in a foundation shall always be considered a part of the LPS.
Electrical continuity of steelwork in reinforced concrete structures shall be ensured. Steelwork within reinforced concrete structures is considered to be electrically continuous if the major parts of vertical and horizontal bars are connected. Connections between metal reinforcement parts shall be either welded, clamped or overlapped by a minimum of 20 times their diameters and bound by conductive thread or otherwise securely connected. Special care should be exercised at the interconnections to prevent damage to the concrete due to localized arcing across poor contacts.
The connections between reinforcement elements shall be specified by the designer, and the installer shall carry out QA control of connections. The requirement for short and straight connections for the lightning protection earthing shall be recognized at all times.
If the metal reinforcement is used for the power system protective earth, the thickness of the metal reinforcement rods and the connections shall comply with the requirements for power system earth-termination systems which are usually stipulated in the electrical code.
Outlets for additional bonding, measurement or expansion of the earth-termination system shall be made at appropriate locations on the foundation."

Example of an earth-termination system in a concrete tower

The down conductors inside the concrete should be made of 10 mm round steel or 30 mm x 3.5 mm flat steel. For equipotential bonding, these conductors have to be connected to the reinforcement at intervals of 2 m.

If a continuous connection of the reinforcement bars can be ensured (e.g. by welding), they can also be used as a down conductor if they have a sufficient diameter.
The single concrete elements can be interconnected by fixed earthing terminal in combination with bridging cables. It has to be ensured that all components used can carry the requested lightning current. The horizontal connections should also be made from 10 mm round steel or 30 mm x 3.5 mm flat steel.

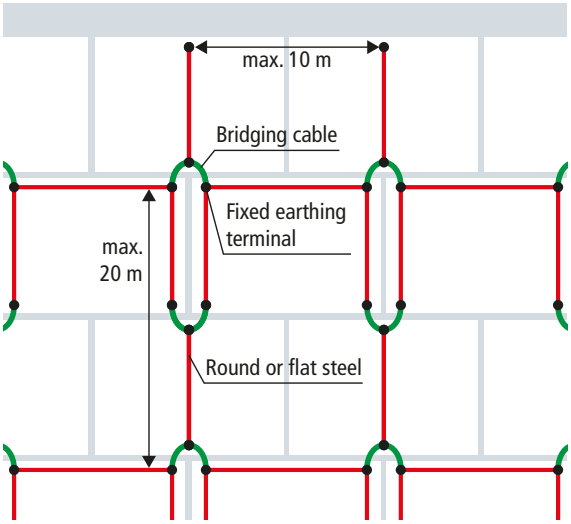

Figure 2 Flat projection of a pre-fabricated concrete tower (example)

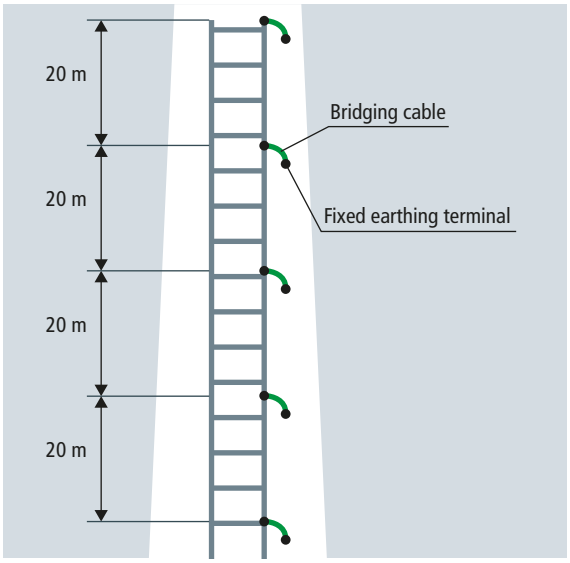

Figure 3 Connection of the ladder to the equipotential bonding system

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This horizontal connection also has to be bonded to the reinforcement at intervals of 2 m.
All metallic components used in a tower have to be bonded to the equipotential bonding system.

Ladder systems have to be connected at every end at intervals of 20 m and at every platform inside the tower. Components like tensioning cables, elevator cables and rail systems have to be connected at both ends.

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