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Offshore Wind Power

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Summary

In the present publication on loss prevention in offshore wind power, the offshore-typical hazards and associated risks are identified, analysed, and assessed, e.g. in comparison to offshore extraction of gas and oil. On this basis we have systematically elaborated measures for fire and machinery protection, in particular for offshore platforms and including the servicing issues and the concept for replacement parts. They complement the existing recommendations by insurers on risk management in the construction of offshore wind farms (VdS 3549) and for fire protection in wind turbines (VdS 3523).

Offshore Wind Power

Content

1 Foreword

With the goal pronounced in politics to foster regenerative sources and carriers of energy as well as to considerably increase their portion in total power supply, offshore wind power (OWP) is becoming more and more important. What distinguishes offshore wind power above all compared to onshore power plants, are the harder and more unsettled conditions of use as well as the far higher investment. And with the requirements for the availability of offshore wind turbines (OWTs) in mind, the GDV [German Insurance Association] felt compelled to develop a new guidance document for loss prevention in the field of OWP in coordination with planners and industry.

This guidance document describes typical causes of loss existing under the particular operating conditions of OWTs, which a systematic analysis of hazards can clearly reveal. This is taken as a basis to recommend measures for loss prevention.

The aim is to minimise the probability of occurrence and/or the extent of the damage to OWTs, e.g. fire loss or machine damage. Regarding fire protection, the required measures can be categorised as follows:

- Reduction of the risks of fire
- Delimitation of the spread of fire and smoke in case of fire
- Ensuring the rescue of persons as required; normally fixed by law / authorities
- Effective fire detection and firefighting

Regarding machine protection, e.g. the following aspects are important offshore:

- Avoidance of unscheduled downtimes by preventive servicing, which should always be timed to the partly limited offshore accessibility of the plants
- Preventive servicing due to the limited accessibility and cost-intensive shipping and helicopter flights, particularly in connection with condition monitoring systems as well as sensors and camera systems for remote monitoring to provide for concerted damage prevention
- Providing for redundancies to maintain the operational availability
- Providing for an emergency power supply to ensure the operational availability and avoid any damage due to downtimes in case of unscheduled interruptions of power supply

The safety-relevant information below is not exhaustive and does not release from compliance with conditions or instructions by authorities.

The present publication is based especially on experiences gained so far with damage occurred to comparable offshore wind turbines and proactive analyses of hazards. We plan an update of this guidance document as soon as fundamental modifications in technology or risk assessment will arise.

Compliance with law requirements and applicable guidelines representing the state of the art in safety engineering is taken for granted.

2 Scope

The present guidance document refers to planning and operation of offshore wind farms, including above all:

- offshore wind turbines (OWTs),
- platforms, and
- their cable systems.

Regarding the hazards, risks, and loss prevention during the construction of offshore wind farms, incl. the corresponding transport of components and equipment, refer to the Code of Practice of the European wind turbine committee (EWTC) and the applicable guidelines.

Generally, this guidance document is intended for the construction of new wind turbines. Existing wind turbines and platforms should be adjusted to the recommendations presented in this guidance document as far as possible.

We explicitly point out that in particular cases the hazards and risks shall be verified for each individual project and object, for instance regarding the installation and operation of battery banks. Therefore, you may require solutions for loss prevention and risk management reaching beyond the requirements laid down in the guidelines.

3 Terms

As defined in the standard by the German Federal Maritime and Hydrographic Agency - the BSH standard - regarding the design of offshore wind turbines (OWTs), offshore wind farms comprise of the following key components:

- wind turbines composed of turbine, nacelle, rotor blades, tower, and base structures, as

well as the corresponding footing structure to provide for statically defined installation into the seabed;
- cable installation between the individual OWT, incl. their junction and connection to the transformer station;
- platforms for
  - AC transformer station,
  - HVDC transmission (AC/DC conversion),
  - living and working station, as well as
  - other stations in the wind farm if required;
- current output systems between OWTs and transformer station, between several transformer stations, and between transformer station and onshore grid connection.

4 Hazards and risks

The recommendations for loss prevention listed in the paragraphs below mainly aim at minimisation of and coping with the typical hazards of OWP as well as the connected risks by taking appropriate measures. This requires consideration not only of the dangers to life but also of the property damage and losses due to business interruptions. These recommendations are based on

- the experiences gained with onshore wind turbines (WTs) and OWTs near the coast,
- the experiences gained with offshore extraction of gas and oil, as well as
- the analysis of hazards and risk assessment developed on experiences and to be adjusted should a project require this.

E.g. the guidance document VdS 3523 presents the experiences gained with onshore WT in a systematic manner along with examples. Experiences gained with OWTs near the coast and with offshore extraction of gas and oil are presented in corresponding guidelines.

Note:

- *Wind turbines, Fire protection guideline (VdS 3523)*
- *International Maritime Organization Code for the Construction and Equipment of mobile Offshore Drilling Units, 2009*

The table below presents an analysis of the fire hazards based on the comparison of the typical areas of use on both, the transformer station in the wind farm and the oil / production platform.

Based on the areas of use listed in Table 1 and the connected risks of outbreak of fire and fire spread, identification and assessment of the fire hazards becomes possible.

Areas of use	Oil / production platforms	Platforms in wind farms
Command centre / control room	Yes	Yes
Liquid separator in the cellar, drill-hole cellar (safety valves), pipeline areas in the bottom cellar.	Yes	No
Transformers	No	Yes
Platform-specific electrical and electrotechnical systems, battery systems	Yes	Yes
Electrical operating rooms		
Large systems, e.g. for energy transfer	No	Yes
■ Switchgears	Yes	Yes
■ Plant rooms (air, water desalination plants)	Yes	Yes
Storage rooms (also those for hazardous substances, wastes if any)	Yes	Yes
Machinery rooms, e.g. diesel-driven generator	Yes	Yes
Workshops	Yes	Yes
Recreation rooms (cabs with bunk, TV rooms, fitness rooms)	Yes	Yes (if manned)
Kitchen / dining zone	Yes	Yes (if manned)
Open deck zone	Yes	Yes
Traffic routes (rescue routes)	Yes	Yes

Table 1: Comparison of the typical areas of use on offshore platforms

This can be used with reference to the respective protection objectives and interests to derive adequate fire protection measures.

Machine protection in wind farms is indispensable to provide for fail-safe operation as the AC transformer station(s) in the wind farm collect(s) and transform(s) the energy generated. These transformer stations shall be the focus of attention. If the AC transformer station fails, power output of the affected wind farm becomes impossible despite of properly functioning OWTs.

Fig. 1 presents a three-floor platform with the floor plans.

To get low losses over larger transmission distances, the power feeds may be rerouted to the level of HVDC transmission.

Should the HVDC transmission station fail, transmission of the power generated in the connected wind farms fails simultaneously. Furthermore, the own power supply in the wind farm in case of an outage shall be covered by a stand-by supply.

This risk appraisal also applies to all cable joints up to the onshore grid connection.

Machine failures can be accidental failures of single machines or serial failures. Table 3 lists the typical causes of loss.

Generally, expenditures in OWP are higher and this among other things due to the offshore-typical ambient conditions. During operation, e.g. accessibility and working conditions are severely limited by the weather conditions. Moreover, we have to reckon with more difficulties during dismounting, re-installation, and clearance work in case of damage.

Use **Fire hazards**		**Oil / production platform**	**Platform in wind farm**
Risks of an outbreak of fire			
■ Lightning		Yes	Yes
■ Deficiencies and faults in the electrical system			
■ General		Yes	Yes
■ Specific		None	Transformers
■ Fire-hazardous tasks		Workshops	Workshops
■ Fire-hazardous equipment		Kitchens	Kitchens
■ Other causes		Uncontrolled leakage of pumping media	No
Risks of fire spread			
Fire loads:	Combustible pumping media	Yes	No
	Stored goods and hazardous substances	Yes	Yes
	Insulating materials	Yes	Yes
Cable ducts, pipes, and ventilation pipes		Structural separation possible to a limited extent only	
Insufficient separation		Yes	Yes

