Offshore substations
FOREWORD

DNV GL standards contain requirements, principles and acceptance criteria for objects, personnel, organisations and/or operations.

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Any comments may be sent by e-mail to rules@dnvgl.com
CHANGES – CURRENT

General
This document supersedes DNV-OS-J201, November 2013.

Text affected by the main changes in this edition is highlighted in red colour. However, if the changes involve a whole chapter, section or sub-section, normally only the title will be in red colour.

On 12 September 2013, DNV and GL merged to form DNV GL Group. On 25 November 2013 Det Norske Veritas AS became the 100% shareholder of Germanischer Lloyd SE, the parent company of the GL Group, and on 27 November 2013 Det Norske Veritas AS, company registration number 945 748 931, changed its name to DNV GL AS. For further information, see www.dnvgl.com. Any reference in this document to “Det Norske Veritas AS”, “Det Norske Veritas”, “DNV”, “GL”, “Germanischer Lloyd SE”, “GL Group” or any other legal entity name or trading name presently owned by the DNV GL Group shall therefore also be considered a reference to “DNV GL AS”.

Main changes April 2016
This document has been totally revised.

Editorial corrections
In addition to the above stated main changes, editorial corrections may have been made.
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SECTION 1  GENERAL

1.1  Introduction
This document is the DNV GL standard for the design of offshore substations. The standard is applicable for typical AC substation associated with offshore renewable energy projects, collectively denoted as "offshore substations".

The performance-based approach promoted in this standard, complemented by prescriptive requirements and guidance, makes this document also relevant for novel designs and platforms beyond the proven concepts of AC substations – as it also covers important aspects of HV/DC converter platforms.

Topics covered by this standard are electrical design, safety aspects including system layout, fire and explosion protection and the response of the substation in emergency situations. Furthermore arrangement and layout concept of the platform as well as transfer and access to and from the substation is being addressed. Structural design, geo-technics, material and fabrication is covered to the necessary and specific extent unique for offshore substations but not in all detail. Whenever necessary or relevant, references are made to the applicable DNV GL standards or other normative references.

Besides design aspects the standard is written to contain information on manufacturing and in-service operation which are important to be considered already during the design phase.

Figure 1-1  Content of this document

The standard does not cover the design of wind turbine components, structures and safety philosophy. Cables are only covered to the extent necessary for the design of the offshore substation.

Guidance note:
The present DNV GL standard will cover the technical requirements to be applied for the DNV GL certification schemes and it is also intended to cover the requirements implied when using IEC 61400-22 related certification schemes.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---
1.1.1 Objectives
The objectives of this standard are to:

— provide an national and internationally acceptable standard for safe design of offshore substations
— promote a holistic, risk-based approach to health and safety of personnel, environmental protection and safeguarding of the installation considering economic consequences
— define minimum design requirements for installations and supplement these with options for improving safety and reliability
— serve as a guideline for designers, suppliers, purchasers and regulators
— serve as a contractual reference document between suppliers and purchasers
— specify requirements for offshore installations subject to DNV GL verification and certification services. Reference is given to DNVGL-SE-0073 Project certification of wind farms according to IEC 61400-22 and DNVGL-SE-0190 Certification of wind power plants.

1.1.2 Application
This standard has been developed primarily to assist in the development of new installations. Retrospective application of this standard to existing installations may not be appropriate.

The standard is applicable to the design of complete platform installations associated with renewable energy projects located offshore, including

— high voltage AC substations
— high voltage DC substations
— associated accommodation platforms.

The standard focuses on fixed, bottom supported installations. Taking into account additional requirements, it may also be extended to floating installations if relevant.

The principles, requirements and guidance shall be applied to all stages in the lifecycle of the installation, beginning at the concept design stage. Updates shall be made throughout the detailed design phase. The principles shall also be applied during the construction, operation and de-commissioning phases and whenever modifications are made.

The standard has been prepared for general worldwide application. Locally applicable legislation may include requirements in excess of the provisions in this standard depending on type, size, location and intended service of the installation.

Guidance note:
In Germany, the Federal Maritime and Hydrographic Agency (BSH, www.bsh.de) decides on the concession of offshore wind farms in the German North and Baltic Sea. The BSH is responsible for the application procedure within the German Exclusive Economic Zone (EEZ).

In the UK, installations that include accommodation are likely to come under the definition of offshore installations as per the Management Regulations Statutory Instrument. This implies that a Safety Case is required to be submitted as part of the development.

It is strongly advised to read applicable standards published for the specific country, where the substation is to be installed, in conjunction with this standard if such standards exist.

---e-n-d---o-f---g-u-i-l-d-a-n-c-e---n-o-t-e---

Country specific guidance is included throughout this standard by example only.

The standard does not cover:

— oil and gas installations
— wind turbines, reference is made to e.g. DNVGL-ST-0126
— subsea installations
— subsea cables (except for the termination point at the offshore substation), references is made to DNVGL-ST-0359
— detailed procedures for operation or decommissioning of the offshore substation. For structural construction, reference is given to DNVGL-OS-C401.
Alternative solutions may be substituted where demonstrated and documented to provide the same or a higher level of safety and reliability.

1.1.3 Certification
Certification principles and procedures related to certification services for offshore renewable energy installations are specified in relevant DNV GL Service Specifications DNVGL-SE-0073 or DNVGL-SE-0190.

Other recognised standards than those listed in [1.2] may be used provided it can be demonstrated that these meet or exceed the requirements of the publications listed in Table 1-1.

Any deviations, exceptions and modifications to the design codes and standards shall be documented and agreed between the contractor, purchaser and verifier, as applicable but may never result in a reduction of safety and reliability compared to the target level identified in the present standard.

1.2 Normative references

1.2.1 General
The latest revisions (unless otherwise agreed) of the standards in Table 1-1 include requirements which, through reference in this text, constitute provisions of this standard.

Table 1-1 Normative references

<table>
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<td>Offshore Concrete Structures</td>
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<td>Fabrication and testing of offshore structures</td>
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<td>DNVGL-ST-0126</td>
<td>Design of support structures for wind turbines</td>
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<tr>
<td>DNVGL-ST-0437</td>
<td>Loads and site conditions for wind turbines (planned published in 2016)</td>
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1.3 Informative references

1.3.1 General
The latest editions of documents listed in Table 1-2 include acceptable, but not mandatory methods for fulfilling the requirements in this standard.

Table 1-2 Informative references

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</tr>
<tr>
<td>DNVGL-OS-C301</td>
<td>Stability and watertight integrity</td>
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<tr>
<td>DNVGL-OS-D101</td>
<td>Marine and machinery systems and equipment</td>
</tr>
<tr>
<td>DNVGL-OS-D201</td>
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<tr>
<td>DNVGL-OS-D202</td>
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<td>DNVGL-OS-D301</td>
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<td>DNVGL-OS-E401</td>
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<td>DNVGL-RP-0001</td>
<td>Probabilistic methods for planning of inspection for fatigue cracks in offshore structures</td>
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<td>DNVGL-RP-0360</td>
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<td>DNVGL-RP-0416</td>
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<td>DNVGL-RP-0419</td>
<td>Analysis of grouted connections</td>
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<td>DNVGL-SE-0073</td>
<td>Project certification of wind farms according to IEC 61400-22</td>
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<td>DNVGL-SE-0190</td>
<td>Project certification of wind power plants</td>
</tr>
<tr>
<td>DNVGL-SE-0420</td>
<td>Certification of meteorological masts</td>
</tr>
<tr>
<td>DNVGL-ST-0359</td>
<td>Subsea power cables</td>
</tr>
<tr>
<td>EN 54</td>
<td>Fire detection and fire alarm systems</td>
</tr>
<tr>
<td>EN 353-1</td>
<td>Personal protective equipment against falls from a height - Part 1: Guided type fall arresters including a rigid anchor line</td>
</tr>
<tr>
<td>EN 353-2</td>
<td>Personal protective equipment against falls from a height - Part 2: Guided type fall arresters including a flexible anchor line</td>
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<tr>
<td>EN 858-1</td>
<td>Separator systems for light liquids (e.g. oil and petrol) - Part 1: Principles of product design, performance and testing, marking and quality control</td>
</tr>
<tr>
<td>EN 858-2</td>
<td>Separator systems for light liquids (e.g. oil and petrol) - Part 2: Selection of nominal size, installation, operation and maintenance</td>
</tr>
<tr>
<td>EN 10204</td>
<td>Metallic products - Types of inspection documents</td>
</tr>
<tr>
<td>EN 10225</td>
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</tr>
<tr>
<td>EN 12599</td>
<td>Ventilation for buildings - Test procedures and measurement methods to hand over air conditioning and ventilation systems</td>
</tr>
<tr>
<td>EN 12907</td>
<td>Ventilation for Buildings - Ductwork - Requirements for ductwork components to facilitate maintenance of ductwork systems</td>
</tr>
<tr>
<td>EN 50272-2</td>
<td>Safety requirements for secondary batteries and battery installations - Part 2: Stationary batteries</td>
</tr>
<tr>
<td>EN 50499</td>
<td>Procedure for the assessment of the exposure of workers to electromagnetic fields</td>
</tr>
<tr>
<td>EN 50522</td>
<td>Earthing of power installations exceeding 1 kV a.c</td>
</tr>
<tr>
<td>EN ISO 5801</td>
<td>Industrial Fans - Performance Testing using Standardized Airways</td>
</tr>
<tr>
<td>EN ISO 5802</td>
<td>Industrial fans - Performance testing in situ</td>
</tr>
<tr>
<td>FSS code</td>
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<tr>
<td>FTP code</td>
<td>International Code for Application of Fire Test Procedures</td>
</tr>
<tr>
<td>GL ND 0013/ND</td>
<td>Guidelines for load-outs</td>
</tr>
<tr>
<td>GL ND 0027/ND</td>
<td>Guidelines for marine lifting &amp; lowering operations</td>
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<tr>
<td>GL ND 0028/ND</td>
<td>Guidelines for steel jacket transportation &amp; installation</td>
</tr>
<tr>
<td>GL ND 0030/ND</td>
<td>Guidelines for marine transportations</td>
</tr>
<tr>
<td>IEC 60076-series</td>
<td>Power transformers</td>
</tr>
<tr>
<td>IEC 60079-10</td>
<td>Electrical apparatus for explosive gas atmospheres – Part 10: Classification of hazardous areas</td>
</tr>
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<table>
<thead>
<tr>
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<td>IEC 60092-series</td>
<td>Electrical installations in ships</td>
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<tr>
<td>IEC 60099-1</td>
<td>Surge arresters – Part 1: Non-linear resistor type gapped surge arresters for a.c. systems</td>
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<td>IEC 60099-4</td>
<td>Surge arresters – Part 4: Metal-oxide surge arresters without gaps for a.c. systems</td>
</tr>
<tr>
<td>IEC 60300-3-11</td>
<td>Dependability management: application guide, reliability centred maintenance</td>
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<tr>
<td>IEC 60331</td>
<td>Tests for electric cables under fire conditions. Circuit integrity</td>
</tr>
<tr>
<td>IEC 60332-series</td>
<td>Tests on electric and optical fibre cables under fire conditions</td>
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<tr>
<td>IEC 60364-7</td>
<td>Low-voltage electrical installations – Part 7: Requirements for special installations or locations</td>
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<tr>
<td>IEC 60502-2</td>
<td>Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1,2 kV) up to 30 kV (Um = 36 kV) – Part 2: Cables for rated voltages from 6 kV (Um = 7,2 kV) up to 30 kV (Um = 36 kV)</td>
</tr>
<tr>
<td>IEC 60598-series</td>
<td>Luminaires</td>
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<tr>
<td>IEC 60700-series</td>
<td>Thyristor valves for high voltage direct current (HV/DC) power transmission</td>
</tr>
<tr>
<td>IEC 60812</td>
<td>Analysis techniques for system reliability - Procedure for failure mode and effects analysis (FMEA)</td>
</tr>
<tr>
<td>IEC 60840</td>
<td>Power cables with extruded insulation and their accessories for rated voltages above 30 kV (Um = 36 kV) up to 150 kV (Um = 170 kV) – Test methods and requirements</td>
</tr>
<tr>
<td>IEC 60865-1</td>
<td>Short-circuit currents – Calculation of effects – Part 1: Definitions and calculation methods</td>
</tr>
<tr>
<td>IEC 60871-series</td>
<td>Shunt capacitors for a.c. power systems having a rated voltage above 1 000 V</td>
</tr>
<tr>
<td>IEC 61000-series</td>
<td>Electromagnetic compatibility (EMC)</td>
</tr>
<tr>
<td>IEC 61025</td>
<td>Fault tree analysis (FTA)</td>
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<tr>
<td>IEC 61071</td>
<td>Capacitors for power electronics</td>
</tr>
<tr>
<td>IEC 61099</td>
<td>Insulating liquids - Specifications for unused synthetic organic esters for electrical purposes</td>
</tr>
<tr>
<td>IEC 61378-series</td>
<td>Converter transformers</td>
</tr>
<tr>
<td>IEC 61400-3</td>
<td>Wind turbines – Part 3: Design requirements for offshore wind turbines</td>
</tr>
<tr>
<td>IEC 61643-1</td>
<td>Low-voltage surge protective devices – Part 1: Surge protective devices connected to low-voltage power distribution systems – Requirements and tests”</td>
</tr>
<tr>
<td>IEC 61643-21</td>
<td>Low-voltage surge protective devices- Part 21: Surge protective devices connected to telecommunications and signaling networks – Performance requirements and testing methods</td>
</tr>
<tr>
<td>IEC 61882</td>
<td>Hazard and operability studies (HAZOP studies) - Application guide</td>
</tr>
<tr>
<td>IEC 61892-series</td>
<td>Mobile and fixed offshore units – Electrical installations</td>
</tr>
<tr>
<td>IEC 61936-1</td>
<td>Power installation exceeding 1 kVA.c. – Part 1: common rules</td>
</tr>
<tr>
<td>IEC 61975</td>
<td>High-voltage direct current (HV/DC) installations - System tests</td>
</tr>
<tr>
<td>IEC 62067</td>
<td>Power cables with extruded insulation and their accessories for rated voltages above 150 kV (Um = 170 kV) up to 500 kV (Um = 550 kV) – Test methods and requirements</td>
</tr>
<tr>
<td>IEC 62271-200</td>
<td>High-voltage switchgear and control gear – Part 200: AC metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV</td>
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<tr>
<td>IEC 62271-203</td>
<td>High-voltage switchgear and control gear – Part 203: Gas-insulated metal-enclosed switchgear for rated voltages above 52 kV</td>
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<td>IEC 62305-1</td>
<td>Protection against lightning – Part 1: General principles</td>
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<tr>
<td>IEC 62305-3</td>
<td>Protection against lightning – Part 3: Physical damage to structures and life hazard</td>
</tr>
<tr>
<td>IEC 62305-4</td>
<td>Protection against lightning – Part 4: Electrical and electronic systems within structures</td>
</tr>
<tr>
<td>IEC 62485-series</td>
<td>Safety requirements for secondary batteries and battery installations</td>
</tr>
<tr>
<td>IEC 62501</td>
<td>Voltage sourced converter (VSC) valves for high-voltage direct current (HV/DC) power transmission - Electrical testing</td>
</tr>
<tr>
<td>ISO 7547</td>
<td>Shipbuilding – Air-conditioning and ventilation of accommodation spaces on board ships – Design conditions and basis of calculations</td>
</tr>
<tr>
<td>ISO 8861</td>
<td>Shipbuilding – Engine room ventilation in diesel-engined ships – Design requirements and basis of calculations</td>
</tr>
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### 1.4 Definitions

#### 1.4.1 Verbal forms

<table>
<thead>
<tr>
<th>Term</th>
<th>Title</th>
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</thead>
<tbody>
<tr>
<td>shall</td>
<td>verbal form used to indicate requirements strictly to be followed in order to conform to the document</td>
</tr>
<tr>
<td>should</td>
<td>verbal form used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required</td>
</tr>
<tr>
<td>may</td>
<td>verbal form used to indicate a course of action permissible within the limits of the document</td>
</tr>
</tbody>
</table>

**Table 1-3 Verbal forms**

<table>
<thead>
<tr>
<th>Reference</th>
<th>Title</th>
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</thead>
<tbody>
<tr>
<td>ISO 8862</td>
<td>Air-conditioning and ventilation of machinery control rooms on board ships – Design conditions and basis of calculations</td>
</tr>
<tr>
<td>ISO 9001</td>
<td>Quality management systems – Requirements</td>
</tr>
<tr>
<td>ISO 9943</td>
<td>Shipbuilding – Ventilation and air treatment of galleys and pantries with cooking appliances</td>
</tr>
<tr>
<td>ISO 12944 series</td>
<td>Paints and varnishes - Corrosion protection of steel structures by protective paint systems</td>
</tr>
<tr>
<td>ISO 13351</td>
<td>Industrial fans – Dimensions</td>
</tr>
<tr>
<td>ISO 13702</td>
<td>Petroleum and natural gas industries – Control and mitigation of fires and explosions on offshore production installations – Requirements and guidelines</td>
</tr>
<tr>
<td>ISO 14122</td>
<td>Safety of machinery – Permanent means of access to machinery</td>
</tr>
<tr>
<td>ISO 14224</td>
<td>Petroleum, petrochemical and natural gas industries - Collection and exchange of reliability and maintenance data for equipment</td>
</tr>
<tr>
<td>ISO 15138</td>
<td>Petroleum and natural gas industries – Offshore production installations. Heating, ventilation and air-conditioning</td>
</tr>
<tr>
<td>ISO/IEC 17025</td>
<td>General requirements for the competence of testing and calibration laboratories</td>
</tr>
<tr>
<td>ISO 19900</td>
<td>Petroleum and natural gas industries – General requirements for offshore structures</td>
</tr>
<tr>
<td>ISO 19901-series</td>
<td>Petroleum and natural gas industries -- Specific requirements for offshore structures</td>
</tr>
<tr>
<td>ISO 19902</td>
<td>Petroleum and natural gas industries - Fixed steel offshore structures</td>
</tr>
<tr>
<td>ISO 20340</td>
<td>Paints and varnishes – Performance requirements for protective paint systems for offshore and related structures</td>
</tr>
<tr>
<td>LSA code</td>
<td>International Life-Saving Appliance (LSA) Code</td>
</tr>
<tr>
<td>MARPOL 73/78</td>
<td>International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 as amended, including Annex V: Prevention of Pollution by Garbage from Ships</td>
</tr>
<tr>
<td>MODU Code</td>
<td>Code for the Construction and Equipment of Mobile Offshore Drilling Units</td>
</tr>
<tr>
<td>NFPA Codes</td>
<td>National Fire Protection Association</td>
</tr>
<tr>
<td>NORSOK C-002</td>
<td>Architectural components and equipment</td>
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<tr>
<td>NORSOK H-001</td>
<td>Heating, Ventilation and Air-Conditioning</td>
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<tr>
<td>NORSOK H-003</td>
<td>HVAC and Sanitary Systems</td>
</tr>
<tr>
<td>NORSOK M-120</td>
<td>Material data sheets for structural steel</td>
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<tr>
<td>NORSOK M-501</td>
<td>Surface preparation and protective coating</td>
</tr>
<tr>
<td>NORSOK N-004</td>
<td>Design of steel structures</td>
</tr>
<tr>
<td>NORSOK N-006</td>
<td>Assessment of structural integrity for existing offshore load-bearing structures</td>
</tr>
<tr>
<td>SOLAS</td>
<td>International Convention for the Safety of Life at Sea</td>
</tr>
</tbody>
</table>
### 1.4.2 Terms

#### Table 1-4 Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
</table>
| "A" class division          | division formed by a wall or deck which is:  
   - constructed of steel or similar material  
   - suitably stiffened  
   - insulated with approved non-combustible materials such that the average temperature rise of the unexposed side will not exceed 140 K average and 180 K maximum within a specified time, e.g. "A-60": 60 min or "A-0": 0 min  
   - capable of preventing the passage of smoke and flame to the end of the 1 hour standard fire test  
   - prototype tested |
| accommodation area          | space used for cabins, offices, lavatories, corridors, public spaces, etc. Service spaces and control stations may be included within the accommodation space |
| administration              | certification body and local governmental body |
| aiming circle               | helicopter aiming point for normal landing with assured main and tail rotor clearances |
| air ducts                   | thin-walled piping or ducting (circular or rectangular) used exclusively to conduct air |
| air gap                     | free distance between characteristic wave crest and the underside of a topside structure supported on column supports allowing the wave to pass under the topside structure |
| atmospheric zone            | the external surfaces of the installation above the splash zone |
| "B" class division          | division formed by a wall or deck which is:  
   - constructed of steel or similar material  
   - suitably stiffened  
   - insulated with approved non-combustible materials such that the average temperature rise of the unexposed side will not exceed 140 K average and 180 K maximum within a specified time, e.g. "B-15": 15 min or "B-0": 0 min  
   - capable of preventing the passage of smoke and flame to the end of the first half hour standard fire test  
   - prototype tested |
| characteristic load         | the reference value of a load to be used in the determination of load effects  
   It is normally based upon a defined quantile in the upper tail of the probability distribution function for load |
| characteristic material strength | the nominal value of material strength to be used in the determination of the design resistance  
   It is normally based upon a 5% quantile in the lower tail of the distribution function for material strength |
| characteristic resistance   | the reference value of structural strength to be used in the determination of the design strength  
   It is normally based upon a 5% quantile in the lower tail of the probability distribution function for resistance |
| characteristic value        | the representative value associated with a prescribed probability of not being unfavourably exceeded or fallen below of (as relevant) during the applicable reference period |
| control station or control room | control stations  
   Spaces with equipment performing control functions essential for operational and emergency services; e.g. spaces containing  
   - operational control systems  
   - emergency source of power  
   - fire control systems  
   - fire extinguishing equipment serving various locations |
| corrosion allowance         | extra wall thickness added during design to compensate for any anticipated reduction in thickness during the operation |
| D-circle                    | a circle, usually imaginary, with a diameter of a helicopter D-value |
| D-value                     | largest overall dimension of a helicopter when the rotors are turning |
Table 1-4 Terms (Continued)

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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</thead>
<tbody>
<tr>
<td>davit crane</td>
<td>a crane that projects over the side of an installation for moving cargo</td>
</tr>
<tr>
<td>ductility</td>
<td>the property of a steel or concrete member to sustain large deformations without failure</td>
</tr>
<tr>
<td>earthing</td>
<td>connection of selected conductive parts to the main earthing (or “grounding”) terminal of the installation for safety of personnel or to ensure trip of safety devices in case of electrical faults</td>
</tr>
<tr>
<td>emergency condition</td>
<td>condition under which services needed for normal operational and habitable conditions are not in working order</td>
</tr>
<tr>
<td>emergency response</td>
<td>action to safeguard the health and safety of persons on or near the offshore installation. This usually includes all actions through alarm, escape, muster, communications and control, evacuation and rescue</td>
</tr>
<tr>
<td>emergency services</td>
<td>services essential for safety in an emergency condition</td>
</tr>
<tr>
<td>environmental state</td>
<td>short term condition of e.g. 10 minutes, 1 hour or 3 hours duration during which the intensities of environmental processes such as waves and wind can be assumed as being stationary</td>
</tr>
<tr>
<td>escape</td>
<td>the act of persons moving away from a hazardous event to a safer place</td>
</tr>
<tr>
<td>evacuation</td>
<td>the planned and controlled method of leaving the installation without directly entering the sea</td>
</tr>
<tr>
<td>fatigue</td>
<td>degradation of material caused by cyclic (mechanical) loading</td>
</tr>
<tr>
<td>fire area</td>
<td>an area divided from other areas by horizontal and vertical fire divisions, of at least A-0 rating</td>
</tr>
<tr>
<td>fixed offshore installation</td>
<td>a non-buoyant construction that is bottom founded at a particular offshore location, transferring all actions on it to the seabed</td>
</tr>
<tr>
<td>foundation</td>
<td>a means for transfer of loads from a support structure to the seabed</td>
</tr>
<tr>
<td>grout</td>
<td>a cementitious material including the constituent materials; cement, water and admixture</td>
</tr>
<tr>
<td>guidance note</td>
<td>information in the standard given to increase the understanding of the statements</td>
</tr>
<tr>
<td>&quot;H&quot; class division</td>
<td>division formed by a wall or deck which is:</td>
</tr>
<tr>
<td></td>
<td>— constructed of steel or similar material</td>
</tr>
<tr>
<td></td>
<td>— suitably stiffened</td>
</tr>
<tr>
<td></td>
<td>— insulated with approved non-combustible materials such that the average temperature rise of the unexposed side will not exceed 140 K average and 180 K maximum within a specified time, e.g. &quot;H-60&quot;: 60 min or &quot;H-0&quot;: 0 min</td>
</tr>
<tr>
<td></td>
<td>— capable of preventing the passage of smoke and flame to the end of the 2 hour standard fire test</td>
</tr>
<tr>
<td></td>
<td>— prototype tested</td>
</tr>
<tr>
<td>hazardous areas</td>
<td>three-dimensional space in which a flammable atmosphere may be expected to be present at such frequencies as to require special precautions for the control of potential ignition sources</td>
</tr>
<tr>
<td>insulation</td>
<td>non-conductive material surrounding or supporting a conductor</td>
</tr>
<tr>
<td>integrity</td>
<td>ability of the installation to remain safe and stable to safeguard personnel and facilities on board</td>
</tr>
<tr>
<td></td>
<td>Integrity is generally taken to mean structural soundness, strength and stability required to fulfil these actions</td>
</tr>
<tr>
<td>islanded conditions</td>
<td>an offshore substation is in islanded condition when the electrical connection with the external grid is not available</td>
</tr>
<tr>
<td>J-tube</td>
<td>a tube mounted in or at the structure for guiding a cable or flexible riser between seabed and installation topsides, its shape being reminiscent of the letter &quot;J&quot;</td>
</tr>
<tr>
<td>legionella</td>
<td>a pathogenic group of Gram-negative bacteria, that includes the species L. pneumophila, causing Legionellosis (all illnesses caused by Legionella) including a pneumonia type illness called Legionnaires’ disease and a mild flu like illness called Pontiac fever</td>
</tr>
<tr>
<td>limit states</td>
<td>states defining the design limits for which the structure satisfies the requirements. For ULS, SLS, ALS, FLS ref. structural codes based on load and resistance factor design (LRFD)</td>
</tr>
</tbody>
</table>
### Table 1-4 Terms (Continued)

<table>
<thead>
<tr>
<th><strong>Term</strong></th>
<th><strong>Definition</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>load effect</td>
<td>effect of a single design load or combination of loads on the equipment or system, such as stress, strain, deformation, displacement, motion, etc.</td>
</tr>
<tr>
<td>machinery spaces</td>
<td>all machinery spaces of category A and all other spaces containing fired processes, oil fuel units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilising, ventilation and air conditioning machinery, and similar spaces, and trunks to such spaces (MODU Code 1.3.33)</td>
</tr>
<tr>
<td>machinery spaces of category A</td>
<td>all spaces which contain internal combustion machinery used for other purposes where such machinery has in the aggregate a total power output of not less than 375 kW; or which contain any oil-fired boiler or oil fuel unit; and trunks to such spaces (MODU Code 1.3.34)</td>
</tr>
<tr>
<td>mechanical ventilation systems</td>
<td>systems through which air is passed by ventilator fans driven hydraulically, pneumatically or by electric motors. Mechanical ventilation may also be called power ventilation or forced ventilation.</td>
</tr>
<tr>
<td>meshed auxiliary power system</td>
<td>a meshed auxiliary power system consists of two independent power sources, each capable of fulfilling the demand on an emergency source of power as described in [5.6] of this standard. A meshed system provides reliable backup power for the emergency case through its fully redundant setup. The arrangement of components and the way of interconnecting switchboards provides sufficient flexibility that equals a system with dedicated emergency source of power.</td>
</tr>
<tr>
<td>muster area</td>
<td>an area for persons to muster safely in an emergency</td>
</tr>
<tr>
<td>(N-1) operational condition</td>
<td>condition following one credible contingency</td>
</tr>
<tr>
<td>natural ventilation systems</td>
<td>systems in which the air movement is caused solely by pressure differences caused by temperature differences or wind</td>
</tr>
<tr>
<td>normally manned installation</td>
<td>installation on which persons are routinely accommodated. Also referred to as normally attended installation (NAI)</td>
</tr>
<tr>
<td>normally unmanned installation</td>
<td>installation on which persons are not routinely accommodated and which is only visited for inspection and maintenance tasks. Also referred to as normally unattended installation (NUI).</td>
</tr>
<tr>
<td>normal operational and habitable conditions</td>
<td>condition under which the substation, as a whole, is in working order and functioning normally</td>
</tr>
<tr>
<td>offshore installation</td>
<td>a collective term to cover any structure, buoyant or non-buoyant, designed and built for installation at a particular offshore location</td>
</tr>
<tr>
<td>offshore substation</td>
<td>a collective term for high voltage AC (transformer) and high voltage DC (converter) platforms as well as associated accommodation platforms located offshore</td>
</tr>
<tr>
<td>operational services</td>
<td>services that need to be in continuous operation for maintaining the systems which are needed to be available on demand to prevent development of, or to mitigate the effects of an undesirable event, and to safeguard the personnel, environment and the installation. Operational services maintain the substation operations within desired operational limits.</td>
</tr>
<tr>
<td>partial safety factor method</td>
<td>method for the design where uncertainties in loads are represented by a load factor and uncertainties in strength are represented by a material factor</td>
</tr>
<tr>
<td>passive fire protection</td>
<td>a coating, cladding, or free standing system which, in the event of fire, will provide thermal protection to restrict the rate at which heat is transmitted to the object or area being protected</td>
</tr>
<tr>
<td>place of safety</td>
<td>a safe onshore location, or a safe offshore location or vessel to which persons or casualties can be safely transferred to in the event of an emergency.</td>
</tr>
<tr>
<td>platform installation</td>
<td>a complete offshore assembly including foundations, structure and topsides</td>
</tr>
<tr>
<td>point of common coupling</td>
<td>cables terminations connecting the substation to the subsea cables that export the power to the grid</td>
</tr>
<tr>
<td>prevailing wind</td>
<td>wind direction which has the highest probability of occurrence.</td>
</tr>
</tbody>
</table>
1.4.3 Abbreviations and symbols

