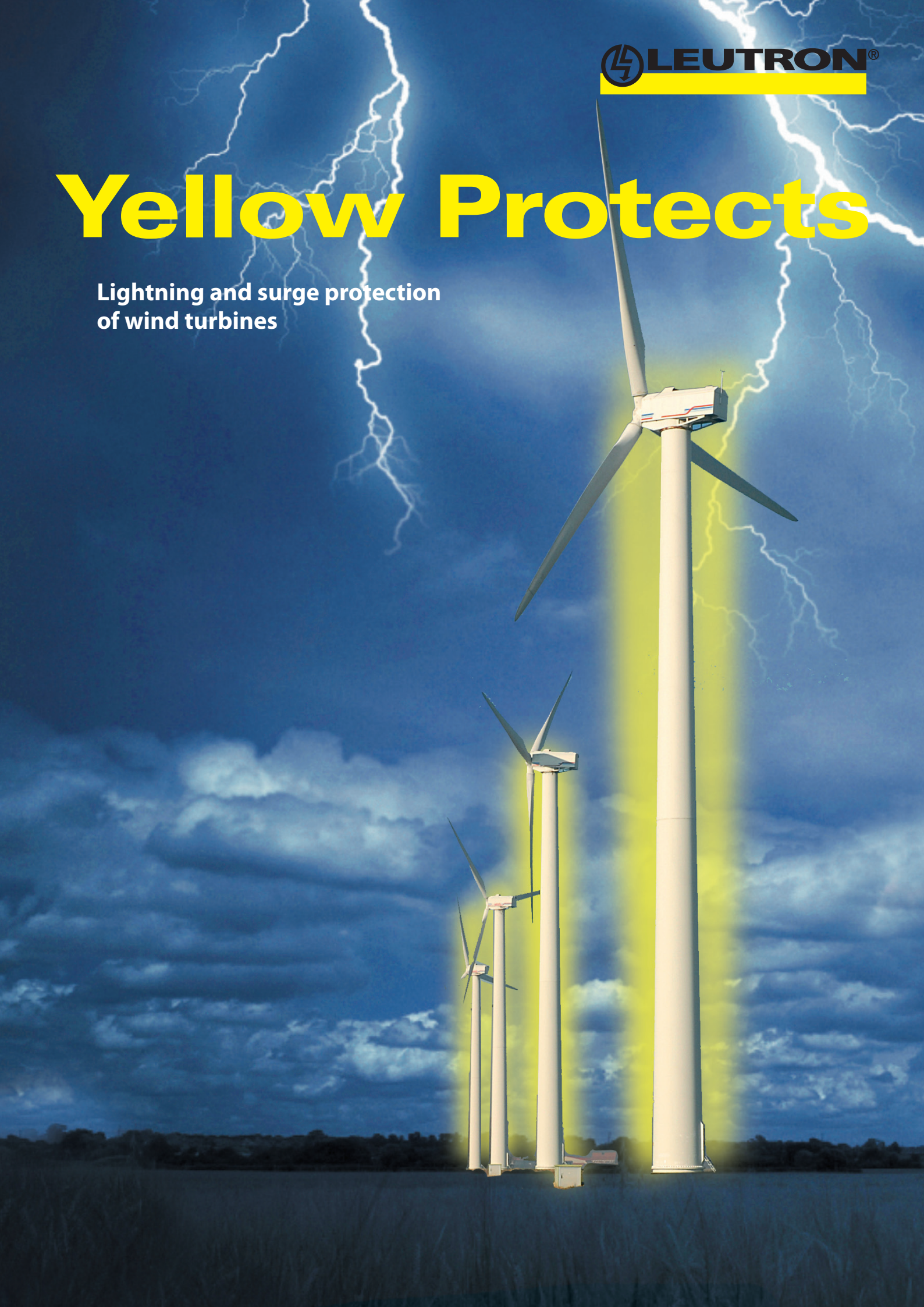


Yellow Protects

Lightning and surge protection
of wind turbines



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BY THE END OF 2009 the performance of all wind turbines installed in the grid worldwide added up to 157,899 MW¹. In Germany alone, wind turbines with an installed performance of 25,777 MW covered about 8.6 % of the power consumption² by that time. In profitability calculations experts assume a minimum life-span of 20 years.

Thus, the feed-in tariffs have to allow for an amortisation of the high investment costs in a time period as short as possible.