Table 2: Typical fire hazards on offshore platforms

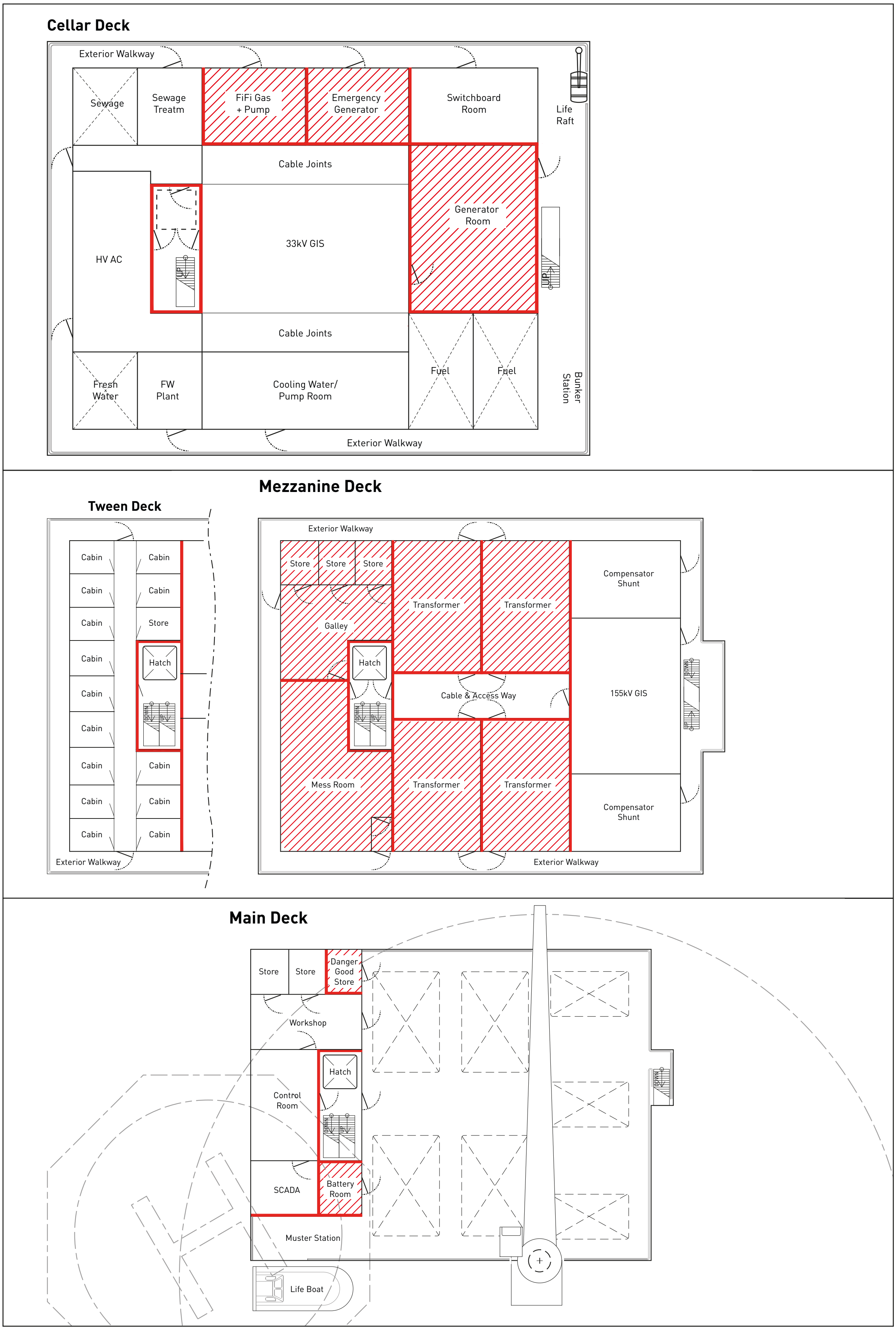

Fig. 1: General layout of a transformer station platform (sketches)

Cause of loss	Damage to or destruction of the following components
Human mistakes: unskilfulness, wilful intent, mistakes in planning, design, material, execution, mounting, operating	All components
Natural hazards: storm, sea state, frost, ice run, earth-/seaquake	All components, especially the rotor blades and rotor bearings, the nacelle
Vibrations	Framework of a platform, footing structure, drivetrain of an OWT
Soil failure	Framework of platforms and OWTs, inclination / turnover
Short circuit, overcurrent, overvoltage	Electrical devices, electrical operating rooms
Failure of measuring, control, or safety instruments	Uncontrollable operation, e.g. failure of fire detection and extinguishing systems on a platform, mechanical consequential loss due to overspeed
Lack of consumables (cooling water, oil, lubricants)	Units to be cooled (e.g. converters, transformers) and movable components (e.g. bearings, gear units, drivetrain of OWTs); outbreak of fire possible
Fire, explosion, fire-hazardous tasks	All components, e.g. bearing with combustible consumables, technical operating rooms, living areas
Lightning stroke and overload due to lightning	Electrical devices, measuring / control / safety instruments, rotor, drivetrain, nacelle, tower in parts
Collision (impact and crash of any type of vehicle)	Frameworks and topside of platforms, OWT towers, as well as helicopter spots and cranes
Forced rupture caused by centrifugal force	Rotor, hub, drivetrain of OWTs
Overpressure or negative pressure	Storage tanks, containments, room closures on platforms
Overload	Bearings, gear units, drivetrain, electrical system
Ocean currents	Footings (scouring), undersea cables (scouring)
Ships riding at anchors	Undersea cables (damaged by anchor)

Table 3: Typical causes of loss and their consequences

5 Protection measures

The substantial requirements for fire and explosion protection as well as machine protection in respect of life safety / environmental protection and property protection call for the development of a comprehensive protection concept for planning and installation of offshore wind farms.

Already the first design shall take into account that fire and machine protection measures will not mutually impair their functions.

To ensure effectiveness and reliability of the fire and machine protection measures for the total proposed operating life of a wind farm, the constructional, technical, and organisational requirements shall be considered already during planning and project engineering. These are e.g.:

- Use of products and systems tested as to their suitability for offshore application and approved correspondingly
- Use of non-combustible components and building materials
- Planning and installation of products and systems in accordance with good engineering practice, e.g. VdS guidelines for planning and installation in the field of fire detection and fire extinguishing technology
- Hiring of companies disposing of appropriate equipment and experts proving sufficient qualification for planning, transportation, and installation
- Acceptance inspection of ready-to-use installed systems and equipment by approved experts
- Regular and proper maintenance and inspection
- Documentation of the fire protection systems as well as of maintenance work and inspections

The individual measures shall be harmonised to prevent any mutual impairment.

Moreover, certification of e.g. systems, measures, and processes could further reduce the risks.

5.1 Fire protection

The operation of offshore wind farms requires fire protection measures to minimise the hazard due to fire of

- anyone staying there (operating personnel and/or third-party personnel, e.g. for servicing),
- the scheduled transmission of power and, consequently, the security of supply,
- expensive buildings and equipment.

During the construction of platforms in the shipyard and on site, fire protection precautions shall also be taken to achieve the aforementioned objectives. Should constructional and technical fire protection measures not be operational during construction, substitute measures to prevent a fire and early fight a fire shall be taken until the other measures will have been taken.

To provide for fire prevention, measures to avoid the outbreak of fire as well as to delimit the fire spread and to effectively fight a fire are required.

5.1.1 Measures to avoid hazards of a fire

Control of operational- and non-operational ignition sources aims at prevention of fire and explosions. Therefore, preventive fire and explosion protection measures shall be observed during planning and design as well as the later operation.

A complete chain of organised fire protection is a condition for guaranteeing planned and installed fire protection standards on a sustained basis.

5.1.1.1 Non-operational igintion sources

Organisational fire protection measures, which provoke anyone staying in the danger zone (operating personnel and third-party personnel) to behave to security and prepare them for a potential fire, are an important contribution to this. Therefore, it makes sense to specify the measures described below in a fire safety regulation, the house rules, or the operating instructions of the windfarm:

- Tidiness and cleanliness

  Tidiness and cleanliness at the workplace are important requisite for safe working. This applies to any single workplace as well as the complete platform; for standard operation and especially during and after installation, maintenance, and repair work.

  During working, the affected areas shall be kept clean as far as work allows. Combustible materials, especially combustible liquids shall be hold available in the working area for maximum the very shift; otherwise they shall be stored in the corresponding storage areas (e.g. material store). Combustible wastes and packaging resulting from and during the work shall be stored in safe manner for a short time and supplied to disposal (see disposal of wastes / non-recyclable waste); any tools and machines, which are not needed, shall be set aside. Fire protection devices, such as fire-resisting closure, fire detection and fire extinguishing systems shall be kept ready-to-use to the extent possible; otherwise, adequate substitute measures shall be taken.

- Ban on smoking and open flames

  A ban on smoking and on handling open flames shall be applicable to the whole area of OWTs and platforms.

  To provide for observance of the ban on smoking, the operating personnel and the third-party personnel should be instructed correspondingly and sanctions should be imposed on any violation of the smoking ban.

  The smoking ban shall be clearly shown already at the entries to the OWT by permanent marking.

  On platforms with recreation rooms it is reasonable to have a smoking area. This should be structurally separated from other areas and be built with non-combustible materials. It shall hold at least one hand fire extinguisher and an automatic fire extinguishing system. Large safety ashtrays to dispose of leftover tobacco etc. shall be installed.

- Provisional heaters shall not be used

  Installation and use of mobile heaters shall be prohibited.

- Waste separation, cleaning rags soiled with oil, grease, and solvent shall be disposed of in closed containers (risk of auto ignition)

  Wastes produced in working areas / hang-out areas / living zones shall be collected once per shift and at least every day and kept in closed containers until they will be transferred off-site. If the containers are placed in closed or roofed areas, these areas shall be equipped with an automatic fire extinguishing system.

  Tobacco residues and other wastes, which could hold embers, shall be collected separately and kept in closed, non-combustible containers. They shall not be mixed with other wastes.

- Fire-hazardous tasks and avoidance of sparking

  Fire-hazardous tasks as a part of repair, mounting, and dismounting work should be avoided. If this is impossible, it ought to be verified whether so-called cold procedures (sawing, screwing, cold bonding) can be used instead.

  If fire-hazardous tasks (welding, flame cutting, cutting off by grinding, soldering, hot bonding, etc.) cannot be avoided, a written procedure to get permission for fire-hazardous tasks shall be passed to prevent the outbreak of fire or to early detect and control a fire. This permission shall document the fire protection measures required before, during, and after such tasks. The operator or a representative shall allow starting the tasks (safety representative, safety officer).

  Fire-hazardous tasks in (stationary) workshops especially built to this end do without this procedure. These areas shall be checked for security and cleanliness prior to starting the work as they could be used not at all for quite a while or to another end.

  It is forbidden to carry out fire-hazardous tasks in explosion endangered areas. First, any explosion risk shall be eliminated totally.

