Earth and lightning protection system for ENERCON WECs

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1 Introduction

Like any other electrical system a wind turbine (WEC) can be exposed to internal and external electrical faults. These include on the one hand internal failures, such as short circuits or earth faults in the electrical components, and on the other hand external faults e.g. overvoltage caused by atmospheric discharges or switching overvoltage.

These factors can result in the destruction of the electrical devices and at worst can put lives at risk. To minimise the potential danger from electrical overvoltage, all ENERCON WECs are equipped with a comprehensive lightning protection and earth system.

The "external lightning protection" comprises, in particular, the measures for lightning protection on the rotor blade and the defined dissipation of the lightning current to the ground. The electrical WEC components are also protected against interfering fields and interference voltage.

The protection of electrical and electronic devices in the WEC itself is referred to as "internal lightning protection".

2 External lightning protection system

2.1 Rotor blade

The rotor blade tip is the highest point of the WEC and therefore is at the highest risk during thunderstorms. A lightning strike on the rotor blade can destroy the blade and other WEC components, as well as endanger any personnel inside the wind turbine.

The whole WEC is fitted with an integrated lightning protection system from the rotor blade tip right through to the foundation, so that lightning strikes are dissipated without causing damage to the rotor blade or other WEC components.

The rotor blade tip is made from moulded aluminium. A lightning conductor links the blade tip with the aluminium ring around the blade root (see figure 2). The aluminium ring is fitted at a sufficient distance from the metal parts in the blade connection area. This prevents unwanted flashover in the event of a lightning strike, and the lightning current is properly dissipated. The rotor bearings are protected from any consequential damage because lightning dissipation takes place on the blade root and not through the hub and the rotor bearings.