Therefore, an uninterrupted availability of all system components is a crucial precondition. Downtimes and repair costs due to damages caused by lightning strikes or overvoltages are not acceptable for any wind farm operator. The application of corresponding protective devices helps (?) to avoid them from the beginning.

I. Risk of Thunderstorms on the High Seas and at Low Mountain Ranges

- Corresponding to the high risk of loss a high lightning protection class has to be applied according to DIN EN 62305 (VDE 0185-305):2006-10. Onshore installations fall into the lightning protection class II with a fusing of up to 150 kA, whereas, for offshore installations the lightning protection class I has to be applied due to expected strikes up to 200 kA.
- Due to their exposed location wind turbines are subject to a high strike probability. Calculations carried out by the Kiel University of Applied Science and REpower have shown, that an offshore 5 MW wind turbine with a hub height of 120 m has an equivalent collection area of 80,000 sqm. The annual strike probability of direct lightning strikes amounts to 60 %. In the worst case, a single spark of such a strike could ignite the lubricating oil of moving parts.
- There are no reliable statistics concerning the risk of locations on the high seas. Such wind farms are set up only recently in Germany.
- However, research projects are under way like RAVE (Research at Alpha Ventus) at the first offshore wind farm Alpha Ventus or the FINO platforms where, among other things, the level of lightning activity and lightning parameters are to be measured to prepare for future offshore installations.
- Onshore, especially wind turbines at low mountain ranges are exposed to lightning strikes. Of the 405 wind turbines in low mountain areas which were registered between 1992 and 2005 in the wind monitor of the Fraunhofer Institute for Wind Energy and Energy System Technology IWES a total of 497 reports of damages caused by lightning strikes were logged with 147 direct hits among them.

¹ World Wind Energy Association (2009)

² Windenergienutzung in Deutschland. updated 31.12.2009. DWEI Magazine No. 36, Feb. 2010

II. Basic Construction of Wind Turbines

Because of their exposed location and construction height, wind turbines run a high risk of lightning strikes. Therefore, manufacturers of wind turbines value a comprehensive surge protection concept. Irrespective of the manufacturer, the basic construction of wind turbines is the same as shown in Fig. 1 and 2.

At the transformer station the generator voltage is transformed to a medium voltage level. At many wind turbines this station is located close to the tower.

Some manufacturers place the medium-voltage switchgear as well as the transformer station inside the bottom of the tower. There, the main distribution board with the main switching elements is located, together with the frequency inverter to adopt the generator frequency to the 50/60 Hz of the grid as well as the control equipment.

The nacelle houses the control equipment for all sensors and actuators, the gear and generator control as well as the yaw system to orient the nacelle to the wind direction.

If the wind turbine has a blade pitch control system, its control and drive system is placed in the hub.

A large part of the electrical devices are relevant for security related tasks. For instance, if the wind is too strong the blades must be turned out of the wind because the mechanical breaking systems have difficulties controlling the moved mass.

Therefore, the availability of the security systems is of utmost importance. Overvoltages caused by lightning current couplings or switching operations can cause serious damage in this area and provoke a downtime of the whole turbine. Hence, the lightning and overvoltage protection is an indispensable part of a wind turbine.