  Fire-hazardous tasks shall be carried out only by employees or third-party personnel proving corresponding qualification and being familiar with these tasks. Moreover, they shall have been instructed on safety and fire protection issues on the platform no longer than 12 months ago.

  A written procedure to get permission should be passed for any accident-prone tasks; this procedure defines the safety measures required before, during, and after such tasks.

  During and after the tasks fire pickets shall be positioned. The adjoining rooms shall be monitored too.

- Admission control

  Entries of the OWT shall be secured so as to make access to technical systems difficult for unauthorised persons.

  Especially, sensitive areas on not permanently manned platforms, such as the control room, the switchgears, etc., shall be locked.

  Any trespass on the platform shall be detected, e.g. by video systems or intruder alarm systems, optionally featuring a system to talk to the unauthorised person(s).

  There may be an open area of free access (rescue platform, sluice chamber, shelter) for anyone in distress on sea, optionally featuring an alarm installation / intercom.

5.1.1.2 Operational igition sources

Components featuring potential ignition sources shall be arranged and operated so that any combustible material cannot be ignited during normal operation or during a malfunction.

Typical operation-depending ignition sources are, e.g.

- Lightning stroke current (lightning / overvoltage protection)
- Faults and defects in the electrical system, electrical installations and appliances, e.g. short circuit and electric arc as well as oscillating circuits.
- Hot surfaces, e.g. heating devices, bearings, brake disks

Hot surfaces shall be covered with non-combustible materials and, moreover, sufficient distance shall be kept.

- Electrical installations and appliances: electric devices, such as distribution devices, transformers, etc., on the platforms shall be separated in a fire-retardant manner from other operating areas. These disconnected areas shall not be used to store combustible materials.

  Electrical installations, e.g. transformers, switchgears, shall be equipped with appropriate protection systems:

- Protection against formation of condensate
- Differential protection
- Earth-leakage protection
- Buchholz relay (only transformer)

Depending on the ambient conditions, it shall be checked whether other protection measures, such as corrosion protection, are required.

The technology used for protection, including all electrical devices as well as measures to detect power system faults and other abnormal operating conditions in OWTs and on the platforms shall be state of the art. The main task of this technology is to selectively detect a fault location as well as to immediately shut down faulty parts of the network or of a single electric device, e.g. transformers, lines, generators. Components of this protection concept are e.g.:

- Residual current protective devices (RCD ≤ 300 mA)
- Accidental arc protection devices (feat. an optical recognition system)

Graduated protection concepts provide for the best fire protection ever; they provide for mutual backup protection through interlocking of the protection systems of adjacent devices. With corresponding configuration, e.g. fire hazards presented by an electric arc in a low-voltage switchgear can be avoided despite of a defective circuit breaker. Appropriate accidental arc protection devices will detect the fault and open the medium-voltage switch on the high-voltage side of the transformer or will activate a device to extinguish the electric arc by generating a short circuit. The protection systems shall provide for immediate shutdown of the OWT in a controlled manner and subsequent all-pole disconnection from power supply on the medium high-voltage side.

Note: See

- *VdS 2025 presenting guidelines for loss prevention in cable and line systems*
- *VdS 2046 presenting safety regulations for electrical installations up to 1000 volt*
- *VdS 2349 dealing with low-interference electrical systems*

An expert shall regularly inspect electrical installations and monitoring systems on site. Generally, a revision inspection of electrical installations acc. to VdS 2871 should take place every two years.

Mobile devices used within the scope of maintenance and repair or by the personnel on living platforms shall be inspected regularly (see DGUV regulation 3).

Note: See

- *Accident prevention regulations for electrical installations and equipment (DGUV regulation 3, formerly BGV A3)*
- *VdS 2871 presenting inspection guidelines acc. to Clause 3602 (the 'fire' clause in fire insurance policies), guidelines for the inspection of electrical installations*
- *DIN EN 50308 (VDE 0127-100) Wind turbines - Protective measures - Requirements for design, operation and maintenance*
- *DIN EN 50110-100 (VDE 0105-100) dealing with the operation of electrical installations*
- *DIN EN 60204-1 (VDE 0113-1) Safety of machinery - Electrical equipment of machines - Part 1: General requirements*
- *DIN EN 61400-3 (VDE 0127-3): Wind turbines - Part 3: Design requirements for offshore wind turbines (IEC 61400-3)*

In addition, thermographic surveys of the electrical installations shall be performed regularly, e.g. in the areas below:

- Conncection areas and - where possible - contacts of the low voltage fuse switches
- Terminal blocks or terminal boards in distribution devices as well as switching and control distributors
- Conncection areas and - where possible - contacts of busbars, contactors, capacitors, etc.
- Conncection areas and surfaces of transformers, converters, and motors
- Power cables or cable bundles
- Surfaces of devices, a dangerous heating of which can be assumed

The thermographic survey shall be performed by a correspondingly approved expert, e.g. a VdS-approved expert of electric thermography.

The interval of thermographic surveys shall be specified on the basis of the inspection results.

Note: See

- *VdS 2858 Thermography in Electrical Installations, a contribute to loss prevention and operational reliability*

- List of VdS-approved experts for electric thermography (electrical thermograph, VdS 2861): http://vds.de/de/zertifizierungen/dienstleistungen/elektrofachkraefte-sachverstaendige/elektrothermografie/verzeichnis/.

  The result of inspections and correction of deficiencies shall be documented in writing, e.g. in the maintenance specifications or a log book.

- Ventilation / air-conditioning systems, heating systems

  Local and mobile heating devices and air-conditioning units shall not be used. Central units and heating / air-conditioning / ventilation appliances shall be installed in independent rooms, which are structurally separated in a fire-retardant manner. To prevent accumulation of fire load, these technical operating rooms shall not be used as storerooms or otherwise (see Cl. 5.1.1).

5.1.1.3 Lightning and overvoltage protection

The necessity of lightning and overvoltage protection measures adapted to comply with EMC for OWTs results from the following:

1. Electric / electronic devices and systems ensure the functionality of an OWT.

2. The German EMC Act lays down special requirements for the interference immunity and electric strength of electric / electronic devices and systems.

Platforms

Platforms shall be equipped with a comprehensive system for lightning and overvoltage protection adjusted to the corresponding type of platform.

Earthing system and equipotential bonding of all metal components serve the life safety and the protection of electric / electronic devices against any damage or destruction due to electrical faults or lightning strike into the platform.

The same as other components of the platforms, the systems for lightning and overvoltage protection shall be designed, installed, and operated in accordance with good engineering practice. To prepare the protection concept, the series of standards DIN EN 62305 along with other standards (DNV GL etc.) shall be used as a basis. Always select the highest possible lightning protection level (lightning protection level I = LPL I).

The earthing resistance for an earthing installation should be ≤ 10 Ω. The earthing system and equipotential bonding should be effected in compliance with contractual requirements and applicable standards as presented by DIN/VDE or EN/IEC.

- DIN VDE 0185-305 and DIN EN 62305 (IEC 62305-3)
- DIN VDE 0100 Part 100
- DIN VDE 0100 Part 410
- DIN VDE 0100 Part 540

Selection of any part used for earthing and equipotential bonding should consider corrosion. These components shall meet maritime requirements and should be made in stainless steel.

Isolated arresters should be preferred to protect electrical and electronic installations on the top deck of the platform (e.g. antenna systems, meteorological stations, etc.). The lightning currents shall be directed into the jacket and, thus, the water or the seabed, e.g. through isolated arresters. Here, the required separation intervals shall be observed.

The foundation piles (jacket piles or monopiles) driven in the seabed serve as basis for earthing. Earthing resistance should be ≤ 10 Ω. The piles shall be connected electrically to the jacket or if monopiles are used, to the transition piece. If jackets are used, each of the three piles should be electrically connected to the jacket. If monopiles are used, three electrical connections should be made between monopile and transition piece, staggered at an angle of 120°.

To provide for equipotential bonding in the platform it is reasonable to define an earthing point in each room proving sufficient connection to the metal framework and providing a potential equalising bar.

All metal structures and components not welded to the steel construction shall be connected electroconductively to the earthing system. DIN EN 62305-3 informs on the cross sections to be used.

DIN EN 62305-3, Table 8 informs on the minimum sizes of conductors designed to connect different potential equalising bars or the latter to the earthing installation. DIN EN 62305-3, Table 9 informs on the minimum sizes of conductors designed to connect the internal metal installation to the potential equalising bar.

Typical connections may be:

- Welded connections
- Screwed connections (for earthing conductors only)
- Riveted connections (for earthing conductors only)

The length of connections should not exceed 350 mm.

OWT

OWTs shall be equipped with a comprehensive system for lightning and overvoltage protection adjusted to the corresponding type of OWT.

The same as other components of the OWT, the systems for lightning and overvoltage protection shall be designed, installed, and operated in accordance with good engineering practice. To prepare the protection concept, the IEC DIN EN 61400-24 (VDE 0127-24) and the series of standards DIN EN 62305 shall be used as a basis.

A risk assessment shall be effected and used as a basis for design of the lightning and overvoltage protection. Generally, the highest possible risk acc. to IEC 62305 (lightning protection level I = LPL I) shall be assumed as long as no risk analysis will have proven a different level.

Planning of the lightning protection system (LPS) of an OWT shall take the risk of lightning strikes and/or potential damage to the OWT into account. Damage by lightning to an unprotected OWT could be damage to rotor blades, to the mechanical components, and to the electrical systems, including the management system. Furthermore, anyone staying in or near an OWT is exposed to the risk of pace and shock-hazard voltage or of explosion and fire resulting from a lightning strike.