Table 1-5 Abbreviation and symbols

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC</td>
<td>alternating current</td>
</tr>
<tr>
<td>ADG</td>
<td>auxiliary diesel generator</td>
</tr>
<tr>
<td>AFP</td>
<td>active fire protection</td>
</tr>
<tr>
<td>AIS</td>
<td>automatic identification system</td>
</tr>
<tr>
<td>AIS</td>
<td>air insulated switchgear (abbreviation used in Sec.5)</td>
</tr>
<tr>
<td>ALARP</td>
<td>as low as reasonably practicable</td>
</tr>
<tr>
<td>ALS</td>
<td>accidental limit state</td>
</tr>
<tr>
<td>AVR</td>
<td>automatic voltage regulator</td>
</tr>
<tr>
<td>CAA</td>
<td>civil aviation authority</td>
</tr>
<tr>
<td>CCTV</td>
<td>closed circuit television</td>
</tr>
<tr>
<td>CFD</td>
<td>computational fluid dynamics</td>
</tr>
<tr>
<td>CO2</td>
<td>carbon dioxide</td>
</tr>
<tr>
<td>CoF</td>
<td>consequence of failure</td>
</tr>
<tr>
<td>COLREG</td>
<td>collision regulations</td>
</tr>
<tr>
<td>CSP</td>
<td>commissioning switching plan</td>
</tr>
<tr>
<td>DB</td>
<td>distribution board</td>
</tr>
</tbody>
</table>
### Table 1-5 Abbreviation and symbols (Continued)

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC</td>
<td>direct current</td>
</tr>
<tr>
<td>DFF</td>
<td>design fatigue factor</td>
</tr>
<tr>
<td>DIFFS</td>
<td>deck integrated firefighting system</td>
</tr>
<tr>
<td>EDB</td>
<td>emergency distribution board</td>
</tr>
<tr>
<td>EHV</td>
<td>extra high voltage (&gt; 230 kV)</td>
</tr>
<tr>
<td>EMF</td>
<td>electromagnetic field</td>
</tr>
<tr>
<td>EN</td>
<td>European norm</td>
</tr>
<tr>
<td>ERRV</td>
<td>emergency response and rescue vessel</td>
</tr>
<tr>
<td>ESB</td>
<td>emergency switch board</td>
</tr>
<tr>
<td>ETA</td>
<td>event tree analysis</td>
</tr>
<tr>
<td>FAT</td>
<td>factory acceptance test</td>
</tr>
<tr>
<td>FEM</td>
<td>finite element method</td>
</tr>
<tr>
<td>FLR</td>
<td>fatigue limit state</td>
</tr>
<tr>
<td>FMEA</td>
<td>failure mode and effects analysis</td>
</tr>
<tr>
<td>FMECA</td>
<td>failure mode, effects and criticality analysis</td>
</tr>
<tr>
<td>FRA</td>
<td>frequency response analysis</td>
</tr>
<tr>
<td>FRP</td>
<td>fibre reinforced plastics</td>
</tr>
<tr>
<td>FTA</td>
<td>fault tree analysis</td>
</tr>
<tr>
<td>FW</td>
<td>fresh water</td>
</tr>
<tr>
<td>GDG</td>
<td>grid diesel generator</td>
</tr>
<tr>
<td>GIS</td>
<td>gas insulated switchgear</td>
</tr>
<tr>
<td>GIT</td>
<td>gas insulated transformer</td>
</tr>
<tr>
<td>GPS</td>
<td>global positioning system</td>
</tr>
<tr>
<td>H₂</td>
<td>Hydrogen</td>
</tr>
<tr>
<td>HAT</td>
<td>harbour acceptance test</td>
</tr>
<tr>
<td>HAZID</td>
<td>hazard identification</td>
</tr>
<tr>
<td>HAZOP</td>
<td>Hazard and operability study</td>
</tr>
<tr>
<td>HCA</td>
<td>helideck certification agency</td>
</tr>
<tr>
<td>HSE</td>
<td>health safety and environment</td>
</tr>
<tr>
<td>HV</td>
<td>high voltage (≥ 1 kV and ≤ 230 kV)</td>
</tr>
<tr>
<td>HV/AC</td>
<td>high voltage alternative current</td>
</tr>
<tr>
<td>HVAC</td>
<td>heating, ventilation and air conditioning (system)</td>
</tr>
<tr>
<td>HV/DC</td>
<td>high-voltage direct current</td>
</tr>
<tr>
<td>IALA</td>
<td>International Association of Marine Aids to Navigation and Lighthouse Authorities</td>
</tr>
<tr>
<td>ICAO</td>
<td>International Civil Aviation Organisation</td>
</tr>
<tr>
<td>IEC</td>
<td>International Electrotechnical Commission</td>
</tr>
<tr>
<td>IMO</td>
<td>International maritime organisation</td>
</tr>
<tr>
<td>ISO</td>
<td>International Organisation of Standardisation</td>
</tr>
<tr>
<td>LOLER</td>
<td>Lifting operations and lifting equipment regulations (U.K.)</td>
</tr>
<tr>
<td>LPL</td>
<td>lightning protection level</td>
</tr>
<tr>
<td>LPZ</td>
<td>lightning protection zone</td>
</tr>
<tr>
<td>LRFD</td>
<td>load and resistance factor design</td>
</tr>
<tr>
<td>LV</td>
<td>low voltage (&lt; 1 kV)</td>
</tr>
<tr>
<td>MAC</td>
<td>major accident hazards</td>
</tr>
<tr>
<td>MIC</td>
<td>microbiologically induced corrosion</td>
</tr>
<tr>
<td>MSB</td>
<td>main switch board</td>
</tr>
<tr>
<td>MTBF</td>
<td>mean time between failures</td>
</tr>
<tr>
<td>MTTR</td>
<td>mean time to repair</td>
</tr>
<tr>
<td>NAI</td>
<td>normally attended installation</td>
</tr>
</tbody>
</table>
Table 1-5  Abbreviation and symbols (Continued)

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAVTEX</td>
<td>navigation telex radio</td>
</tr>
<tr>
<td>NDE</td>
<td>non-destructive examination</td>
</tr>
<tr>
<td>NFPA</td>
<td>National Fire Protection Association</td>
</tr>
<tr>
<td>NUI</td>
<td>normally unattended installation</td>
</tr>
<tr>
<td>O&amp;M</td>
<td>operation and maintenance</td>
</tr>
<tr>
<td>OLTC</td>
<td>on load tap changer</td>
</tr>
<tr>
<td>OS</td>
<td>offshore standard</td>
</tr>
<tr>
<td>OSS</td>
<td>offshore substation</td>
</tr>
<tr>
<td>PA</td>
<td>public address system</td>
</tr>
<tr>
<td>PCC</td>
<td>point of common coupling</td>
</tr>
<tr>
<td>PFP</td>
<td>passive fire protection</td>
</tr>
<tr>
<td>PLL</td>
<td>potential loss of life</td>
</tr>
<tr>
<td>PoB</td>
<td>persons on board</td>
</tr>
<tr>
<td>PoF</td>
<td>probability of failure</td>
</tr>
<tr>
<td>QACP</td>
<td>quality assurance and control plan</td>
</tr>
<tr>
<td>QRA</td>
<td>quantitative risk assessment</td>
</tr>
<tr>
<td>RCM</td>
<td>reliability centred maintenance</td>
</tr>
<tr>
<td>RP</td>
<td>recommended practice</td>
</tr>
<tr>
<td>SAR</td>
<td>search and rescue</td>
</tr>
<tr>
<td>SART</td>
<td>search and rescue transponder</td>
</tr>
<tr>
<td>SAT</td>
<td>site acceptance test</td>
</tr>
<tr>
<td>SCADA</td>
<td>supervisory control and data acquisition</td>
</tr>
<tr>
<td>SCE</td>
<td>safety critical elements</td>
</tr>
<tr>
<td>SDOF</td>
<td>single degree of freedom</td>
</tr>
<tr>
<td>SE</td>
<td>service specification</td>
</tr>
<tr>
<td>SF₆</td>
<td>sulphur hexafluoride</td>
</tr>
<tr>
<td>SLS</td>
<td>serviceability limit state</td>
</tr>
<tr>
<td>SOLAS</td>
<td>safety of life at sea</td>
</tr>
<tr>
<td>SPD</td>
<td>surge protection device</td>
</tr>
<tr>
<td>SPMT</td>
<td>self-propelled modular transporters</td>
</tr>
<tr>
<td>ST</td>
<td>standard</td>
</tr>
<tr>
<td>STATCOM</td>
<td>static synchronous compensator</td>
</tr>
<tr>
<td>SWL</td>
<td>safe working load</td>
</tr>
<tr>
<td>ULS</td>
<td>ultimate limit state</td>
</tr>
<tr>
<td>UPS</td>
<td>uninterruptible power supply</td>
</tr>
<tr>
<td>VdS</td>
<td>VdS Schadenverhütung GmbH</td>
</tr>
</tbody>
</table>
SECTION 2  FORMAL SAFETY ASSESSMENT

2.1 General
This section provides general information on safety assessment which is a systematic process of identifying and evaluating hazards and managing the risks.

2.2 Safety philosophy

2.2.1 General
The integrity of an offshore substation designed and constructed in accordance with this standard is ensured through application of a safety philosophy covering different aspects as illustrated in Figure 2-1 and their implementation in the different parts of the management system.

2.2.2 Safety objective
An overall safety objective meeting statutory or stricter voluntary criteria shall be established, planned and implemented, covering all phases from conceptual development until de-commissioning.

The safety objective can be quantified by key figures such as individual risk of death and group fatality risk. As an alternative, the safety objective can be that risks are lower than risk in comparable activities or to make the risks as low as reasonably practicable (ALARP). These can be interpreted qualitatively or quantitatively.

For a typical AC substation related to one wind farm or a part of the wind farm, which is based on known and proven concepts, the overall safety can be obtained by complying with the prescriptive requirements in this standard combined with a risk assessment (HAZID-based) that assures that all additional risks not covered by the prescriptive requirements are identified and mitigated.

For novel concepts the risk based approach shall be followed, while satisfying but without overriding the given minimum prescriptive requirements.

![Figure 2-1  Safety philosophy structure](image)

Figure 2-1  Safety philosophy structure

2.2.3 High-level safety assessment
As far as practicable, all work associated with the design, construction and operation of the offshore substation shall be such as to ensure that no single failure will lead to life threatening situations for any person or to unacceptable damage to the environment or the installation. Single failures shall include realistic sequences or combinations of failures that result from a single common cause.

A systematic review or analysis shall be carried out for all phases in order to identify and evaluate the
consequences of single failures and series or combination of failures in the offshore substation, such that necessary remedial measures can be taken. The extent of the review or analysis shall reflect the criticality of the installation, the criticality of a planned operation, and previous experience with similar systems or operations.

The systematic review shall use appropriate techniques and methodologies for safety assessment, such as those described in [2.3].

2.2.4 Quality assurance

The safety philosophy within this standard requires that gross human errors shall be controlled by requirements for organisation of the work, competence of persons performing the work, verification of the design, and quality assurance during all relevant lifecycle phases.

For the purpose of this standard, it is assumed that the owner of the offshore structure has established a quality objective. The quality system shall comply with the requirements of ISO 9001. All work performed in accordance with this standard shall be subject to quality control in accordance with an implemented quality plan. The quality plan shall ensure that all responsibilities are defined.

2.2.5 Interface management

An interface manual related to safety critical interfaces shall be developed and updated throughout the project which defines all interfaces between the various parties and disciplines involved, and ensure that responsibilities, reporting and information routines are established as appropriate.

Coordination procedures between data providers and the various designing, manufacturing, transporting, installing and other relevant parties shall be defined, in particular when information must be exchanged between different contractors. The interface manual shall describe:

- responsibilities
- data requirements covering all necessary aspects over the lifetime of the installation
- data format
- data schedule.

2.3 High-level safety assessment process

2.3.1 General

An offshore structure installation shall be planned in such a manner that it can meet all requirements related to its functions and use as well as its safety requirements. Adequate planning shall be done before actual design is started in order to have sufficient basis for the engineering and by that obtain a safe, workable and economical installation that will fulfil the required functions.

Appendix A contains basic information on risk evaluation and presentation.

Preliminary risk assessment work should aim at ensuring that a safe, practicable concept is carried forward to more detailed design. Matters to be considered include inherent safety through avoiding unnecessary hazards, reducing hazards, optimising layout, etc.

Design assessment work should be used to provide input to detailed design by addressing design basis hazards and optimising the protection measures to manage them.

A typical assessment process starting with the definition of safety objectives is shown in Figure 2-2. The preliminary design is assessed through hazard identification and evaluation steps after which risks can be evaluated, reduced and managed. Where safety criteria are exceeded, design modifications are required. The updated design shall be rechecked to avoid introduction of new hazards. The process is iterative as the concept develops and more details are known.

The results of the risk assessment shall be documented. This should be reviewed as the design evolves in case of additional or changed hazards.
2.3.2 Hazard identification

Hazard identification (HAZID) is the systematic process of identifying events which, unless controlled or mitigated, could result, directly or indirectly, in harm such as:

- injury or loss of life
- environmental impact
- failures with economic consequences
- the need for escape or evacuation,

considering the arrangement of equipment, physical and chemical properties of fluids being handled and operating and maintenance procedures.

The objective of hazard identification is to obtain a complete list of such events including:

- loss of structural integrity or foundation failure
- major fire or explosion
- vessel collision or helicopter crash
- dropped objects
- loss of containment
- hazardous gases in confined spaces
- release of toxic or other hazardous substance

**Figure 2-2 Safety assessment in the design process**
— loss of mooring or station keeping (floating units)
— contact with live electrical equipment.

Appendix B contains a list of hazards associated with offshore substations.

Hazard identification methods include single-failure-oriented techniques such as:

— preliminary hazard analysis (HAZID)
— hazard and operability analysis (HAZOP)
— failure mode and effects analysis (FMEA)
— what-if techniques,

and methods for further investigation of failures such as:

— fault tree analysis (FTA)
— event tree analysis (ETA), also used for hazard evaluation.

Hazard identification shall be performed by competent personnel from a suitable variety of engineering disciplines, operational and design backgrounds.

2.3.3 Hazard evaluation

Identified hazards and potential escalation shall be evaluated based on the causes, consequences and probability of occurrence.

The evaluation should address the sources and contributors in the chain of events leading to a hazard. Prevention and protection measures should be considered in a realistic way as far as possible. Where the benefit of these measures is uncertain, or their presence cannot be assured, they should be considered to be absent.

To provide input for comparison with safety targets and safety criteria, the evaluation may be made by means ranging from qualitative to quantitative analysis. In practice, techniques are often a blend of both:

— **Qualitative methods**: Consequence and probability are determined purely qualitatively.
— **Semi-quantitative methods**: Consequence and probability are approximately quantified within ranges.
— **Quantitative methods**: Consequence and probability are fully quantified, e.g. by Quantitative Risk Assessment (QRA).

The choice of approach shall depend on the estimated risk level and its proximity to the acceptability limit as well as the complexity or novelty of the problem or scenario.

Hazard evaluation shall be performed by competent personnel with expertise in the relevant areas. Models and data should be appropriate, and from industry recognised sources.

2.3.4 Risk mitigation and management

Risk reduction involves identifying opportunities to reduce the probability and consequence of incidents aiding the decision making on the need to introduce such measures.

Risk reduction measures include those:

— to eliminate incidents (by reducing the probability of occurrence to zero)
— to prevent incidents (by lowering the probability of occurrence)
— to control incidents (by limiting the extent and duration of events)
— to mitigate the effects (by reducing the consequences).

Identified hazards should be avoided wherever practicable, e.g. through:

— removal of the source of a hazard (without introducing new sources of hazard)
— breaking the sequence of events leading to realisation of a hazard
— introduction of inherently safe designs.
Where hazards cannot be avoided, installation design and operation should aim at lowering the probability of hazards occurring where practicable, e.g. by:

- simplifying operations, avoiding complex or illogical procedures and inter-relationships between systems
- reducing the number of leak sources (flanges, instruments, valves, etc.)
- removing or relocating ignition sources
- selecting other materials
- introducing mechanical integrity or protection
- reducing the probability of external initiating events, e.g. lifting operations
- reducing inventory, pressure, temperature
- using less hazardous materials, processes or technology.

The consequences of hazards should be controlled and mitigated with the aim of reducing risk to personnel where practicable, e.g. through:

- relocation of equipment, improved layout
- provision of physical barriers, distance separation, fire walls, etc.
- provision of detection and protection systems
- provision of means to escape and evacuate.

2.4 Application in the design process

2.4.1 General

Safety aspects of offshore platforms associated with wind farms are covered by standards to varying depth, depending on the field of engineering.

Design of offshore installations is normally of such a complex nature that it will be necessary to evaluate safety aspects of each design in detail.

This standard promotes a performance-based approach to safety by assessing and managing risks of design alternatives, supported and complemented by prescriptive guidance.

Safety assessment is intended to be complementary to, and integrated with, the application of recognised design standards. The guidance and requirements of national and international standards will provide the basis for detailed engineering design that can be optimised by the application of, and findings from, the assessment.

The basic principles of the assessment, as described in [2.3], [2.4] and App.A, shall be applied to all aspects of the installation design including arrangement, structural and electrical design, fire and explosion protection, access and transfer as well as emergency response.

Risk acceptance criteria, which are the limits above which the operator will not tolerate risk on the installation, shall be defined for each type of risk assessed.

Different risk levels may require different approaches to manage them. For instance, major risks may require quantitative assessment while negligible risks may be controlled by simple compliance with codes or standards.

2.4.2 Prescriptive approach

Use of prescriptive requirements given in standards together with responsible operation is intended to result in an acceptable level of safety on standard offshore installations. However the risk assessment (HAZID-based) is required in addition, as all possible additional risks not covered by the prescriptive requirements needs to be identified and mitigated.

The prescriptive requirements are based on previous experience and safety studies and attempt to generalise with respect to design and application. In some cases this generalisation may not be appropriate to a specific design.
2.4.3 Performance-based approach

Safety assessment is applied in the design process to safeguard the health and safety of personnel, the environment and that the installation itself (asset integrity) meets acceptable safety targets.

Relevant safety assessment work that already exists for similar designs need not be duplicated. Differences between the designs should be identified and addressed in order to ensure that:

— no additional hazards have been omitted
— prevention and protection measures are adequate for any new or changed hazards
— safety targets are not exceeded
— new knowledge and technology have been considered.

The demonstration that certain risks have been controlled is not a straightforward process. Subject (engineering) areas define specific performance criteria to facilitate the management of risks.

Performance requirements are statements which can be expressed in qualitative or quantitative terms, of the performance required of a system, item or procedure and which are used as the basis for managing a risk through the lifecycle of the installation. A suitable performance requirement satisfies the following conditions:

— it defines measurement/monitoring of the performance/capability of a parameter of the component/system
— the measured/monitored parameter provides evidence of the ability of the component/system to prevent, or limit the effect of, an unplanned event
— acceptance criteria/range is defined for the parameter in question.

**Guidance note 1:**
Performance requirements should be at a level that sets an objective for the element in question. They should not describe how that objective is to be achieved or demonstrated; this is part of the verification plan.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

As a minimum the following characteristics should be considered in generating performance requirements:

— functionality: what the element shall achieve
— reliability: how low the chance shall be that the element fails to operate satisfactorily when needed
— survivability: the conditions under which it shall be required to operate, e.g. exposed to fire, blast, vibration, ship impact, dropped objects, adverse weather, etc.

**Guidance note 2:**
Performance requirements referred here are referred in some legislations (e.g. U.K. and Australia) as Performance Standards. These standards are based on identifying Major Accident Hazards (MAH), defining Safety Critical Elements (SCE) and the Performance Standards detailing how to deal with the identified SCE. This approach will differ in that they are limited to MAH as defined in legislation and may be based on personnel risk/fatalities only and not consider environment or asset integrity or loss of operation effects.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---
SECTION 3 ARRANGEMENT PRINCIPLES

3.1 General
This section provides general principles for the arrangement of foundations, structures, topsides and facilities.

Sections in this standard containing important information related to arrangement include:

— [8.3], vessel access and transfer systems
— [8.4], helicopter access and transfer systems
— [8.4.3], heli-hoist areas
— [8.5], ladders, stairs, lifts.

For further information on general arrangement principles for offshore units and installations see DNVGL-OS-A101. In addition country specific guidance notes should be followed if available.

3.2 Safety philosophy and design principles

3.2.1 General
The objectives of arrangement and layout optimisation of an offshore substation are to:

— meet functional and operational requirements
— reduce the effects of hazards
— separate areas of different hazard and/or danger level
— prevent escalation of hazardous events
— minimise the consequences of fire and explosion as low as reasonably practicable (ALARP)
— facilitate escape and evacuation
— meet additional requirements due to its function as an offshore installation.

3.2.2 Safety criteria and evaluation
The layout and configuration of the installation shall be such that risks to persons on it are reduced to the lowest practicable level.

Initial and further advanced arrangement considerations shall be assessed with hazard identification and evaluation techniques in order to demonstrate that appropriate solutions were chosen.

For a typical AC substation based on well-known principles the safety level can to a large extent be based on the prescriptive requirements given in this standard combined with a risk assessment (HAZID-based) that assures that all additional risks not covered by the prescriptive requirements are identified and mitigated.

3.2.3 Design basis
Boundary conditions for the general layout of the installation which shall be considered include, but are not limited to:

— environmental and oceanographic conditions
— installation location and installation method
— functional requirements
— access and transfer options.

The requirements to the offshore substation is a function of the manning frequency, the number of persons on board (PoB), platform size, the risks (probability and consequence) including accidental events and should be documented in Basis of Design documents.
3.3 Platform arrangement

3.3.1 Substation location

The location and orientation of the substation within a wind farm shall be chosen considering:

- other fixed or floating installations
- electrical infrastructure (subsea cabling)
- risk of ship collision (traffic, prevailing sea currents, "protection" by wind turbine array)
- prevailing wind, wave and current strengths and direction (MetOcean data)
- maintenance or repair requirements e.g. supply vessel approach or accessibility for jack-up barge
- wind farm turbulence and impact on helicopter operations e.g. obstacle free sectors.

The orientation of the substation, with respect to prevailing wind, wave and current direction, shall be chosen considering:

- meteorological and oceanographic conditions impacting boat access
- direction of approach and turbulence generation impacting helicopter operations
- potential smoke impairment of accommodation, escape, muster and evacuation areas.

The site location shall be specified so that the appropriate environmental (e.g. ambient temperature), meteorological (e.g. wind), oceanographic (e.g. currents) and soil conditions can be established, including rare events with a low probability of occurrence (Seismic).

3.3.2 Manning and type of platforms

Platform installations are commonly defined as either:

- **Type A**: Normally unmanned platform with power equipment. Persons are only expected to be present for inspection and maintenance activities during daytime working hours. This is often the case for small AC platforms.
- **Type B**: Temporarily or permanently manned platform shared by power equipment and accommodation space. Persons are permanent (i.e. spare time and sleeping on the platform) during scheduled work or maintenance campaigns residing on the installation. On departure of personnel from the installation all systems are to be returned to a safe and unmanned state. The platform shall have all the personnel safety systems of a normally manned platform but also the added functions of being able to be left vacated for extended periods of time, without adding additional hazards such as Legionella developing in water systems. This is often the solution chosen for larger platforms e.g. high voltage direct current (HV/DC) platforms.
- **Types C**: Persons are normally present at day and night time. This may be a separate accommodation platforms or a platform connected by a bridge.

Guidance note:
During the installation, commissioning and run-in phase of offshore substation and associated wind farm, the substation is commonly manned during daytime for extended periods, normally for several months. Adequate provisions should be made for this period at the design stage. These may include provisions which are normally only expected for manned installations.

---end---of---g-u-i-d-a-n-c-e---n-o-t-e---

For a particular installation, formal safety assessment according to Sec.2 should be used to identify the most suitable platform arrangement.

The manning level and pattern for each phase of the substation’s lifecycle shall be defined, including:

- installation
- commissioning
- initial operational phase (1 to 2 years)
- normal operation
- inspection and maintenance.
Guidance note:
Where a helicopter deck is available the maximum PoB should include the helicopter crew (pilots and passengers) to be taken into account for the dimensioning of means for evacuation and rescue.

---end---of---guidance---note---

Minimum and maximum number of persons expected to be on the substation at any time (and for whom accommodation is to be provided) shall be defined for all relevant types of work and foreseeable emergency situations such as e.g. a grounded helicopter.

The manning procedure shall include:

— maximum persons on board (PoB)
— methods of access to and egress from the substation
— weather condition limits allowing approach of, transfer to/from and departure from the substation including wave height, tides, wind speed, visibility, temperatures and daylight
— monitoring of the weather situation before and while the substation is manned
— means of communication.

3.4 Segregation of areas

3.4.1 General
The installation shall be divided into different areas according to the type of activities that will be carried out and the associated hazard and/or danger potential.

Areas of high risk potential shall be segregated from areas required to be of low risk potential, and from areas containing important safety functions. Open, non-hazardous areas should not be significantly enclosed by hazardous areas. Incident escalation between areas shall be avoided. Hazardous areas shall be separated from working and accommodation areas.

Segregation of redundant electrical equipment (i.e. segregation between electrical equipment of same type that together constitutes a redundant system) shall be applied to maintain substations availability, see [5.3.3]. At least following redundant electrical equipment shall be duly separated:

— main transformers
— high voltage (HV) switchgears
— shunt-reactors
— auxiliary transformers
— main and emergency switchboards
— diesel generators
— redundant equipment of meshed power supply for auxiliary system.

Separation by fire walls, blast walls, fire barriers etc. shall be applied if segregation by physical distance is not sufficient or not feasible. In such cases minimum fire rating of A-60 shall be provided.

Guidance note:
If segregation is achieved by physical distance alone, it should be demonstrated that the distance is selected to be bigger than the potentially disadvantageous reach of the effect.

---end---of---guidance---note---

3.4.2 Hazardous areas
The following fluids shall be considered as sources requiring area classification:

— flammable gas or vapour
— flammable liquids with flashpoint less than 10 °C above maximum ambient temperature for the installation
— flammable liquid that could form a flammable mist, i.e. including lubricating oils, hydraulic oils under pressure or being heated from hot running bearings, oil used for insulation purpose in electrical equipment.
Area classification should be carried out to a suitable Standard, e.g. IEC 60079-10

Guidance note 1:
Areas on offshore substations requiring attention include fuel storage / handling for helicopters, fuel storage / handling for emergency (diesel) generators, battery charging with potential for hydrogen release, gas welding stations.

The level and extent of the hazardous area depend on the fluid properties, rate of release and ventilation conditions. Adequate ventilation is required to ensure that releases are rapidly dispersed.

Openings, penetrations or connections between areas of different hazardous area classification shall be avoided, e.g. through ventilation systems and drain systems.

Guidance note 2:
Ventilation systems for hazardous areas should be separate from ventilation systems for non-hazardous areas, ref. Sec.6 below. Ventilation solutions include under-pressure (hazardous space), over-pressure (non-hazardous space), dilution and air locks. This supply air can be taken from other system as long as the area in question has dedicated extract to outside area and have dampers installed on the supply side.

Electrical equipment and cables installed in hazardous areas shall be limited to the necessary extent for operational purposes, and items remaining live must be provided with suitable Ex-rating.

3.4.3 Dangerous areas
Areas where electric, magnetic, and electromagnetic fields (EMF) exist hazardous to human health or safety should be segregated and access restricted as far as practicable. Risk assessments shall be carried out to ensure that EMF exposure to people on board does not exceed the limit set by applicable national standards and directives. The following characteristic areas are relevant for according consideration:

- Areas which can have low oxygen content following release of firefighting systems based on gas flooding systems.
- Enclosed spaces where oxygen has been consumed by corrosion, or toxic gases (H2S) produced by anaerobic bacterial action on hydrocarbon (oil) residues.
- Areas which contain SF6 gas following leakage in gas-insulated switchgear (GIS).

3.4.4 Other zones
Areas which could be impacted by crane operations potentially involving dropped objects and swinging loads shall be considered.

Danger areas should be equipped with means such as barriers or signposts preventing persons from unauthorised access.

3.5 Location of equipment

3.5.1 General arrangement
Equipment shall be arranged with a view to achieving:
- layout meeting functional and operational requirements
- suitable interfaces to the structure
- access for operation, inspection and maintenance, internal and external
- safe escape from working areas in emergency situations
- efficient ventilation of hazardous areas
- minimal explosion overpressure (e.g. by pressure relief where needed)
- minimal possibility for escalation of fires and other failures or accidents
- access for firefighting and emergency response
- prevention of serious consequences from dropped and swinging objects
- replacement of heavy equipment
- replacement of equipment during the operation lifetime
— safe containment of accidental release of liquids which are toxic, flammable or hazardous to personnel or to the marine environment.

Location, layout, weight, centre of gravity and exposure to the environment of equipment and materials shall be specified.

### 3.5.2 High voltage equipment

An AC substation shall contain minimum two main transformers. The main transformers should have a capacity that assures that the wind farm can for most wind conditions continue operation in the event of a single main transformer failure, see [5.3.3].

High voltage equipment should be placed in a ventilated areas or it should be ensured that the temperature does not impact the operation.

### 3.5.3 Submarine power cables

Space requirements and loads during pull-in of submarine power cables shall be considered during layout of decks and determination of height between decks.

For further information on submarine power cables see DNVGL-ST-0359 and DNVGL-RP-0360.

**Guidance note:**

Submarine power cables insulated by combustible material should be routed in a way minimizing the risk of fire propagation.

Submarine power cables routed above escape routes should be shielded against dropping burning materials in case of a fire.

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### 3.5.4 Emergency power

The emergency power systems and associated controls shall be self-contained, easily accessible and located where they are likely to perform in situations they are called upon and such that they are not vulnerable to events that affect the main power supply.

Combustion engines and heaters shall normally be located at a safe distance from hazardous areas. Escalation shall be minimised, e.g. through use of segregation and fire barriers.

The integrity of the emergency electrical supply and the transitional source of power shall not be affected by fire, explosion, mechanical impact, flood or other faults in the main electrical supply.

Uninterruptible power supply (UPS) or battery systems for operation of the main power distribution shall not be located together with equipment necessary for operation of the emergency power generation or distribution. Detailed requirements for the installation of the substation electrical auxiliary equipment are given in [5.5].

### 3.5.5 Cranes and lay down areas

Offshore substations shall be fitted with lifting equipment with a capacity and reach suitable for foreseeable lifts during the complete operational life of the installation.

**Guidance note:**

Maximum safe working load, access reach and boom rating to cover the farthest and heaviest lifts required on installation and from service vessel decks should be considered. The lifting equipment could also include man-riding capability for personnel transfer operations.

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Cranes and lay down areas shall be located so as to minimise the risk associated load handling or dropped object damage to systems and structures.

The need for load handling above hazardous inventories and equipment important for safety shall be avoided as far as possible. Suitable impact protection shall be provided where such lifting cannot be avoided.

Lay down areas shall normally be located in non-hazardous areas and be provided with heavy-duty barriers to prevent damage to adjacent equipment from swinging loads. On floating installations, necessary points for securing of deck loading shall be provided.
Lay-down areas in the vicinity of helicopter decks should be located significantly below or away from the helicopter deck level.