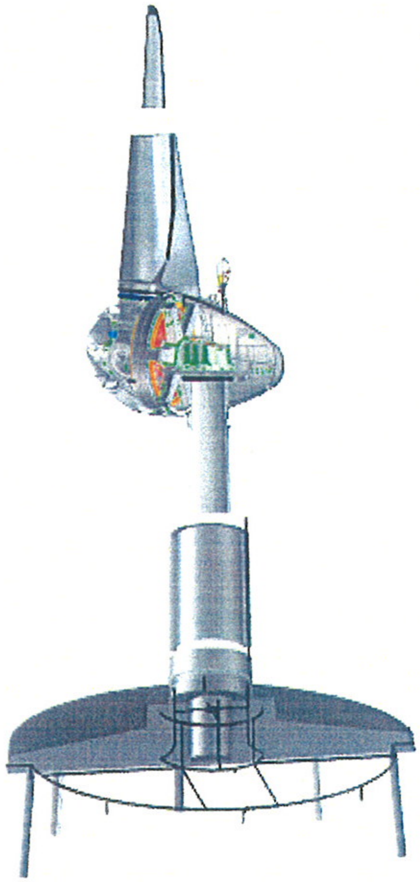

Fig. 1: External lightning protection design

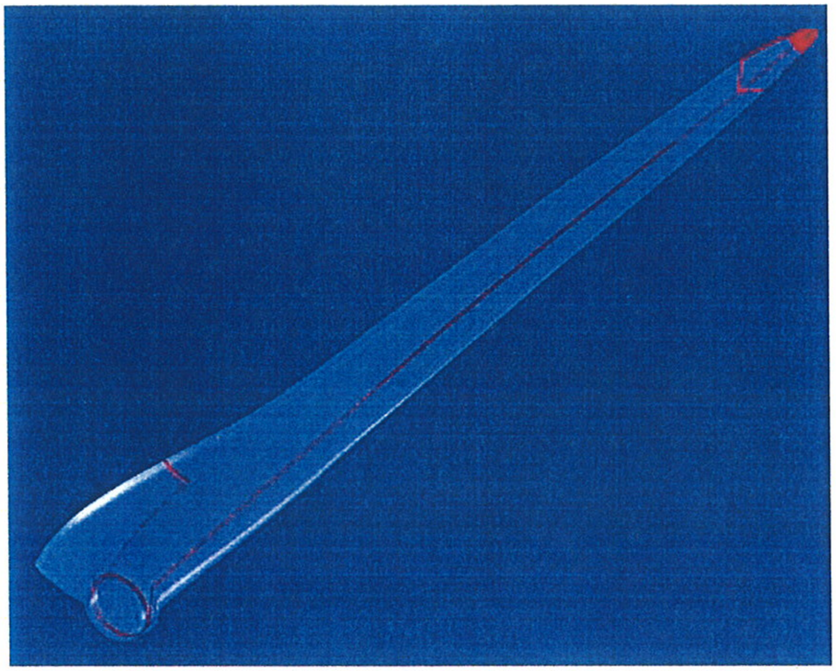

Fig. 2: Rotor blade lightning protection design

2.2 Nacelle

The dissipation of the lightning current from the rotating part (rotor blades) to the fixed part of the WEC (nacelle) takes place for each rotor blade through a spark gap, which is formed with lightning rods on the nacelle and an aluminium ring on the rotor blade. The lightning rods are on the rotor casing (each attached to one of the three blades) and on the back part of the nacelle casing. Each lightning rod has a conical tip in order to establish as large an electrical field as possible at this point in comparison to the surroundings.

The lightning current is conducted from the rotor casing via another ring and another spark gap to the nacelle.

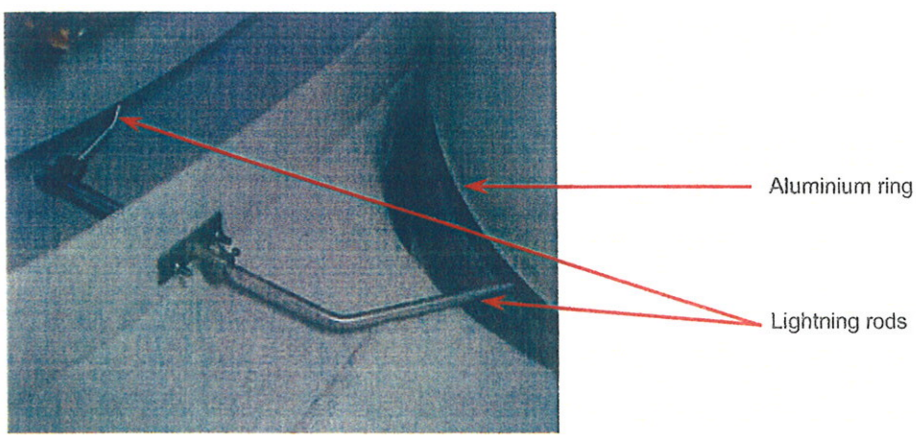

Fig. 3: Lightning rods

This arrangement allows a lightning strike to be conducted to the load-bearing structure regardless of the current position of the rotor and the current rotor blade angle.

On the back part of the nacelle casing there is also a lightning rod to protect the nacelle and the measuring equipment (anemometer and wind vane).
Within the machine house, the lightning current is conducted from the main carrier to the tower via a slip ring system on the yaw gear rim. In addition, the machine house is connected with a flexible copper cable to the bonding bar inside the tower basement.

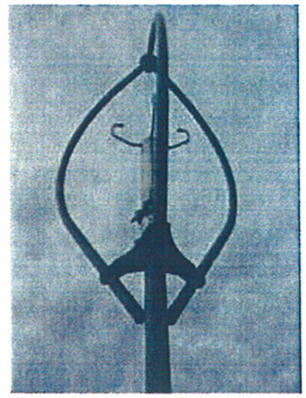

Fig. 4: Nacelle anemometer

2.3 Tower

Steel tower:
In steel towers the lightning current is dissipated from the nacelle to the earth electrode through the conducting tower itself. In order to ensure this, the flange joints on the tower sections are spray-galvanised. Two brackets welded to the tower are used to connect the foundation earth electrode.

Fig. 5: Connection between steel tower and foundation earth electrode

Precast concrete tower:
To ensure lightning protection in precast concrete towers, four steel strips ($3.5 * 30\ mm^2$) are installed inside the towers and interconnected from the foundation to the steel tower section.

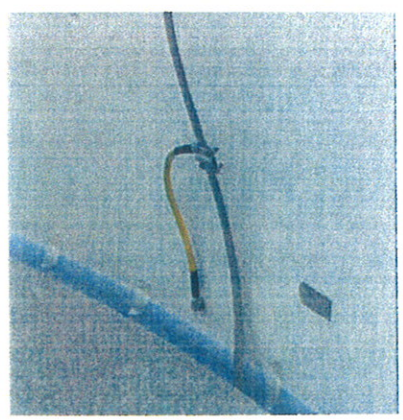

Fig. 6: Connection between concrete tower and foundation earth electrode

2.4 Bonding bar

The bonding bar is the central connection point for all usually non-conducting metal parts such as control cabinet housing, oil pan, fixings, etc. These components are connected directly to the bonding bar via appropriate cable cross-sections. This central connection point provides equipotential bonding within the WEC and prevents excessive touch voltage. The bonding bar is connected directly with the neutral point of the wind turbine transformer and, depending on the WEC type, is positioned either within the low-voltage distribution system or on the oil pan.