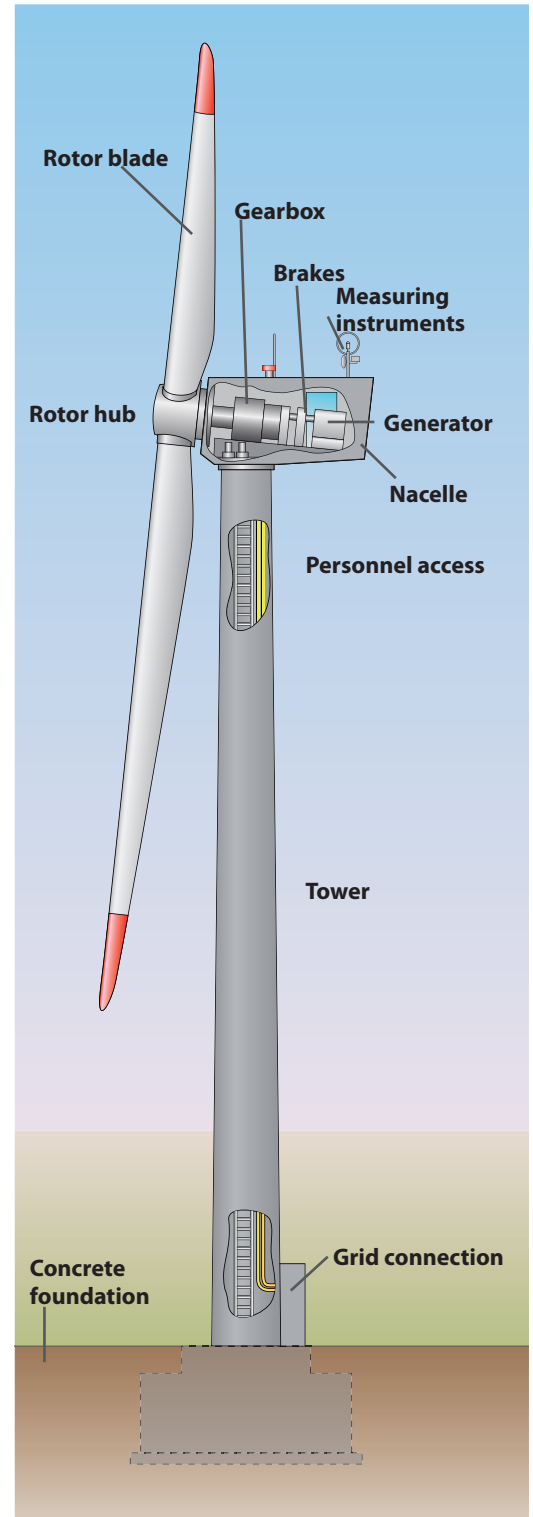


Fig. 1: Basic construction of a wind turbine

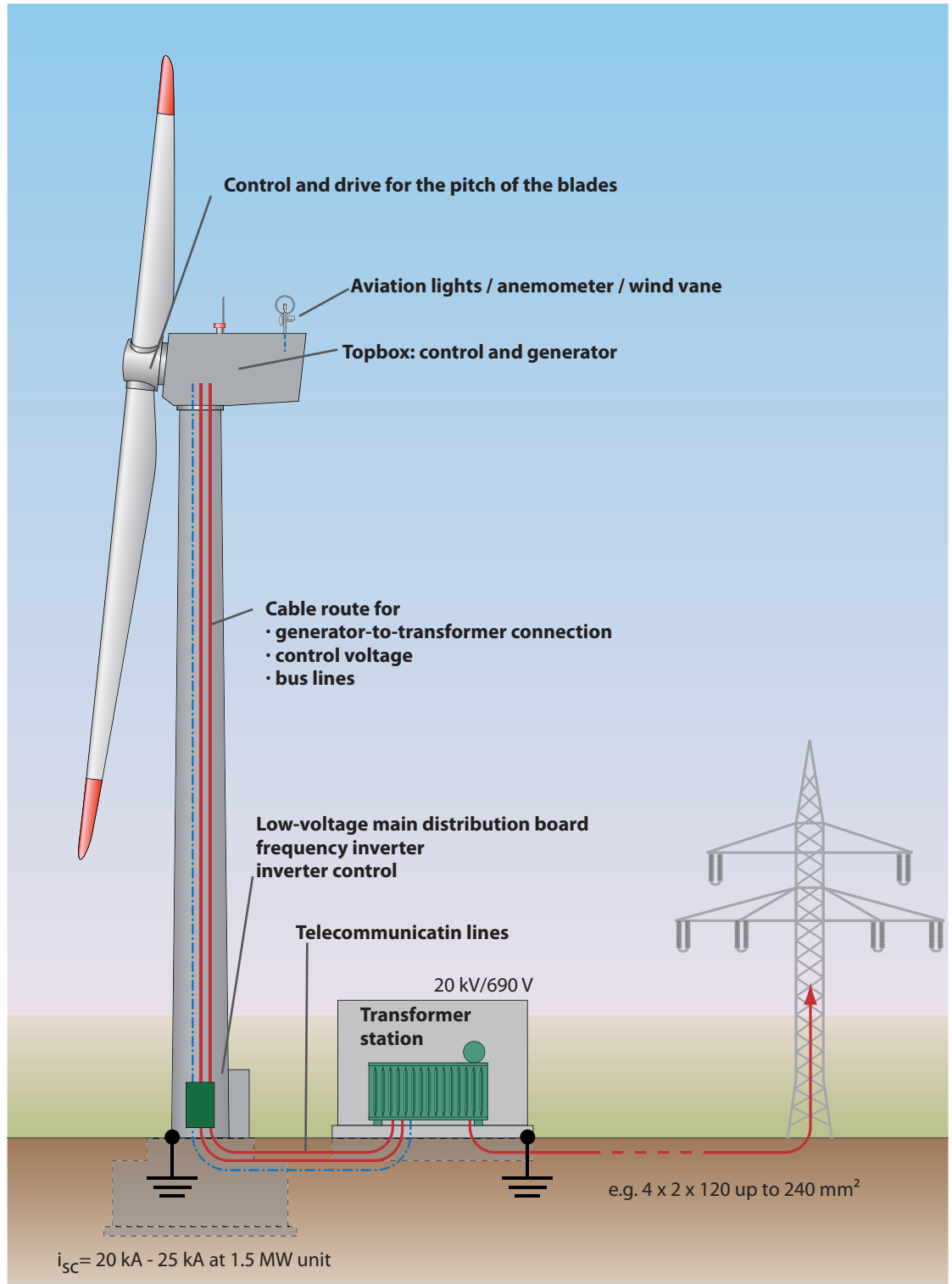


Fig. 2: Components in detail

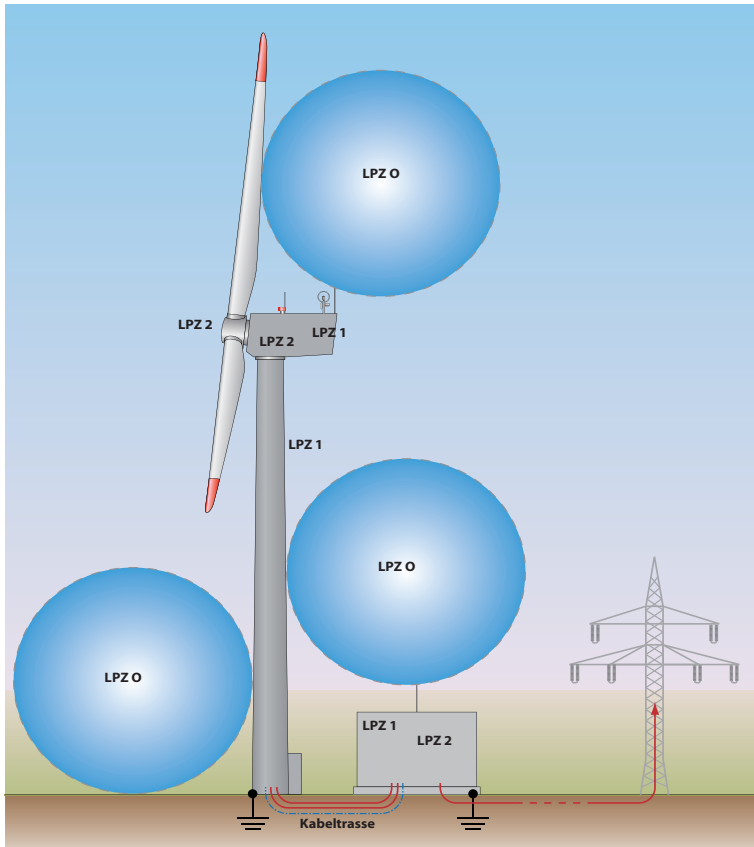


Fig. 3: Lightning Protection Zones (LPZ)

III. Arrangement of Lightning Protection Zones

The arrangement of lightning protection zones (LPZ) is done according to the valid lightning protection standards IEC 62305 and DIN EN 62305 (VDE 0185-305-x) (Fig. 3).

LPZ 1 and 2 can be found inside the transformer station. The transition point from LPZ 0 to LPZ 1 is defined at the transfer point of the 400/690 V power grid to the transformer station.

An LPZ 2 has to be set up if the transformer station houses any control equipment for data communications of performance parameter, error log readout or remote switching of the power suppliers at this site.

If the transformer station is built detached from the wind turbine a transition between LPZ 0 and LPZ 1 has to be set up at the l.v. main distribution board inside the tower base as well.

An LPZ 2 is defined for additional control equipment and all frequency inverters or thyristor starters.

The nacelle itself is divided into the zones LPZ 1 and LPZ 2.

In any case, a zone boundary between LPZ 0 and LPZ 1/LPZ 2 has to be installed for the outside sensors like the anemometer and the aviation lights.