Where used, the crane shall be located in an area of the installation minimising the impact on helicopter access during prevailing weather conditions.

3.5.6 Meteorological mast
Where used, the meteorological mast shall be located in an area of the installation minimising the impact on helicopter access during prevailing weather conditions.

Arrangement and structural design shall take possible fatigue loading and ALS accidental collapse of the meteorological tower into account. Such collapse should not lead to further structural failure. Details on the design and certification of meteorological masts can be found in DNVGL-ST-0126 and DNVGL-SE-0420.

3.5.7 Inlets and outlets
Intakes for ventilation and combustion air shall be located to avoid ingress of hazardous substances. Such intakes shall be areas classified safe.

Exhausts from combustion equipment and ventilation systems shall be located to avoid cross contamination of air inlets.

External entrances to areas important for safety shall be provided with air locks if located where smoke or gas ingress is possible during an emergency.

Bundled areas, drain systems and spill trays shall be designed to meet maximum foreseeable fluid volumes. Drain from rooms shall be sized so that bundled areas will not overflow and the final spill/drain/overflow tank shall be sized for the largest oil filled equipment complete with the possible addition of fire water media, and also consider possible flow due to overfilling due to mistakes.

Guidance note:
The system should as a minimum be dimensioned for the amount of liquid likely to leak from the largest unit e.g. one main transformer plus fire water media plus some contingency of 10 to 20%. If relevant, precipitation is to be taken into account.

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Pressure relief openings shall be provided for rooms containing high voltage and/or oil filled equipment if explosions can occur.

3.5.8 Safety systems
Safety systems and controls shall be located such that they can remain operational during the defined accidental events.

Where redundant safety equipment is used, this shall not be vulnerable to the same accidental events as the main system.

Controls for safety systems shall be located where they are accessible and available for safe, simultaneous use during an emergency.

Safety systems are further described in the following sections:
— Sec.6, fire protection
— Sec.9, emergency response.

3.6 Workplaces

3.6.1 General
Workplaces are places on the installation mainly for the performance of work and for rest (not including areas infrequently occupied to carry out inspection or maintenance tasks).

All offshore substations, manned or unmanned, shall have minimum provisions which include, but are not limited to:
— protection from weather, vibration, noise and strong electromagnetic fields
— emergency toilet
— emergency rations of water and food
— sleeping bags
— desk space for working with computers.

Accommodation and other areas important for safety, such as control rooms, shall be located in areas classified as non-hazardous by location, as far as practicable away from dangerous areas and where they are least affected by fires and explosions. In some cases these areas may have to be designed to withstand fire and explosion for a specific time to enable persons to escape and evacuate.

Enclosed workplaces and accommodation shall have sufficient lighting, be sufficiently ventilated and maintain a reasonable room temperature.

Floors of workplaces shall be fixed and stable, have no bumps or holes and have a non-slippery surface. Floors, walls and ceilings shall be cleanable.

Doors shall be positioned and dimensioned by reference to the use of the area including escape requirements.

Smoking shall be prohibited anywhere on the installation, except in designated areas.

3.6.2 Control room
Workstations shall be designed and constructed while considering safety. Ease of action and ergonomic principles shall be considered.

Guidance note:
Provisions should be made for inspection and maintenance personnel to work at (portable) computers as required. Storage facilities for documentation such as drawings and manuals should be provided.

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Control panels shall be protected from major accidental events such as fire, explosion and mechanical impact.

3.6.3 Workshop and storage areas
A workshop may be provided on the substation so that small repairs can be carried out locally without delay or the need for multiple transfers.

Means to safely dispose of scrap and waste materials should be provided, e.g. in line with MARPOL Annex V. Specific national requirements may apply.

Hazardous substances shall be collected and removed in order not to endanger health or safety of persons on the installation. Stores for hazardous substances shall be segregated from, and located at a safe distance from accommodation spaces and control stations.

Indoor storage areas shall have sufficient ventilation.

3.6.4 Accommodation area
For platforms with planned overnight stays an adequate number of beds for maximum POB shall be provided.

Sleeping rooms shall provide reasonable comfort and contain adequate space for changing, drying and storage of clothes and personal protective equipment. In addition, lavatories, washing facilities and showers shall be provided.

Guidance note 1:
Provision of fresh water and disposal of waste water can become a major operational task even for less frequently manned offshore substations and should be planned at the design stage. Water treatment should be considered.

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Accommodation as well as emergency accommodation shall have adequate ventilation, heating and lighting and protection from vibration, noise, electromagnetic fields, fumes and inclement weather.
Guidance note 2:
For HV/DC platforms electromagnetic fields in the accommodation may not be completely avoidable. However, the accommodation should be separated in order to reduce risk from the electromagnetic fields and the level should fulfil the requirements set by the local authorities.

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Drinking water and food shall be properly stored. Cooking and eating facilities shall be provided as appropriate.

Rest rooms or areas shall be provided if the activities on the installation necessitate space for relaxation during breaks. National legislation and requirements for separate sanitary and sleeping facilities for men and women should be complied with.

3.6.5 Personal protective equipment
Personal protective equipment shall be available in a suitable location for any person transferring to or from the substation, including:

— lifejacket
— immersion/survival suit, depending on water temperature, see Sec.9
— personal locator beacon
— head protection with chinstrap and preferably a light (not a strict requirement during helicopter transfers)
— gloves
— safety footwear with steel reinforced toes and non-slip soles (not a strict requirement during helicopter transfers)
— harness for use with fall arrest system.

The installation should have suitable provisions for storing protective equipment temporarily.

Additional lifejackets and immersion suits should be available at places which may be used for mustering or access to the sea. Normally life jackets corresponding to number of PoB should be located at the primary and secondary muster areas.

Where helicopter decks are used, fire fighter’s outfits shall be stored so that they are ready for use. Self-contained breathing apparatus sets plus reserve cylinders should be readily available and appropriately stored.

Guidance note:
CAP 437 and local regulations should be consulted to determine the applicable requirements including the number of fire fighters’ outfits and number of breathing apparatus. In Denmark reference is given to BL 3-5.

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3.6.6 First aid facilities
A minimum of first aid equipment shall be provided for the substation, including:

— medication
— eye wash station
— rigged stretcher
— defibrillation equipment.

The substation shall be designed for stretcher transport to sea level and helideck or hoist area.

3.7 Marking
A marking system shall be established to facilitate ease of identification of significant items for improved operation, inspection, safety and emergency response.
3.8 Documentation

Guidance note:
DNV-RP-A201 Plan Approval Documentation Types – Definitions provides a detailed description of documentation types that may be used to help specify adequate documentation for relevant disciplines.

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The arrangement and layout of the offshore substation shall be documented by:

— elevation and plan view drawings including plans showing escape routes, muster stations, etc.
— Safety plans showing location of muster areas, life boats, firefighting equipment and relevant safety equipment, etc.

Hazardous area classification shall be documented by drawings including location and selection of equipment, air inlets and exhausts and D&ID drawings for the duct system.

The standards, design specifications and assumptions on which the design work is based should be presented in a Basis of Design report.
SECTION 4 STRUCTURAL DESIGN

4.1 General
This section provides principles and requirements for the design of complete structures, including topsides, substructures, structural components and foundations.

Usually the design of the substructure and the topside should cover the following situations: SPMT transport, lifting, load-out, sea transportation, in-place and de-commissioning.

Sections in this standard containing important information related to structural design include:

— Sec.3 Arrangement principles
— Sec.5 Electrical design
— Sec.6 Fire and explosion protection
— Sec.10 Construction.

Structural design needs to accommodate requirements from above mentioned sections. This could be requirements to minimum space, bending radius of cables, resistance to temperature and pressure, access and escape routes, etc.

4.2 Safety philosophy and design principles

4.2.1 General
The objective of structural design is to ensure that structures and structural elements are, for the duration of their design life, designed to:

— provide acceptable safety of structure, personnel and environment
— sustain operational and environmental loads liable to occur during all temporary, operating and damaged conditions
— provide simple stress paths that limit stress concentrations and have adequate robustness with small sensitivity to local damage
— have suitable functionality and survivability for prevention of, or protection from, design accidental events, further described in DNV-RP-C204, Design Against Accidental Loads
— have adequate durability against mechanical, physical and chemical deterioration (e.g. corrosion)
— offer the option for condition monitoring, inspection, maintenance and repair
— fulfil requirements for removal if required
— take account of manufacturing, installation and removal issues.

A performance-based approach (see [2.4.3]) shall be adopted for structural design. The general design process flow is depicted in Figure 4-1. Desired safety class and target safety are defined first. The site condition assessment which follows is explained in detail in DNVGL-ST-0126, Sec.3. A design basis shall then be established based on which a preliminary design can be established and assessed. After optimisation the design can be finalised.
4.2.2 Safety criteria and evaluation

4.2.2.1 Safety classes
In this standard, structural safety is ensured by use of a safety class methodology. The structure to be designed is classified into a safety class based on the failure consequences. The classification is normally determined by the purpose of the structure. For each safety class, an acceptable target safety level is defined in terms of a nominal annual probability of structural failure.

For structures in offshore wind farms, three safety classes are considered:

— Low safety class is used for structures, whose failures imply low risk for personal injuries and pollution, low risk for economic consequences and negligible risk to human life.
— Normal safety class is used for structures, whose failures imply some risk for personal injuries, pollution or minor societal losses, or possibility of significant economic consequences.
— High safety class is used for structures, whose failures imply large possibilities for personal injuries or fatalities, for significant pollution or major societal losses, or very large economic consequences.

Substation structures and their foundations as well as J-tubes shall be designed to high safety class.

Alternatively the consequence category according ISO 19902, section 6.6.3 can be applied. In this case the substation shall be designed to high consequence category C1 and exposure level L1.

4.2.2.2 Target safety
The target safety level for design of substation structures and their foundations to high safety class according to this standard is a nominal annual probability of failure of $10^{-5}$. This target safety is the level aimed at for structures, whose failures are ductile, and which have some reserve capacity.

Guidance note 1:
Ductility is a mechanism that contributes to the fracture resistance in metals. Hence, ductility of metallic materials is important for the safety of metallic structures such as monopiles and jackets. Weight considerations due to limitations of installation equipment etc. may lead to use of high strength steels where yield strength is a larger percentage of ultimate strength than for normal steels, with apparent less ductility. Also, higher strength steels normally have no higher fatigue strength than ordinary steels.

Structural components and structural details should be shaped in such a manner that the structure as far as possible will behave in the presumed ductile manner. Connections should be designed with smooth transitions and proper alignment of elements to a recognised code for manufacturing tolerances. Stress concentrations should be kept as low as possible and complex stress flow...
patterns should be reduced. A structure or structural component may behave as brittle (unstable fracture) even if it is made from ductile materials, for example for parts with large thicknesses when 3-dimensional effects cause additional restraints in deformations, or when there are sudden changes in section properties.

---end---of---guidance---note---

The target safety level is the same, regardless of which design philosophy is applied.

Guidance note 2:
A design of a structural component which is based on an assumption of inspections and possible maintenance and repair throughout its design life may benefit from a reduced structural dimension, e.g. a reduced cross-sectional area, compared to that of a design without such an inspection and maintenance plan, in order to achieve the same safety levels for the two designs. This refers in particular to designs which are governed by the fatigue or the serviceability limit states. It may be difficult to apply this to designs which are governed by the ultimate or the accidental limit states.

---end---of---guidance---note---

4.2.2.3 Evaluation
The overall structural safety shall be evaluated on the basis of preventive measures against structural failure put into design, fabrication and in-service inspection as well as the installation’s robustness against total collapse in the case of structural failure of vital elements.

4.2.3 Design basis
A design basis document shall be created in the initial stages of the design process to document the basic criteria to be applied in the general design. The basic data should be described by at least the following:

— platform location and main functionalities
— general description, main dimensions and water depth
— type of sub-structure and foundation
— applicable codes, standards, regulations etc.
— structural analysis concept including safety factors
— service life of platform.

The meteorological and oceanographic conditions should be described by at least the following:

— wind: average and extremes, directional distribution, turbulence and gusts, atmospheric stability (wind shear)
— waves: average and extreme heights, directional distribution, periods and spectrum
— currents: average and extremes, directional distribution
— water level: average depth, highs and lows, storm surges
— temperature: seawater and air temperature ranges
— density of air and water
— ice: sea ice and icing of structure
— salinity and corrosiveness of air and water
— atmospheric pressure
— relative humidity
— precipitation: rain, snow, hail
— solar radiation, ultraviolet radiation
— lightning frequency
— seismicity and earthquakes
— extreme weather events like cyclones, tsunamis, hurricanes
— marine growth
— temporary conditions related to transport and installation.

Guidance note:
For normal environmental conditions, reference can be made to DNVGL-ST-0437.

---end---of---guidance---note---
The geotechnical conditions should be described by at least the following:

- extent and relevance of geotechnical investigation programme
- sea bed and soil description
- characteristic data
- stability, initial and long-term settlements and inclination, subsidence
- driveability / constructability
- sand waves and moving sand banks
- scour.

The elements of the steel structure should be described by at least the following:

- categorisation of structural components (Special/Primary/Secondary),
- materials (including certification)
- welding
- fabrication tolerances
- non-Destructive Examination (extent, methods and acceptance criteria) at fabrication
- corrosion protection system.

The topsides should be described by at least the following:

- deck elevation(s) and clearance above design wave crest
- structural interface between support structure and topsides
- geometry, weight and centre of gravity of major components
- access and escape routes (helideck, lifeboats, ...)
- crane coverage,
- categorisation of structural components
- materials (including certification)
- welding
- bolting, including preloading
- fabrication tolerances
- non-destructive examination (extent, methods and acceptance criteria) at fabrication
- corrosion protection system
- additional functionalities required of topsides walls and decks for explosion and/or fire resistance (ref. Sec.6 below), including availability of suitably approved penetrations for fire rating of ventilation ducts, piping, electrical cables
- tightness requirements to barriers around areas protected by fire gas flooding systems, or OxyReduct fire suppression systems
- strength and tightness for watertight barriers as relevant.

4.2.4 Design process

The choice of the structural system and materials is governed by the aim to maintain adequate structural integrity during normal service and specific situations.

The design format within this standard is based on a limit state and partial safety factor method, where uncertainties in loads are represented with a load factor and uncertainties in resistance are represented with a material factor. Load effects in the structure due to each applied load process are separately assessed. The partial safety factor method is described in detail in [4.3].

Alternative design methods, further described in DNVGL-OS-C101, include:

- design assisted by testing
- full probability-based design.

Methods described in ISO 19902 can be applied alternatively if the overall safety level defined in this standard is being met.
4.3  Design by the partial safety factor method

4.3.1  Limit states

A limit state is a condition beyond which a structure or structural component will no longer satisfy the design requirements.

The following limit states are considered in this standard:

- ultimate limit states (ULS) correspond to the maximum load-carrying resistance
- fatigue limit states (FLS) correspond to failure due to the effect of cyclic loading
- accidental limit states (ALS) correspond to (1) maximum load-carrying resistance of the integral structure for (rare) accidental loads or (2) post-accident integrity for damaged structures
- serviceability limit states (SLS) correspond to tolerance criteria applicable to intended use or durability.

Examples of limit states within each category are:

Ultimate limit states (ULS):
- loss of structural resistance (excessive yielding and buckling)
- failure of components due to brittle fracture
- loss of static equilibrium of the structure, or of a part of the structure, considered as a rigid body, e.g. overturning or capsizing
- failure of critical components of the structure caused by exceeding the ultimate resistance (which in some cases is reduced due to repetitive loading) or the ultimate deformation of the components
- excessive deformations caused by ultimate loads
- sliding of the soil
- Pile pull-out
- transformation of the structure into a mechanism (collapse or excessive deformation).

Fatigue limit states (FLS):
- cumulative damage caused by cyclic loading.

Accidental limit states (ALS):
- structural damage caused by accidental loads (ALS)
- ultimate resistance of damaged structures (post damaged analysis)
- maintenance of structural integrity after local damage or flooding (post damaged analysis).

Serviceability limit states (SLS):
- deflections which may prevent the intended operation of equipment
- excessive vibrations producing discomfort or affecting non-structural components
- deformations that exceed the limitation of equipment (induced by load and/or temperature)
- deformations that may change the distribution of loads between supported rigid objects and the supporting structure
- differential settlements of foundations soils causing intolerable tilt of the platform
- temperature-induced deformations.

4.3.2  Partial safety factor method

The partial safety factor method is a design method by which the target safety level is obtained as closely as possible by applying load and resistance factors to characteristic values of the governing variables and subsequently fulfilling a specified design criterion expressed in terms of these factors and these characteristic values. The governing variables consist of

- loads acting on the structure or load effects in the structure
- resistance of the structure or strength of the materials in the structure.
The characteristic values of loads and resistance, or of load effects and material strengths, are chosen as specific quantiles in their respective probability distributions. The requirements to the load and resistance factors are set such that possible unfavourable realisations of loads and resistance, as well as their possible simultaneous occurrences, are accounted for to an extent which ensures that a satisfactory safety level is achieved.

The level of safety of a structural element is considered to be satisfactory when the design load effect $S_d$ does not exceed the design resistance $R_d$:

$$S_d \leq R_d$$

This is the design criterion. The corresponding equation $S_d = R_d$ forms the design equation.

**Guidance note 1:**

The load effect $S$ can be any load effect such as an external or internal force, an internal stress in a cross section, or a deformation, and the resistance $R$ against $S$ is the corresponding resistance such as a capacity, a yield stress or a critical deformation.

There are two approaches to establish the design load effect $S_{di}$ associated with a particular load $F_i$:

1. The design load effect $S_{di}$ is obtained by multiplication of the characteristic load effect $S_{ki}$ by a specified load factor $\gamma$

   $$S_{d_i} = \gamma S_{k_i}$$

   where the characteristic load effect $S_{k_i}$ is determined in a structural analysis for the characteristic load $F_{k_i}$.

2. The design load effect $S_{di}$ is obtained from a structural analysis for the design load $F_{di}$, where the design load $F_{di}$ is obtained by multiplication of the characteristic load $F_{k_i}$ by a specified load factor $\gamma f$

   $$F_{d_i} = \gamma F_{k_i}$$

Approach (1) shall be used to determine the design load effect when a proper representation of the dynamic response is the prime concern, whereas approach (2) shall be used if a proper representation of nonlinear material behaviour or geometrical nonlinearities or both is the prime concern.

The design load effect $S_d$ is the most unfavourable combined load effect resulting from the simultaneous occurrence of $n$ loads $F_{i}, i = 1...n$. It may be expressed as

$$S_d = f(F_{d1},...,F_{dn})$$

where $f$ denotes a functional relationship.

According to the partial safety factor format, the design combined load effect $S_d$ resulting from the occurrence of $n$ independent loads $F_{i}, i = 1...n$, can be taken as

$$S_d = \sum_{i=1}^{n} S_{di}(F_{i})$$

where $S_{di}(F_{k_i})$ denotes the design load effect corresponding to the characteristic load $F_{k_i}$.

When there is a linear relationship between the load $F_i$ acting on the structure and its associated load effect $S_i$ in the structure, the design combined load effect $S_d$ resulting from the simultaneous occurrence of $n$ loads $F_{i}, i = 1...n$, can be achieved as

$$S_d = \sum_{i=1}^{n} \gamma S_{k_i}$$

When there is a linear relationship between the load $F_i$ and its load effect $S_i$, the characteristic combined load effect $S_k$ resulting from the simultaneous occurrence of $n$ loads $F_{i}, i = 1...n$, can be achieved as

$$S_k = \sum_{i=1}^{n} S_{k_i}$$

Characteristic load effect values $S_{ki}$ are obtained as specific quantiles in the distributions of the respective load effects $S_i$. In the same manner, characteristic load values $F_{k_i}$ are obtained as specific quantiles in the distributions of the respective loads $F_i$. 
Guidance note 2:
Which quantiles are specified as characteristic values may depend on which limit state is considered. Which quantiles are specified as characteristic values may also vary from one specified combination of load effects to another among the load combinations that are specified to be investigated in order to obtain a characteristic combined load effect \( S_k \) equal to a particular quantile in the distribution of the true combined load effect \( S \).

---end---of---guidance---note---

In this standard, design in the ULS is either based on a characteristic combined load effect \( S_k \) defined as the 99% quantile in the distribution of the annual maximum combined load effect, or on a characteristic load \( F_k \) defined as the 99% quantile in the distribution of the annual maximum of the combined load.

Guidance note 3:
When \( n \) load processes occur simultaneously, the standard specifies more than one set of characteristic load effects \( (S_{k1}, \ldots, S_{kn}) \) to be considered in order for the characteristic combined load effect \( S_k \) to come out as close as possible to the 99% quantile. For each specified set \( (S_{k1}, \ldots, S_{kn}) \), the corresponding design combined load effect \( S_d \) is determined. For use in design, the design combined load effect \( S_d \) is selected as the most unfavourable value among the design combined load effects that result for these specified sets of characteristic load effects.

---end---of---guidance---note---

The resistance \( R \) against a particular load effect \( S \) is, in general, a function of parameters such as geometry, material properties, environment, and load effects themselves, the latter through interaction effects such as degradation.

There are two approaches to establish the design resistance \( R_d \) of the structure or structural component:
The design resistance \( R_d \) is obtained by dividing the characteristic resistance \( R_k \) by a specified material factor \( \gamma_m \):

\[ R_d = \frac{R_k}{\gamma_m} \]

(2) The design resistance \( R_d \) is obtained from the design material strength \( \sigma_d \) by a capacity analysis

\[ R_d = R(\sigma_d) \]

in which \( R \) denotes the functional relationship between material strength and resistance and in which the design material strength \( \sigma_d \) is obtained by dividing the characteristic material strength \( \sigma_k \) by a material factor \( \gamma_m \),

\[ \sigma_d = \frac{\sigma_k}{\gamma_m} \]

Which of the two approaches applies depends on the design situation. In this standard, the approach to be applied is specified from case to case.

The characteristic resistance \( R_k \) is obtained as a specific quantile in the distribution of the resistance. It may be obtained by testing, or it may be calculated from the characteristic values of the parameters that govern the resistance. In the latter case, the functional relationship between the resistance and the governing parameters is applied. Likewise, the characteristic material strength \( \sigma_k \) is obtained as a specific quantile in the probability distribution of the material strength and may be obtained by testing.

Load factors account for:

- possible unfavourable deviations of the loads from their characteristic values
- the limited probability that different loads exceed their respective characteristic values simultaneously
- uncertainties in the model and analysis used for determination of load effects.

Material factors account for:

- possible unfavourable deviations in the resistance of materials from the characteristic value
- uncertainties in the model and analysis used for determination of resistance
- a possibly lower characteristic resistance of the materials in the structure, as a whole, as compared with the characteristic values interpreted from test specimens.
4.3.3 Characteristic load effect

For operational design conditions, the characteristic value $S_k$ of the load effect resulting from an applied load combination is defined as follows, depending on the limit state:

- For load combinations relevant for design against the ULS, the characteristic value of the resulting load effect is defined as the 99% quantile in the distribution of the annual maximum of the load effect, i.e. the load effect whose return period is 100 years.
- For load combinations relevant for design against the FLS, the characteristic load effect history is defined as the expected load effect history.
- For load combinations relevant for design against the SLS, the characteristic load effect is a specified value, dependent on operational requirements.
- For load combinations relevant for design against the ALS, the characteristic load effect is a specified value, dependent on operational requirements.

For temporary design conditions, the characteristic value $S_k$ of the load effect resulting from an applied load combination is a specified value, which shall be selected dependent on the measures taken to achieve the required safety level. The value shall be specified with due attention to the actual location, the season of the year, the duration of the temporary condition, the weather forecast, and the consequences of failure.

4.3.4 Characteristic resistance

Characteristic strengths and characteristic resistances are specified in DNVGL-OS-C101 for steel structures and in DNV-OS-C502 for concrete structures and in DNVGL-ST-0126 for pile/soil interaction. For aluminium alloys reference is made to DNVGL-OS-B101 Ch.2 Sec.5.

4.3.5 Load and resistance factors

Load and resistance factors for the various limit states are given in [4.5].

4.4 Loads and load effects

4.4.1 General

The requirements in this subsection define and specify load components and load combinations to be considered in the overall strength analysis as well as design pressures applicable in formulae for local design.

4.4.2 Basis for selection of characteristic loads

Unless specific exceptions apply, the basis for selection of characteristic loads or characteristic load effects as defined below shall apply in the temporary as well as the operational design conditions.

Temporary design conditions cover design conditions during transport, assembly, maintenance, repair and de-commissioning of structures. Operational design conditions cover normal operation. For design conditions and loads during load-out, transport and installation reference can be made to relevant parts of DNV-OS-H101, DNV-OS-H102, GL ND 0027, GL ND 0028 and GL ND 0030.

For the operational design conditions, the basis for selection of characteristic loads and load effects are specified in Table 4-1.
Characteristic values of environmental loads or load effects, which are specified as the 99% quantile in the distribution of the annual maximum load or load effect, shall be estimated by their central estimates.

### 4.4.3 Permanent loads (G)

Permanent loads are loads that will not vary in magnitude, position or direction during the period considered. Examples are:

- mass of structure
- mass of permanent ballast and equipment
- external and internal hydrostatic pressure of a permanent nature
- reactions to the above.

The characteristic load of a permanent value is defined as the expected value based on accurate data of the unit, mass of the material and the volume in question.

### 4.4.4 Variable functional loads (Q)

Variable functional loads are loads which may vary in magnitude, position and direction during the period under consideration, and which are related to operations and normal use of the installation. Examples are:

- personnel
- stored materials, equipment, gas, fluids and fluid pressure
- crane operational loads
- ship impacts and loads from fendering
- loads associated with installation operations
- loads from variable ballast and equipment
- helicopters
- lifeboats.

For an offshore substation in the in-place situation, the variable functional loads usually consist of:

- crane operational loads
- ship impacts and loads from fendering
- loads on access platforms and internal structures such as railing, ladders and platforms
- operational loads on helideck.

Loads on access platforms and internal structures are used only for design of the same and do therefore usually not appear in any load combination for design of primary structures and foundations.

---

**Table 4-1 Basis for selection of characteristic loads for operating design conditions**

<table>
<thead>
<tr>
<th>Load category</th>
<th>ULS</th>
<th>FLS</th>
<th>ALS Intact structure</th>
<th>ALS Damaged structure</th>
<th>SLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permanent (G)</td>
<td></td>
<td></td>
<td>Expected value</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variable (Q)</td>
<td></td>
<td></td>
<td>Specified value</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environmental (E)</td>
<td>99% quantile in distribution of annual maximum load or load effect (load or load effect with return period 100 years)</td>
<td>Expected load or load effect history</td>
<td>n/a</td>
<td>Load or load effect with return period not less than 1 year (^1)</td>
<td>Specified value</td>
</tr>
<tr>
<td>Accidental (A)</td>
<td>n/a</td>
<td>n/a</td>
<td>Specified value</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Deformation (D)</td>
<td></td>
<td></td>
<td>Expected extreme value</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) Loads of a recurrence period not shorter than twice a conservative estimate of the time required to design, fabricate, inspect and install all repairs necessary to restore the structure’s design resistance shall be assumed, however not less than one year.
functional loads on platform areas shall be determined in accordance with DNVGL-ST-0126 [3.7.2] or DNVGL-OS-C101.

Guidance note 1:
Cable or flexible riser pulling during installation is a variable functional load on the structures and the cables. For handling of the main cables during installation reference is made to DNVGL-RP-360 covering specifications for cable handling.

Loads and dynamic factors from maintenance and service cranes on structures shall be determined in accordance with requirements given in DNV Standard for Certification No. 2.22 Rules for Certification of Lifting Appliances.

Operational ship impact loads are used for the design of primary structures and foundations and for design of some secondary structures such as ladders and boat landings.

The characteristic value of a variable functional load is the maximum (or minimum) specified value, which produces the most unfavourable load effects in the structure under consideration.

The specified value shall be determined on the basis of relevant specifications. An expected load history or load effect history shall be used in the FLS, as applicable.

Impacts from approaching service vessels shall be considered as variable functional loads. Analyses of such impacts in design shall be carried out as ULS analyses. The analyses of operational impact shall include associated environmental loads from wind, waves and current. The added water mass contributes to the kinetic energy and shall be taken into account.

For design against operational ship impact in the ULS, the load shall be taken as the largest unintended impact load in normal service conditions. It is a requirement that the primary substation structure and its foundation do not suffer any damage in consequence of this operational ship impact. Secondary structural parts such as boat landings and ladders shall not suffer from damage leading to loss of their respective functions.

Guidance note 2:
A risk analysis forms the backbone of a ship impact analysis. The largest unintended impact load is part of the results from the risk analysis.

In lieu of data, it is an option to consider the impact from an approaching, maximum authorized service vessel, assuming broadside collision with appropriate fendering and assuming a speed not less than 0.5 m/s.

Design information on further variable loads is contained within DNVGL-OS-C101 Ch.2 Sec.2:

— functional loads on deck areas
— tank pressures
— lifeboat platform.

For operational helideck loads reference is made to DNVGL-OS-E401 Ch.2 Sec.2 or CAP 437 Ch. 3.

4.4.5 Environmental loads (E)

Environmental conditions consist of all site-specific conditions which may influence the design of a substation structure and its foundation by governing its loading, its capacity or both. They include but are not limited to meteorological conditions, oceanographic conditions, seismicity, biology and various human activities. Wind, waves, current and water level (taking due account of potential settlements and subsidence) directly govern the environmental loads. Rain, snow, hail and ice may all produce additional loads of importance for design. Humidity, salinity and sunlight will not necessarily imply any loading, but may over time cause degradation of the material strength and the structural capacity, e.g. by corrosion.

Environmental loads are loads which may vary in magnitude, position and direction during the period under consideration, and which are related to operations and normal use of the installation. Examples are:

— hydrodynamic loads induced by waves and current, including drag forces and inertia forces
— wind
— earthquake
— tidal effects
Practical information and guidance regarding environmental conditions and environmental loads are given in DNV-RP-C205.

Characteristic environmental loads and load effects shall be determined as quantiles with specified probabilities of being exceeded. The statistical analysis of measured data or simulated data should make use of different statistical methods to evaluate the sensitivity of the result. The validation of distributions with respect to data should be tested by means of recognised methods. The analysis of the data shall be based on the longest possible time period for the relevant location. In the case of short time series, statistical uncertainty shall be accounted for when characteristic values are determined.