Among other things the risk assessment shall reveal and analyse the paths the lightning current may take, e.g. from the rotor blade, through the hub, nacelle, tower, and transition piece, down to the footing. Particularly, the lightning and overvoltage protection shall include the nacelle and the rotor blades as well as any safety-relevant electronic installation or device, incl. cable trays, that is important for the operation of the OWT.

The assignment of the OWT components to lightning protection zones to allow for the corresponding disturbance due to partial lightning currents and switching surges to be expected shall be taken into consideration. Design of the lightning protection components requires definition of the corresponding protection class. Here, a comprehensive lightning protection system for OWTs should provide for at least protection class I. Lightning strikes of low current already pose a particular challenge to OWTs - similar to high towers. Therefore, the rolling sphere method (radius of the sphere 20 m - BSK I) should be used to determine the protection zones of tower, nacelle, hub, and rotors (also in rotation).

5.1.2 Measures to delimit the fire spread (structural fire protection)

From the point of view of fire protection engineering, a use of combustible materials, e.g. expanded plastics, such as PU (polyurethane) or PS (polystyrene), as an insulating material or GFRP (glass-fibre reinforced plastics) for covering and other components shall be avoided as far as possible.

If the use of non-combustible materials is impossible in a particular case, at least "not easily flammable" materials (building material class DIN 4102-B1 or DIN 13501-1 C) shall be used. Moreover, closed-cell materials featuring a washable surface should be used to prevent any soiling, spilled oil, and the like, which would increase the fire danger during operating time.

Should two or more platforms be arranged one next to the other in close proximity (distance < 500 m), e.g. to increase redundancy, not only those potential hazards and risks caused by e.g. a ship impact or anchors shall be considered but also that of a fire spread due to heat radiation and via connecting components, e.g. electric cables and pipes, bridge buildings. Those hazards shall be prevented effectively so as to avoid a loss of two and more platforms at the same time.

Platforms

The structures on the platform shall be made of appropriate steel and regarding the fire protection be protected additionally with non-combustible materials if applicable.

Rooms shall be separated from adjacent areas on the platform by means of walls and ceilings. These components, including the load-bearing or bracing structures as well as the exterior walls shall be fire-retardant (proving a fire resistance capability classified to be min. 30 minutes = A30 acc. to Modo Code, which is comparable to F30 acc. to DIN 4102-2 or REI30 / EI30 acc. to DIN EN 13501-2). Perhaps existing requirements for the structural separation

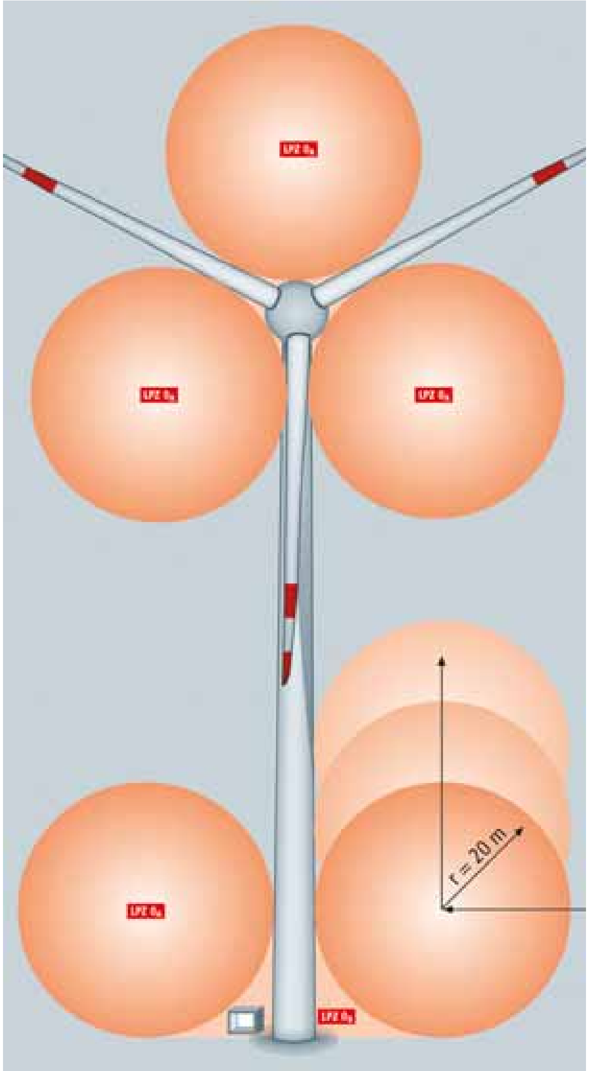

Fig. 2: Rolling sphere (r = 20 m, source: Dehn Company)

from escape and rescue routes, e.g. A60, remain unaffected.

Any operating openings, such as windows, doors, openings for cables and pipes (electrical system, ventilation, pipelines) in room-closing components inside the building (ceilings and walls) shall be at least fire-retardant proving a fire resistance capability classified to be min. 30 minutes = K30 acc. to DIN 4102-2 or EI30 acc. to DIN EN 13501-3).

OWT

The application of combustible material, e.g., foamed plastics such as PUR (polyurethane) or PS (polystyrene) as insulating material or GRP (glass-reinforced plastics) for coverings and other components should preferably be avoided for fire protection reasons.

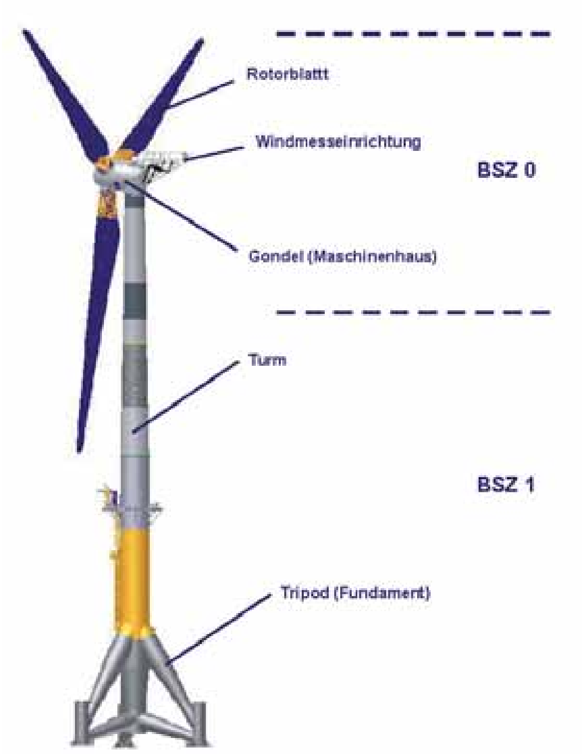

Fig. 3: Lightning protection zones of OWTs (source: Multibrid)

If the application of non-combustible material is impossible in individual cases, the material used should at least be of low flammability (building material class DIN 4102-B1). Moreover, closedcell material with washable surface should be used in order to avoid intrusion of impurities, oil leakage, etc., which otherwise would increase the risk of fire in the course of the operating time.

Note: See VdS 3523 Wind turbines, Fire protection guideline

Cable systems

Outside cable trays shall be separated in a fire-retardant manner (A30) from adjacent areas. As an alternative, you may isolate feed-throughs for cable trays into rooms in a fire retardant manner (K30 or EI30) with systems approved for offshore use.

5.1.3 Measures for effective fire detection and firefighting

The following shall be observed for fire protection systems and devices, e.g. fire detection and fire extinguishing systems:

- Only admitted and approved components shall be used. They shall prove component test and approval corresponding to the conditions of use by a certification body accredited for fire protection. Regarding the conditions of use, there are especially the ambient conditions, e.g. air humidity, corrosive air, max./min. temperatures, and fluctuations in temperature, to be taken into consideration.
- Approved experts shall carry out the acceptance inspection of ready-to-use installed systems and equipment.
- Approved experts shall regularly inspect all systems and equipment; skilled engineers shall carry out the maintenance work. Results of maintenance, inspection, as well as perhaps required repair shall be documented.
- Proper functioning and availability of security and fire protection systems (e.g. fire detection and fire alarm systems, fire extinguishing systems) shall be monitored at a permanently manned location (e.g. permanently manned platform, onshore control room, etc.). Faults shall be detected at once and repair be ordered immediately.

  Until faults will have been repaired, adequate substitute measures shall be taken, e.g. fire pickets or the like. Should this be impossible, the measures defined in the emergency manual shall be taken; this may even be a shutdown of the system.

The following tables inform on the general suitability of fire protection systems for fire detection and firefighting and list examples.

Additional systems and devices for fire detection and firefighting in special areas, e.g. the helicopter deck, may be required.

Fire detection

The publication VdS 3523 informs on the general suitability of FDAS for wind turbines and gives explanations (also see Table 4).