The design of the external lightning protection and the choice of Class I lightning current arresters depends on the lightning protection class of the wind turbine.

According to Germanischer Lloyd*, directives wind turbines with a hub height lower than 60 m are in principle initially classified as lightning protection class III. Hub heights higher than 60 m lead to a classification into the lightning protection class II.

Further criteria may result in a higher classification.

* Germanischer Lloyd (GL)

Besides the classification of ships, the GL group developed further fields of activity and, meanwhile, won a high reputation in these respective sectors. GL is, e.g., worldwide one of the leading certification authorities for wind turbines.

IV. Partitioning of the Expected Lightning Impulse Currents

According to the lightning protection level (LPL) or lightning protection classes 1 to 4 lightning impulse currents between 100 and 200 kA (10/350 μ s) may occur in a wind turbine, especially as direct lightning strikes to the blades.

Lightning impulse currents split up as follows: approximately 50 % flow directly into the earth-termination system and the remaining approximately 50 % disperse through the supply lines.

An equal distribution to the different supply lines is assumed (Fig. 4).

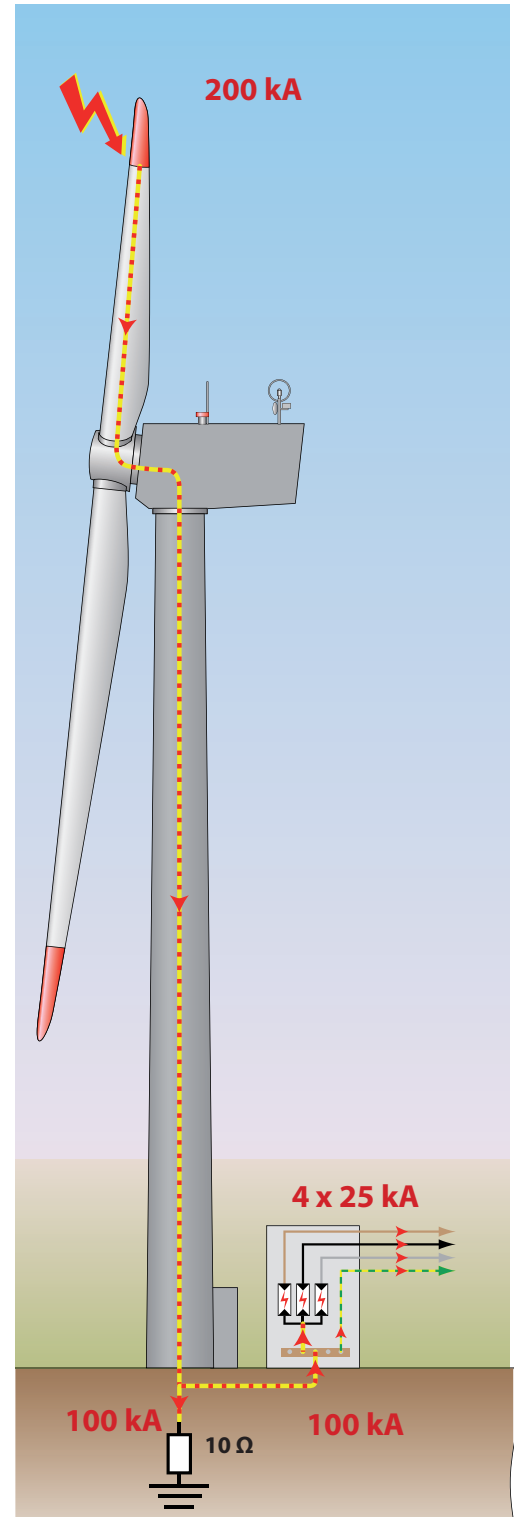


Fig. 4: Partitioning of the lightning current

V. Standards and Directives

- IEC 62305
- IEC 61400-24 Fd.1
- CLT/TS 50539-22:2010 „Low-voltage surge protective devices – Surge protective devices for specific application including d.c. – Part 22: Selection and application principles – Wind turbine applications“ was published in the German version as DIN CLC/TS 50539-22 (VDE 0675-39-22) in October 2010.
- The draft prEN 50539-21 „Low voltage surge protective devices – Surge protective devices for specific application including d.c. – Part 21: Requirements and tests for wind turbine applications“ is still undergoing consultations.

VI. The Protection Concept

Frequency inverters and the thyristor starters with a low withstand voltage are protected against partial lightning currents and transient overvoltages by class I spark gaps at the voltage level of 690 V which is typical for wind turbines.