For prediction of characteristic wave loads, appropriate wave theories and wave kinematics shall be selected with due consideration of the actual water depth. Guidance in this respect is given in DNV-RP-C205. Guidance for calculation of the wave loads themselves is also provided in DNV-RP-C205. For large-volume structures where the wave kinematics is disturbed by the presence of the structure, radiation analysis or diffraction analysis shall be performed to determine the wave loads, e.g. excitation forces and pressures. For slender structures such as bracings and jacket legs, for which Morison’s equation is applicable for prediction of the wave loads, the involved drag and inertia coefficients should be carefully computed according to guidance given in DNV-RP-C205.

For prediction of characteristic wind loads, appropriate wind profiles shall be selected. Guidance in this respect is given in DNV-RP-C205. Guidance for calculation of the wind loads themselves is also given in DNV-RP-C205. Characteristic values of loads from current shall be based on current velocity profiles with due account for the directionality of the current. Methods and current profiles given in DNV-RP-C205 may be used for this purpose.

Intervals of velocities of wind, waves and currents, in which lock-in to the frequencies of vortices shed from individual elements can potentially develop, may be determined based on the methods described in DNV-RP-C205. Also vortex-induced vibrations of frames shall be considered. Material damping and structural damping of individual elements in welded steel structures shall not be set higher than 0.15% of critical damping. The structure and its elements should in general be designed so as to avoid lock-in to vortex shedding, be in temporary situations or in the in-place operational phase.

Water level loads consist of tidal effects and storm surge effects. Characteristic tidal effects and storm surge effects shall be considered in evaluation of responses of interest. Higher water levels tend to increase hydrostatic loads and current loads on the structure; however, situations may exist where lower water levels will imply the larger hydrodynamic loads. Higher mean water levels also imply a decrease in the available air gap to access platforms and other structural components which depend on some minimum clearance. In general, both high water levels and low water levels shall be considered, whichever is most unfavourable, when water level loads are predicted. For prediction of characteristic extreme responses in the ULS there are thus two 100-year water levels to consider, i.e. a low 100-year water level and a high 100-year water level.

Guidance note:
Situations may exist where a water level between the two 100-year levels will produce the most unfavourable responses.

The air gap is defined as the vertical clearance between the substation topside structure and the maximum wave crest elevation. Further details are given in [4.8.6].

Ice loads from moving ice as well as from ice accretion shall be accounted for in design wherever applicable. Loads from laterally moving ice shall be based on relevant full scale measurements, on model experiments which can be reliably scaled, or on recognised theoretical methods. Guidance for prediction of ice loads is given in DNVGL-ST-0437.

When a substation structure is intended for installation on a site which may be subject to an earthquake, the structure and its foundation shall be designed to withstand the earthquake loads. Some guidance in this respect is given in DNVGL-ST-0126.
Effects of marine growth shall be taken into account by increasing the outer diameter of the structural component in question in the calculation of hydrodynamic wave and current loads. The thickness of the marine growth depends on the depth below sea level and on the orientation of the structural component. The thickness shall be assessed based on relevant local experience and existing measurements. Further guidance is given in DNVGL-ST-0126, DNVGL-RP-C205 [6.7.4] or ISO 19901-2.

Effects of scour shall be accounted for in design. Scour is the result of erosion of soil particles at and near a foundation and is caused by waves and current. Scour is a load effect and may have an impact on the geotechnical capacity of a foundation and thereby on the structural response that governs the ultimate and fatigue load effects in structural components. Guidance for prediction of scour and for means to prevent scour is given in DNVGL-ST-0126 and in Classification Note No. 30.4.

Criteria shall be defined for acceptable external conditions during transportation, installation and dismantling of substation structures and their foundations. Based on the applied working procedures, on the vessels used and on the duration of the operation in question, acceptable limits for the following environmental quantities shall be specified:

— wind speed
— wave height and wave crest
— water level
— current
— ice.

It shall be documented that lifting fittings mounted on a structure subject to lifting are shaped and handled in such a manner that the structure will not be damaged during lifting under the specified environmental conditions. DNV GL service documents relevant parts of DNV-OS-H101, DNV-OS-H102, GL ND 0027, GL ND 0028 and GL ND 0030 for load out, transport and installation apply.

The combined load effect in the structure due to concurrent wind and wave loads and possible other concurrently acting environmental loads shall be considered in design. When information is not available to produce the characteristic combined load effect, in the ULS defined as the 100-year value of the combined load effect, the characteristic combined load effect may be established as the largest combined load effect that results from the load combinations specified in DNVGL-OS-C101 Ch.2 Sec.2 Table 4. Also refer to subsection [4.3.2], in particular the last guidance note therein.

4.4.6 Accidental loads (A)

Accidental loads are loads related to abnormal operations or technical failure, which in general are insufficiently or not at all covered by statistics of past observations. Examples of accidental loads are loads caused by:

— dropped objects
— collision impact
— explosions
— fire
— accidental impact from vessels, helicopters or other objects.

Relevant accidental scenarios shall be identified on the basis of international practice, experience with offshore designs and results from risk assessments. For relatively standardised designs the prescriptive requirements given in standards are intended to anticipate the most likely hazards which may be encountered. For complex or non-standard applications a more comprehensive assessment shall be carried out, see Sec.2.

For temporary design conditions, the characteristic load may be a specified value dependent on practical requirements. The level of safety related to the temporary design conditions is not to be inferior to the safety level required for the operating design conditions.

The requirements shall be based on consideration of the integrity of the following main safety functions:

— integrity of shelter areas
— usability of escape ways
— usability of means of evacuation
— global load bearing capacity
— Safe usability of the structure, both globally and locally, when subject to reduced loads in the post-
damage situation.

The selection of relevant characteristic accidental loads is dependent on a safety philosophy considered to
give a satisfactory level of safety. The characteristic loads defined here are generally based on accidental
loads which affect safety functions and which have an individual and mostly not reliably predictable
frequency of occurrence.

Guidance note:
For individual accidental loads caused by extreme weather, the characteristic load is defined as the environmental load whose
probability of being exceeded is $10^{-4}$, i.e. a 10 000-year load. However, since the substation often is located in shallow water the
100-year ULS load multiplied by partial safety factors will normally be larger than the ALS load and the ALS load case will then not
be relevant and can be left out.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

For ALS design, the maximum wave crest elevation above still water level shall be taken as the crest
elevation whose return period is 10 000 years and can be calculated according to DNV-RP-C205. The still
water level shall be taken as the high water level whose return period is 10 000 years.

4.4.6.1 Dropped objects
For accidental loads from dropped objects, it is assumed that lifting arrangements comply with DNV Rules
for lifting appliances with regard to location of cranes and lay down areas and with respect to lifting
operations over pressurised equipment, if any. It is recommended that critical areas (such as
accommodation, workshops, storage areas) are designed for dropped object loads.

The weights of the dropped objects to be considered for design of the structure are normally taken as the
operational hook loads in cranes.

The impact energy $E$ (in kJ) should not be less than:

$$E = m \cdot g \cdot h$$

where:

$m$ = mass of object, in t
$g$ = acceleration due to gravity, 9.81 m/s$^2$
$h$ = drop height in air, in m

Critical areas on structures incorporating a meteorological tower shall be designed for accidental collapse
of the tower.

A distinction may be made between crane-dropped objects and helicopter-dropped objects. Helicopter-
dropped objects consist of loads accidentally dropped from the helicopter that carries them and of the
helicopter itself in the case of a helicopter crash. For estimation of accidental loads associated with
helicopter transportation, DNVGL-OS-E401 may be consulted.

In order to reduce accidental loads from dropped objects, it is recommended to install protection, such as
lattice works, for example around drop-off zones for helicopter loads. For the same purpose, it is also
recommended to avoid lifting over pressurised vessels.

4.4.6.2 Ship collision
The characteristic accidental ship collision load shall normally be taken as the load from unintended collision
by the maximum authorised service vessel size, assumed to be adrift towards the structure. The speed of
the drifting vessel shall be assessed in each case, but shall not be assumed to be less than 2 m/s. A laterally
drifting ship shall be assumed and added mass (water) shall be considered in the analysis. The impact
energy $E$ (in kJ) is given as:

$$E = \frac{1}{2} (m + a) v^2$$

where:
If the offshore substation will be located in or near a shipping lane, a detailed assessment of collision risks and loads shall be carried out.

**Guidance note:**
The detailed assessment is often carried out very early as a part of the environmental impact assessment.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

### 4.4.6.3 Fire

Where accommodation areas, temporary refuge or shelter areas can be exposed to a heat load, A60 passive fire protection shall be foreseen. Critical items shall be designed to withstand anticipated heat loads, including:

- protective walls
- structures of which the collapse can potentially block escape ways
- essential safety systems
- main structure.

Loss of structural strength due to heat loads and hereby high temperatures shall be taken into account.

**Guidance note:**
The critical temperature for aluminium with respect to structural integrity is highly dependent on type of alloy and it is therefore important to identify correct critical temperature for relevant material and alloy. Other critical temperatures may be used provided that corresponding changes are taken into account concerning the thermal and mechanical properties.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

### 4.4.6.4 Explosion

Evaluation of explosion loads on offshore substations should consider the following sources:

- explosive atmospheres involving, for instance, hydrogen (battery charging) or aviation fuel (local fuel storage)
- internal transformer short circuit causing tank rupture with subsequent oil-mist explosion
- overpressure of oil-cooled equipment
- overpressure in high voltage switchgear.

In a ventilated compartment the explosion load given by the explosion overpressure and duration is mainly determined by the relative ventilation area and the level of congestion.

Designs shall as far as possible aim to minimise the possibility of gas build up.

The following items shall be designed to withstand the specified design overpressure:

- protective walls
- structures of which the collapse can potentially block escape ways
- safety systems (and control lines).

### 4.4.7 Deformation loads (D)

Deformation loads are loads caused by inflicted deformations such as:

- temperature loads
- built-in deformations
- shrinkage in concrete
- settlement of foundations.
Structures shall be designed for the most extreme temperature differences they may be exposed to. This applies to, but is not limited to:

- storage tanks
- structural parts that are exposed to radiation
- structural parts that are in contact with electrical equipment.

The characteristic ambient sea or air temperature is calculated as an extreme value with an annual probability of being exceeded (or fallen below of, as relevant) equal to $10^{-2}$, i.e. a temperature whose return period is 100 years.

Settlement of the foundation shall be considered for permanently located structures founded on the seabed. The possibility of, and the consequences of, subsidence of the seabed during the service life of the structure shall be considered.

4.5 Load and resistance factors

4.5.1 Load factors

Requirements to load factors to be used in design depend on which safety class is aimed for in design. Unmanned offshore structures are usually designed to normal safety class, whereas manned structures are usually designed to high safety class. Owing to the severe economic consequences associated with a failure of the offshore substations, they shall be designed to high safety class even if normally unmanned.

Table 4-2 provides two sets of load factors to be used when characteristic loads or load effects from different load categories are combined to form the design load or the design load effect for use in design against the ULS.

<table>
<thead>
<tr>
<th>Load factor set</th>
<th>Load category</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>Q</td>
</tr>
<tr>
<td>(a)</td>
<td>1.3</td>
</tr>
<tr>
<td>(b)</td>
<td>$\psi$</td>
</tr>
</tbody>
</table>

For values of $\psi$, see further below.

When permanent loads (G) and variable functional loads (Q) are well defined, e.g. hydrostatic pressure, a load factor of 1.2 may be used in combination a) for these load categories.

For permanent loads (G) and variable functional loads (Q), the load factor in the ULS shall normally be taken as $\psi = 1.0$ for load combination (b) of Table 4-2.

When a permanent load (G) or a variable functional load (Q) is a favourable load, then a load factor $\psi = 0.9$ shall be applied for this load in combination (b) of Table 4-2 instead of the value of 1.0 otherwise required. The only exception from this applies to favourable loads from the weight of foundation soils in geotechnical engineering problems, for which $\psi = 1.0$ shall be applied. A load is a favourable load when a reduced value of the load leads to an increased load effect in the structure and/or a reduced safety against loss of global stability.

Guidance note:

One example of a favourable load is the weight of a soil volume which has a stabilising effect in an overturning problem for a foundation.

Another example is pretension and gravity loads that significantly relieve the total load response.

The structure shall be able to resist expected fatigue loads which may occur during temporary and operational design conditions. Whenever significant cyclic loads may occur in other phases, e.g. during manufacturing and transportation, such cyclic loads shall be included in the fatigue load estimates. The load factor $\gamma_f$ in the FLS is 1.0 for all load categories.

For design against the SLS, the load factor $\gamma_f$ is 1.0 for all load categories, both for temporary and operational design conditions.
For design against the ALS, the load factor $\gamma_f$ is 1.0.

Useful information for selection and application of load factors is also provided in ISO 19901-3 and ISO 19902.

4.5.2 Resistance factors

Material factors for the ULS are given in the relevant sections of DNVGL-OS-C101 for steel structures, in the relevant sections of DNV-OS-C502 for concrete structures and in DNVGL-ST-0126 Sec.6 for grouted connections.

Alternatively the methods and partial resistance factors according to ISO 19902 can be applied if the overall safety level defined in this standard is being met.

The design fatigue factor (DFF) for design of steel structures and concrete structures against the FLS is given in Table 4-3. The material factor $\gamma_m$ for design of grouted structures against the FLS is given in DNVGL-ST-0126 [6.4.1].

**Table 4-3 Design fatigue factor for steel structures and for concrete structures**

<table>
<thead>
<tr>
<th>No access for inspection and repair</th>
<th>Accessible 1) location in the submerged zone 2)</th>
<th>Accessible 1) location above the splash zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.0</td>
<td>3.3</td>
<td>2.0</td>
</tr>
</tbody>
</table>

1) For accessible areas, use of the specified DFFs is based on the assumption that programmed and systematic in-service inspections with respect to fatigue are carried out.

The parts of a structure where a failure can lead to substantial consequences shall be inspected for cracks on a yearly basis by appropriate NDT methods.

In case a proper inspection planning by crack growth calculation justifies a less frequent inspection interval, the interval may be adjusted accordingly. The inspection intervals shall be determined by consideration of criticality, calculated fatigue life, crack growth characteristics and probability of crack detection. For the assessment of inspection intervals reference is made to DNV-GL-RP-0001. However the period between inspections shall not exceed 5 years.

2) In areas with harsh environments, such as in the North Sea, it is common to assume that structural details located below or in the splash zone are not accessible for inspection and repair. The splash zone is defined in DNVGL-ST-0126.

The material factor $\gamma_m$ for the ALS and the SLS shall be taken as 1.0.

4.6 Materials

4.6.1 General

Material specifications shall be established for all structural materials. Such materials shall be suitable for their intended purpose and have adequate properties in all relevant design conditions.

The material properties and verification that these materials fulfil the requirements shall be documented.

4.6.2 Steel materials

For selection of steel materials, DNVGL-OS-C101 Ch.2 Sec.3 *Structural Categorisation, Material Selection and Inspection Principles* shall apply.

In case steel materials according to EN 10225, EN 10025, EN 10210, EN 10219, API Spec 2Y, API Spec 2W or others shall be used, selection will be according to the flow chart in Figure 4-2.

Selection of equivalent steel grades has to consider the following parameters:

- chemical composition especially CEV and Sulfur-Value
- impact properties (Charpy Values and test temperature)
- location and orientation of impact test pieces.

**Guidance note:**

During the production process of steel plates at the mill the raw material is hot rolled several times with influence on the grain structure. For the outer area as seen perpendicular to the plate surface, the flat grains are oriented parallel to the surface. These grains have different Charpy values in different directions: high values in longitudinal direction, medium values in transversal direction and low values in through thickness direction, caused by grain structure and Manganese Sulfide on the grain boundaries. The presence of less homogenous grain structure towards the middle of thick steel plates causes a much higher variation of grain geometry, i.e. more or less flat grains with more or less different Charpy Values in longitudinal, transversal and through thickness direction. This effect is only relevant for steel plates exceeding a certain thickness (about 70 mm), as in thinner plates the perpendicular distance
from the surface is not reached. Furthermore the cool down process of a slab of metal before it is further processed, promotes a different chemical composition towards the middle of the material. The presence of a less homogenous grain structure and less advantageous chemical properties towards the middle of thick steel plates causes a much higher variation and therefore in some cases lower transversal impact properties.

Steels according to EN 10225 of higher quality groups (2 and 3) are specified and tested for ductile properties not only at subsurface position or one fourth of the plates’ thickness, like ship building steels according DNVGL-OS-B101, but additional to subsurface also at mid thickness. In this way it is assured that deficiencies, that lead to the thickness limitations according DNVGL-OS-C101 cannot occur.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

Figure 4-2 Selection of equivalent steel grades

For the DNV GL ship building steel grades, equivalent steel grades according EN 10225, EN 10025, EN 10210, EN 10219, API Spec 2W and API Spec 2Y, shown in Table 4-4 to Table 4-6, may be used.
Table 4-4  Thickness limitation (mm) of equivalent steel grades for Special structural category and service temperatures

<table>
<thead>
<tr>
<th>Steel Grade</th>
<th>Steel Grade</th>
<th>Product type</th>
<th>$\geq+10^\circ$C</th>
<th>0$^\circ$C</th>
<th>-10$^\circ$C</th>
<th>-20$^\circ$C</th>
<th>-25$^\circ$C</th>
<th>-30$^\circ$C</th>
</tr>
</thead>
<tbody>
<tr>
<td>VL A36 4) / AW36</td>
<td>S355J2 4) / EN 10025-2</td>
<td>Plates/sections</td>
<td>15</td>
<td>10</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
</tr>
<tr>
<td></td>
<td>S355J2H 4), EN 10210</td>
<td>Hot finished tubes</td>
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1) Test temperature -60°C, Option S2
2) 2.30, Option S4 or $S_{\text{max}} \leq 0.006$, Option S5
3) $S_{\text{max}} \leq 0.008$  
4) 3.35, Option for thickness $\geq 25$ mm
5) For service temperature below -20°C the upper limit for use of this grade must be specially considered
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1) Test temperature -60°C, Option S2
2) Z30, Option S4 or \(\sqrt{\text{min}} \leq 0.006\), Option S5
3) \(\sqrt{\text{min}} \leq 0.008\)
4) Z35, Option for thickness \(\geq 25\) mm
5) For service temperature below -20°C the upper limit for use of this grade must be specially considered
Material certificates are required as specified in [10.3] and DNVGL-OS-C401.

Structural categorisations shall be defined in accordance with DNVGL-OS-C101.

**Guidance note:**
Tubular joints are categorised as “Special” due to their biaxial or tri-axial stress patterns and risk of brittle like (unstable) fracture.

In case of using Eurocode, tubular joints are categorised as EXC4 due to their biaxial or tri-axial stress patterns and risk of brittle like (unstable) fracture. This will influence the thickness limitations as specified in DNVGL-OS-C101.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

### Table 4-6 Thickness limitation (mm) of equivalent steel grades for Secondary structural category and service temperatures

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1) Test temperature -60°C, Option S2
2) Z30, Option S4 or $S_{max} \leq 0.006$, Option S5
3) $S_{max} \leq 0.008$
4) Z35, Option for thickness $\geq 25$ mm
5) For service temperature below -20°C the upper limit for use of this grade must be specially considered

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4.6.3 Concrete materials
For selection of structural concrete materials, DNV-OS-C502 Sec.4, Materials shall apply.

4.6.4 Grout materials
The materials for grouted connections shall comply with relevant requirements given for both concrete and grout in DNV-OS-C502 Sec.4 Materials. The properties of structural grout shall be documented on a material certificate as defined in DNVGL-ST-0126 [6.3].

4.6.5 Aluminium materials
For selection of aluminium materials, DNVGL-OS-B101 Ch.2 Sec.2, shall apply.

4.7 Structural analysis

4.7.1 Structural modelling
The calculation model (“idealization”) used has to take account of all main load bearing and stiffening components, and of the relevant supporting and constraining effects.

The degree of subdivision (detailing) shall take account of the geometry of the structure and its influence on the load distribution and introduction, of the distribution of external loads, and of the expected stress pattern.

Elements or members considered as being of “secondary” importance may nevertheless have to be accounted for where they have an influence on stress distribution or dynamical properties of the structure.

Appurtenances need to be taken into account if they contribute to the overall weight or attract aerodynamic or hydrodynamic forces as boat landings, anodes, conductors or risers do.

Where modelling is made by means of beam elements, the actual rigidities are to be accounted for as precisely as practicable, particularly in way of connections (joints). The effective width of associated plating may be chosen according to accepted standards.

In beam structures (e.g. jackets) the nodes of the model shall be the intersection points (working points) of the centre lines of the braces with the centre line of the chord. The offset is the distance between brace working points. For global analyses, only offsets larger than chord diameter D/4 shall be included in the model.

Depending on the diameter of the chord in beam structures, the length between the physical end of the brace stub and the centre line of the chord can be significant. In such cases the length of braces between the outer surface of the chord and its centre line should be modelled as rigid connections with a stiffness at least one order of magnitude (10 times) greater than that of the brace. Rigid links shall not contribute to the mass and shall not attract direct hydrodynamic or aerodynamic forces.

Stress concentration effects shall be carefully investigated, either by using adequate calculation methods (e.g. finite elements), or by applying stress concentration factors where proven and applicable design data exist. Stress concentration factors (SCF) shall be applied in accordance with requirements given in DNVGL-RP-0005:2014-06, Sec.3.

The soil stiffness is to be represented as precisely as practicable when designing structures resting on or penetrating into the sea floor.

For calculations analysing the dynamic behaviour of the whole structure (global behaviour), the mass distribution may generally be simulated in a simplified form, using equivalent or lumped masses under consideration of its centre of gravity and moments of inertia. Details may have to be agreed upon.

Model investigations (tests) may be accepted as a supplement to structural analysis provided that a recognized institution is involved and the particulars have been agreed. In special cases model tests may be required.
4.7.2 Load effect analysis
Structural analysis is the process of determining the load effects in a structure, or part thereof, in response to each significant set of loads. Load effects, in terms of motions, displacements, and internal forces and stresses in the structure, shall be determined with due regard to:

— their spatial and temporal nature including possible nonlinearities of the load and dynamic character of the response
— the relevant limit states for design checks
— the necessary accuracy in the relevant design phase.

Permanent loads, functional loads, deformation loads, and fire loads can generally be treated by static methods of analysis. Environmental loads (by wind, waves, current, ice and earthquake) and certain accidental loads (by impacts and explosions) may require dynamic analysis. Inertia and damping forces are important when the periods of steady-state loads are close to natural periods or when transient loads occur.

In general, three frequency bands need to be considered for offshore structures:

— High frequency band (HF): Rigid body natural periods below the dominating wave periods, e.g. ringing and springing responses.
— Wave frequency band (WF): Typically wave periods in the range 4 to 25 seconds. Applicable to all offshore structures located in the wave active zone.
— Low frequency band (LF): Relates to slowly varying responses with natural periods beyond those of the dominating wave energy (typically slowly varying motions).

For fully restrained structures a static or dynamic wind/wave-structure-foundation analysis is required.

Uncertainties in the analysis model are expected to be compensated for by the load and resistance factors. If uncertainties are particularly high, conservative assumptions shall be made.

If analytical models are particularly uncertain, the sensitivity of the models and the parameters utilised in the models shall be examined. If geometric deviations or imperfections have a significant effect on load effects, conservative geometric parameters shall be used in the calculation.

In the final design stage theoretical methods for prediction of important responses of any novel system should be verified by appropriate model tests. Full scale tests may also be appropriate, in particular for substation installations in large wind farms.

Earthquake loads need only be considered for restrained modes of behaviour, and it should be considered that a main problem is likely to be the dynamic responses of the support of major equipment.

Load effects in the structures and in the foundation soils, consisting of displacements, forces and stresses in the structure and its foundation, shall be determined for relevant combinations of loads by means of recognised methods, which take adequate account of the variation of loads in time and space, the motions of the structure and the limit state which shall be verified.

Nonlinear and dynamic effects associated with loads and structural response shall be accounted for whenever relevant.

The stochastic nature of environmental loads shall be adequately accounted for.

4.7.3 Motion analysis
Global motion analysis can be carried out to determine displacements, accelerations, velocities and hydrodynamic pressures relevant for the loading on the structure. Excitation by waves, current and wind should be considered.

A dynamic analysis of the substation structure and its foundation shall be carried out for determination of motions of the topside and verification that motions which are unacceptable for topside equipment will not occur in the in-place condition. The analysis shall be carried out for loading conditions in an extreme sea state characterised by the 100-year significant wave height (in-place condition).

Characteristic loads shall be assumed for the analysis.
Guidance note 1:
Motion studies may be particularly important to assess the suitability of the HV equipment the design of which is mainly based on equipment used on onshore installations and with support arrangements that may not be prone to support fatigue or overload if subject to movements or accelerations. Support improvements may be limited or impossible due to the space requirements and large insulating creep distances to be observed in supports.

In lieu of detailed motion analysis for the transport phase, standard simplified sea transport criteria may be used for design of structure, sea-fastening and grillage.

Guidance note 2:
For transport the sea transport criteria according 0030/ND Guidelines for Marine Transportations should be applied. Further references are provided in Sec.10.4.

During transportation phases temporary fixations of sensitive equipment may be required.

Requirements to lift operations are given in DNV-OS-H205 Lifting Operations or GL ND 0027 Guidelines for Marine Lifting & Lowering Operations.

4.7.4 Results
Results of the analysis will normally take the form of load effects which the structure shall be designed to withstand. Typical load effects required for consideration in the design of fixed offshore structures include the following:

— displacements and vibrations, which shall be within acceptable limits for operation of the platform and its equipment
— section forces, from which the capacity of structural members and components can be determined
— section strains, used to determine crack widths and water tightness
— stress occurrences, used to check the fatigue life of the structure.

Each structural analysis shall be thoroughly documented to record its extent, applicability, input data, verification and results obtained. The following information shall be produced as a minimum to document each analysis:

— purpose and scope of the analysis and the limits of its applicability
— references to methods used and the justification of any assumptions made
— the assumed geometry, showing and justifying any deviations from the current structural geometry
— material properties used in the analysis
— boundary conditions applied to the structure or component
— summed magnitude and direction of all loads
— essential results from the analysis and crosschecks to verify the accuracy of the simulation
— a clear presentation of those results of the analysis that are required for further analysis, structural design or reassessment.

4.8 Design
4.8.1 General
Characteristic values as defined in [4.4.2] and load factor requirements as given in [4.5.1] are prerequisites for design and overrule characteristic values and load factors specified in DNVGL-OS-C101, DNV-OS-C502 and DNVGL-ST-0126 which are referenced in [4.8.2] to [4.8.8].

4.8.2 Steel structures
Steel structures shall be designed according to the requirements given in DNVGL-OS-C101. For design against failure in the FLS, the requirements to the DFF given in [4.5.2] overrule those given in DNVGL-OS-C101.
4.8.3 Concrete structures
Concrete structures shall be designed according to the requirements given in DNV-OS-C502. For design against failure in the FLS, the requirements to the DFF given in [4.5.2] overrule those given in DNV-OS-C502.

4.8.4 Grouted connections
Grouted connections shall be designed according to the requirements given in DNVGL-ST-0126 Ch.6, however with a material factor reflecting the substations’ reference to high safety class.

Guidance note:
Grouted connections in substation structures may be predominantly axially loaded; however, a horizontal shear force may give rise to a significant bending moment in the grouted connection. The axial bearing capacity of grouted connections can be improved by use of shear keys.

Guidance on the detailed analysis of grouted connections by making use of the finite element method is given in DNVGL-RP-0419. Furthermore NORSOK N-004 Annex K provides useful information regarding grouted connections with a specific geometry and subjected to shear force and bending moment in addition to the axial loading.

4.8.5 Foundations
Geotechnical design of foundations shall be carried out in accordance with DNVGL-OS-C101. Guidance for geotechnical design can be found in Classification Note No. 30.4.

The geotechnical design shall be based on the outcome of a soil investigation campaign at the site of the offshore substation. The soil investigation shall comprise at least one soil boring at the location, carried out to adequate depth, and one cone penetration test (CPT) per footing for foundations which comprise more than one footing, if there is no soil boring at the footing.

Borings and cone tests shall as a minimum cover the total depth of pile penetration subsequently designed for.

4.8.6 Air gap
The air gap shall fulfil the below requirements:

— The air gap shall be at least 1 m for the 100-year design wave crest.
— The minimum air gap shall be 20% of the 50 year significant wave height.

Installation tolerances and global water level rise shall be included in the air gap as shall a potential subsidence.

Guidance note:
Sufficient air gap is necessary in order to avoid slamming forces on the platform. The requirements for the air gap are partly intended to account for possible local wave effects due to local seabed topography and shoreline orientation. For large-volume structures, air gap calculation should include a wave diffraction analysis.

The design water level is the high water level with a return period of 100 years. The design wave crest height is the crest height with a return period of 100 years.

Wave run-up, i.e. water pressed upwards along the surface of the structure or the structural members that support the access platform, shall be considered if relevant, either by including such run-up in the calculation of the necessary air gap or by designing the platform for the loads from such run-up.

4.8.7 Auxiliaries
Auxiliary components such as J-tubes, sling platforms and boat fenders shall be designed in accordance with DNVGL-OS-C101. Important issues to consider for design of J-tubes include, but are not necessarily limited to:

— slamming forces
— vibrations
— vortex shedding
— fatigue of supports
— corrosion allowance
— pull-in forces when cables are pulled through
— distance between successive J-tubes
— impact protection
— cable minimum bending radius.

**Guidance note 1:**
Guidance on the design of J-tubes for submarine power cables is contained in DNVGL-RP-0360.

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J-tubes shall be considered as primary structures as they are one of the most critical elements of the offshore substation.

**Guidance note 2:**
If J-tubes are closely spaced they may act as a wall, causing blocking, and attract larger wave loads than they otherwise would.

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### 4.8.8 Corrosion control

Corrosion control of structural steel for offshore structures comprises:

— coatings and/or cathodic protection
— use of a corrosion allowance
— inspection/monitoring of corrosion
— corrosion protective friendly design
— control of environment (internal zones only).

Requirements for corrosion control generally refer to three zones: the atmospheric zone, the splash zone, and the submerged zone. The limits of the splash zone, which is located between the atmospheric zone and the submerged zone, shall be calculated as detailed in DNVGL-ST-0126 [4.16.3] and/or DNVGL-RP-0416 [4.16.3]. The submerged zone may further be divided into a seawater-exposed and a sediment-buried zone. For any internal compartments associated with these three (or four) zones, requirements and methods of corrosion protection may differ from those of externally exposed surfaces.

**Guidance note 1:**
If adequately designed, cathodic protection will provide full corrosion control in the submerged zone (seawater-exposed zone and sediment-buried zone) and in the splash zone up to the mean astronomical tide. Cathodic protection will further contribute to corrosion control in a tidal zone up to highest astronomical tide.