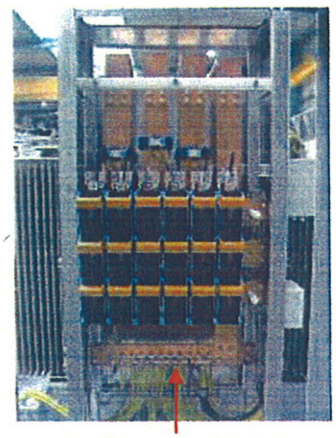

Fig. 7: Bonding bar in LV distribution system (E-70)

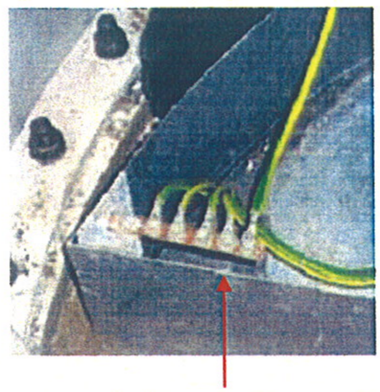

Fig. 8: Bonding bar on oil pan (E-48)

2.5 Foundation earth electrode

2.5.1 Foundation earth electrode – General information

Earth systems generally have the following tasks:

Protection of lives and property in the event of
- faults such as short circuits and earth faults
- transient events such as lightning strikes and switching operations

Each electrical system must be earthed in order to create a low-resistance connection between the electrical device and the general mass of the ground. The earth system should ensure effective operation of protective devices, provision of a reference potential for electrical devices and prevent excessive voltage peaks and potential differences.

A lightning strike e.g. on the wind turbine's rotor blade, produces electricity, which is dissipated into the ground through the rotor blade, the nacelle, the tower and the foundation earth electrode. Depending on the form and the dimensions of the foundation earth electrode and the earth system outside the foundation, the potential in and around the WEC foundation will increase. It is very important that the official step and touch voltages caused by the fault current/lightning current are not exceeded, in order to minimise the potential danger to any people in the vicinity of the WEC.

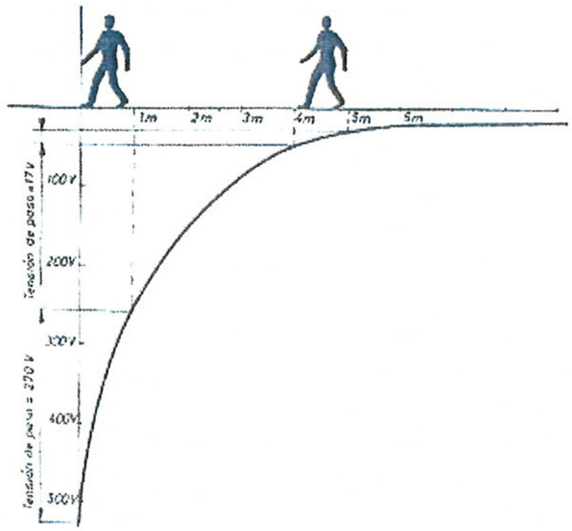

Fig. 9: Ground potential curve

2.5.2 Foundation earth electrode design

Four ring earth electrodes are laid at different positions in the foundation. They consist of hot-dip galvanised steel strips with a minimum cross-section of 100 mm² (3.5 x 30mm²) and are interconnected through foundation earth electrode connectors. If, in addition to hot-dip galvanised flat steel electrodes, country-specific standards require the installation of copper conductors, consult with the electrical project manager in charge.

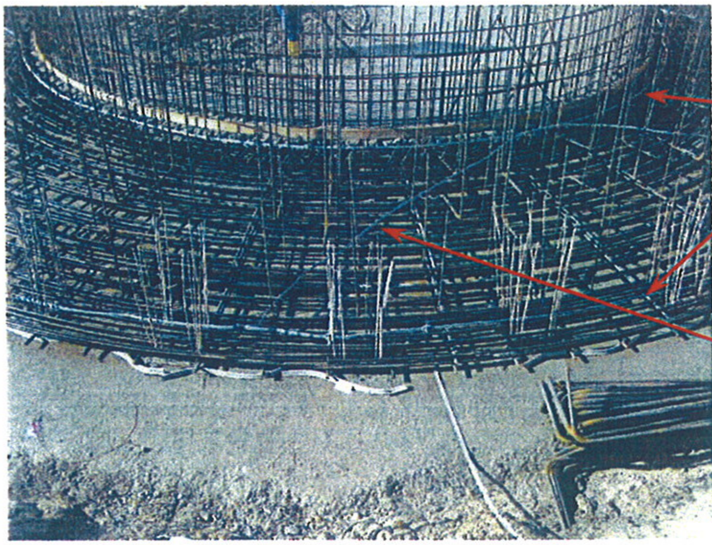

Fig. 10: Foundation earth electrode installation

Stainless steel (V4A) with a minimum cross-section of 100 mm² is used at the transition from foundation to ground. V4A steel strips or bare or tin-coated copper conductors can be installed in the ground itself.