Type of detector / Room / facility	Smoke detector			Heat detector (index "R" acc. to DIN EN 54-5)		Flame detector		Multi-sensor detector	
	Point / Stray light	Multi-point / Suction	Line / Light beam	Point	Line	IR	UV	Smoke and heat	Smoke and CO_2
Offshore wind turbines (OWTs)									
Nacelle with transformer, incl. hub and false floors	-	+	-	-	-	-	-	-	-
Rooms for control cabinets	+	+	+	+	+	-	-	+	+
Tower base / platform with installations if any	-	+	-	+	-	-	-	-	-
Control cabinets	+	+	-	-	-	-	-	+	-
Hydraulic system	-	+	-	+	-	-	-	-	-
Transformer	-	+	-	Buchholz relay		-	-	-	-
Offshore platforms (HVDC transmission, transformer platform, service platform)									
Control centre of transformer station, rooms for control cabinets	+	+	+	+	+	-	-	+	+
Control cabinets	+	+	-	-	-	-	-	+	-
Hydraulic system	-	+	-	+	-	-	-	-	-
Transformer	-	+	-	Buchholz relay		-	-	-	-
Workshop areas	+	+	+	-	-	-	-	-	-
Living and hang-out areas, corridors, staircases	+	+	+	-	-	-	-	-	-
Storage areas	+	+	+	-	-	-	-	-	-
Machinery rooms, e.g. diesel-driven generator	+	+	+	+	+	+	+	+	+
Storage areas for hazardous substances, e.g. combustible liquids	+	+	+	+	+	+	+	+	+

\+ generally suitable
\- rather unsuitable

The information in this table refers to the general suitability of different detector types regarding their way of functioning and general conditions of use in the corresponding area on offshore platforms; it is intended to be a first help and does not replace the required proof of suitability nor the object-specific expert engineering by an expert planner, e.g. a VdS-approved installer. Here, the type-dependent special features of wind turbines, of offshore use and use in fire detection and fire alarm systems as agreed upon with the insurer (e.g. engineering department), VdS Schadenverhütung GmbH, and perhaps the certification body for OWTs shall be taken into account (see VdS 2095 - Automatic Fire Detection and Fire Alarm Systems, Planning and Installation).

Table 4: Information on the selection of fire detectors for monitoring of rooms / facilities

Firefighting

The publication VdS 3523 informs on the general suitability of fire extinguishing systems for wind turbines and gives explanations (also see Table 5).

Extinguishing systems (extinguishing medium) / Room / facility	Gas extinguishing systems		Water extinguishing systems				Other fire extinguishing systems	
	CO_2 (high-pressure)	Chem. and inert exting. gases	Sprinklers	Water spray	Water mist	Foam	Powder	Aerosol[1)]
Room protection, e.g.:								
Nacelle feat. generator, transformer, hydraulic systems, gear unit, brake, azimuth drive	+	+	+	+	+	+	-	-
Hub feat. pitch drive and perhaps generator	+	+	+	+	+	-	-	-
False floors with oil pan and cables and electrical system	+	-	+	+	+	+	-	-
Control centre of transformer station, rooms with switchgears (without transformer)	+	+	-	-	+	-	-	-
Tower base / platform with installations if any	+	+	+	+	+	-	-	-
Living / hang-out areas, corridors and staircases	-	-	+	-	+	-	-	-
Storage areas	-	-	+	-	+	-	-	-
Storage areas for hazardous substances, e.g. combustible liquids	+	+	-	+	+	+	-	-
Workshop areas and other rooms	-	-	+	-	+	-	-	-
Local protection, e.g.:								
Inverter and control cabinets (low- / medium-voltage), closed	+	+	-	-	+	-	-	-
Transformer	+	-	-	+	+	-	-	-
Inverter and control cabinets (low- / medium-voltage), open	+	-	-	-	+	-	-	-
Hydraulic system, open	+	-	+	+	+	+	-	-
Protection of kitchen	-	-	-	-	+	+	-	-

\+ generally suitable
\- rather unsuitable

The information in this table refers to the general suitability of different fire extinguishing systems regarding their way of functioning and general conditions of use in the corresponding area on offshore platforms; it is intended to be a first help and does not replace the required proof of suitability nor the object-specific expert engineering by an expert planner, e.g. a VdS-approved installer. Here, the type-dependent special features, the special features of offshore areas and fire extinguishing systems as agreed upon with the insurer (e.g. engineering department), VdS Schadenverhütung GmbH, and perhaps the certification body for OWTs shall be taken into account (see the VdS guidelines for planning and installation of the corresponding fire extinguishing systems).

1) We have not gained any experience so far regarding the use of aerosol extinguishing systems and their reliability and effectiveness.

Table 5: Information on the selection of fire extinguishing systems for room and local application protection.

5.1.3.1 Fire detection

To effectively fight a fire and repair any consequential loss, all areas / rooms of the OWT (nacelle, tower, and intermediate levels if any) and of the platforms shall be subject to monitoring with automatic fire detection and fire alarm systems. The monitoring shall include false floors and ceiling voids or the like with fire loads, e.g. cables and other lines. Automatic fire detection serve alerting on the spot and starting of evacuation measures where required. In addition, an alarm is sent to a permanently manned location and if required, an automatic switch-off of systems is triggered and extinguishing devices are released.

Cameras (featuring a suitable lens-cleaning function when installed outside) installed in relevant areas are designed to transmit real pictures to the people in the control centre so that they can assess the situation and take additional measures via the control technology if required.

To visualise the situation on the spot in case of a fire / an emergency, video cameras and/or infrared cameras should be installed in especially exposed rooms and areas, corridors, recreation rooms, the helicopter deck, and "evacuation accommodations". The pictures shot during monitoring shall be transmitted to the permanently manned control centre so that the people there can assess the situation and take measures. The extent to which on-line transmission is required permanently or in particular situations, only, depends on the respective security demand and use of functions.

Note: See VdS 2095 Automatic Fire Detection and Fire Alarm Systems, Planning and Installation

Monitoring of the systems in addition to the room monitoring is required for systems that are e.g.

- encased,
- force-ventilated, and
- operated in rooms of an high air exchange rate,

e.g. control and inverter cabinets. The monitoring of systems should also use smoke as fire characteristic. In particular cases, especially if rapid fire development threatens, the use of flame detectors makes sense.

Note: See VdS 2304 Local application protection for electric and electronic equipment - Planning and Installation

The suitability of fire detectors shall be examined for a particular object on the basis of the corresponding conditions of use and by agreement with the system owner (manufacturer). Here, special attention shall be paid to optimum fire detection and restriction of false and deceptive alarms.

Automatic fire detection should release at least the following reactions:

- Alerting of the affected areas as well as the entire offshore turbine (life safety)
- Fire call with reliable alarm transmission to a permanently manned location
- Switch-off of the affected turbine and complete disconnection from the mains
- Release of the local application and room protection extinguishing system in coincidence detection

Alarm systems that allow different alarm thresholds provide the option to start graduated reactions for each alarm threshold, e.g. first alarm, main alarm, etc.

As the turbines are hard to get to, always attention shall be paid when selecting the fire alarm technology to the issue that the servicing required is practicable and can be guaranteed.

5.1.3.2 Firefighting

We do recommend automatic, stationary fire extinguishing systems for offshore turbines to get effective fire protection.

This can be gas extinguishing systems, water mist systems, or foam extinguishing systems. Hang-out areas on platforms can be equipped with sprinkler systems as well.

These fire extinguishing systems can be designed as a local application system, or as a total flooding system, or as a combination of both. Here, a local application system selectively protects the corresponding device or component to be protected.

As the turbines are not within easy reach for the intervention force, it should be considered to provide an equipment protection system to provide for back-up in cases where room protection systems are used.

Before a fire extinguishing system will be released, the air-conditioning or ventilation system should automatically switch off.

In mechanical areas of offshore turbines an extinguishing agent should be used that leaves as little residues as possible, is not corrosive and not electrically conductive, and is suitable for the ambient conditions prevailing at offshore turbines (temperature, weather, tightness of the systems and rooms to be protected) and the fire loads.

For a use in OWTs e.g. the following systems are possible for the different applications:

- CO_2 fire extinguishing systems,
- inert gas extinguishing systems,
- chemical gas extinguishing systems,
- water mist systems,
- water spray systems (transformers and transformer station).

The use of powder and aerosol extinguishing systems or extinguishing systems working with foam proportioning in offshore applications shall be considered carefully as on the one hand it is absolutely required that the fire is extinguished totally and on the other hand the extinguishing medium could lead to consequential loss, e.g. corrosion.

The suitability of automatic fire extinguishing systems for room or local application protection shall be examined for a particular object on the basis of the corresponding conditions of use in an OWT and by agreement with the manufacturer. Especially to be taken into consideration are the following aspects:

- Extinguishing effectiveness
- Required extinguishing concentration or design density
- Exposure time for gas extinguishing systems (take potential reignition into account)
- Operating time for water extinguishing systems (consider effective extinguishing success)
- Tightness of the room / pressure relief
- Stocking up of extinguishing medium (required quantity, weight, ...)
- Volume / space occupied
- Installation, approval inspection, commissioning
- Servicing
- Reliability (ruggedness of the systems in view of their susceptibility to failure to define intervals for maintenance and inspection)
- Consequential loss due to the extinguishing medium
- Costs

Furthermore, we would like to point to the required protection provisions regarding the life safety in case of gas extinguishing systems.

Platforms

Every room on the platform, especially

- technical operating rooms (rooms housing transformers / inverters, switchgears / control technology, emergency power supply / battery, UPS[1]),
- cable ducts, vertical cable ducts, warehouses, helicopter deck, footing structure, etc.,
- Rooms for redundant systems, storage rooms (consumables, spare parts, combustible liquids),
- workshops, and
- living space,

shall be protected by an appropriate automatic fire extinguishing system (room protection) as the structural separation of those rooms proves only limited fire resistance capability (A30).

Moreover, the technical equipment below should be protected by means of an appropriate fire extinguishing system (local application) to minimise the fire hazard:

- transformers and battery systems,
- electrical installations (control cabinets, inverters, cable trays, busbars),
- tanks with combustible liquids,
- open-air systems.

Selection and required storage of the effective extinguishing medium shall be based on the fire load to be extinguished.

If a progressive fire event is to be expected, the object-monitoring system designed to provide for early detection of fire shall automatically trigger a stationary extinguishing system as well.