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Steel structure components in the atmospheric zone shall be protected in accordance with requirements given in DNVGL-OS-C101 Ch.2 Sec.9.

Steel structure components in the splash zone shall be protected in accordance with requirements given in DNVGL-OS-C101 Ch.2 Sec.9.

Steel structure components in the submerged zone shall be cathodically protected, preferably in combination with coating. Cathodic protection design shall be carried out according to a recognised standard. Requirements and guidelines to cathodic protection by galvanic anodes are given in DNVGL-RP-0416. In accordance with this standard, cathodic protection design shall consider current drain to any surfaces of the structure or to other electrically connected components that do not need corrosion control.

**Guidance note 2:**
There is at present no standard covering the detailed cathodic protection design of fixed offshore steel structures by impressed current from rectifiers.

For internal submerged zones, use of cathodic protection may not be required if adequate corrosion control can be achieved by corrosion allowance, environmental control and coatings. For permanently sealed compartments, oxygen depletion may reduce the needs for corrosion control. Microbiologically induced corrosion (MIC) should still be considered for compartments containing seawater or seabed sediments.

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Coating systems for surfaces in the splash and submerged zones shall be qualified for compatibility with cathodic protection systems.

**Guidance note 3:**
Coating systems should meet the requirements of NORSOK M-501 and/or ISO 20340. Guidance regarding coating systems can also be found in DNVGL-RP-0416.

Concrete rebars and pre-stressing tendons are adequately protected by the concrete itself, provided that adequate coverage and adequate type/quality of the aggregate is used.

**Guidance note 4:**
It is recommended to always install cathodic protection for a concrete substructure. Reference can be made to DNVGL-ST-0126 [4.16].

### 4.9 Marking

#### 4.9.1 General

A marking system shall be established to facilitate ease of identification of significant items for later inspection. The extent of marking should take account of the nature of the deterioration to which the structure is likely to be subjected and of the regions in which defects are most prone to occur. The identification system should be devised during the design phase. In choosing a marking system, consideration should be given to using materials less prone to attract marine growth and fouling.

Marking of the unit or installation shall be in accordance with relevant national and international regulations.

The name of the unit or installation shall be marked on all sides to be identifiable by sea or air and shall be easily visible in daylight and at night. No name, letters or figures shall be displayed which are likely to be confused with the installation name or designation of another offshore installation.

**Guidance note:**
(N)orth, (E)ast, (S)outh, (W)est markings on the substation structure may be considered for ease of identification.

Platform lights shall meet IALA regulations. Navigational aids should be provided with independent battery backup.
SECTION 5 ELECTRICAL DESIGN

5.1 Introduction
This section provides functional requirements for the safe and reliable operation of electrical components and systems on offshore substations. Sections in this standard are containing important information related to electrical design mainly including:

— [4.2.3], design basis - environmental and oceanographic conditions
— [6.4.7], fire safety considerations in electrical equipment
— [5.10], maintenance.

5.2 Applicability and design process

5.2.1 General
This section is applicable to the electrical equipment installed on the offshore substation, between the EHV/ HV subsea transmission cable terminations (excluded) and the HV subsea inter-array cable terminations (excluded) or, in case of converter platforms, between HV cable terminations AC and cable termination (excluded) of the HV/DC transmission system.

Grid code compliance is not part of this standard. Further information on this topic can be found in DNV GL SE-0125.

5.2.2 Electrical infrastructure
Power engineering equipment usually installed on offshore substations or converter platforms, if applicable, form the infrastructure for power transmission to shore and local internal platform energy conversion and distribution. It therefore asks for high reliability and safe operation even during abnormal conditions. Exposure of human beings to hazards caused by faults in the electrical system or e.g. cloud or arc-flash discharge shall be reduced to a minimum. As a basis, electro technical equipment therefore shall comply with established technical standards and practices stipulated in publications of the International Electrotechnical Commission (IEC). Where the requirements for electrical equipment, facilities or special applications are not laid down in these standards, the scope of the third party involvement is subject to agreement, including the potential use of other guidelines, regulations and/or standards. This may include other publications like e.g. recommendations by CIGRE. Nevertheless, additional standards of local authorities shall be applied whenever necessary. Deviations or exceptions to the present rules will be assessed and granted by DNV GL in each individual case. Deviations from the requirements within this chapter may be approved where there are special reasons. DNV GL reserve the right to specify requirements additional to these rules where they are related to new systems or installations or where they are necessary because of new knowledge or operating experience. Electrical installations shall be designed so that:

— the maintaining of normal operational and habitable conditions will be ensured without recourse to the emergency source of electrical power
— the operation of emergency equipment required for safety will be ensured under various defined emergency conditions
— the safety of personnel and units/installations from electrical hazards will be ensured and risks of injury to human life will be reduced to a minimum
— the integrity of equipment and installations will reach the expected life times in order to secure the asset integrity and continuity of production
— high operational is reached of the entire system.

5.2.3 Design process
The design process is depicted in Figure 5-1. Design objective and performance criteria shall be chosen before design work begins. The design shall be evaluated against the performance criteria and modifications shall be made until the performance criteria are met.
### 5.3 Common definitions and requirements

#### 5.3.1 Operational conditions

##### 5.3.1.1 Normal operational and habitable conditions

Normal operational and habitable condition is a condition under which the substation, as a whole, is in working order and functioning normally. As a minimum, the following functions shall be operational: fire safety, internal and external communications and signals (at least the public address system, general alarm system and platform navigation and identification lights), mechanical ventilation, means of escape, life-boat and fast rescue craft winches and flood lights, and lighting necessary to perform normal operation and maintenance of the unit and emergency lighting. In case of manned or temporarily manned substation, designed conditions for habitability including cooking, heating, domestic refrigeration, mechanical ventilation, sanitary facilities and fresh water shall be planned. All utility systems for the listed functions and the main power system including associated equipment shall be operational as well.

##### 5.3.1.2 (N-1) operational condition

An (N-1) operational condition is a condition following a credible contingency due to:

- loss of function due to a failure in any of the components in the substation main power equipment and its associated control and protection systems,
- loss of function due to a failure in any of the components comprising the substation auxiliary power system that could generally lead to a loss of important operational conditions
- faults causing loss of inadvertent important operations or services types.

(N-1) operational conditions shall be assessed and analysed in a Failure Mode Effect Analysis (FMEA) at the basic design stage of the project in order to assess the feasibility of continued operation in the N-1 mode.

##### 5.3.1.3 Islanded conditions

An offshore substation is in islanded condition when the electrical connection with the external grid is not available.
5.3.1.4 Emergency condition
An emergency condition is a condition under which services needed for normal operational and habitable conditions are not in working due to a failure of the main source of auxiliary power, usually due to an accidental event like fire, flooding, extreme waves and similar. Worst case scenarios and necessary emergency services and procedures shall be considered.

5.3.2 Services

5.3.2.1 Operational services
Operational services are those services that need to be in continuous operation for maintaining the systems which are needed to be available on demand to prevent development of, or to mitigate the effects of an undesirable event, and to safeguard the personnel, environment and the installation. Moreover operational services maintain the substation operations within desired operational limits.

5.3.2.2 Emergency services
a) Emergency services are those services that are essential for safety in an emergency condition.
b) Examples of equipment and systems for emergency services:
   — equipment and systems that need to be in operation in order to maintain, at least, those services that are required to be supplied from the emergency source of electrical power
   — equipment and systems that need to be in operation in order to maintain, at least, those services that are required to be supplied from transitional source(s) of emergency electrical power such as accumulator battery
   — equipment and systems for starting and control of emergency generating sets
   — equipment and systems for starting and control of diesel engines for emergency fire-fighting pumps, if any
   — equipment and systems enabling restoration of main power supply for auxiliary electrical power system after outage.

   c) Requirements for emergency services are given in [5.6.2.9].

5.3.3 Availability and reliability

5.3.3.1 Substation main power availability
The substation main power availability denotes the state of the offshore substation power system when it is able to collect, transform and deliver the active power produced by the wind turbines.

   Guidance note:
   An offshore substation main power system should still be considered available when it is able to collect, transform and deliver active power, even if unable to participate in the required grid regulations (i.e. active or reactive power set point control).

5.3.3.2 Substation minimum availability rate
a) The substation minimum availability rate is the minimum ratio between the active power that can be delivered by the substation under (N-1) operational condition or mode and the nominal active power of the offshore substation:

   \[ AR_{\text{min}} = \min_{i=1}^{m} \left( \frac{P_{\text{N-1}}}{P_n} \right) \times 100 \]

   where:
   \[ P_n \] = nominal active power of the offshore substation at the Point of Common Coupling.
   \[ P_{\text{N-1}} \] = active power of the offshore substation at the Point of Common Coupling under (N-1) operational conditions.
   \[ m \] = number of substation elements of which a failure can cause a permanent decrease of the delivered active power.
Guidance note:
The availability rate has to be increased through redundancy in the main and/or auxiliary power equipment, and flexibility in the main power network (i.e. interconnecting the busbar/nodes at the HV level).
The main transformers should have a capacity that assures that the wind farm can for most wind conditions continue operation in the event of a single main transformer failure.
National grid codes can require a specific redundancy.

b) The substation main power availability rate shall be assessed in the substation failure mode and effect analysis.
c) The (N-1) contingencies to be considered in the FMEA analysis for the AR_{96} assessment shall not be limited to the main power equipment but also to the auxiliary equipment, if these can cause a significant decrease of deliverable active power through their failure.

5.3.3.3 Failure mode and effect analysis
Failure mode and effect analysis (FMEA) is a systematic procedure for the analysis of a system to identify the potential failure modes, their causes on the system performance (IEC 60812). Note that additional techniques may be required if dealing with simultaneous multiple failures.

5.3.3.4 Fault tree analysis
Fault tree analysis (FTA) is a deductive (top down) method of analysis aimed at pinpointing the causes or combinations of causes that can lead to the defined top event (IEC 61025).

5.3.3.5 Mean time between failure
Mean time between failure (MTBF) is defined as the mean time between two consecutive failures (ISO 14224).
The MTBF shall comprise all the relevant components faults.

5.3.3.6 Mean time to repair
a) Mean time to repair (MTTR) is defined as the mean time before the item is repaired (ISO 14224).
b) The MTTR shall include the time to detect the failure, the time to repair/replace and the time to access the platform.

Guidance note:
The definition of MTTR doesn't usually include voluntary or forced waiting time. Forced waiting time can be when items needed for repair are not immediately available as spare part; voluntary waiting time can be when the offshore substation platform is still fully operational due to redundancy, and the optimal time for repair (including possible shut down) is considered to be at a specific later point in time.

5.3.3.7 Substation reliability
a) Substation reliability is the probability that the offshore substation power system is able to collect, transform and deliver the active power produced by the wind turbine generators for the period of time intended under the operating condition encountered.
b) A substation performance based design approach shall be focused on the optimization of the substation reliability, achieved by the four step process shown in Figure 5-2.

The method of reliability centred maintenance (RCM) may be applied. This is a method to identify and select failure management policies to efficiently and effectively achieve the required safety, availability and economy of operation.
5.3.4 Power systems

5.3.4.1 Main and auxiliary power

a) The substation electrical installation shall be divided in two functional subsystems:
   — main power system
   — auxiliary power system.

b) The main power system comprises all the high voltage and medium voltage equipment necessary to
   — collect and transform the power produced by the wind farm and deliver into the offshore transmission system, and their associated control and protection systems (AC-AC transformer station) or
   — collect and convert the incoming AC power to DC power and inject it into the offshore transmission system, and their associated controls and protection systems (AC-DC converter station).

c) The auxiliary power system comprises equipment necessary to the main power system and to the substation in general to safely operate within the design operational conditions.

5.3.4.2 Main supply for auxiliary power system and emergency power supply system

a) The substation auxiliary power system shall be composed by two mutually independent and self-contained electric power supply systems:
   — main supply for auxiliary power system (to enable safe operation of the substation within the design operational conditions)
   — emergency power supply system (to supply emergency services and enable restoration of main power supply for auxiliary power system after outage).

b) Services required for normal operation of the offshore substation shall be operable with the main power system being unavailable.
c) All consumers that support functions required to be available in normal operation, shall be supplied from distribution systems independent of the emergency electrical power supply system.

d) All consumers required to be available in emergency operation shall be supplied from distribution systems independent of the main power system.

e) An overview of a substation electrical system realised according to the design principles described in [5.3.4.1] and [5.3.4.2] a) is shown in Figure 5-3.

Figure 5-3  Electrical system comprising a main supply for auxiliary power system and an emergency power supply system

5.3.4.3  Meshed auxiliary system

a) A meshed auxiliary power supply system will be accepted when the platforms distribution network is provided with the proper redundancy and flexibility in order to assure the operation of emergency services in case of failure of any of the auxiliary power supply system sources.

b) An overview of a substation electrical system realised according to the design principles described in [5.3.4.1] and [5.3.4.3] a) is shown in Figure 5-4.
5.3.5 Boundary conditions

5.3.5.1 Environmental conditions for outdoor installations

a) Equipment located outdoors will be subject to the actual site ambient conditions, which should be described in the basis of design, such as:

- atmospheric pressure (maximum and minimum values) [hPa]
- rain fall (maximum and average values) [mm/year]
- wind speed (at deck elevation [m] as 10 min average and 10 sec gusts) [m/s]
- snow load [kg/m²]
- temperature range [°C]
- relative humidity (not condensing) [%]
- lightning occurrence [average number of lightning strikes per km² per year]
- monthly average daily total solar radiation on horizontal surface [MJ/m²]
- electromagnetic interference e.g. from aerials or high frequency parts of the installation.

b) The design of the electrical equipment foreseen for outdoor installation shall also take into account environmental conditions characterized by UV radiation exposure, high salinity and corrosiveness of the air. Unless otherwise stated, an ambient temperature range of -25°C to +45°C, relative humidity of up to 95% and sun radiation of 1000 W/m² shall be assumed as design basis.

c) The presence of dripping water, condensation, ice, sand, dust and sea bird droppings and guano shall also be considered, when applicable.

5.3.5.2 Environmental conditions for indoor installations

a) Equipment located indoors subjected to weather-protected and environment-controlled installation conditions, should be described by at least the following requirements:

- equipment temperature range [°C]
- relative humidity (not condensing) [%].
b) The design of the electrical equipment foreseen for indoor installation shall also take into account possibility of alteration of environment-controlled installation conditions by penetration of moisture, salinity and dust.

c) Unavailability of the environment-controlled installation conditions at pre-commissioning stage or due to heating, ventilation and air conditioning (HVAC) system equipment failure shall be taken into account.

d) Possible movements/accelerations by platform in high wave conditions.

5.3.5.3 Electrical conditions

a) The substation main power system is connected to the wind farm through the inter-array offshore cabling system. The characteristics of the inlet power depend on the wind turbines and inter-array cables, and should be available at the design stage.

Guidance note 1:
In order to correctly evaluate the current and voltage harmonic contents that will be experienced by the offshore substation equipment, the wind turbine manufacturer should make available to the substation designer the harmonic model of the wind turbine converter as a voltage harmonic source in series to harmonic impedance.

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b) The electrical characteristics at the substation Point of Common Coupling strongly depend on the type of upstream network (AC grid connected or HV/DC connected). As a minimum the following network characteristics should be available from the grid operator:

— positive and negative steady state voltage variation [%]
— positive and negative steady state frequency variation [%]
— maximum and minimum short circuit power [MVA]
— background harmonic content and network impedance loci [%]
— grid inertia (expressed by its acceleration time constant) [s]
— fault clearing time [s]
— reactive power regulation requirements [MVAR].

Guidance note 2:
Not all the network characteristics listed are applicable in case of AC substation connected to a DC-link.

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5.3.5.4 Other conditions

a) Space limitations, if any, shall be defined.

b) Seismicity at the installation location and vibrations (acceleration, deflection) of the platform due to wind and waves, and their impact on electrical equipment shall be evaluated. Results from a motion analysis shall be used to verify electrical equipment suitability.

5.3.6 Design principles

5.3.6.1 Basic design principles and performance criteria

a) Electrical installations shall be such that the safety of substation personnel from electrical hazards is ensured.

b) The electrical design shall be in compliance with applicable recognised international standards and guidelines, national regulations and accepted industry practice known to provide designs with an adequate safety level.

c) Performance criteria may include:

— fire and explosion risk
— risk of electric shock
— exposure of operators to electromagnetic fields
— reliability and availability
— electromagnetic compatibility of equipment.
5.4 Main power system

5.4.1 References

5.4.1.1 General

a) The substation main power system comprises the totality of the electrical power equipment and its associated measuring and protection system, necessary to correctly and safely collect and transform the power which is generated by the wind turbines, to be injected in the offshore transmission system.

b) The substation main power system can also comprise the electrical power equipment necessary to fulfil the power quality characteristics and the reactive power capability (e.g. STATCOM, static filters, etc.) required to comply with the applicable Grid Code and/or project specific grid connection agreements.

c) The substation main power system can also comprise the electrical power equipment (if any) necessary to compensate the charging reactive power of the inter-array cabling system, when the substation is under islanded conditions.

5.4.1.2 Compliance with standards

The requirements of this section refer to applicable parts of the standard DNVGL-OS-D201 and to applicable international standards and guidelines. In case of conflict between IEC standards and DNVGL-OS-D201, the IEC standards shall prevail.

5.4.2 General requirements

5.4.2.1 Electrical design

The electrical design of the equipment in the main power system shall ensure correct operation under all the electrical operating conditions specified in clause [5.3.1]. Major electrical equipment, such as switchgears, power transformers and frequency converters shall be installed in rooms with controlled atmosphere, wherever possible, as specified in IEC 61892-1.

5.4.2.2 Mechanical design

The mechanical design of the equipment comprised in the main power system shall ensure a correct operation under the foreseen installation conditions (e.g. vibration); moreover, the mechanical design and the material properties must be such that the stresses resulting from external electrical fault events do not lead to permanent deformation, fracture, or buckling of the materials. This is to be ensured by selecting an equipment type tested to the relevant short circuit current level or alternatively by calculations.

With the enclosed spaces on an offshore installation, adequate separation between panel compartments and e.g. spark chutes for circuit breakers to be assessed to avoid flash-over events from break-down of air insulation properties by ionised air.

5.4.2.3 Neutral arrangement

a) The neutral arrangement of the substation HV main power system shall be agreed with the grid operator.

b) Main transformers with high voltage neutral point solidly earthed can be accepted with non-uniform insulation. In case of the neutral point connected to the earth by a single pole disconnecting switch, the closing consent to the transformer HV circuit breaker should be interlocked with the status of the disconnecting switch.

c) HV main transformer windings are typically arranged in delta configuration to avoid the zero-sequence currents to be transferred to the high voltage network. In order to avoid a neutral isolated configuration in the HV power network, a neutral point can be created through the installation of earthing transformers or earthing reactors (one for each busbar of the HV switchgear), provided that the requirements in d) are fulfilled.

d) In order to avoid circulating paths for zero-sequence currents during normal operations in the medium voltage network, the following requirements shall be met:

- the neutral of each shunt reactor/capacitor shall be isolated from the ground
- only one HV earthing transformer (if present) shall be connected at the same HV busbar.
5.4.2.4 Switching and interlocking

a) Improper switching operations can lead to failures for the electrical equipment and harmful situations for the personnel. Therefore the interlocking conditions for the operation of the substation main power system shall be provided in an operations manual.

b) It shall be possible to perform switching operations from different locations (e.g. local or remote control panels, substation HMI systems, onshore HMI systems).

c) Only one command location shall be permitted at the same time utilizing local keys, remote keys or software interlocking conditions, with a clear procedure and indications for transfer of responsibility if wanted.

d) During commission activities it shall be possible to “force” the software interlocks. In this case the operator is responsible for preventing possible undesired effects of the switching operation, since the SCADA system is disabled from checking the interlocking conditions.

e) It is recommended that all HV / EHV equipment designed for the purpose of switching or disconnecting power frequency or direct current shall be designed, for normal use, where reasonably practicable, to avoid the exposure of personnel to local operation of live equipment. Consideration for the design of the system should be given to encourage remote operation of all live high voltage equipment in normal operating conditions. Special consideration should be given during commissioning or abnormal operational circumstances to ensure that, where reasonably practicable, considerations should be given to install arc-flash protective circuits for added protection of personnel, and all efforts are to be made to reduce local operation of high voltage live equipment. Where this is not possible safe systems of work shall be arranged.

5.4.3 Installation requirements

5.4.3.1 Reference standards

The substation main power system installation shall generally comply with IEC 61936-1, where applicable. General principles for the arrangement of large electrical appliances are given in [3.5].

5.4.3.2 Arrangement of main power electrical rooms

General installation requirements for bunded areas are given in [3.5.7].

Arrangement of main power electrical rooms:

a) The space where high voltage and medium voltage switchboards are installed shall be so arranged that hot gases escaping from the switchboard in case of an internal arc are led away from an operator present in front of the switchboard.

b) Passages needed for installation and maintenance work and the free passages behind (if applicable) the main power switchgears shall be as specified in Table 5-1.

Table 5-1 Minimum switchboard room passages

<table>
<thead>
<tr>
<th>System</th>
<th>Width of front passage</th>
<th>Width of passage behind (only if applicable)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unobstructed</td>
<td>With doors open or switchgear drawn out</td>
</tr>
<tr>
<td>Switchgear with nominal voltage above 1000 V</td>
<td>1.0 m</td>
<td>0.5 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Minimum free passage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Minimum free passage at frame</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.0 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.6 m</td>
</tr>
</tbody>
</table>

c) The layout of the transformer room shall allow easy access to valves or areas foreseen for oil sampling.

5.4.3.3 Main power cables installation

Cables should be installed in one piece as far as reasonably practicable. Design of possible cable splices are subject to review.
5.4.4 Main power transformers

5.4.4.1 Reference
The design of the main power transformers shall in general comply with the requirements of the relevant parts of IEC 60076.

5.4.4.2 Electrical design requirements

a) Requirements given in [5.4.2] shall be applied.

b) If the electrical system design of the offshore substation assumes redundancy in the main step-up transformers system, each main transformer shall be sized according to the stated Availability Rate, as specified in [5.3.3.2].

c) Beside the active power, the determination of the main transformer nominal power shall take into consideration also the reactive power demand and the voltage range, according to the relevant grid code reactive power exchange requirements.

d) The rated power of the transformer shall be based on the fundamental frequency components of voltage and current. The temperature rise and cooling requirements of the transformer shall be determined after the evaluation of losses due to harmonics, if applicable.

Guidance note:
In order to maintain the voltage level at the LV terminals of the transformer at a value as close as possible to 1 p.u., for all the possible transformer load conditions, an OLTC might be installed. The tap-changer voltage regulation is usually performed continuously by a dedicated Automatic Voltage Regulator (AVR).

Some grid operators explicitly require the installation of main transformers equipped with OLTC; often in these cases the voltage regulation range and voltage step per tap have to be agreed with the grid operator. Some national grid codes explicitly state these parameters.

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e) Main transformers shall be equipped with a set of sensors/ and relays able to monitor the conditions of the insulation system, the conditions of the cooling system and the temperature of the windings. Sensors and the relays installed on-board the transformer shall be designed to withstand the environmental installation conditions as specified in the [5.3.5.1] and [5.3.5.2].

f) In case of the main transformer being installed outdoors or installed indoors with a nominal power equal or exceeding 100 MVA, an online monitoring system for the oil/gas condition is recommended (i.e. oil moisture/gas detector). The online detector shall be of an early-warning type and shall enable maintenance activities based on oil/gas conditions monitoring.

5.4.4.3 Mechanical design requirements

a) Requirements given in [5.4.2.2] shall be applied.

b) The transformer mechanical design shall consider the transformer to be permanently subjected to the vibrations experienced by the substation structure due to wind and waves. These vibrations might lead to damages due to infrequent high-magnitude acceleration or to fatigue or loosening due to long-term low-level vibrations.

c) Implementation of extra supports for internal leads to prevent fatigue failure from the constant vibrations shall be considered in the transformer design.

d) Operation of Buchholz relays may experience problem during large displacements: generally it should be considered that electromechanical auxiliary relays can be sensitive to vibration.

e) If the transformer is equipped with an OLTC it should be considered if this device will be able to cope with the expected vibrations.

f) The transformer shall be designed to be able to withstand, in its complete assembled configuration, the acceleration forces experienced during the transportation from the construction yard to the offshore site. The expected acceleration forces shall be provided by the substation designer to the transformer manufacturer. Alternatively the transformer manufacturer shall specify temporary measures to be taken during the transportation from the construction yard to the offshore site (e.g. partial oil filling during transportation).

g) Consideration should be given to provide an oil filtering unit to avoid long term deterioration of the oil. Alternatively, the expected oil change-out intervals should be made clear at the design stage.
h) The mechanical assessment of the transformer should include measures to contain the effects of a possible short-circuit in the oil-filled transformer.

**Guidance note:**
A short circuit in a transformer produces a gas bubble of the order of 100 cc per kJ (see CIGRE Technical Brochure 537) within approximately a 1/3 cycle, consisting mainly of a mix of hydrogen and acetylene, i.e. about 1 m³ for a short circuit level of 10 MJ. Since transformers are normally rated liquid tanks and not designed as pressure vessels, it is very possible that the short circuit will cause a rupture of the tank. The initial (primary) gas escape/explosion may cause a pressure pulse large enough to cause damage to walls, decks and fittings, and if ignited straight away may lead to a fire and subsequent pool fire of the oil escaping.

If the gas mixes with air to between Lower Explosive Limit (LEL) and Upper Explosive Limit (UEL) with subsequent ignition, a secondary explosion occurs with explosion pressures with a potential to cause major damage to the installation.

It may be possible with a high enough transformer oil tank pressure rating, limiting short circuit levels and installation of quick acting relief valves to stop the transformer oil containment to burst open.

Since the transformer oil tanks are not usually rated as a pressure vessel, an assessment needs to be carried out assuming that the tank will burst open, i.e. assess the effects of both primary and secondary explosions and possible subsequent fires, and consideration of necessary mediating measures. The secondary explosion should take account of likely gas concentrations, congestion of equipment in the room and likely ignition sources which may all influence the explosion overpressures reached.

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5.4.4.4 Finishing
The coating system applied on the main transformer and associated cooling systems / radiators (where applicable) shall guarantee a sufficient corrosion protection at the installation location; in case of outdoor installation a C5-M atmospheric corrosivity category, according to ISO 12944-2, shall be assumed. Transformer fittings or mounting parts shall ensure adequate corrosion resistance, too.

5.4.4.5 Marking and handling
It is recommended to specify the following on the transformer rating plate in addition to the data listed in IEC 60076:

- whether the transformer tank is suitable for complete oil filled transformer lifting;
- whether the transformer tank is suitable for vacuum treatment;
- the minimum height for crane hook total lifting.

Beside the data specified on the transformer rating plate, further details are needed for handling the transformer. Handling operations shall be based on detailed instructions and drawings to be provided by the transformer manufacturer.

5.4.4.6 Liquid immersed transformers

a) Main transformers’ insulating liquid shall be compliant with recognised international standards and characterized by suitable properties at low temperature conditions.

b) The transformer insulating liquid chemical, electrical and HSE related characteristics shall be type tested according to relevant recognised international standards (i.e. IEC and ISO).

c) Main transformers’ insulating liquid shall be provided with a safety data sheet containing, as a minimum, the following information:

- fire-fighting measures: specification of suitable and unsuitable material to be used by the transformer fire-fighting system and special protective equipment to be used by fire-fighters (if any)
- first aid measures: actions to be taken in case of inhalation, ingestion, skin contact and eye contact.
- handling and storage recommendations.
- personal and environmental precautions to be considered for the transformer installation and actions to be taken in case of small and large spills.

If offshore handling of transformer insulating liquid is assumed, then the necessary provisions for this handling shall be made.

5.4.4.7 Gas insulated transformers
Gas Insulated Transformers (GIT) are being considered as an alternative to oil filled transformers. The design evaluation framework related to this type of component shall be established on a case-by-case basis. A reference standard for GITs is the IEC 60076-15.
5.4.5 High voltage switchgears

5.4.5.1 Reference
The design of HV switchgear shall comply with the requirements of the IEC 62271-203 (high voltage switchgear), IEC 62271-200 (medium voltage switchgear) and with the IEC 62271 series in general.

5.4.5.2 Electrical design requirements
a) Requirements given in [5.4.2.1] shall be applied.
b) If vacuum type circuit breakers are included in the main power system, they can lead to potentially hazardous transient overvoltages. In case such breakers are used, for both shunt reactors and transformers it should be considered to provide an additional protection consisting for example of RC-circuits, or at least this shall be considered as an option to be verified in the insulation coordination study.

5.4.5.3 Mechanical design requirements
a) Requirements given in [5.4.2.2] shall be applied.
b) The switchgear mechanical design shall consider the switchgear to be permanently subjected to the vibrations experienced by the substation structure due to wind and waves that might lead to damages due to infrequent high-magnitude acceleration or to fatigue or loosening due to long-term low-level vibrations.
c) The switchgear shall be designed to be able to withstand, in their complete assembled configuration, the acceleration forces experienced during the transportation from the construction yard to the offshore site. Relevant temporary measures to be taken during the transportation from the construction yard to the offshore site shall be stipulated.

5.4.5.4 Gas insulated switchgear
a) In offshore installations reliability, resilience to corrosive atmospheres and minimal maintenance are key requirements, therefore GIS is generally the only type of switchgear considered suitable.
b) The possibility to transport the switchgear from the construction yard to the offshore site at its gas working pressure shall be confirmed.
c) The SF6 shall comply with IEC 60376.
d) The gas density or temperature compensated gas pressure in each compartment shall be continuously monitored. The monitoring device shall provide at least two sets of alarm levels for pressure or density (alarm and minimum functional pressure or density). Gas monitoring devices shall be capable of being checked with the high-voltage equipment in service.
e) If offshore handling of SF6 is assumed, then the necessary provisions for this handling shall be made.

The requirements given in b), c), d) and e) can be applied also to gas insulated systems comprising both GISs and GITs.

5.4.5.5 Air insulated switchgear
The use of Air Insulated Switchgear shall be considered only in areas with controlled environmental conditions.

5.4.6 Power quality and power factor correction equipment

5.4.6.1 Electrical design
Requirements given in [5.4.2.1] shall be applied.

5.4.6.2 Mechanical design
a) Requirements given in [5.4.2.2] shall be applied.
b) The mechanical design of the power quality and power factor correction equipment shall consider the equipment to be permanently subjected to the vibrations experienced by the substation structure due to wind and waves that might lead to damages due to infrequent high-magnitude acceleration and fatigue or loosening due to long-term low-level vibrations.
c) The power quality and power factor correction equipment shall be designed to be able to withstand, in their complete assembled configuration, the acceleration forces experienced during the transportation from the construction yard to the offshore site. Relevant temporary measures to be taken during the transportation from the construction yard to the offshore site shall be stipulated.