To optimise dissipation of the lightning current into the ground and to reduce touch voltage, a maximum earth resistance of $\leq 2\,\Omega$ is required, which is achieved either through foundation earth electrode alone or with additional surface or deep earth electrodes.

Earth systems for installations electrically connected to the WEC, such as transformer stations, substations or communications shelters, are directly connected to the WEC earth system.

After completion of the earth system, an authorised specialist company should measure and record the earth resistance (2 Ω) and forward the earthing report to the ENERCON project manager in charge before WEC assembly.

3 Internal lightning protection/protection of electronic components

The electronic components on the wind turbines are galvanically isolated and located in earthed metal housings. In the event of a lightning strike or even in the event of an unusual increase in voltage (overvoltage) all the electrical and electronic parts are protected by fixed energy-absorbing components.
Further measures to protect against overvoltage:
Control cabinet and generator are protected with surge arrestors.
All PCBs with their own power supply units are fitted with high attenuation filters.
Analogue and digital signal inputs and outputs are protected by RC elements and suppressor diodes.
Open-loop and closed-loop electronic systems are galvanically decoupled by optocouplers, isolation amplifiers and relays. Signals are transmitted via fibre optic cables inside the WEC.
The data communication module (modem) for remote monitoring is protected with a special protection module for data interfaces, to prevent external interferences through cabling and wires.

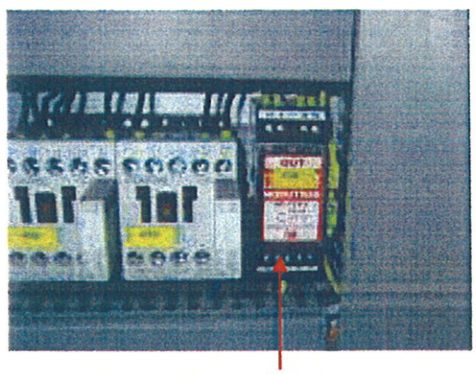

Fig. 11: Overvoltage protection data cable

4 Standards and guidelines for the construction of earth and lightning protection systems

- DIN 18014:1994-02
  Fundamenterdererrichtung (Foundation earth electrode installation)

- DIN VDE 0151 (VDE 0151):1986-06
  Werkstoffe und Mindestmaße von Erdern bezüglich der Korrosion (Materials and minimum dimensions of earth electrodes concerning corrosion)

- DIN EN 62305 (VDE 0185-305):2006-10
  Nationale Normenreihe – Blitzschutz (National series of standards – Lightning protection)

- DIN EN 50164-2 (VDE 0185 Part 202):2007-05
  Blitzschutzbauteile - Teil 2: Anforderungen an Leitungen und Erder (Lightning protection components – Part 2: Requirements for conductors and earth electrodes)

- DIN EN 50308 (VDE 0127 Part 100):2005-03
  Windenergieanlagen – Schutzmaßnahmen; Anforderungen für Konstruktion, Betrieb und Wartung (Wind turbines – Protective measures; Requirements for design, operation and maintenance)

- European harmonisation document HD 637 S1:1999
  National version in DIN VDE 0101 (VDE 0101):2000-01
  Starkstromanlagen mit Nennwechselspannungen über 1 kV (Power installations exceeding 1 kV)

- IEC 61936-1:2002
  INTERNATIONAL STANDARD – Power installations exceeding 1 kV a.c.;

- IEC 62305:2006-01
  INTERNATIONAL STANDARD – Blitzschutz (Lightning protection)

- IEC 61400-1:2005, German version DIN EN 61400-1 (VDE 0127-1):2006-07
  INTERNATIONAL STANDARD - Wind turbines - Part 1: Design requirements;

- IEC 60364-5-54:2002-06 - INTERNATIONAL STANDARD - Electrical installations of buildings, German versions DIN V VDE V 0800-2-548:1999-10 and DIN VDE 0100 Part 540:1991-11;

- IEEE Std 80-2000
  IEEE Guide for Safety in AC Substation Grounding