If there are systems located in the outdoor area which involve an increased fire risk, e.g. transformers, generators, or helicopter spots, they should be included in the scope of protection.

OWT - protection of nacelle

The following equipment in the nacelle shall be protected by fire extinguishing systems:

Fire extinguishing systems - local application protection

- Inverter and control cabinets (low- / medium-voltage)
- Transformer
- Hydraulic system
- Slip ring housing of the generator

1 UPS = uninterruptible power supply

Fire extinguishing systems - room protection

- False floors with oil pan, cables, and electrical system
- Nacelle with generator, transformer
- Hydraulic systems
- Gear unit, brake, azimuth drive
- Hub feat. pitch drive and perhaps generator

The guidelines listed below can be used to assess effectiveness of an extinguishing system. For planning, availability, and reliability the special requirements of an offshore turbine shall be taken into account. This could lead to, e.g. longer hold times, operating times, or redundancies.

Note: See

- *VdS 2093 CO2 Fire Extinguishing Systems, Planning and Installation*
- *VdS 2108 Foam Extinguishing Systems, Planning and Installation*
- *VdS 2109 Water Spray Systems, Planning and Installation*
- *VdS 2304 Local application protection for electric and electronic equipment - Planning and Installation*
-
- *VdS 2380 Fire Extinguishing Systems using non-liquefied Inert Gases, Planning and Installation*
- *VdS 2381 Fire Extinguishing Systems using Halocarbon Gases - Planning and Installation*
- *VdS 2496 VdS Guidelines for the Triggering of Fire Extinguishing Systems, Planning and Installation*
-
- *VdS 3188 VdS Guidelines for Water Mist Sprinkler Systems and Water Mist Extinguishing Systems*
- *VdS 2562 Procedure for the approval of new extinguishing techniques*
- *VdS 4001 Sprinkler Systems, Planning and Installation*

5.1.4 Fire protection organisation

5.1.4.1 Safety officer

It is recommended to appoint a central contact person (a safety officer) responsible for the entire fire protection. You should see to it that the safety officer is correspondingly trained and does further training, e.g. acc. to vdfb Guideline 12/09-01 or European CFPA standard. The safety officer shall coordinate and supervise all issues regarding fire protection on the platform and the OWTs connected to it. The safety officer may be responsible for more than one platform / wind farm, in particular if platforms / wind farms are not permanently manned.

5.1.4.2 Alarm plan and plan to avert risks (emergency plan)

An alarm plan and plan to avert risks (emergency plan) shall be developed as a part of the log book. This shall include instructions for actions intended for employees and third-party personnel for at least the following incidents:

- Fire
- Explosion
- Medical emergency
- Average / ship impact
- Environmental damage
- Outage of normal power supply
- Restart
- Weather risk etc.

Here, you may assign special jobs to designated employees. E.g. contacting a rescue service (onshore), shutdown of turbines, taking measures to fight the risk, etc.

The emergency plan shall be subject to revision every 6 months at the latest. When required (e.g. after an incident), it shall be updated.

- Security instruction / fire prevention instruction (to be adapted)

  The operating personnel and the personnel hired from third parties (if any) shall be instructed regularly in the fire hazards in the OWT, e.g.

  - how to prevent a fire hazard;
  - how installed fire protection systems and equipment do work and how to operate them;
  - how to behave properly in case of fire, e.g. giving alarm to providers of assistance;
  - how to handle properly a fire extinguisher.

  We do recommend regular fire drills, e.g. test alarm, implementation of the emergency plan, evacuation of the nacelle. Personnel of an external rescue service should also take part.

  The operating personnel and any personnel perhaps hired from third parties working at or on the platform shall be instructed in security every 6 months at the latest. This instruction shall cover at least:

  - how to behave safely on the platform;

- the ban on smoking and on handling open flames;
- special risks of accident and fire hazards;
- procedure to get permission for fire-hazardous tasks;
- emergency calls, meaning of alarm signals (sirens etc.);
- how to behave after an accident, first-aid facilities;
- how to behave in case of fire, fire extinguishing facilities;
- how to behave in special weather conditions;
- assembly points, evacuation of the platform/ leaving it.

The instruction shall be documented with name and kept for min. 3 years.

Visitors on the platform shall get a short briefing.

- Instruction on fire protection issues, fire drills

  The operating personnel and any personnel perhaps hired from third parties staying on the platform regularly or occasionally shall be instructed in the tasks of the fire safety team every 12 months at the latest. Apart from theory they shall practice fire extinguishing using fire extinguishing equipment, such as available on the platform (e.g. portable and travelling fire extinguishers, wall hydrants). E.g. fire extinguishers designed as training equipment or a building / plant for hot fire drills of fire brigades suit this purpose. Furthermore, the functioning of as well as the options of manually triggering stationary fire extinguishing systems on the platform shall be known.

  The instruction shall be documented with name and kept for min. 3 years.

  It is recommended to carry out one fire drill per month on the platform (test alarm). This trains correct behaviour of the operating personnel and any personnel perhaps hired from third parties in the case of fire. Among other things this includes correct interpretation of alarm signals, correct execution of particular activities, use of fire extinguishing equipment, going to the assembly point, and so on.

- Redundancies / monitoring of security-relevant functions and plausibility

  Proper functioning and availability of security and fire protection systems (e.g. fire detection and fire alarm systems, fire extinguishing systems) shall be monitored at a permanently manned location (e.g. permanently manned platform, onshore control room, etc.) Faults shall be detected at once and repair be ordered immediately.

  Until faults will have been repaired, adequate substitute measures shall be taken, e.g. fire pickets or the like. Should this be impossible, the measures defined in the emergency manual shall be taken; this may even be a shutdown of the system.

5.1.4.3 Fire extinguishers

In order to fight initial fires, appropriate and functional fire extinguishers in sufficient number have to be ready. These should be available at appropriate and easily accessible locations in the OWTs and on the platforms.

The extinguishing medium shall be adjusted to the fire load there. As extinguishing powder adversely affects electric and electronic equipment, you should do without powder fire extinguishers.

5.1.4.4 Reduction of damage

After a fire, the fire gases shall be drawn off through existing openings using perhaps mobile fans and directly out of the fire room wherever possible.

5.2 Machine protection

Machine protection aims at safely functioning and trouble free operation of the entire plant technology. Fundamental components of machine protection can be, especially:

- Plant technology and structural design adjusted to the specific ambient conditions on the spot (e.g. scour protection, air conditioning, etc.)
- Use of offshore-proven technology
- Construction and assembly by experienced manufacturers and installers
- Well-tried offshore logistics to assure reliable transportation of people and material
- Efficient and reliable servicing

Note: See publication by GDV [German Insurance Association] "Renewable energies; Overall survey of Engineering Insurers within the German Insurance Association (GDV) on the level of technologi-

cal development and the technical hazard potential" as of April 2013.

Unless indicated otherwise you will find in the following clauses a summary of information applying to both, the offshore platforms and the OWTs. In addition to this, OWT-specific information is given separately.

5.2.1 Stability and resistance

5.2.1.1 Corrosion protection

The following measures are recommended to be taken to protect against corrosion above water level:

- Yearly inspection acc. to the manufacturer's specifications and - if applicable - acc. to the IMS manual (integrated management system) to be prepared
- Inspection acc. to DIN EN ISO 12944, which could include
  - a visual inspection
  - an inspection using appropriate holiday detectors
  - should any damage be detected, the strength of the coating is examined, e.g. bond strength measurement (pull testing) acc. to DIN EN ISO 4624

Note: Also see

- *DIN EN ISO 12944 Paints and varnishes - Corrosion protection of steel structures by protective paint systems*
- *DIN EN ISO 4624: Paints and varnishes - Pull-off test for adhesion (ISO 4624:2002)*

Corrosion protection under water level shall be effected by an active corrosion protection (cathodic protection). Sacrificial anodes shall not be used.

- Verification of the effectiveness of the cathodic protection by means of
  - reference cells / electrodes of the off-site power for permanent monitoring. Taking an off-potential reading every 8 h has proven to be effective. The measured values of the reference cells / electrodes shall be stored and subject to monthly analyses;
  - measurements, e.g. ROV (remotely operated vehicle) as part of the yearly inspection.
- The passive corrosion protection under water level shall be applied so as to get a diffusion-controlled oxygen corrosion due to a reduction of oxygen just to the point where the material steel corrodes slowly or not at all.

5.2.1.2 Protection against scouring

Ocean currents can cause scouring of the footing structures. In the worst case, this adversely affects the stability.

If dimensioning already allows for the calculated scouring, you can do without additional scour protection.

Otherwise scour protections, such as

- riprap,
- geotextile sand containers

shall be installed to compensate scouring.

If the revision inspection reveals inadmissible scouring, appropriate scour protection shall be installed later to re-establish the calculated load-bearing capacity.

5.2.1.3 Protection against natural hazard

Storm, waves, and ice

Depending on the wind farm location, there is the risk of damage to the footing and bearing structures by storm, waves, ice (e.g. ice run, ice sheets, and compressed ice sheets). OWTs involve the additional risk that the functioning of rotor blades is impaired by storm and icing. This applies to e.g. locations in the Baltic Sea. Therefore, the structures shall be designed in compliance with applicable regulations and standards and protected where required, e.g. by bollard for ice protection.

Note: See publication by GDV [German Insurance Association] "Renewable energies; Overall survey of Engineering Insurers within the German Insurance Association (GDV) on the level of technological development and the technical hazard potential" as of April 2013.

In addition the OWT shall be designed so that either no icing can occur or this will not impair the functionality of components. Here, especially the functionality of the helicopter deck, the ventilating flaps, the pressure relief, the passageways, the bearing structures shall be guaranteed.