5.4.6.3 Shunt reactors

a) The design of shunt reactors shall in general comply with the requirements of the relevant parts of IEC 60076-6 and with the IEC 60076 series in general.

b) Implementation of additional supports for internal leads to prevent fatigue failure from the constant vibrations shall be considered in the reactor design.

c) It is recommended to specify the following on the reactor rating plate in addition to the data listed in IEC 60076:

- whether the reactor tank is suitable for complete oil filled reactor lifting
- whether the reactor tank is suitable for vacuum treatment
- the minimum height for crane hook total lifting.

Beside the data specified on the reactor rating plate, further details are needed for handling the reactor. Handling operations shall be based on detailed instructions and drawings.

5.4.6.4 Capacitor banks

The design of the capacitor banks used for compensation modules, static filters or static synchronous compensators (STATCOM) shall comply with the requirements of IEC 60871 series.

5.4.7 Surge arresters

5.4.7.1 References

The design of the surge arresters installed in the main power system shall comply with the requirements of the IEC 60099-4.

5.4.7.2 Placement

The electrical parameters and the optimum placement of the surge arresters in the main electrical power system shall be decided based upon the results obtained by an insulation coordination study.

5.4.7.3 Installation

The surge arresters used to protect the main power transformers and the shunt reactors shall be installed as close as reasonably practicable to the transformer’s terminals, or as decided based on a detailed insulation coordination study.

5.4.8 Instrument transformers

The design of instrument transformers shall comply with the requirements of the relevant parts of the IEC 60044 series.

5.4.9 Cable installations

5.4.9.1 General

Cables are installed on the platform at different locations for different applications. Due to abnormal operation or fire hazards cables, lines and busbars have to be selected carefully to ensure high reliability and safe operation of the overall system also during faulty conditions. Cable fire safety, cable routing, proper fixation as well as special cable penetrations for fire rated walls are the challenges for low-voltage and high-voltage cables on offshore transformer substations.

5.4.9.2 High voltage cables

a) High voltage cables shall not run through the accommodation area.

b) Cables shall be designed and tested according to applicable parts of standard IEC 60331 and IEC 60332 for fire safety purposes.
c) Cables with rated voltage above 1 kV shall be designed and tested according to following standards depending on their rated voltage
   - IEC 60502-2
   - IEC 60840
   - IEC 62067.

d) HV accessories shall be conforming to the standards mentioned in clause c) above. Type tests records of used accessories shall be provided for certification.

e) Care shall be taken when routing and fixing free-running HV cables. Appropriate cable clamps and fixing components shall be used in consideration of the environment, but also in terms of mechanical forces applied during platform operation.

f) High voltage cables laid in open cable trays must be provided with a continuous metal shield or armoring against mechanical damage; shields and armoring shall have an electrically conductive connection to the structure.

g) High voltage cables without shield or armoring shall be laid in closed metal ducts or cable conduits, which are to have an electrically conductive connection to the structure.

h) For the installation of single core cables for AC wiring the metal ducts shall be made of non-magnetic material, unless the cables are installed in trefoil formation.

i) Cables shall be installed in a way that mechanical forces and operation do not lead to unacceptable forces and thermal overload.

j) Forces which are a result of electromagnetic interaction of cables during short-circuit events can be estimated by applying calculations of IEC 60865-1.

k) The advantages of better mechanical durability of armoured cables shall be considered for narrow or open installation areas on the platform.

5.4.9.3 Low voltage cables

a) Cables and wires shall be flame-retardant and self-extinguishing as per IEC 60332.

b) If cable- and wire types have passed a bundle fire test according to IEC publication 60332-3, category A/F, the installation of fire stops is dispensed with when laying in bundles.

c) Where fire-resistant cables shall be used (safety related systems), it is permitted to use cables with retention of insulating capability in accordance with IEC publication 60331.

d) Cables manufactured in accordance with the relevant recommendations of IEC publication 60092-350, 60092-351, 60092-352, 60092-353, 60092-354, 60092-359, 60092-373, 60092-374, 60092-375 and 60092-376 will be accepted provided that they are tested to its satisfaction. Cables manufactured and tested to standards other than those specified like above-mentioned will be accepted provided they are in accordance with an acceptable and relevant international or national standard.

e) The materials used for insulation shall be of standardized types for which the maximum permissible temperatures at the conductors during undisturbed operation are specified.

f) Under normal service conditions, the voltage drop between the busbars (main/emergency switchboard) and the consumers shall not exceed 6%, or 10% in the case of battery-supplied networks of 50 V or less.

g) Where short-term peak loads are possible, for instance due to starting processes, it is to ensure that the voltage drop in the cable does not cause malfunctions.

h) Cables shall be rated according to the expected operating load based on the connected load and mode of operation of the consumers. The values given on the consumer’s name plate are valid.

i) If the connected consumers in a part of the system are not in operation simultaneously, a diversity factor may be used for determining the cross section of the group supply cable. A diversity factor is the ratio of the highest operating load expected under normal operating conditions to the sum of rated loads of all connected consumers. Diversity factors should not be used for emergency services.

j) The load determined by the application of a diversity factor shall be deemed to be the continuous load for the determination of the cross-section.

k) For cranes with one drive motor, the supply cable shall be rated according to the current rating of the maximum load capacity.
l) Where cranes have more than one motor, the feeder cable to an individual crane can be rated as follows:

— The value of the current used for cross-section determination shall be equal to 100% of the output of the lifting motors plus 50% of the output of all the other motors. With this calculated current the cross-section of the cable shall be selected for continuous operation.

— If current diagrams for the various operating conditions of cranes have been ascertained, the average current based on the diagram may be used instead of application of adversity factor.

5.4.9.4 Cable laying for circuits

a) For single-phase and three-phase AC systems, multi-core cables are to be used wherever possible.

b) Where single-core cables are used for large cross-sections, the outgoing and return cables shall be laid as close as possible to each other over their entire length to avoid magnetic stray fields.

c) The generator cables, all cables run from the main or emergency switchboard or an auxiliary switchboard, and all interconnecting cables for essential equipment, shall be laid as far as possible uninterrupted in length to the distribution panels or to the equipment.

d) The cables of intrinsically safe circuits shall be laid at a distance of at least 50 mm separated from the cables of non-intrinsically safe circuits. The laying of intrinsically safe circuits together with non-intrinsically safe circuits in a pipe is not permitted. Cables of intrinsically safe circuits shall be marked, preferably with light blue color.

5.4.9.5 Routing of cables

a) The routing of cables shall be such that cables are laid as straight as possible and are not exposed to mechanical damage.

b) For bends, the minimum bending radius permitted by the manufacturer shall be observed. The radius shall be not smaller than 6 times of the outer diameters of the cables.

c) Heat sources such as boilers, hot pipes, etc. shall be by-passed so that the cables are not subjected to additional heating. If this is not possible, the cables are to be shielded from thermal radiation.

d) The tensile stress of the cables at long cable runs caused by thermal expansion and/or movement of the structure shall not damage the cables, cable runs or cable penetration systems. At long and straight cable runs like in passage ways or void spaces, etc. or at positions where unacceptable tensile stresses are liable to occur at the cables and cable trays, precautions shall be taken to distribute the expansion movement uniformly over a cable loop provided for such purpose, so that there is no damaging of the cables, cable runs or cable penetration systems. The diameter of the cable loop shall be at least 12 times the diameter of the thickest cable. In each division should be provided at least one cable loop. Other solutions that provide same level of safety are subject to evaluation of DNV GL and could be accepted likewise.

e) Cables shall not be installed within room isolations. Exceptions are permitted for lighting, socket outlets and control circuits in accommodation and refrigeration rooms, provided that the maximum loading of the cables does not exceed 70% of their current carrying capacity.

f) Where, for safety reasons, a system has duplicated supply and/or control cables, the cable routes are to be placed as far apart as reasonable. The cable routes shall not be vulnerable to the same accidental events and shall therefore be subject to a risk assessment.

g) Supply cables for emergency consumers shall not be run through fire zones containing the main source of electrical power and associated facilities. Exceptions are made for cables supplying emergency consumers located within such areas.

h) The electrical cables to the emergency fire pump shall not pass through the machinery spaces containing the main fire pumps and their sources of power and prime movers. They shall be of a fire resistant type, in accordance with IEC 60331.

i) Cables for supply of essential equipment and emergency consumers, e.g. lighting and important communications and signaling systems shall, wherever possible, by-pass galleys, laundries, category A engine rooms and their casings and areas with a high fire risk. On installations/units whose construction or small size precludes fulfilment of these requirements, measures shall be taken to ensure the effective protection of these cables where they have to be run through the rooms mentioned above, e.g. by the use of fire-resistant cables or by flame-retardant coating, such an installation has to be approved case by case.
j) Cables for high voltage, low voltage, control and instrumentation shall not run on the same cable ways (tray / ladder). If constructional reason does not allow such separation, only cables for low voltage, control and instrumentation may be installed on the same cable way. Bundling of such cables shall be avoided in any case.

k) In case of cables, lines and accessories installed and laid outdoors UV resistance shall be ensured or corresponding protection shall be applied.

l) Proper mechanical protection and strain relief shall be observed whenever a single cable or cable bundles are routed on the deck floor.

m) Submarine power cables shall be so routed in such way that the risk of fire propagation is improbable. Submarine power cables routed above escape routes shall be shielded against dropping burning materials in case of a fire.

5.4.9.6 Fastening of cables and wires

a) Cable trays and cableways shall be made preferably of heat resistant metallic materials which are protected against corrosion. Cables and wires shall be fastened with corrosion-resistant, flameproof clips or bindings. Exceptions are made for cables which are laid in pipes or cable ducts. Cables and wiring shall be installed and supported in such a manner as to avoid chafing or other damage. This also applies for the installation of cables and wires in connection boxes of electrical equipment and switchboards.

b) Suitable materials shall be placed together when cables are fastened to aluminum plates or laminations. Clips for mineral-insulated cables with copper sheaths have to be made of copper alloy if they are in electrical contact with the latter.

c) Single-core cables are to be fastened in such a manner that they are able to withstand the electrodynamic forces occurring in the event of short circuits.

d) The distances between the supports for cable racks and the fastenings used shall be selected with due regard to the cable type, cross-section and number of cables concerned.

e) Where cables suspended are fastened by the use of plastic clips or straps, metallic cable fixing devices, spaced not more than 2 m apart shall be used additionally in the following areas:
   — generally in escape routes and emergency exits, on the open deck, in refrigeration rooms and in boiler rooms
   — Machinery rooms, control rooms and service rooms, where bunched cables are fastened on riser cable trays or under the cable trays.

f) Cable trays made from plastics shall be tightened in such a way that they do not obstruct together with the cables the escape routes in case of fire. The suitability of cable trays shall be proved. In escape routes only metallic cable trays should be used.

g) It is recommended that cables and cable bunches shall not be painted. If they still would be painted the following shall be observed:
   — the paint shall be compatible with the material of the cables, and
   — the flame-retardant property respectively fire resistance of the cables and cable bunches shall be maintained.

5.4.9.7 Laying of single-core cables and wires in single-phase and three-phase AC systems

In cases where use of multi-core cables is not possible, single-core cables and wires may be permitted for installation, if the following provisions are made and the requirements of IEC 60092-352 are observed:

a) The cables shall not be armored or shrouded with magnetic material.

b) All conductors belonging to one circuit shall be run together in the same pipe or duct, or clamped by common clamps, unless the clamps are made of non-magnetic materials.

c) The cables forming a circuit shall be laid immediately beside of each other and preferably in triangular configuration. If spacing cannot be avoided, the spacing shall not exceed one cable diameter.

d) No magnetic material shall be placed between single-core cables passing through steel walls.

e) No magnetic materials shall be between the cables of deck and bulkhead penetrations. Care shall be taken to ensure that the distance between the cables and the steel wall is at least 75 mm, unless the cables belonging to the same AC circuit are installed in trefoil formation.
For the installation of single-core parallel cables between the cable groups these measures are not necessary, if the cable groups are arranged in trefoil formation.

f) Single-core parallel cables shall be of the same length and cross-section. Furthermore, to avoid unequal division of the current, the cables of one phase are to be laid, as far as is practicable, alternatively with the cables of the other phases, e.g. in the case of two cables for each phase:

L1, L2, L3, L2, L1  or  L1, L2, L3
L3, L2, L1

or  L3, L1, L2  or  L2, L3, L1
L2, L1, L3  or  L1, L3, L2

g) To balance the impedance of the circuit in single-core cables more than 30 m long and with a cable cross-section of more than 150 mm², the phases are to be alternated at intervals of not more than 15 m.

h) For single-core cables, metallic sheaths are to be insulated from each other and from the structure over their entire length. They shall be earthed at one end only, except earthing is required at both ends for technical reasons (e.g. for high voltage cables). In such cases the cables shall be laid over their entire length in triangular configuration.

5.4.9.8  Cables in the vicinity of radio-communication and navigation equipment

a) Except where laid in metallic pipes or ducts, cables and wires with metal sheaths or metal braiding are to be used above the uppermost metallic deck and in positions where the cables and wires are not separated by metallic bulkheads or decks from aerials, aerial down leads, the radio room, direction finder or other radio navigation or receiving equipment. The metallic sheaths and shields are to be earthed.

b) Only cables required in the radio room shall be laid there. If cables without a braid shielding have to be run through a radio room, they shall be installed in a continuous metallic pipe or duct which is earthed at the entrance to and exit from the room.

c) Single-core cables are not permitted in the radio room.

d) If the radio equipment is installed on the bridge, the requirements stated above are to be complied with as and where applicable.

5.4.9.9  Measures to limit the propagation of fire along cable and wire bundles

All cables shall be installed so that the original flame-retardant properties of the individual cables are not impaired. This requirement can be considered to be fulfilled if:

— the bundled cable types are individually flame-retardant and have successfully passed bundle fire test in accordance with IEC 60332-3, category A/F
— suitable measures have been taken during installation, e.g. the providing of fire stops or the application of flame-proof coatings.

5.4.9.10  Application of fire-resistant cables

a) Cables for services required to be operable under fire conditions including those for their power supplies shall be of a fire resistant type, especially when they pass through high fire risk areas, fire zones or decks, other than those which they serve.

b) Systems that are self-monitoring, fail safe or duplicated with cable runs as widely separated as reasonable may be exempted provided their functionality can be maintained.

c) Emergency services required to be operable under fire conditions include:

— fire and general alarm system
— fire extinguishing systems and fire extinguishing medium alarms
— fire detection system
— control and power systems to power operated fire doors and status indication for all fire doors
— control and power systems to power operated watertight doors and their status indication
— emergency lighting
— public address system
— low level lighting
— emergency shutdown system.

d) For installation of fire-resistant cables the following shall be observed:

— The cables shall be arranged in such a way as to minimise the loss of operational availability as a result of a limited fire in any area.
— The cables shall be installed as straight as possible and with strict observance of special installation requirements, e.g. permitted bending radii.

5.4.9.11 References

All the electrical cables installed shall comply with the requirements of applicable IEC publications and all electrical cables and wiring external to equipment shall be at least of a flame-retardant type. (This requirement is intended to cover SOLAS Ch. II-1/45.5.2)

5.4.10 High voltage direct current converter substations

5.4.10.1 General

For HV/DC converter substations dedicated equipment is required for the conversion from AC to DC voltage or vice versa. HV/DC substations are connected to one or more offshore wind farms via HV submarine cable on the one side. In the other direction, these substations are connected to the onshore grid via a pair of DC submarine cables (bi-polar system). Depending on the transmitted electrical power and the distance to the onshore converter substation, the DC voltage may vary between typically ±150 kV DC and ±450 kV. This section covers the specific equipment which is installed on HV/DC converter substations, which are mainly:

— the high power semiconductors for power conversion (e.g. IGBT (Insulated Gate Bipolar Transistors) or Thyristors)
— the HV/DC converter transformers
— smoothing reactors.

Where possible, the above components shall be made of flame-retardant material, e.g. air insulated smoothing reactors shall be preferred, rather than oil-insulated types. In case combustible materials are part of the equipment, e.g. in the case of oil filled converter power transformers, capacitors, etc., suitable fire detection and protection facilities shall be provided. For the converter valves, optical fibers shall be preferably used for communication/controls to avoid electromagnetic interference with other equipment on the substation.

Electrical systems and instrumentation shall be qualified for operation in environments with high electromagnetic fields, like e.g. CCTV or fire protection systems.

5.4.10.2 Power transformers and reactors on converter platforms

a) Converter substation power transformers, smoothing reactors or shunt reactors shall comply with the respective requirements as per standard series IEC 60076 if not otherwise specified in IEC 61378-2.

b) Transformers shall be designed for both, rectification and inversion, when not specified otherwise.

c) Specific requirements resulting from their operation have to be considered in the design, which are:

— increased dielectric stress, caused by simultaneous presence of AC and DC voltage on the converter side
— high current harmonics which lead to increased stray and leakage losses.

d) The increased sound level due to DC-magnetization during operation should be observed and counteraction may be necessary, where the sound level reaches critical levels

e) Actual load loss in service shall be determined according to the calculation scheme given in IEC 61378-1 in consideration of a defined field of distribution of the harmonics expected at site.

f) The transformer shall have reliable design, also for transient conditions (voltage transients, frequency transients), e.g., caused by GIS or converter switching. Type and Routine tests shall be in compliance with the requirements of IEC 61378-2.
g) Smoothing and filter reactors shall comply with IEC 60076-6.

h) Suitable protection devices shall be considered for DC and AC components of the HV/DC converter substation. These normally include at least:

- over-current protection of AC circuit breakers
- abnormal AC voltage protection
- earth fault protection
- AC filter protections
- differential protection
- over-current protection of the converter
- abnormal DC voltage protection
- DC discharge unit
- valve protection, e.g., in the valve gate electronics.

i) The converter valves shall be cooled by a water-based cooling system with redundant pumps during operation. The power supply of the converter cooling pumps shall be maintained by an appropriately rated UPS system to cover as a minimum the time period between a main power supply failure and the availability of the auxiliary generator. A total failure of the cooling system shall result in an immediate shut down of the converter valves to avoid any hazards or severe damage of the converter valves.

5.4.10.3 Power semiconductors and protection

a) IGBT shall generally be designed and type tested according to IEC 62501. Thyristor valves shall comply with IEC 60700-1.

b) AC filter capacitors shall comply with IEC 60871-1. Whereas IEC 62001 shall be observed additionally.

c) DC Filter capacitors shall comply with IEC 61071.

5.4.10.4 Testing

Testing of the HV/DC Converter Station shall be based on the guidance given in IEC 61975. A test specification shall be issued and provided for approval. At least following tests shall be contained:

- testing of inversion and rectifying equipment
- switching/connection of reactors, filters and capacitor banks
- EMV
- high-voltage test
- short-circuit test.

Control system disturbance tests performed at the manufacturing facility shall be based on IEC 61000-4 and related parts.

5.5 Automation system

5.5.1 General

5.5.1.1 Overview of the substation automation system functions

a) The main purpose of the substation automation system is to supervise, control and manage the operation of the substation power system and protect the personnel and the electrical power equipment, clearing all the fault events that occur in the power plant during its operative life. Beside this, it must also assure the maximum possible availability of the substation through a selectivity achieved by proper parameters setting of relays, sensors and PLCs.

b) Figure 5-5 provides an overview of the functions and subsystems that are comprised in an offshore substation automation system.

c) The protection relay installed in the substation HV switchgear(s) shall protect also the offshore inter-array cabling system.

d) Main transformers shall be provided with a back-up protection.
5.5.1.2 Power supply to substation automation system

All the automation system consumers shall be supplied by a UPS or DC battery charger system; examples of these loads are:

- SCADA system
- bay units
- protection relays
- automatic voltage regulators
- hardwired interlocks logic circuits
- transformer monitoring systems
- reactive power control systems.

**Guidance note:**
The duration of the supply from UPS/DC battery charger should be sufficient to account for factors such as distance from the shore, average weather and marine conditions, and should in any case be agreed with the grid operator.
The UPS systems that feed the control and protection system loads can be the same that feed other auxiliary loads.

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5.5.1.3 Consequences of a single failure

a) Following a single failure in the main power system, the substation automation system shall be able to provide sensitive selective operation of the devices, thereby, in the event of a fault, minimizing interruption of service, limiting damage to faulted apparatus, and reducing time required for correcting or isolating the problem and restarting the system.

Guidance note:
In case of (N-1) conditions, in order to prevent overloading of the equipment, it may be necessary to limit the wind turbine output power as needed. The proper input to the wind turbine generators’ SCADA system can be given automatically by the substation SCADA system or by a command from the substation operator.

b) In case of fire detection system activation, relevant provision shall be taken, such as:

— automatically opening the circuit breakers by the fire-detection system and substation SCADA system;
— checking through the CCTV system the presence of fire and, if needed, opening the circuit breakers by a remote command from the substation operator.

c) In case of fire a response plan shall be followed, including automatic disconnection of relevant systems.

5.6 Auxiliary power supply system

5.6.1 References

5.6.1.1 General

a) The substation auxiliary power supply system comprises the electrical power equipment necessary to the main power system in order to correctly and safely collect, transform and deliver the power produced by the wind turbines. Therefore the substation auxiliary power supply system comprises the electrical equipment necessary to supply the operational and emergency services.

b) The substation auxiliary power supply system might also comprise the electrical power equipment necessary to supply the power needed by the wind turbines during standstill periods in islanded conditions (downtime of main power system). Such equipment typically utilizes Grid Diesel Generators (GDGs).

5.6.1.2 Compliance with standards
The requirements of this section refer to standard DNVGL-OS-D201. Where discrepancy occurs between the present standard and the DNVGL-OS-D201, the present standard shall prevail. Alternatively a design fulfilling the requirements given in IEC 61892 will be considered as equivalent.

5.6.2 Main and emergency source of power

5.6.2.1 Main source of auxiliary power
The main source of the substation auxiliary power supply is the source intended to supply electric power to the main switchboard(s) (MSB) for distribution to all services necessary for maintaining the substation in normal operational, (N-1) operational and islanded conditions. In case of manned or temporarily manned substation, the main source of power has also the purpose to maintain the substation in habitable conditions.

A main source of power for supply of auxiliaries can consist of

— external grid supplying power through the substation auxiliary transformers
— dedicated generator set(s) (auxiliary diesel generator(s), GDG).

In case of external grid loss (blackout), main power supply for auxiliary power supply system shall be ensured by means of the dedicated generator set(s) for at least 7 days.
5.6.2.2 Main power supply for auxiliary system

a) A main power supply for the substation auxiliary system consists of the main source of electric power and associated electrical distribution, including main switchboards, distribution boards (DB), all cables from the main source of auxiliary power to the final consumers, batteries and transforming equipment, if any.

b) All the associated control systems and auxiliary systems needed to be in operation for the above mentioned systems or equipment shall be considered as part of the main power supply for auxiliary power system.

Guidance note:
It is considered good practice to rate the main power supply for auxiliary power system to allow for an additional load of 15% to cover future increase.

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5.6.2.3 Main switchboard

a) A main switchboard (MSB) is a switchboard directly supplied by the main source of auxiliary power or by a power transformer and is intended to distribute electrical energy to the unit’s services.

Guidance note:
Normally, all switchboards between the main source of auxiliary power and (inclusive) the first level of switchboards for power distribution, to small power consumers, will be considered to be main switchboards (MSB), i.e. at least the first level of switchboards for each voltage level used. Cubicles for other system voltages attached to a main switchboard are considered part of the main switchboard.

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5.6.2.4 Emergency source of electric power

The emergency source of electric power is a source of electric power intended in the event of outage of main power supply for auxiliary power system

— to supply electric power to the emergency switchboard (ESB) and/or equipment for emergency services
— to enable restoration of main power supply for auxiliary power system.

Guidance note:
An emergency source of electrical power may be emergency generator(s), battery(ies) or connections to other platforms able to supply power.

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5.6.2.5 Emergency electric power supply system

a) An emergency electric power supply system consists of the emergency source of electric power and associated electrical distribution. This includes emergency generators, batteries, associated transforming equipment, if any, the transitional source of emergency power, the emergency switchboards (ESB), emergency distribution boards (EDB) and all cables from the emergency source of electrical power to the final consumer.

b) A transitional source of power, see [5.6.2.8], is considered to be part of the emergency electric power supply system mainly to cover potential delays in start of the Emergency Generator for consumers needing continuous supply.

c) All the associated control systems and auxiliary systems needed to be in operation for the above mentioned systems or equipment are included in this term.

d) The emergency power source shall fulfil the following requirements:

— It shall be a self-contained emergency source of electrical power.
— It shall be located in a safe location and be readily accessible. This is related to associated transforming equipment, emergency switchboard, emergency lighting switchboard and transitional source of emergency power.
Guidance note:
For floating installations the emergency generator need to follow IMO SOLAS or MODU code requirements to position, i.e. above main deck and above damage water line, not next to outer hull, not forward of collision bulkhead, etc. Also the emergency generator need to be able to operate up to the maximum damage condition heel of the vessel.

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— It may be either a generator and/or an accumulator battery.
— It shall be automatically connected to the emergency switchboard in case of failure of the main source of electric power. If the power source is a generator, it shall be automatically started and in 45 s supply at least the services required in Table 5-2 upon loss of main power and supply.
— Its cooling arrangements, e.g. pipes, pumps and heat exchangers, shall be located in the same space. Heat exchangers may be accepted outside, in close vicinity to the emergency source of power.
— It shall not be used for supplying power during normal operation of the offshore installation. Exceptionally, and for short periods, the emergency source of power may be used for blackout situations, starting from dead installation, short term parallel operation with the main source of electrical power for the purpose of load transfer and for routine testing of the emergency source of power.
— Emergency generating sets are to be so designed that they can be started up readily at minimum ambient temperature for the installation.
— The operational readiness of the set shall cover all 100 year return weather conditions (strong wind, snow or rain fall, etc.).
— Each emergency generating set required to be capable of automatic starting, is to be equipped with a starting system to an acceptable standard and the capacity of which shall be sufficient for at least three consecutive starts.
— Additionally a second source of start energy shall be provided automatically in the case if the first source of energy is consumed or failed. The second source of energy shall be capable of three further automatic starting operations within 30 minutes.

5.6.2.6 Emergency switchboard

a) An emergency switchboard (ESB) is a switchboard, which in the event of failure of the main electrical power supply system, is directly supplied by the emergency source of electrical power and/or the transitional source of emergency power and is intended to distribute electrical energy to the emergency power consumers.

Guidance note:
Normally all switchboards between the emergency source of electrical power and (inclusive) the first level of switchboards, for power distribution to small power consumers, will be considered to be emergency switchboards (ESBs), i.e. at least one level of switchboards for each voltage level used.

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c) The emergency switchboard shall be arranged as near as is practicable to the emergency source of power and where the emergency source of power is a generator, the emergency switchboard shall preferably be located in the same space.

d) No accumulator battery fitted in accordance with this requirement for emergency or transitional power supply shall be installed in the same space as the emergency switchboard, unless appropriate measures are taken to extract the gases discharged from the said batteries. An indicator shall be mounted in a suitable place on the main switchboard or in the platform control room to indicate when the batteries constituting either the emergency source of power or the transitional source of power are being discharged.

e) The emergency switchboard shall be supplied in normal operation from the main switchboard by an interconnector feeder which shall be adequately protected at the main switchboard against overload and short circuit. The arrangement at the emergency switchboard shall be such that the interconnector feeder is disconnected automatically at the emergency switchboard upon failure of the main power supply. Where the system is arranged for feedback operation, the interconnector feeder shall also be protected at the emergency switchboard at least against short circuit.
f) In order to ensure ready availability of emergency supplies, arrangements shall be made where necessary to disconnect non-emergency circuits automatically from the emergency switchboard to ensure that power is available automatically to the emergency circuits.

5.6.2.7 Distribution board and emergency distribution board
A distribution board (DB) or an emergency distribution board (EDB) is any switchboard utilised for distribution to electrical consumers, but which is not considered as a main or emergency switchboard.

5.6.2.8 Transitional source of emergency electrical power
a) Where the emergency source of electrical power is a generator, a transitional source of power is required.
b) The transitional source of emergency electrical power may consist of batteries or other types of sources meeting the requirements of this section. It shall be suitably located for use in an emergency.
c) The battery source shall be charged by the emergency power distribution system and shall be able to operate, without recharging, while maintaining adequate voltage for the consumers throughout the discharge period. The battery capacity shall be sufficient to supply automatically, in case of failure of either the main or the emergency source of electrical power, for the duration specified, at least the services required by Table 5-2, if they depend upon an electrical source for their operation. See notes to Table 5-2.

5.6.2.9 Emergency services
a) The services listed in Table 5-2 shall be supplied by the emergency power supply system having regard to the listed durations, as well as to the starting currents, transitory nature of certain loads and simultaneous supply.
b) The duration of the transitional power shall be in accordance with the time to evacuation estimated according to the methodology described in Table 5-2 provides the minimum values.

Table 5-2 Services to be supplied by an emergency power supply system, including required duration

<table>
<thead>
<tr>
<th>Service</th>
<th>Emergency power consumers</th>
<th>Duration of emergency power, (h)</th>
<th>Duration of transitional power, (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency lighting</td>
<td>At every muster and embarkation station, for survival craft and their launching appliances, and at the area of water into which it shall be launched.</td>
<td>18</td>
<td>0.5&lt;sup&gt;1)&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>In all service and accommodation alleyways, stairways and exits, personnel lift cars and personnel lift trunks.</td>
<td>18</td>
<td>0.5&lt;sup&gt;1)&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>In the machinery spaces and main generating stations including their control positions.</td>
<td>18</td>
<td>0.5&lt;sup&gt;1)&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>In all control stations, machinery control rooms, locations where operation of safety equipment may be necessary to bring the installation to a safe stage, and at each main and emergency switchboard.</td>
<td>18</td>
<td>0.5&lt;sup&gt;1)&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>In all spaces from which control of the main power managing process is performed and where controls of machinery essential for the performance of this process, or devices for the emergency switching-off of the power plant are located.</td>
<td>18</td>
<td>0.5&lt;sup&gt;1)&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>At all stowage positions for firemen's outfits.</td>
<td>18</td>
<td>0.5&lt;sup&gt;1)&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>At the fire pump referred to in this table and its starting position.</td>
<td>18</td>
<td>0.5&lt;sup&gt;1)&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>At the sprinkler pump and its starting position, if any.</td>
<td>18</td>
<td>0.5&lt;sup&gt;1)&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Floodlight and perimeter lights on helicopter landing decks.</td>
<td>18</td>
<td>0.5&lt;sup&gt;1)&lt;/sup&gt;</td>
</tr>
<tr>
<td>Navigation lights</td>
<td>The navigation lights and other lights required by the National and International Regulations for Preventing Collisions at Sea in force.</td>
<td>96</td>
<td>0.5&lt;sup&gt;5)&lt;/sup&gt;</td>
</tr>
<tr>
<td>Structure marking</td>
<td>Any signalling lights or sound signals that may be required for marking of offshore structures.</td>
<td>96</td>
<td>0.5&lt;sup&gt;5)&lt;/sup&gt;</td>
</tr>
<tr>
<td>Active fire protection</td>
<td>Fire pumps and other firefighting equipment dependent on the emergency source of electrical power</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Lifeboat</td>
<td>Secondary means of launching of free fall lifeboat.</td>
<td>4&lt;sup&gt;1)&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>
5.6.2.10 Meshed power supply for auxiliary system

a) A meshed power supply for auxiliary system is a substation auxiliary system for which a distinction between main and emergency auxiliary systems is not assumed. This is a system where the main source of electrical power is located in two or more spaces which have their own power distribution and control systems, such that a fire or other damage in any one space will not affect the power distribution from the others and will not affect the services listed in Table 5-2. This implies that the requirements for self-contained emergency power source may be considered satisfied without an additional emergency source of electrical power, provided that:

— the electrical power available from the emergency source of power is sufficient to supply all services essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously, also taking into account starting currents and transitory nature of certain loads. (Ref. MODU code 5.4.6)

Guidance note:
The emergency generator rating should be based upon the consumed power for all consumers that may be in simultaneous operation. Non-emergency consumers, which will not automatically start, should be automatically disconnected.