The generator in an LPZ 1 is protected by class II arresters at the stator and the rotor side.

Leutron surge voltage protectors have to be selected in accordance to the dominating system (TN or TT system) of the wind turbine.

Attention has to be paid to the wind metering equipment as well as to the bus connections of the blade hub and the tower base since these components control the shutdown, the operation and the run up of the turbine.

Therefore, wind metering equipment and bus lines are connected to D1/C2 surge protective devices at the entrance point to the top box. The 24 V control voltage and the heating as well have to be included in the protection concept.

The control equipment inside the hub which has to turn the rotor blades out of the wind in case of too strong winds or a voltage breakdown is situated in an LPZ 2. The protection of drives, emergency-power supply, pitch control and bus system is mandatory.

Furthermore, the aviation lights are a prerequisite for the secure operation of a wind turbine.

The signal light is installed on top of the nacelle in an LPZ 0. The power supply of the control box in an LPZ 2 is protected by class II arresters. In addition, the signal lines for sequence control, intensity and error messages as well as the 24 V control voltage have to be accounted for.

The wind turbines of a wind farm are interconnected to allow for data transmission and parameterisation. These interfaces are connected to surge protective devices too and, newly, galvanically decoupled by radio communication systems.

Fig. 5 presents an overview of all wind turbine components that require protection.

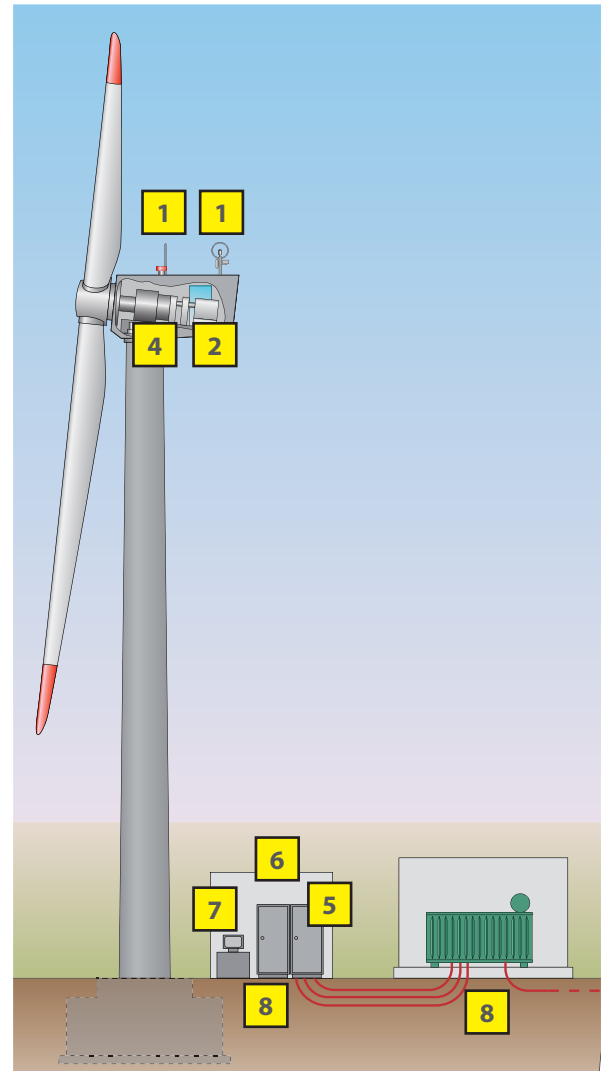


Fig. 5

- 1** Protection of aviation lights and weather sensors
- 2** Protection of 230/400 V power supply for measuring systems and automatic control devices
- 3** Protection of the blade hub (power supply as well as signal and bus lines)
- 4** Protection of the generator, stator and rotor
- 5** Protection of the inverter
- 6** Protection of the switchgear and control cabinet
- 7** Protection of telecommunication systems
- 8** Lightning and surge protection of the main supply