Invasion of animals (sea birds, insects, etc.) and penetration of other foreign bodies

All openings of the platform, such as doors, windows, maintenance doors, openings for ventilation and air conditioning, shall be protected by grids, filters, and closing mechanisms so that any invasion of animals (even of insects) and penetration of foreign bodies is prevented to the greatest extent possible.

Any soiling by animals shall be prevented to the greatest extent possible, too, e.g. by reducing the areas where birds can land / nest to a minimum.

Fouling above and/or under sea level

The design and servicing shall allow for fouling caused by the sea water and in compliance with applicable standards and regulations.

Fouling of structures above and under sea level is part of observation / monitoring carried out by divers or by means of ROVs.

Any fouling detected on the occasion of maintenance and inspection shall be removed where required because this can impose additional load on the corresponding structure.

Note: See publication by GDV [German Insurance Association] "Renewable energies; Overall survey of Engineering Insurers within the German Insurance Association (GDV) on the level of technological development and the technical hazard potential" as of April 2013.

The cable inlets on the bottom side of the platform, e.g. the J-tubes, shall be checked for any fouling to remove this where required.

5.2.1.4 Protection against theft and vandalism

Protection against theft and vandalism shall be designed so as to meet the requirements of the individual risk analysis and assessment. Admission control is always required (see Cl. 5.1.1.1).

5.2.2 Ensuring availability, operational safety

Cable systems

Cable systems and other electrical installations shall be planned, installed, and operated in accordance with good engineering practice, e.g. DIN VDE standards, recommendations by ICPC on cable crossings. Accordingly they shall be equipped with overvoltage protective devices and overvoltage arresters.

Servicing and observations / monitoring shall also cover the cable systems because experience has shown that they could be damaged during mounting and repair.

To prevent any damage to cable systems, the measures below shall be taken:

- Specify cable protection zones already before starting any construction work (zones covering the cable tray itself and an area around to be defined). Except for the cable laying vessel (CLV), no other ship should anchor, jack up (e.g. jack-up barges), and/or work in cable protection zones!
- Specify locations where ships can anchor and jack up to carry out assembly work on OWTs and platforms prior to starting any work. Such locations shall be selected so that no cable protection zone is touched wherever possible!
- Provide for a complete recording of foot prints (e.g. made by jack-up barges).
- Permanently and promptly record and document foot prints and locations of cables. All cable positions and foot prints shall be on hand (x, y, z-coordinates). Any changes shall be immediately documented on the spot.
- Foot prints shall be made available to any party involved.
- Carry out cable inspections after mounting work and close to the moment of putting a cable into operation (incl. first electrification) or when resuming its operation.
- Take the reading of partial discharge as an electric finger print of the cables in the wind farm to determine the actual condition of the cable.
- Analyse the condition of the cables in the wind farm, e.g. partial discharge and dissipation factor after approx. 5 years of operation (compare this to the finger print of the cable systems recorded when having put the cable system into operation).
- Lay the cables in closed loops.
- Include the cable inlets, e.g. cable J-tubes, in the yearly inspection.
- Protect against scouring, offset, and mechanical damage by regularly inspecting the covering and the scouring (especially in the area of cable entries into OWTs and platforms). Moreover, this is intended to early reveal sagging of the cable!
- Permanently monitor (online monitoring of the condition) the most important parameters of the cables (voltage, current, power, temperature, etc.) during operation.

Note: See publication by GDV [German Insurance Association] "Renewable energies; Overall survey of Engineering Insurers within the German Insurance Association (GDV) on the level of technological development and the technical hazard potential" as of April 2013.

5.2.2.1 Operational safety, emergency operation, emergency power supply

There are planned and unplanned failures of export and import cables. Therefore, an emergency power supply is required to maintain fundamental functions of an OWT and the control room.

Platforms

Emergency operation of the platform shall be ensured by:

- Stand-by power plants and UPS / stand-by generators to ensure all fundamental functions during emergency operation.
- For the case that a stand-by power plant fails, an USP ensuring at least 18 h of emergency operation and/or a second stand-by generator to maintain all safety functions during emergency operation shall be provided.
- If the stand-by power plant is located on the platform, the following operating supplies shall be stored - depending on the supply ship available:
  - One DP vessel designed for a wave height up to Hmax = 2.5 m is available and the corresponding construction site provides for an access probability based on weather conditions of at least 65 % per month (approx. 20 days acc. to weather service).
    - Operating supplies for at least two weeks with a connection of the emergency lubrication of rotor bearings, the heating system for control cabinets, etc. in clusters if applicable. Daily check and entry into the log book of the filling heights of the systems with operating supplies.
  - No DP vessel is available. Access for wave height up to Hmax < 1.0 m possible.
    - Operating supplies for at least 90 days with a connection of the emergency lubrication of rotor bearings, the heating system for control cabinets, etc. in clusters if applicable. Daily check and entry into the log book of the filling heights of the systems with operating supplies.

Functions of the following components shall be guaranteed during emergency operation:

- Communication technology: access to wind farm per remote-control link. This is required to carry out remote switching.
- Fire protection systems: fire detection and fire extinguishing system
- Medium-voltage switchgear to carry out remote switching
- Marine light: standard operation of marine lights

OWT

Emergency operation of each OWT shall be ensured in addition to the emergency operation of the platform:

- Appropriate storage medium, e.g. UPS in each OWT for at least 30 min. You shall strive for 60 min. After this time, it shall be automatically possible to remotely connect to carry out switching via the platform.

Storage at the OWT of fuels for emergency operation shall be designed so as to meet the requirements for platforms.

Functions of the following components of the OWT shall be guaranteed during emergency operation:

- Communication technology: access to OWT per remote-control link. This is required to carry out remote switching.
- Fire detection and fire alarm system: fire detection and fire extinguishing system
- Emergency lubrication of the rotor bearings to protect the main bearing
- Condensation heating systems on electronic or electrotechnical components to prevent short circuits
- Feathering
- Marine light: standard operation of marine lights

5.2.2.2 Diversification and redundant systems

Technical faults, defects, or damage to systems can never be excluded. Should important systems, such as transformers or switchgears, fail, the entire wind farm comes to a standstill. Therefore, it is important to strive for partial or complete redundancy in important systems.

The output of bottleneck machines and components shall be distributed to independently working partial systems (diversification of risk).

The systems below shall be available redundantly:

- Communication systems
- Transformers
- Reactive current capacitors
- High-voltage switchgear
- Control technology, computers and peripheral devices (redundancies in rooms that are disconnected in view of fire protection)
- Air-conditioning and ventilating system, maritime air desalination plant
- Reverse osmosis plant

In OWTs, the systems below shall be available redundantly:

- Energy storage of blade driving systems (normally pitch drive)
- Hydraulic or pneumatic systems, pressure reservoirs
- Wind gauges (wind speed, direction)
- Air-conditioning systems (heating and cooling) shall be designed redundantly.

Other specifications for redundancy should be based on analyses of availability.

5.2.2.3 Fail-safe principle

The fail-safe mode aims at avoidance of damage to the systems if control signals get lost or power fails. The systems shall be brought into safe condition. They remain in this safe condition so as to continue proper operation when the malfunction will have been cleared.

The fail-safe mode causes e.g. switchgears to get into defined switching positions (normally an open contact).

At least the systems below of offshore platforms and OWTs shall provide a fail-safe mode:

- Heating / ventilation / air-conditioning (preventing from an input of maritime air and formation of condensed moisture and the corrosion etc. caused by this)
- Reactive current capacitors
- Transformers
  - AC transformer stations
  - distribution transformers
  - HVDC transmission transformer stations
- Switchgears
- Rectifier units
- Control systems (in case of power failures UPS / emergency power supply)
- Emergency generators
- Generation of fresh water (e.b. by reverse osmosis)

At least the systems below of OWTs shall provide a fail-safe mode:

- Rotor blades (feathering)
- Azimuth drive (nacelle aligned in wind direction)
- Air-conditioning, ventilation, maritime air desalination plant
- Security system acc. to DIN EN ISO 13849
- Switchgears

Information see DIN EN ISO 13849: Safety of machinery - Safety-related parts of control systems

5.2.2.4 Facility monitoring

Monitoring as defined in the present publication comprises of both, automatic and manual monitoring of the conditions of systems and components.

Meteorological and hydrological effects can impair the stability of structures. Therefore, they shall be detected automatically and included in the alarm messages of the wind farm.

Measurement and control values required to maintain operation shall be transmitted reliably in REAL time and on-line to a permanently manned control room (24/7/365) to be able to take immediate countermeasures when required. Countermeasures are, e.g. reducing the output or antedating of maintenance work.

In addition to collecting the data of single control systems, a central and continuous data logging and documentation of the operating values shall be implemented. The systems, which can be used to this end, are SCADA (supervisory control and data acquisition) and CMS (condition monitoring systems). These monitoring systems allow early detection of any deviations from setpoints.

Monitoring systems shall be tested regarding their suitability for offshore application and prove corresponding certification.

Note: See publication by GDV [German Insurance Association] "Renewable energies; Overall survey of Engineering Insurers within the German Insurance Association (GDV) on the level of technological development and the technical hazard potential" as of April 2013.

The time intervals for data logging shall be defined so that retroactive analyses of the trends of system conditions, changes, and deviations are possible.

Only accordingly trained and experienced persons are able to interpret the data correctly.

Preferably, such records shall be kept for the entire service life of components, in any case at least 5 years.