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— these generator sets are located in each of at least two spaces, see Table 6-2
— a damage in any one space will not affect the control system for automatic start and connection of both or all these generator sets
— power to all required emergency functions, as listed in Table 5-2, supplied from main switchboards and sub distributions is automatically available within 45 seconds when power is automatically restored after a black-out
— load shedding/trip is arranged to prevent overload of these generator sets, if needed
— the location of each of the spaces referred to in this paragraph is such that one of these generator sets remains operable and readily accessible in the final condition of credible damages
— the arrangement of the main electric lighting system is such that fire, flood or other casualty, in spaces containing the main source of electrical power, associated transforming equipment, if any, the Main Switchboard and the main lighting switchboard, will not render the emergency electric lighting system inoperative. (Ref. MODU code 5.3.5)
— the arrangement of the emergency electric lighting system is such that fire, flood or other casualty, in spaces containing the emergency source of electrical power, associated transforming equipment, if any, the Emergency Switchboard and the emergency lighting switchboard, will not render the main electric lighting system inoperative. (Ref. MODU code 5.3.6)
the integrity of the main electrical supply is only affected by fire, flood or other damage conditions, in one space. The Main Switchboard shall be located as close as is practicable to the main generating station. (Ref. MODU code 7.9.2)

— the main switchboards are located as close as practicable to the diesel generator sets

— the integrity of the emergency electrical supply and the transitional source of power is not affected by fire, flood or other casualty in the main electrical supply, or in any machinery space of category A. The Emergency Switchboard shall be located in the same space as the emergency generating station. (Ref. MODU 5.4.3 and 5.4.11)

— common boundaries consist of a steel wall insulated to class A-60 on both sides

— bus tie breakers between the spaces have short circuit protection providing discrimination

— the arrangements of these generating sets comply with the requirements given in DNVGL-OS-D201 Ch.2 [2.3.1.8], i.e. bus-tie breakers shall open automatically upon blackout; DNVGL-OS-D201 Ch.2 [2.3.1.13]; DNVGL-OS-D201 Ch.2 [2.3.3.1].

Guidance note:
The electrical Basis of Design should describe how this paragraph is complied with, through a contingencies analysis examining any possible N-1 operation scenarios and abnormal operation scenarios. The electrical Basis of Design should also describe the physical locations of main components and cable routings. A test program for offshore testing should describe in detail how the functionality of the electrical power supply system should be tested.

An offshore unit built in accordance with this item will not have any dedicated emergency power system, since the two (or more) independent main power systems are considered to ensure power supply to emergency consumers at all times. Compliance with DNVGL-OS-D201, Chapter 2, [2.3.3.2] is not required.

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b) When a GDG is included in a meshed configuration as possible available source of power, in case of fault to the main source of power, it will be automatically connected to supply the loads listed in Table 5-2.

Guidance note:
Depending on the needs of power of the wind turbines under islanded conditions, it might be necessary to assume redundancy in the GDG set.

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c) Consumers like HVAC or lighting shall be separately fed in one room so that in case of failure in one MSB, almost half of the services will still be fed by the other MSB without any switchover or dead moment. When the installation of local DBs is foreseen, at least two of them should be installed on each level of the substation and should be located as far apart as suitably separated.

d) In order to simplify the low voltage switchboards load balance, large consumers, like foam pumps or blowers, may be supplied directly by the MSBs.

5.6.2.11 Auxiliary power distribution system
DNVGL-OS-D201 Ch.2 [2.6] is to be applied, where applicable.

Guidance note:
The low voltage distribution earthing arrangement might depend on the grid operator requirements.

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5.6.3 Battery system

5.6.3.1 General

a) For UPS systems installed in unmanned substations remote reset and remote shutdown shall be possible.

b) UPS systems foreseen for parallel operations shall be provided with output synchronization.

c) The installation of sealed batteries in switchboard rooms and control rooms shall be agreed in each individual case. Reference is made to [5.6.2.6] and EN 50272-2.

d) Batteries for starting of diesel generator engines shall be installed near the engine, so as to minimize the voltage drop in the power lines.

e) If two or more auxiliary engines are started electrically, at least two mutually independent batteries are to be provided. The capacity of the batteries has to be sufficient for at least three start-up operations per engine. If only one of the auxiliary engines is started electrically, one battery is sufficient.

f) Batteries that shall be used for power supply required by these rules shall be dimensioned for the time required for the intended function at an ambient temperature of 0°C, unless heating is provided.
5.6.3.2 Battery charging

a) Each battery powered system shall have a separate charging device, suitable for the actual service. This may alternatively be:
   — a charging device supplied from the offshore unit's primary or secondary electric distribution. Such charging devices are considered as important consumers
   — a charging dynamo driven by one of the engines which the battery normally supplies, except that this is not allowed for auxiliary engines for emergency generator and emergency fire pump
   — each battery required by these rules shall have its own dedicated charging device.

b) Each charging device is, at least, to have sufficient rating for recharging to 80% capacity within 10 hours, while the system has normal load.

c) The battery charger shall be suitable to keep the battery in fully charged condition, (float charge), taking into account battery characteristics, temperature and load variations. If the battery requires special voltage regulation to obtain effective recharging, then this is to be automatic. If manual boost charge is provided, then the charger is to revert to normal charge automatically.

d) An alarm shall be given at a manned control station if the charging of a battery fails, alternatively an alarm shall be given if the battery is being discharged.

5.6.3.3 Battery monitoring

Alarm shall be given for power supply failure and trip of unit.

For power supply units with batteries included, the following additional alarms shall be provided:
   — when the charging of a battery fails, alternatively if the battery is being discharged
   — when the automatic bypass is in operation for on-line units
   — operation of battery protective device.

   **Guidance note:**
   A single common alarm signal to a central alarm system may be accepted for the two alarms listed in this paragraph. If other alarms are included in the common alarm signal, it must be ensured that an active alarm will not prevent initiation of any new alarm with its audible and visual indication.

5.6.3.4 Battery system arrangement

a) These requirements are applicable to all types of rechargeable NiCd and lead acid batteries. Other rechargeable battery technologies are covered by DNV Rules for Classification of Ships Pt.6 Ch.28.

   **Guidance note:**
   Installation of battery types which may not produce explosive gasses but which may require other safety precautions will be evaluated on a case-by-case basis. Installation and ventilation recommendations from the manufacturer should always be followed.

b) Requirements for installation of electrical equipment in battery rooms, lockers or boxes are given in DNVGL-OS-D201 Ch.2 [11.3.2.5].

c) Requirements for the location and ventilation of vented batteries are given in Table 5-3 and of valve regulated/dry batteries are given in Table 5-4.

d) Accumulator batteries shall be suitably housed and compartments shall be properly constructed and efficiently ventilated.

e) The connection cable from the charger to the batteries should be provided with short circuit protection close to the battery, and the cable between this and the battery should be double insulated or a suitably higher voltage cable be used.

f) The batteries shall be so located that their ambient temperature remains within the manufacturer’s specification at all times.

g) Battery cells shall be placed so that they are accessible for maintenance and replacement.

h) In battery boxes, the cells shall be placed at one height only.

i) The space above cells shall be sufficient for maintenance and cooling.
j) Normally, batteries shall not be located in sleeping quarters.

**Guidance note:**

Normally batteries should not be located in a battery box at open deck exposed to sun and frost. Batteries may exceptionally be accepted located at open deck on the following conditions:

- the box should be white in colour, and be provided with ventilation and heating
- the charger must be provided with temperature compensation capability.

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k) Ventilation shall be arranged for all battery rooms, lockers and boxes to avoid accumulation of flammable gas. The air intake shall be in the lower part. The air outlet shall be arranged in the upper part so that gas pockets cannot accumulate.

1) Ventilation openings from rooms where batteries are installed should be of a non-closable type suitable for all weather conditions.

2) Ventilation rate, (m3/hour), for battery rooms and lockers with mechanical extract ventilation to open air should comply with the following:

   - for vented batteries, 10 x sum of battery kVAh
   - for dry batteries, 2 x sum of battery kVAh.

3) Rooms into which battery lockers or boxes are ventilated should have an extract ventilation duct at ceiling level. The area of the room (m2) should be at least 0.3 times battery kVAh. Ventilation rate of the room should be at least 6 air changes per hour.

In case of natural ventilation by openings to the room or by extract duct to free air, the following is given for cross section (cm2) of openings and duct. Except for boxes, the inlet shall be of same size as the outlet.

- for dry batteries, 20 x battery kVAh
- for vented batteries, 50 x battery kVAh
- for dry batteries located in electrical panels, 500 x battery kVAh.

For natural ventilation sufficient amount of air flow shall be ensured, otherwise mechanical (i.e. forced / artificial) ventilation shall be implemented. (Interpretation of IEC 62485-2, sec. 6.3).
Natural ventilation may be employed if ducts can be run directly from the top of the room or locker to the open air above, with no part of the duct more than 45 degrees from the vertical. These ducts shall not contain appliances (for example barring frames) which can impede the free passage of air or gas mixtures. Where lockers are provided for batteries, the duct shall terminate not less than 0.9 m above the top of the battery enclosure. (Ref. IEC 61892-7, sec. 25.3).

Specific consideration shall be given to accumulation of flammable gas and ignition sources in the arrangement of charging stations for battery powered fork lifts.

Guidance note:
1) A charging station is defined as a separate room, only used for this purpose, or a part of a large room, for example a cargo hold, based on the area occupied by the fork lift plus 1 m on all sides.
2) Socket outlets for the charging cables, mechanically or electrically interlocked with switchgear, can be placed in the charging station. Such socket outlets should have at least enclosure IP 44 or IP 56, depending upon the location (see Table 10-1). In general no other electrical equipment, except explosion protected equipment (according to Sec. 11) as specified for battery rooms may be installed.
3) Charging stations should generally be mechanically ventilated with at least 30 changes of air per hour. An arrangement as specified for battery rooms with battery capacity in accordance with the actual battery capacity, but not less than 20 kVAh should be used. For charging stations in enclosed storage spaces having mechanical overpressure ventilation, an alternative arrangement should provide a natural ventilation outlet duct of sufficient capacity from the upper part of the charging station to free air.

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5.6.4 Auxiliary system protections
DNVGL-OS-D201 Ch.2 [2.7] is to be applied, where applicable.

5.6.5 Auxiliary system control
DNVGL-OS-D201 Ch.2 [2.8] is to be applied, where applicable.

The substation SCADA system of an unmanned substation shall enable the users to remotely control the auxiliary system, allowing, as far as practicable, operations like remote switching, remote reset and remote testing.

5.6.6 Auxiliary system installation arrangement
DNVGL-OS-D201 Ch.2 [2.9] and Ch.2 Sec.10 are to be applied, where applicable.

5.6.7 Auxiliary system cable selection
DNVGL-OS-D201 Ch.2 [2.10] is applied, where applicable.

5.6.8 Generators
Auxiliary Diesel Generators and Grid Diesel Generators shall comply with DNVGL-OS-D201 Ch.2 [5.1] and [5.2] and shall be suitable for offshore applications. Generators not type approved for offshore applications will be acceptable if installed in a climate controlled environment: in this case a redundant HVAC system for the generator installation locations shall be assumed. Alternatively, a stand by heating system can be considered.

Dimensioning of the diesel generator sets and their associated fuel tank(s) shall be based on the analysis of the specific site installation characteristics i.e. distance from the shore, expected marine and weather conditions, electricity demand from offshore wind turbines in the case of grid loss (blackout).

Bunded areas with adequate spill trays and/or drain facilities shall be assumed for each electrical room containing diesel generators sets.

Scheduled test runs of the generators shall be arranged. Simultaneous test runs of different generators shall not be allowed. In case of unmanned substation the test run can be performed from shore, but it is recommended to plan it to be executed during a preventive maintenance operation.
Guidance note:
In order to perform the test run of the generator it might be necessary to synchronize the generator with the HV main power network. Due consideration should be given to the possible limitation on synchronous running of the various system parts if mixing systems with isochronous and speed droop load shedding philosophies.

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If relevant, Grid Diesel Generators shall be properly equipped in order to prevent high electromagnetic torque oscillations that might result from the high inrush currents of the wind turbine transformers during the energization procedure in islanded conditions and that might otherwise shorten the generators lifespan or lead to improper interventions of overcurrent and undervoltage protections. Provision of automatic voltage regulators with adjustable setting or series resistances shall be considered. Load shedding arrangements need to be specially considered. Synchronizing and parallel operation of mixed isochronous (constant speed) parts (main net) with generator sets arranged with speed droop type of load shedding should be avoided due to high risk of instabilities and generator set drop-out due to reverse power trip.

The Grid Diesel Generator and the Auxiliary Diesel Generator can be the same generator, provided that other requirements in [5.6.2] are fulfilled.

5.6.9 Auxiliary transformer
Auxiliary transformers shall comply with DNVGL-OS-D201 Ch.2 [6.1].

5.6.10 Auxiliary system cables
The cables comprised in the substation auxiliary system shall comply with DNVGL-OS-D201 Ch.2 Sec.9, where applicable.

Requirements in IEC 60092 have to be considered as mandatory only for outdoor power and control cables. Cables installed in open decks shall be protected against UV rays.

5.6.11 Miscellaneous equipment
Sockets, lighting equipment, heating equipment, cooking and other galley equipment shall comply with DNVGL-OS-D201 Ch.2 Sec.8, where applicable.

5.7 Lightning protection and earthing

5.7.1 References

5.7.1.1 General
The lightning protection system shall comply with the international standard series IEC 62305 and IEC 61892. National requirements in excess thereof and any additional requirements of the grid operators shall be observed.

5.7.1.2 Basic design criteria
Lightning protection level (LPL)

The platform and its sub-components shall be protected according to the lightning protection level I (LPL I). A corresponding set of maximum and minimum lightning current parameters is to be found in IEC 62305-1 Protection against lightning – Part 1: General principles, Table 5 and 6.

Lightning protection zone (LPZ)

The offshore substation owner or his subcontractors shall establish a lightning protection zone concept following the principles given in IEC 62305-4 Protection against lightning – Part 4: Electrical and electronic systems within structures. The definition of the lightning protection zones is given in IEC 62305-4 Protection against lightning – Part 4: Electrical and electronic systems within structures, subclause 4.2. Each lightning protection zone has the task of reducing the electromagnetic field and the conducted emission disturbances to the stipulated values. The requirements for choosing the one or the other lightning protection zone depend on the electromagnetic disturbance immunity of the equipment installed in the higher lightning protection zone. Thus, the manufacturer shall state the voltage protection level, the discharge current and the impulse current of each LPZ. At each zone boundary, it must be ensured that cables and wires crossing
the boundary do not conduct large parts of the lightning current or voltage transients into the lightning protection zone with the higher number. This is achieved by means of proper bonding and shielding practices and surge protection devices (SPD) of all cables and wires at the zone boundary as described in subsequent sections.

SPD protection is always required for all incoming cables at the entrance of a lightning protection zone. The number of required SPDs can be reduced by connecting or extending zones.

Lightning protection zones can be interconnected via shielded cables (with the shield connected to the bonding system at both ends) or metallic conduits. Also, a lightning protection zone can be extended with a shielded cable to include external metal sensor housing. The measures for connection and extension of lightning protection zones taken by the designer shall be stated in the lightning protection documentation of the offshore substation. Examples of connected zones or extended zones can be found in IEC 62305-4 Protection against lightning – Part 4: Electrical and electronic systems within structures, subclause 4.2.

Lightning protection zones LPZ 0A and LPZ 0B typically include the following areas:
- roof top installations, antennas, cranes and heliports
- the inside of lattice towers
- cable connections outside of the substation on deck, if no shielding measures are provided.

Lightning protection zone LPZ 1 typically includes the following areas:
- internals of control-rooms and containers, provided that effective lightning-conducting, shielding and SPD measures are taken
- the interior of all metal deck equipment enclosures, insofar as they are connected in a suitable manner to an equipotential bonding system and SPD protection
- shielded cables, or cables which are laid in metallic pipes whereby mesh shields or metallic pipes shall be connected to the equipotential bonding of LPZ 1 zones on both sides
- the external sensors and measurements devices (e.g. meteorological measurement equipment), insofar as these are fitted with lightning cages, appropriate conductors sheathed in a metal shield with both sides of the shield bonded to the turbine earthing system and SPDs Lightning protection zone LPZ 2 includes facilities within lightning protection zone LPZ 1, if additional protection measures have to be taken for a further reduction in the effects of electromagnetic fields and over-voltages, especially for sensitive electronic systems.

**Offshore application and environment**

Outside equipment (e.g. lightning rods, earthing connection, etc.) shall be of copper or other corrosion-resistant material and, where necessary, protected against corrosion. They shall be protected against damage, where necessary.

Connection and fixation elements shall be chosen depending on corrosion characteristics.

**Electrical systems and installations**

Electrical systems and installations have to be protected against the effects of lightning current, overvoltage and lightning electromagnetic impulses (LEMP). This shall be done by means of equipotential bonding, magnetic and electrical shielding of cables and line routing, coordinated surge protection devices and earthing.

**Surge arresters**

Surge arresters for low-voltage applications shall comply with
- IEC 61643-1 “Low-voltage surge protective devices – Part 1: Surge protective devices connected to low-voltage power distribution systems – Requirements and tests” for power systems
- IEC 61643-21 “Low-voltage surge protective devices- Part 21: Surge protective devices connected to telecommunications and signalling networks – Performance requirements and testing methods” for telecommunication and signalling systems.

The energy coordination of surge arresters shall be in compliance with IEC 62305-4 Protection against lightning – Part 4: Electrical and electronic systems within structures, Annex C. Proof shall be given by
testing, calculations or selection of coordinated surge arrester families. In each case, a description of the measures taken and the results achieved or protection levels achieved is required for assessment.

Surge arresters for high-voltage or medium-voltage applications shall comply with

— IEC 60099-1 Surge arresters – Part 1: Non-linear resistor type gapped surge arresters for a.c. systems
— IEC 60099-4 Surge arresters – Part 4: Metal-oxide surge arresters without gaps for a.c. systems

**Earthing system**

Solid and durable earthing of the platform and its components is required by means of functional and protective arrangements. The design of the substations earthing system shall be in accordance with the requirements stipulated in the applicable parts of standard series IEC 60364, and IEC 62305. For the design and installation of the HVPS reference is made to EN 61936-1 and EN 50522 for voltage levels exceeding 1 kV, too.

Although above mentioned standards generally apply to onshore installations only, they shall be the basis for the earthing system of offshore substations. The earthing system shall be designed so that sufficient protection against damage due to lightning flashes is provided. Furthermore, step and touch voltages shall never exceed the limits given in standards to prevent harmful shock currents that endanger human life.

Required functional and protective earthing shall be determined and elaborated in a detailed earthing study taking into account worst case operating scenarios and fault currents. Functional earth conductors shall be selected in consideration of thermal and mechanical stresses during faults e.g. according to the principles given in EN 61936-1 and EN 50522 as indicated above.

The selection of neutral earthing method shall be defined in consideration of the grid structure, protection concept and desired service security. Selection of appropriate cross-sectional areas of protective bonding conductors shall be described. Connection and marking of bonding conductors shall be specified based on the standards above. Bolted connections for the fixing of units or components are not considered electrically conductive connections.

The equipotential bonding system shall be assessed on the basis of an equipotential bonding plan for all major bonding and earthing connections of the substation, showing the general equipotential bonding system including the locations of the bonding bars within the different lightning protection zones, the bonding conductors with their cross-sectional areas.

The connection of the earthing conductor to the structure shall be located at a point where it can easily be checked. Connections of earthing conductors shall be protected against corrosion.

Unintentional potential transfer between the earthing system of the platform and others like, e.g., the earthing system of the wind turbines shall be considered and avoided. Containers installed on the platform shall be connected to the structure by minimum 2 additional earthing conductors evenly distributed.

Each container /or installation room shall be equipped with one main earthing terminal inside.

Electrical equipment, cabinets, metal frames and other enclosures shall be connected using startype washers in earth conductors connected to this earthing bar.

Insulated mounted sub-structures, like, e.g., machinery mounted on vibration dampers, or aluminum superstructures or helicopter decks shall be connected to the structure by flexible cables or stranded copper straps. The connections shall have a high electrical conductivity and shall be corrosion-resistant. The minimum cross-section is 50 mm² per conductor.

**Equipotential bonding**

All conductive, but in normal operation non-live, components and metal parts shall be provided with an electrically conductive connection to the structure.

Touchable conductive parts of equipment which are normally not live, but which may present a dangerous contact voltage in the event of a fault, are to be connected (earthed) to the main metal structure of the installation. Such equipment may be regarded to be directly connected to the structure, provided that surfaces in contact are clean and free from rust, scale or paint when installed and firmly bolted together.
All metal components in the electrical operational compartments shall be included in the equipotential bonding. This comprises

— structural metal parts
— metal installations
— internal systems
— external conductive parts and service lines connected to the structure.

The bonding conductors shall be kept as short as possible and shall have a cross-sectional area according to IEC 62305-3 Protection against lightning - Part 3: Physical damage to structures and life hazard, Tables 8 and 9.

Metallic cable sheaths, armoring and shields shall be earthed effectively.

Where possible, incoming cables should enter the lightning protection zone at the same location and be connected to the same bonding bar. If incoming cables enter the lightning protection zone at different locations, each cable shall be connected to a bonding bar and the respective bonding bars of the zone shall be connected (see IEC 62305-3, subclause 5.4).

5.8 Lighting systems on offshore substations

5.8.1 Main lighting

There shall be a main lighting system supplied by the main source of electrical power and illuminating all areas normally accessible to and used by personnel.

The arrangement of the main lighting system shall be such that a fire or other casualty in the space or spaces containing the main source of power, including transformers or converters, if any, will not render the emergency lighting system inoperative.

The lighting level of the main lighting shall generally comply with Table 6 of IEC 61892-2. Respective requirements of local authorities and rules and standards shall be also observed.

A lighting calculation and a lighting layout shall be prepared for the main lighting.

5.8.2 Emergency lighting

An emergency lighting system is to be installed. The arrangement of the emergency lighting system shall be such that a fire or other casualty in the space or spaces containing the emergency source of power, including transformers or converters, if any, will not render the main lighting system required by [5.8.1] inoperative.

The emergency lighting e.g. in control or machinery spaces shall be so dimensioned to facilitate the start of the substation’s operation from “total shut down” condition by personnel on board.

The emergency lighting system shall be switched on automatically in case of a failure of the main source of electrical power. Local switches are to be provided only where it may be necessary to switch off the emergency lighting.

Emergency lights shall be marked for easy identification.

The lighting level of the emergency lighting shall not fall below 30% of the main lighting level.

A lighting layout shall be created, identifying the emergency lighting.

5.8.3 Escape lighting

Escape lighting is understood as the emergency lighting according to [5.8.2], supplied by the transitional source of emergency power according to [5.6.2.8]. The escape lighting shall be operational immediately after main power failure to facilitate a safe evacuation of personnel. Normally the escape lighting power supply will be based on an accumulator battery integrated in the escape lighting fixture or a central battery with sufficient capacity for half an hour of illumination.

The lighting level of the escape lighting shall comply with Table 8 of IEC 61892-2. Respective requirements of local authorities shall be also observed.
A lighting calculation and a lighting layout shall be established for the escape lighting.

For installation of light fittings or switches in bathrooms and shower rooms please refer to IEC 60364-7-701.

5.8.4 Design of light fittings

Luminaries, floodlights and searchlights are to conform to Publications IEC 60598 and IEC 60092-306.

For lighting in spaces with explosion hazard, such as paint stores, battery rooms or welding gas storage rooms the lighting fixtures and the associated switches shall be type-approved with regard to explosion-protection. Emergency and escape lighting fixtures in non-hazardous areas shall be suitable for a zone 2 location, in case the danger of explosion can spread into these areas. The following explosion groups and temperature classes are applicable:

- for battery rooms: IIC, T1
- for paint stores: IIB, T3
- for storerooms containing welding gas bottles: IIC, T2.

Specific environmental conditions, e.g. strong electromagnetic radiation and high temperatures at ceilings in HV/DC converter rooms shall be considered for lighting fixtures installed in such areas.

The surface temperature of easily touchable parts of light fittings shall normally not exceed 60°C.

High-power lights with higher surface temperatures are to be protected against unintentional contact by additional means.

The terminals and spaces for the connection of cables shall have temperature ratings for operating exceeding the temperature permissible for the insulation of the wires or cables used.

All the metal parts of a light fitting shall be conductively connected to each other and shall be provided with a suitable terminal for earthing.

Wiring inside lighting fixtures shall have a minimum cross section of 0.75 mm². A cross section of at least 1.5 mm² is to be used for through wiring. Heat-resistant wires are to be used for internal wiring.

Each luminaire shall be durably marked with the following details:

- maximum permitted lamp wattage
- minimum mounting distance.

Supports of live parts in lamp holders shall be at least of flame retardant material for fluorescent lights and at least of incombustible material for incandescent lamps.

5.8.5 Special requirements for searchlights and arc lamps

All parts of searchlights or arc lamps to be handled for their operation or adjustment while in use shall be so arranged that there is no risk of electrical shock to the operator.

Disconnection of every searchlight or arc lamp shall be by a multi-pole (all poles) disconnecting switch. If a series resistor is used with an arc lamp, the disconnecting switch shall be so placed in the supply circuit that both the series resistor and arc lamp are disconnected when the switch is in the off position.

5.8.6 Power supply to lighting systems

In general lighting systems are to be supplied from the main switchboard, emergency lighting from the emergency switchboard or from the main switchboard if provided with fittings with individual battery back-up.
5.8.7 Final circuits

The maximum permissible fused current of final lighting circuits is 16 A.

The number of lighting points (lamps) connected to one final circuit shall not exceed:

- 10 lamps for voltages up to 55 V
- 14 lamps for voltages over 55 V
- 24 lamps for voltages over 125 V.

Switches shall act simultaneously on all the non-earthed conductors of a circuit. The single pole disconnection of final lighting circuits in systems insulated on all poles is permitted only in the accommodation area.

In the important rooms listed below the lighting shall be supplied by at least two separate fused circuits:

- machinery and other important service spaces, safety stations and control rooms
- large galleys
- passageways and other escapes
- stairs and passageways leading to the lifeboats
- messes and day rooms for the personnel
- helicopter landing area.

Where an emergency generator set is installed, it is recommended that one of the circuits should be supplied from the emergency switchboard. However, it is not permitted to supply all the lighting circuits exclusively from the emergency switchboard. The light fittings are to be so arranged that adequate illumination is maintained should any circuit fail.

Where an installation is divided into main fire zones, at least two circuits shall be provided for the lighting of each main fire zone, and each of these shall have its own power supply line. The supply lines shall be routed in such a way, that a fire in one main fire zone does not, if possible, interfere with the lighting of the other zones.

5.9 Manufacturing, testing and commissioning

5.9.1 Manufacturing

General requirements on to manufacturing and the qualification of manufacturers are defined in Chapter 10 and in DNVGL-SE-0073 and DNVGL-SE-0190.

5.9.1.1 General

Testing and commissioning of the substation electrical system is usually performed in three stages:

- factory acceptance tests (FAT)
- harbour, yard or site acceptance tests (SAT)
- offshore commissioning.

Guidance note:

Reference guidance on the best practices to be adopted for the testing and commissioning of offshore substations for wind power plants can be found in the Cigré Guidelines for the Design and Construction of AC Offshore Substations for Wind Power Plants, Working Group B3.26, December 2011, chapter 3.7.

5.9.1.2 Factory acceptance tests (FAT)

All the substation main power equipment shall be tested at a test facility which shall be accredited according to definition in EN ISO/IEC 17025. Tests shall comply with applicable IEC standards. The set of routine tests as specified in the applicable IEC standards shall always be performed and documented. Type tests or special tests shall be performed as agreed.

Major components included in the substation auxiliary system, consisting of diesel generators, UPS and main and emergency switchboards, shall be tested as prescribed by the applicable IEC standards. The set of routine tests shall always be performed and documented.
Large main power electrical equipment (i.e. main transformers, shunt reactors, etc.) after successfully completion of the FAT are shipped to be sent to the construction yard for installation. The shipping shall include a shock-recorder device able to detect harmful shock impacts that might occur during the transportation. Functional tests between main and emergency switchboards shall also be performed at the manufacturer’s facility where possible.

5.9.1.3 Site acceptance test (SAT)

After receiving the electrical equipment at the construction yard, visual inspections and analysis of shock recording device results shall be performed to identify possible damages occurred during the transportation. In case of evident damages occurred during the transportation, the electrical equipment shall be repaired and the necessary routine tests shall be repeated if needed and as far as practicable.

After assembling and installation completion at the construction yard and prior to the transportation to the transportation vessel, the large electrical power equipment shall be checked at least through:

— insulation tests
— electrical parameters check
— functional checks.

Guidance note:
It is recommended to perform a frequency response analysis (FRA) on main transformers and reactors, to be repeated and compared with the initial analysis after the installation offshore in case of damages occurred during the transportation.

After the assembling and installation completion at the construction yard, auxiliary power equipment shall be gradually powered up and all the systems, including the auxiliary system, shall be tested together with the SCADA system at its highest practical extent.