VII. Installation Points of Surge Protection Devices

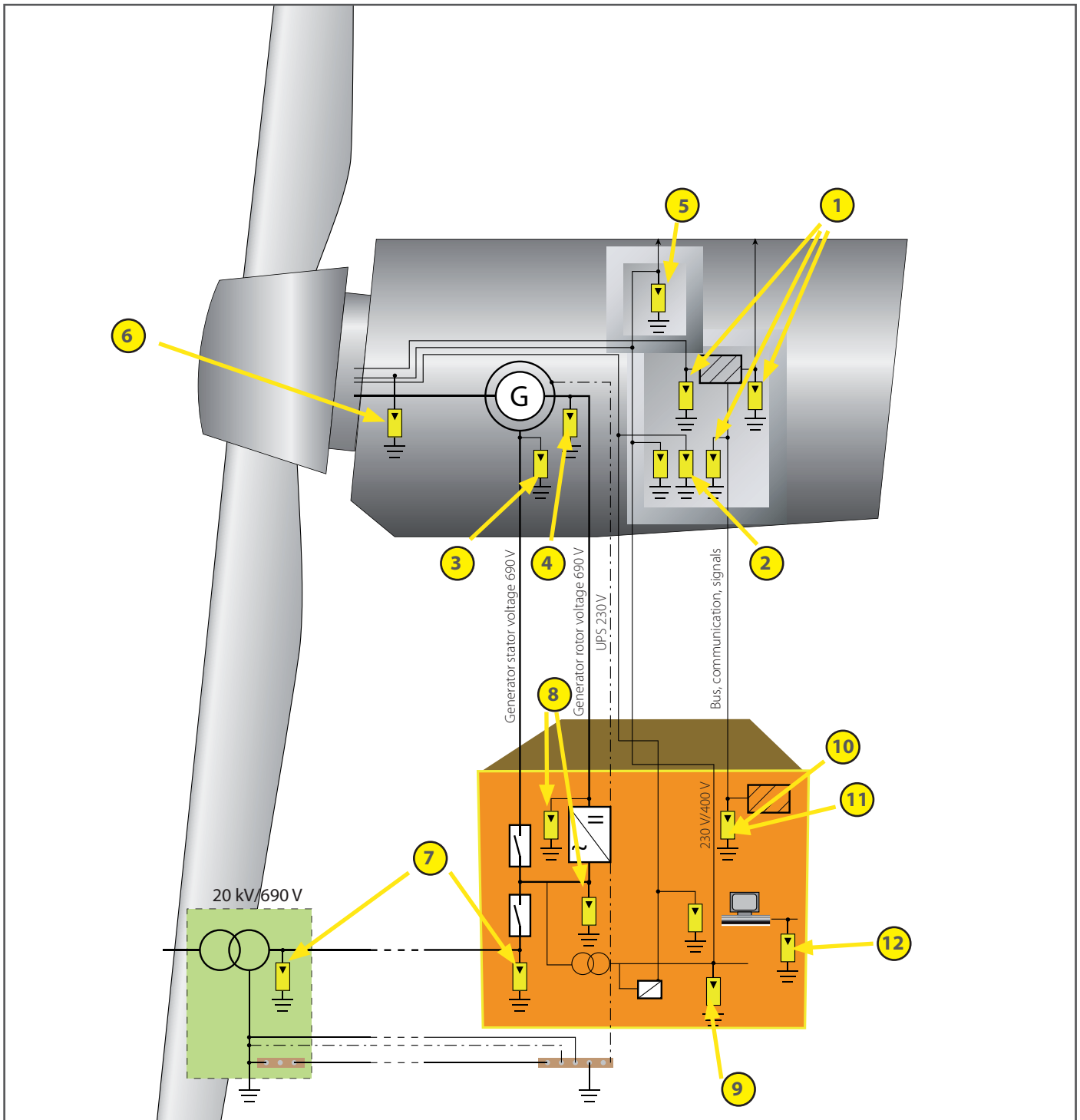


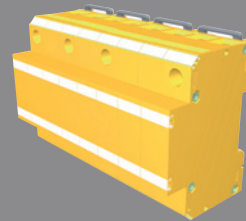
Fig. 6: Installation details and product allocation **1** up to **12** see on next page