The following components of a platform should be subject to monitoring:

- Transformers
- Reactive current capacitors
- Cable systems
- Other systems depending on the rating of the platform, such as
  - air-conditioning and ventilating system, maritime air desalination plant,
  - corrosion protection system (cathodic),
  - pumps
- Corrosion protection

At least the systems listed below shall be subject to monitoring. At least the corresponding characteristics shall be recorded in the condition monitoring.

- Transformers:
  - electrical characteristics (voltages, currents, etc.),
  - pressure, temperatures, vibrations,
  - on-line gas-in-oil
- Reactive current capacitors:
  - electrical characteristics (voltages, currents, etc.),
  - pressure, temperatures,
  - on-line gas-in-oil
- Cable systems:
  - electrical characteristics (voltages, currents, etc.),
  - temperatures
- Pumps / pump drives:
  - delivery rates,
  - electrical characteristics (voltages, currents, etc.),
  - temperatures, vibrations

At least the following operating values of OWTs shall be subject to monitoring:

- Vibrations
- Oil temperatures
- Pressures
- Particles
- Gap dimension (gearless OWT)
- Corrosion protection

Camera systems should be used in parallel with fire protection for monitoring of the machine technology. This way you will get a real and prompt view of the situation on site.

Note: The significance of camera monitoring is even more important for offshore platforms without personnel. This is another source of information about the situation on site.

5.2.3 Servicing and spare parts concept

Servicing (maintenance, inspection, and repair) of offshore platforms and OWTs shall cover all components of a wind farm.

5.2.3.1 Servicing

Servicing shall include, especially

- the mechanical design, incl. the footing structures;
- the cables in the wind farm and the export cables as well as corresponding protection measures;
- all fire protection systems and equipment.

The maintenance and repair strategy should be preventive. This is imperative for the following components as they could cause bottlenecks:

- Transformers
- Switchgears
- Reactive current capacitors
- Stand-by power plants (emergency generators)

Already prior to the construction and before starting operation, the maintenance and repair schedules shall be developed and implemented in cooperation with the manufacturers. This way servicing becomes fully effective from installation onward. This shall take into account revision inspections to be carried out in a reliable manner.

Consideration of a limited accessibility of the wind turbines is of high importance. This shall already be allowed for in the planning stage and for maintenance and repair.

Access to the platforms at all times except for extreme weather events shall be ensured by boat landing or a second access system and a helicopter deck.

Experienced personnel proving the required expert qualification shall carry out servicing.

Quality assurance is indispensable in all operating areas to ensure good and professional execution of any work and process.

Maintenance and repair work shall be carried out as defined and recommended by the manufacturer. Subsequently, they shall be checked and accepted.

Any required inspections shall be carried out by experts. The deadlines of inspections shall be observed. If the experience gained so far is insufficient, the revision inspections shall be carried out more often.

For heavy lifting and heavy transport (e.g. of the rotor blades), process descriptions shall be prepared, which appropriate certification companies shall certify. An appropriate expert shall monitor the execution (MWS: Marine Warranty Survey).

The servicing records shall include at least:

- All measures
- Lifetime records of the systems and components
- All plans, e.g. circuit diagrams, plans of the hydraulic systems, drawings

The records shall provide for traceability and always be up-to-date.

5.2.3.2 Spare parts concept

The manufacturer's specifications and the availability analysis are used as the basis for stockkeeping of spare parts (which spare parts and how many). If not already provided for, the spare parts for the components below shall be kept in stock:

- Standard wear and tear parts, such as bearings, hydraulic valves, electric drives, pumps, cables, conduits, fixtures, etc.
- Pitch and azimuth drives
- IGBTs (power thyristors)
- Rotor stars, completely equipped nacelles which have passed the acceptance inspection as to functioning
- Batteries and components of UPS

Components and spare parts shall correspond at least to the manufacturer's specifications.

The location(s) where spare parts are stored - offshore or onshore - shall be defined on the basis of the servicing and logistics concept. The following criteria are of particular importance for stockkeeping of spare parts:

- Delivery times of components
- Distance from next harbour
- Platform accessibility:
  - North Sea: accessibility despite critical wave heights
  - Baltic Sea: accessibility despite icing
- Possibility to deliver heavy spare parts:
  - with special vessel
  - required crane capacity
  - accessibility into the platform
- Availability of experts proving corresponding offshore aptitude and of special tools.

5.3 Transportation during operation

Transportation is a decisive factor to provide for a reliable operation of wind farms.

Allowing for the limited accessibility due to environmental conditions, transports of operating and servicing personnel as well as material to the wind turbines and platforms shall be ensured to provide for reliable operation.

Already at the beginning of installation, a functioning concept how to realise supply to the site shall exist. This concept shall be adapted as required for later operation. Design and availability of ships, crew transfer vessels, personnel transfer vessels, helicopters determine the access to the wind farm. DP vessels shall be preferred and may augment access times.

The following documents shall be prepared in advance for all standard transports:

- Operating instructions,
- procedure instructions, and
- risk assessments.

All transports that are not described in a standard document, require a separate transportation concept to be developed and certified.

The process description of heavy lifting shall be observed (see Cl. 5.2.3.1).

6 Literature

6.1 Laws and Ordinances

EMVG - the German Law on electromagnetic compatibility of electrical equipment

6.2 Regulations, rules, and information by the statutory accident insurance institutions (DGUV)

German Social Accident Insurance – Accident prevention regulations for electrical installations and equipment (DGUV regulation 3, formerly BGV A3)

http://www.dguv.de/dguv/de/

6.3 Technical rules and regulations

DIN VDE 0100 (VDE 0100) – Low-voltage electrical installations
- Part 100: Fundamental principles, assessment of general characteristics, definitions (IEC 60364-1, modified);
- Part 4-41: Protection for safety - Protection against electric shock (IEC 60364-4-41, modified)
- Part 5-54: Selection and erection of electrical equipment - Earthing arrangements and protective conductors (IEC 60364-5-54)

DIN EN 62305 (VDE 0185-305) – Protection against lightning (IEC 62305-3)

DIN EN 50308 (VDE 0127-100) - Wind turbines - Protective measures - Requirements for design, operation and maintenance

DIN EN 50110-100 (VDE 0105-100) – Operation of electrical installations

DIN EN 60204-1 (VDE 0113-1) - Safety of machinery - Electrical equipment of machines
- Part 1: General requirements

DIN EN 61400-3 (VDE 0127-3) - Wind turbines
- Part 3: Design requirements for offshore wind turbines (IEC 61400-3)

DIN EN 62305 (VDE 0185-305) – Protection against lightning

DIN EN ISO 4624 - Paints and varnishes - Pull-off test for adhesion

DIN EN ISO 12944 - Paints and varnishes - Corrosion protection of steel structures by protective paint systems

DIN EN ISO 13849 - Safety of machinery - Safety-related parts of control systems

IEC DIN EN 61400-24 (VDE 0127-24) – Wind turbines
- Part 24: Lightning protection

Beuth Verlag, Berlin, www.beuth.de

International Maritime Organization – Code for the Construction and Equipment of mobile Offshore Drilling Units, 2009

www.imo.org

6.4 Publications by the German Insurers on the issue of loss prevention

Gesamtverband der Deutschen Versicherungswirtschaft e. V.: Renewable energies; Overall survey of Engineering Insurers within the German Insurance Association (GDV) on the level of technological development and the technical hazard potential as of April 2013,

www.gdv.de

VdS 2025 presenting guidelines for loss prevention in cable and line systems

VdS 2046 presenting safety regulations for electrical installations up to 1000 volt

VdS 2349 dealing with low-interference electrical systems

VdS 3523 - Wind turbines, Fire protection guideline

6.5 Publications by VdS Schadenverhütung GmbH (VdS)

VdS 2093 - CO_2 Fire Extinguishing Systems, Planning and Installation

VdS 2095 - Automatic Fire Detection and Fire Alarm Systems, Planning and Installation

VdS 2108 - Foam Extinguishing Systems, Planning and Installation

VdS 2109 - Water Spray Systems, Planning and Installation

VdS 2304 - Local application protection for electric and electronic equipment - Planning and Installation

VdS 2380 - Fire Extinguishing Systems using non-liquefied Inert Gases, Planning and Installation

VdS 2381 - Fire Extinguishing Systems using Halocarbon Gases - Planning and Installation

VdS 2496 Triggering of Fire Extinguishing Systems, Guidelines

VdS 2562 - Procedure for the approval of new extinguishing techniques

VdS 2858 - Thermography in Electrical Installations

List of VdS-approved experts for electric thermography (electrical thermograph, VdS 2861): http://vds.de/de/zertifizierungen/dienstleistungen/elektrofachkraefte-sachverstaendige/elektrothermografie/verzeichnis/

VdS 2871 - presenting inspection guidelines acc. to Clause 3602 (the 'fire' clause in fire insurance policies), guidelines for the inspection of electrical installations

VdS 3111 - dealing with safety officers (the company specialist for fire protection); this is a guidance document that has no binding force and describes the tasks, appointment, qualification, and position of a safety officer in the company

VdS 3188 - VdS Guidelines for Water Mist Sprinkler Systems and Water Mist Extinguishing Systems

VdS 4001 - Sprinkler Systems, Planning and Installation

VdS Schadenverhütung Verlag
Amsterdamer Straße 174, D- 50735 Cologne
www.vds.de and https://shop.vds.de

6.6 Literature

German Fire Protection Association - the Vereinigung zur Förderung des Deutschen Brandschutzes e.V. - vfdb - guidelines (vfdb 12-09/01) dealing with the appointment, tasks, qualification, and training of safety officers for fire protection]

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