| Installation Location | SPD Type | Item Name | Item Number |
|--|----------|--|--|
| 1. e. g. power supply 24 V vane Signal lines (analogue, digital) Bus lines RS 485 | | EP D TN 24V/16A | 38 05 50 |
| | | DP2x1-24V/24V-0.3 Ohm | 26 24 24 |
| | | DP2x1 SDSL-Tr | 24 00 18 |
| | | DP-RS 485-Tr | 37 04 85 |
| 2. Power supply 230/400 V | 2 | EP C ST 275 | 38 12 70 |
| 3. Generator stator side (in 400/690 V TN systems) (in 690 V IT systems) Special solutions, if necessary | 2 | EP C ST 440 | 38 13 00 |
| | 2 | EP WE TNC 750 | 38 17 06 |
| | 1+2 | NAK 600TT-100kA | 37 80 01 |
| | 2 | PP WEA Y 1000 | 37 70 52 |
| 4. Generator rotor side (in 400/690 V TN systems) (in 690 V IT systems) Special solutions, if necessary | 2 | EP C ST 440 | 38 13 00 |
| | 2 | EP EW TNC 750 | 38 17 06 |
| | 1+2 | NAK 600TT-100kA | 37 80 01 |
| | 2 | PP WEA Y 1000 | 37 70 52 |
| 5. Aviation light (corresponding to power supply and signal, respectively, bus lines) | | DPS 2x1 ST series resp. DPS 2x1...HF | 26 10 02 resp. 26 10 04 |
| | 2 | EP C ST 275 DPS 2x1 ST series resp. DPS 2x1...HF | 38 12 70 26 10 02 resp. 26 10 04 |
| 6. Blade hub (power supply 230/400 V) Signal lines, respectively, bus lines | 2 | EP C ST 275 DPS 2x1 ST series resp. DPS 2x1...HF | 38 12 70 26 10 02 resp. 26 10 04 |
| 7. Main supply (400/690 V TN or IT lightning current arrester) | 1 | PP BC TNC 50-400/690 | 37 45 04 |
| 8. Inverter Special solutions, if necessary | 2 | EP C ST 440 | 38 13 00 |
| | 2 | EP WE TNC 750 | 38 17 06 |
| | 1+2 | NAK 600TT-100kA | 37 80 01 |
| | 2 | PP WEA Y 1000 | 37 70 52 |
| 9. Switchgear and control cabinet (power supply 230/400 V) | 2 | EP C ST 275 | 38 12 70 |
| 10. - 11. Control (power supply 24 V) Signal lines, respectively, bus lines | 3 | EP D TN 24V/16A DPS 2x1 ST series | 38 05 50 26 10 02 |
| | 2 | EP C ST 275 DPS 2x1..HF DP RJ45 f/f | 38 12 70 26 10 04 24 00 11 |
| 12. Modem / telecommunications system (power supply 230/400 V) Communication | 2 | EP C ST 275 DPS 2x1..HF DP RJ45 f/f | 38 12 70 26 10 04 24 00 11 |



EP D TN 24V/16A
Art.-No. 38 05 50
 optional remote signalling contact

- 1
- 10
- 11



PP WEA Y 1000
Art.-No. 37 70 52
 optional remote signalling contact

- 3
- 4
- 8



DP2x1-24V/24V-0,30hm
Art.-No. 26 24 24
 fine and coarse protection

- 1



DPS 2x1xST 24V/24V-Tr
Art.-No. 26 10 02
 pluggable lightning and current
 arrester for data signal lines

- 5 11
- 6
- 10



DataPro2x1 SDSL
Art.-No. 24 00 18
 fine and coarse protection

- 1



DPS 2x1xST 24V/24V-Tr HF
Art.-No. 26 10 05
 pluggable lightning and current
 arrester for data signal lines

- 5
- 6
- 12



DP-RS 485-Tr
Art.-No. 27 04 85

- 1



EP EW TNC 750
Art.-No. 38 17 06
 optional remote signalling contact

- 3
- 4
- 8



EPC ST 275
Art.-No. 38 12 70
 optional remote signalling contact

- 2 12
- 6
- 9



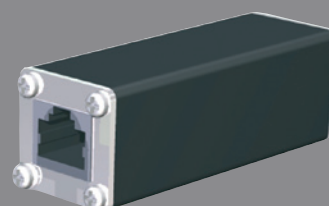
PP BC TNC 50-400/690
Art.-No. 37 45 04
 optional remote signalling contact

- 7



EPC ST 440
Art.-No. 38 13 00
 optional remote signalling contact

- 3
- 4
- 8



DP RJ45 f/f
Art.-No. 24 00 11
 shield grounding

- 12



Leutron GmbH

Lightning and Surge Protection
Humboldtstrasse 30/32
70771 Leinfelden-Echterdingen/ Germany

Tel.: +49 (0) 711 94771-0
Fax: +49 (0) 711 94771-70
www.leutron.de
info@leutron.de