All the performed construction yard acceptance tests and construction yard commissioning activities shall be documented.

5.9.1.4 Offshore tests and commissioning

After the substation topside has been positioned onto the substructure, at the offshore site, visual inspections and analysis of shock recording device results shall be performed to identify possible damages occurred during the transportation. In case of evident damages occurred during the transportation, the electrical equipment shall be removed (if necessary) and repaired; routine tests shall be repeated if needed.

Prior to any main power energization offshore activity, an assessment of the status of the emergency services and operational services shall be performed.

At a minimum, before any main power energization offshore activity, the status of the electrical installation shall be checked through:

— insulation resistance tests
— verification of the tightness of the connections
— functional checks
— no-load switching operations (to be performed both locally and remotely)
— verification of the main power transformers auxiliary systems (fans and/or pumps).

Guidance note:
It is recommended to perform a partial discharge (PD) test on HV power cables according to the Cigré Brochure 502 High-Voltage On-Site Testing with Partial Discharge Measurement.

PD testing can be completed during the HAT testing period where applicable, specifically if the equipment is not going to be moved in relation to the adjoining termination or equipment.

Verification of the tightness of connections might not be required where disassembly of the equipment is necessary.

The main power energization activities shall be performed according to a commissioning switching program (CSP), to be submitted for information to the grid operator.

All the performed site acceptance tests and site commissioning activities shall be documented.
5.10 Maintenance

5.10.1 Preventive and corrective maintenance
A substation inspection and maintenance plan shall be established. The maintenance plan shall state which actions shall be taken for preventive and corrective maintenance.

The maintenance plan shall be developed through a reliability centred maintenance approach as defined in the IEC 60300-3-11.

Preventive maintenance shall include both scheduled maintenance activities and conditions monitoring based maintenance activities.

Findings and repairs following findings from inspection and maintenance activities are subject to review and accept by DNV GL in line with a contract covering in-operation involvement.

5.10.2 Maintenance on the oil filled electrical equipment
For large oil filled electrical equipment, (i.e. shunt reactors, main, earthing and auxiliary transformers), oil samples need to be taken on regular basis. The frequencies of the analysis and the frequencies of the interventions to improve the oil can be based on trends and comparisons of analysis results.

If the main transformer is equipped with an online monitoring system as specified in 5.4.4.2 f), intervention on the main transformer oil may be based on output from the transformer condition monitoring system.

The oil removal concept shall distinguish between removal and refilling operation for small quantities and for big quantities of oil, for the three following operations:

— oil emptying and removal (waste product)
— temporary oil removal and storage
— oil refilling.

Small containers used for operations on small quantities of oil shall be of a sealable double-walled type.

The collection tanks for bounded areas of the oil transformers and reactors shall be drained only when a bunker vessel is present.

Emptying of the diesel generator’s sumps or collection tanks for bounded areas may be performed through a portable pump connected to the respective tanks.

5.11 Marking
Marking of the electrical equipment shall be in accordance with DNVGL-OS-D201 Ch.2 [3.5], and with the applicable IEC standards and national requirements.
SECTION 6  FIRE AND EXPLOSION PROTECTION

6.1  Introduction
This section provides principles for the design, construction and installation of fire and explosion protection for offshore substations.

Sections of this standard containing important information related to fire and explosion protection include:

- [3.6.5] Personal protective equipment
- [4.4.6.4] Explosion
- Sec.5 Electrical design
- [8.4.2] Helicopter decks
- Sec.9 Emergency response

6.2  Safety philosophy and design principles

6.2.1  General

The objectives of fire and explosion protection are to:

- ensure time for safe evacuation of personnel
- minimise the risk of fire and explosion
- provide automatic monitoring functions to detect fire or gas
- relieve hazardous overpressure
- control fires and limit damage and escalation
- for both manned and unmanned installations eliminate escalation for the typical fire scenarios by means of active and passive fire protection, see [2.4].

The principle of a performance-based fire protection design is shown in Figure 6-1. Performance criteria shall be evaluated in fire (and explosion) scenarios and corresponding trial designs. Improvements shall be made to the design until performance criteria are met. The evaluation may reveal that certain fire scenarios are beyond the capability of the protection system. In these cases it may be necessary to re-evaluate the approaches.

Guidance note:
Reference is made to "SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings".
6.2.2 Safety criteria and evaluation

Performance criteria related to health and safety of persons shall be evaluated for manned areas. The criteria are valid during the waiting time in a temporary safe area or during an evacuation process. The performance criteria should include:

a) The temperature below any generated smoke layer shall be +60°C maximum.

b) The height from floor to a generated smoke layer shall be \( z > 1.6 \text{ m} + 0.1 \text{ H} \), where \( \text{H} \) is the height of the room in meters.

c) The oxygen concentration shall be at least 15%. However, where inert gas systems are used the oxygen level may be reduced down to 10% - 12%.

d) Thermal radiation on the floor due to a generated smoke layer shall be below 2.5 kW/m². For a short period (max. 10 s) a radiation level up to 10 kW/m² may be permitted.

Performance criteria related to the safety of the structure shall be evaluated for all areas affected. Acceptance criteria include:

- thermal radiation and convective heat exposure
- overpressure caused by fire
- explosion overpressure depending on type of explosion and duration time, see also [4.4.6.4].

6.2.3 Design basis

Fire and explosion analysis shall be based on information such as:

- layout of the installation and arrangement of equipment
- geometry, ventilation conditions and thermal inertia of the enclosures to be analysed
- nature and risk of fires, fire escalation and explosions
- fluids handled and their properties including substances that can catch fire
- manning philosophy, distribution of persons and human factors.
6.2.4 Design process

Applicable regulations and guidance shall be reviewed.

Prescriptive requirements exist for offshore platform installations and in addition to these an analysis should be made. The analysis is often following a deterministic process, supplemented by performance-based fire safety engineering.

The process is based upon the design objective definition followed by performance criteria selection for the specific offshore substation. These shall include human and structural acceptance criteria.

A fire scenario development follows, during which a relatively large number of initial fire scenarios are reduced to a number of selected scenarios. The scenarios are subject to fire engineering assessment as described in [6.3].

Explosion protection design considers the explosion loads and shall adopt one or more of the following design approaches:

- hazardous areas are located in unconfined (open) locations and sufficient shielding mechanisms, e.g. blast walls, are installed
- hazardous areas are located in partially confined locations and the resulting, relatively small overpressures are accounted for in the structural design
- hazardous areas are located in enclosed locations and pressure relief mechanisms are installed, e.g. blast panels designed to take the resulting overpressure.

The selected fire and explosion protection system components shall be described by:

- performance parameters
- integrity, reliability, redundancy and availability
- survivability under emergency conditions
- dependencies on other systems.

The following typical fire scenarios for an unmanned AC substation should as a minimum be evaluated if relevant:

- main/auxiliary transformer fire e.g. due to overload, faults, oil degradation, or lack of cooling
- HV switchgear fire / explosion due to faults, poor maintenance, or incorrect procedures
- LV equipment fire due to short circuits, or overloads
- emergency generator fire due to faults, leakage, or malfunction
- fire in control room or social areas due to smoking, unattended electrical devices, poor housekeeping etc.

Guidance note:
In order to decrease the possibility of a transformer fire a less-flammable or fire safe dielectric fluid should be used in the transformers if possible.

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6.2.5 Minimum requirements

For installations where passive fire protection is applicable, [6.4] describes minimum requirements.

- Substation type A: Control rooms (public room on unmanned platform) and similar areas shall be isolated from the rest of the platform by suitable passive fire protection for a period compatible with the evacuation time for the installation.
- Substation type B: Control rooms, accommodation and similar areas shall be isolated from the rest of the platform by suitable passive fire protection.
- Substation type C: Suitable passive fire protection shall be used to separate rooms and open areas.

Portable fire extinguishing equipment is required on all installations according to [6.5.8]. [6.5] describes further active firefighting systems that should be considered depending on the type of installation.
Where the formal safety assessment indicates an appreciable risk of explosions, necessary provisions shall be in accordance with the requirements of [6.6].

Fire detection systems are required on all installations. These, and possible gas detection systems, are described in [6.7].

The following electrical services are required to be operable under fire conditions:

- fire and general alarm system; public address system
- emergency fire pump, fire extinguishing systems and fire extinguishing medium alarms
- fire and gas detection system
- control and power systems to power operated fire doors (if used) and status indication for all fire doors
- control and power systems to power operated watertight doors (if used) and their status indication
- emergency lighting
- remote emergency stop/shutdown arrangements for systems which may support the propagation of fire and or explosion
- communication system.

**Guidance note:**
Examples of high fire risk areas are galleys and pantries containing cooking appliances, laundry with drying equipment and areas with fuel handling equipment.

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### 6.3 Fire safety engineering

#### 6.3.1 General

Fire safety engineering is utilised in order to prove that a selected design fulfils the performance-based requirements.

A fire scenario is a combination of a design fire and different incident scenarios.

**Guidance note:**
An example of an incident in connection with a fire scenario could be a blocked door, maybe caused by the fire, and the evacuees not being able to use this door for egress/evacuation. Thus, such an incident will result in an increased evacuation time.

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The design fires connected to each fire scenario are selected from the infinite number of possibilities. The analyses are carried out on the basis of the limited number of fires selected. Design fires should be selected from two categories:

- fires having a high possibility to occur
- fires having a severe consequence.

**Guidance note:**
It is often enough to select 4 to 6 design fires. For each project it should be carefully assessed whether there is a chance of a glowing fire, which is, with respect to toxicity, often more dangerous than a flaming fire because of the large carbon monoxide generation.

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A trial design development shall be made according to design objective definitions, performance criteria and selected/developed fire scenarios. The trial design shall be evaluated and analysed in order to confirm that all requirements are met. If not, a new design shall be developed and evaluated until all requirements are met.

The heat generation is governed by the design fire and the properties of the fire room. The energy release rate of the fire, the thermal properties of the wall and deck, the size of any ventilation, etc. will impact the generation of heat, smoke, pressure, radiation and the heat transfer. Simple calculations as well as zone and CFD models are used to assess the physical properties.

The energy release rate can in most cases be estimated by:

\[
\dot{Q}_b = m^* \cdot \Delta H_e \cdot \chi \cdot A_f
\]
It shall be investigated whether there is enough oxygen present to reach the energy release rate. An estimate can be obtained from:

\[ \dot{Q}_v = 1.518 \cdot A_0 \sqrt{H_0} \]

where

- \(\dot{Q}_b\) = combustion controlled value of energy release rate, in MW
- \(\dot{m}^*\) = burning rate, in kg s\(^{-1}\) m\(^{-2}\)
- \(\Delta H_c\) = heat of combustion, in MJ/kg
- \(\chi\) = combustion coefficient
- \(A_f\) = burning area, in m\(^2\).

A sensitivity analysis shall always be carried out as a part of the process in order to check that changes of any input value to the fire model will not result in unacceptable changes of the results. If the sensitivity is found to be high, a risk analysis should normally be made.

The temperature distribution in the structure should be determined based on the actual temperature/time curve and the required fire resistance, taking the effects of insulation and other relevant factors into consideration.

### 6.4 Passive fire protection

#### 6.4.1 General

The objectives of passive fire protection (PFP) are to prevent or mitigate the serious consequences of a fire, such as to:

- prevent escalation of fire from one area to an adjacent area
- ensure the temporary safe area is intact for the time necessary
- protect personnel from the fire (heat and smoke) and make escape or evacuation possible
- protect systems and equipment of essential importance for safety
- maintain structural integrity for the required period of time.

PFP is less widely used on small, open-type installations, but should be considered when developing the fire protection strategy. Selection of passive fire protection shall take the types of fire, duration of protection and limiting temperatures for the protected systems or areas into account.

#### 6.4.2 Fire integrity of walls and decks

Fire integrity of walls separating adjacent spaces shall be as given in Table 6-1 and Table 6-2.

The Table 6-1 and Table 6-2 are interpretations of MODU code table 9-1 and 9-2 adapted for offshore substation purposes.
Table 6-1 Fire integrity of walls separating adjacent spaces

<table>
<thead>
<tr>
<th>Spaces (MODU definition)</th>
<th>Typical spaces (substation)</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
<th>(9)</th>
<th>(10)</th>
<th>(11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) control stations</td>
<td>control and communication room, UPS, emergency diesel generator, SCADA and control room</td>
<td>A-0</td>
<td>A-0</td>
<td>A-60</td>
<td>A-0</td>
<td>A-15</td>
<td>A-60</td>
<td>A-15</td>
<td>A-60</td>
<td>A-60</td>
<td>*</td>
<td>A-0</td>
</tr>
<tr>
<td>(2) corridors</td>
<td></td>
<td>C</td>
<td>B-0</td>
<td>B-0</td>
<td>A-0</td>
<td>B-0</td>
<td>A-0</td>
<td>A-0</td>
<td>A-0</td>
<td>A-0</td>
<td>*</td>
<td>B-0</td>
</tr>
<tr>
<td>(3) accommodation spaces</td>
<td>public room, locker room</td>
<td>C</td>
<td>B-0</td>
<td>A-0</td>
<td>A-0</td>
<td>B-0</td>
<td>A-60</td>
<td>A-0</td>
<td>A-0</td>
<td>A-0</td>
<td>*</td>
<td>C</td>
</tr>
<tr>
<td>(4) stairways</td>
<td></td>
<td>B-0</td>
<td>A-0</td>
<td>A-0</td>
<td>A-0</td>
<td>B-0</td>
<td>A-60</td>
<td>A-0</td>
<td>A-0</td>
<td>A-0</td>
<td>*</td>
<td>B-0</td>
</tr>
<tr>
<td>(5) service spaces (low risk)</td>
<td>workshop, storage</td>
<td>C</td>
<td>A-0</td>
<td>A-0</td>
<td>A-0</td>
<td>A-0</td>
<td>A-0</td>
<td>A-0</td>
<td>A-0</td>
<td>A-0</td>
<td>*</td>
<td>B-0</td>
</tr>
<tr>
<td>(6) machinery spaces of category A</td>
<td>diesel generator room (&gt;375 kW), HV transformer room</td>
<td>* a)</td>
<td>A-60 a)</td>
<td>A-60</td>
<td>*</td>
<td>A-0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(7) other machinery spaces</td>
<td>diesel generator room (&lt;375 kW), rooms for LV HV, utility rooms</td>
<td>A-0 a) c)</td>
<td>A-0</td>
<td>A-0</td>
<td>*</td>
<td>A-0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(8) hazardous areas</td>
<td>hell fuel skid, diesel tanks d)</td>
<td>-</td>
<td>A-0</td>
<td>-</td>
<td>A-0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(9) service spaces (high risk)</td>
<td></td>
<td>A-0 c)</td>
<td>*</td>
<td>A-0</td>
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<tr>
<td>(10) open decks</td>
<td>walkways</td>
<td>-</td>
<td>*</td>
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<td></td>
</tr>
<tr>
<td>(11) sanitary and similar spaces</td>
<td></td>
<td>C</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

See notes under Table 6-2.
The following requirements should govern application of the tables:

a) The required fire integrity should be qualified through the accidental loads that apply. Special attention shall be paid to areas containing large oil-filled equipment (e.g. oil-filled transformers or shunt reactors for which at least "A-60" divisions between such equipment are required by default, see [3.4.1]), accommodation areas, temporary refuge or shelter areas (see [4.4.6.3]) and living quarters (see DNVGL-OS-A101). Where well proven designs are implemented, the prescriptive requirements given in Table 6-1 and Table 6-2 can be applied directly.

b) For determining the appropriate fire integrity standards to be applied to divisions between adjacent spaces, such spaces are classified according to their fire risk, as shown in categories (1) to (11) below. The title of each category is intended to be typical rather than restrictive. The number in parenthesis preceding each category refers to the applicable column or row in the tables:

   (1) “Control Stations” are spaces with equipment performing control functions essential for operational and emergency services; e.g. spaces containing
      — operational control systems
      — emergency source of power

   (2) corridors

   (3) accommodation spaces

   (4) stairways

   (5) service spaces (low risk)

   (6) machinery spaces of category A

   (7) other machinery spaces

   (8) hazardous areas

   (9) service spaces (high risk)

   (10) open decks

   (11) sanitary and similar spaces

Table 6-2  Fire integrity of decks separating adjacent spaces

<table>
<thead>
<tr>
<th>Spaces above →</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
<th>(9)</th>
<th>(10)</th>
<th>(11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) control stations control and communication room, UPS, emergency diesel generator, scada and control room</td>
<td>A-0</td>
<td>A-0</td>
<td>A-0</td>
<td>A-0</td>
<td>A-60</td>
<td>A-0</td>
<td>A-0</td>
<td>A-0</td>
<td>*</td>
<td>A-0</td>
<td></td>
</tr>
<tr>
<td>(2) corridors</td>
<td>A-0</td>
<td>*</td>
<td>*</td>
<td>A-0</td>
<td>A-0</td>
<td>A-60</td>
<td>A-0</td>
<td>A-0</td>
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<td>*</td>
<td>*</td>
</tr>
<tr>
<td>(3) accommodation spaces public room, locker room</td>
<td>A-60</td>
<td>A-0</td>
<td>*</td>
<td>A-0</td>
<td>A-0</td>
<td>A-60</td>
<td>A-0</td>
<td>A-0</td>
<td>A-0</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>(4) stairways</td>
<td>A-0</td>
<td>A-0</td>
<td>A-0</td>
<td>*</td>
<td>A-0</td>
<td>A-60</td>
<td>A-0</td>
<td>A-0</td>
<td>A-0</td>
<td>*</td>
<td>A-0</td>
</tr>
<tr>
<td>(5) service spaces (low risk) workshop, storage</td>
<td>A-15</td>
<td>A-0</td>
<td>A-0</td>
<td>A-0</td>
<td>*</td>
<td>A-60</td>
<td>A-0</td>
<td>A-0</td>
<td>A-0</td>
<td>*</td>
<td>A-0</td>
</tr>
<tr>
<td>(6) machinery spaces of category A</td>
<td>A-60</td>
<td>A-60</td>
<td>A-60</td>
<td>A-60</td>
<td>* a)</td>
<td>A-60</td>
<td>A-60</td>
<td>A-60</td>
<td>*</td>
<td>A-0</td>
<td></td>
</tr>
<tr>
<td>(7) other machinery spaces</td>
<td>A-15</td>
<td>A-0</td>
<td>A-0</td>
<td>A-0</td>
<td>A-0</td>
<td>A-0</td>
<td>A-0</td>
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<td>*</td>
<td>A-0</td>
<td></td>
</tr>
<tr>
<td>(8) hazardous areas hell fuel skid, diesel tanks d)</td>
<td>A-60</td>
<td>A-0</td>
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<td>A-0</td>
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<tr>
<td>(9) service spaces (high risk)</td>
<td>A-60</td>
<td>A-0</td>
<td>A-0</td>
<td>A-0</td>
<td>A-0</td>
<td>A-0</td>
<td>A-0</td>
<td>A-0</td>
<td>A-0</td>
<td>c)</td>
<td>A-0</td>
</tr>
<tr>
<td>(10) open decks walkways</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>(11) sanitary and similar spaces</td>
<td>A-0</td>
<td>A-0</td>
<td>*</td>
<td>A-0</td>
<td>A-0</td>
<td>*</td>
<td>A-0</td>
<td>A-0</td>
<td>A-0</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

a) Where the space contains an emergency power source or components of an emergency power source, adjoining a space containing HV systems the boundary wall or deck between those spaces should be an “A-60” class division.

b) For clarification as to which note applies see [6.4.5].

c) Where spaces are of the same numerical category and superscript “c” appears, a wall or deck of the rating shown in the tables is only required when the adjacent spaces are for a different purpose, e.g. in category (9). A galley next to a galley does not require a wall but a galley next to a paint room requires an “A-0” wall.

d) The room definition for diesel tanks is given by EN/IEC 60079-10 and depend on the type of diesel, ventilation etc.

* The divisions should be of steel or equivalent material, but need not be of “A” class standard. However, where a deck is penetrated for the passage of electric cables, pipes and vent ducts, such penetrations should be made tight to prevent the passage of flame and smoke and minimise the impact of the fire rating of the penetrated deck / wall.
— fire control systems
— fire extinguishing equipment serving various locations.

(2) “Corridors” means corridors and lobbies.

(3) “Accommodation spaces” are spaces such as public spaces, recreational rooms, cabins, offices, cinemas and the like.

(4) “Stairways” are interior stairways, lifts and escalators (other than those wholly contained within the machinery spaces) and enclosures thereto. In this connection a stairway which is enclosed only at one level should be regarded as part of the space from which it is not separated by a fire door.

(5) “Service spaces (low risk)” are workshop, storage, lockers and working spaces in which flammable materials are not stored, drying rooms and laundries.

(6) “Machinery spaces of category A” are spaces which contain internal combustion type machinery (>375 kW) or any fuel-fired boiler or heated oil fuel units; and trunks to such spaces. For substations this will typically be HV transformer rooms and diesel generator rooms.

(7) “Other machinery spaces” are all machinery spaces outside Category A (<375 kW), rooms for LV- and HV-equipment and utility rooms.

(8) “Hazardous areas” are all those areas where, due to the possible presence of a flammable atmosphere arising from the process operations, for example batteries or stored and handled substances, the use of mechanical or electrical equipment without proper consideration may lead to ignition and fire or explosion hazard.

(9) “Service spaces (high risk)” are lockers, storerooms and working spaces in which flammable materials are stored, galleys, pantries containing cooking appliances, paint rooms and workshops other than those forming part of the machinery space.

(10) “Open decks” are areas fully subject to natural ventilation such as walkways and open deck spaces, excluding hazardous areas.

(11) “Sanitary and similar spaces” are communal sanitary facilities such as showers, baths, lavatories, etc., and isolated pantries containing no cooking appliances. Sanitary facilities which serve a space and which have an access only from that space shall be considered a portion of the space in which they are located.

When designing structural fire protection details, the risk of heat transmission at intersections and terminal points of required thermal barriers shall be considered.

Escape ways shall be protected sufficiently so escape and evacuation is possible. Additional time for rescue of lost or harmed personnel shall be included.

### 6.4.3 Penetrations

Openings and penetrations in fire rated divisions shall be arranged so as to maintain the fire rating of the divisions. Penetrations shall be qualified, tested and approved, in accordance with DNVGL-OS-D301 Ch.2 Sec.1, for the actual divisions where they are to be installed.

Openings in “H” class walls should be avoided. If penetrated, fire rating of the division shall be maintained.

The fire and explosion resistance of doors should, as far as practicable, be equivalent to that of the division in which they are fitted. External doors in superstructures and deckhouses should be constructed to at least “A-0” class standard and be self-closing, where practicable.

(MODU Code 9.2.9)

Windows and side scuttles, should be of the non-opening type.

(MODU Code 9.2.8)
6.4.4 Structural elements

Special attention shall be given to the insulation of aluminium alloy components of columns, stanchions and other structural members used to support lifeboat and life raft stowage, launching and embarkation areas, helicopter decks, or if used in "A" and "B" class divisions, so as to ensure that for such members:

— supporting lifeboat and life raft areas, helicopter decks, and "A" class divisions, the temperature rise limitation (see guidance note) shall apply at the end of one hour
— required to support "B" class divisions, the temperature rise limitation (see guidance note) shall apply at the end of half an hour.

Guidance note 1:
The critical temperature for aluminium with respect to structural integrity is highly dependent on type of alloy and it is therefore important to identify correct critical temperature for relevant material and alloy. Other critical temperatures may be used provided that corresponding changes are taken into account concerning the thermal and mechanical properties.

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Heat transmissions at intersections and terminal points of required thermal barriers in fire rated divisions shall be specially considered.

Guidance note 2:
Any such heat bridge should be insulated to the same rating as the thermal barrier for a distance of not less than 450 mm.

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6.4.5 Protection of accommodation spaces, service spaces and control stations

All walls forming "B" class divisions should extend from deck to deck and to the deckhouse side or other boundaries, unless continuous "B" class ceilings or linings are fitted on both sides of the wall, in which case the wall may terminate at the continuous ceiling or lining. In corridor walls, ventilation openings may be permitted only in and under the doors of cabins, public spaces, offices and sanitary spaces. The openings should be provided only in the lower half of the door. Where such an opening is in or under a door, the total net area of any such opening or openings should not exceed 0.05 m². When such an opening is cut in a door, it should be fitted with a grille made of non-combustible material. Such openings should not be provided in a door in a division forming a stairway enclosure.

(MODU Code 9.3.3)

Stairs should be constructed of steel or equivalent material. If fibre reinforced plastics (FRP) stair treads are used they shall have a suitable certificate depending on the risk exposure of the considered area.

Stairways which penetrate only a single deck should be protected at least at "B" class divisions and self-closing doors so as to limit spread of fire from one deck to another. Personnel lift trunks should be protected by "A" class divisions. Stairways and lift trunks which penetrate more than a single deck should be surrounded by "A" class divisions and protected by self-closing doors at all levels. Self-closing doors should not be fitted with hold-back hooks. However, holdback arrangements incorporating remote release fittings of the fail-safe type may be utilised.

(MODU Code 9.3.5 and 9.2.10)

Air spaces enclosed behind ceilings, panelling or linings should be divided by close fitting draught stops spaced not more than 14 m apart. In the vertical direction, such enclosed air spaces, including those behind linings of stairways, trunks, etc., should be closed at each deck.

(MODU Code 9.3.6)

Insulation material, pipe and vent duct lagging, ceilings, linings and walls should be of non-combustible material.

The framing, including grounds and the joint pieces of walls, linings, ceilings and draught stops, should be of non-combustible material.

(MODU Code 9.3.8)
All exposed surfaces in corridors and stairway enclosures and surfaces in concealed or inaccessible spaces in accommodation and service spaces and control stations should have low flame spread characteristics. Exposed surfaces of ceilings in accommodation and service spaces and control stations should have low flame spread characteristics.

(MODU Code 9.3.9)

Walls, linings and ceilings may have combustible veneers provided that the thickness of such veneers should not exceed 2.5 mm within any space other than corridors, stairway enclosures and control stations where the thickness should not exceed 1.5 mm. Combustible materials used on these surfaces should have a calorific value not exceeding 45 MJ/m² of the area for the thickness.

(MODU Code 9.3.10)

Primary deck coverings, if applied within accommodation and service spaces and control stations, should be of approved material which will not readily ignite, this being determined in accordance with the FTP code.

(MODU Code 9.3.11)

Paints, varnishes and other finishes used on exposed interior surfaces should not be capable of producing excessive quantities of smoke and toxic products, this being determined in accordance with the FTP code.

(MODU Code 9.3.12)

6.4.6 Ventilation ducts for accommodation spaces, service spaces and control stations

Ventilation ducts should be of non-combustible material.

Where ventilation ducts with a cross-sectional area exceeding 0.02 m² pass through class “A” walls or decks, the opening should be lined with a steel sheet sleeve unless the ducts passing through the walls or decks are of steel in the vicinity of penetrations through the deck or wall; the ducts and sleeves at such places should comply with the following:

1) The ducts or sleeves should have a thickness of at least 3 mm and a length of at least 900 mm. When passing through walls, this length should be divided preferably into 450 mm on each side of the wall. These ducts, or sleeves lining such ducts, should be provided with fire insulation. The insulation should have at least the same fire integrity as the wall or deck through which the duct passes. Equivalent penetration protection may also be provided.

2) Ducts with a cross-sectional area exceeding 0.075 m², except those serving hazardous areas, should be fitted with fire dampers in addition. The fire damper should operate automatically for unmanned installations but should also be capable of being closed manually from both sides of the wall or deck for manned installations. The damper should be provided with an indicator which shows whether the damper is open or closed. Fire dampers are not required, however, where ducts pass through spaces surrounded by “A” class divisions, without serving those spaces, provided those ducts have the same fire integrity as the divisions which they pierce.

(MODU Code 9.3.14)

Ducts provided for the ventilation of machinery spaces of category A, galleys and hazardous areas should not pass through accommodation spaces, service spaces or control stations. Ducts provided for the ventilation of accommodation spaces, service spaces or control stations should not pass through machinery spaces of category A, galleys or hazardous areas.

Ventilation ducts with a cross-sectional area exceeding 0.02 m² passing through “B” class walls should be lined with steel sheet sleeves of 900 mm in length divided preferably into 450 mm on each side of the wall unless the duct is of steel for this length.

(MODU Code 9.3.17)

Where ventilation ducts pass through accommodation spaces or spaces containing combustible materials, the exhaust ducts from galley ranges should be of equivalent fire integrity to “A” class divisions. Each such external exhaust duct should be fitted with:

1) a grease trap readily removable for cleaning
2) a fire damper located in the lower end of the duct
3) arrangements, operable from within the galley, for shutting off the exhaust fans.

(modified MODU Code 9.3.16 and 9.3.18)

The main inlets and outlets of all ventilation systems should be capable of being closed from outside the spaces being ventilated.

(MODU Code 9.3.20)

Power ventilation of accommodation spaces, service spaces, control stations, machinery spaces and hazardous areas should be capable of being stopped from an easily accessible position outside the space being served. The accessibility of this position in the event of a fire in the spaces served should be specially considered. The means provided for stopping the power ventilation serving machinery spaces or hazardous areas should be entirely separate from the means provided for stopping ventilation of other spaces.

(MODU Code 9.3.21)

The ventilation of the accommodation spaces and control stations should be arranged in such a way as to prevent the ingress of flammable, toxic or noxious gases, or smoke from surrounding areas.

(MODU Code 9.3.23)

6.4.7 Fire safe components in electrical equipment

Insulation material shall be of fire resistant material approved for offshore use, if possible.

Guidance note:
Fire safe and biodegradable dielectric liquid should be used where possible in high voltage equipment such as main transformers. Equipment filled with less-flammable dielectric fluids are much less likely to burn in the case of an overheating or electrical fault. Reference is given to Cigre Technical Brochure 483: Guidelines for the Design and Construction of AC Offshore Substations for Wind Power Plants, December 2011.

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6.5 Active fire protection

6.5.1 General

The objectives of active fire protection (AFP) systems are to:

— extinguish fires
— provide efficient control of fires
— limit damage to structures and equipment.

The horizontal extent of the area requiring protection may be limited by adjacent vertical class "A" or "H" divisions and/or the external boundaries of the installation

Manual local release of firefighting systems and equipment shall be possible from a location outside the area to be protected. The location shall be such that personnel operating the release will not be exposed to excessive heat loads.

Active fire protection systems and equipment shall be designed for testing without interruption of normal operation.

All firefighting equipment shall be protected against freezing to the extent necessary.

A range of active fire protection systems should be considered for the installation. The selected system(s) shall be suitable for the intended duty and environment. When selecting a system, effects of its discharge on equipment shall be considered.
Guidance note: Table 6-3 provides guidance for the choice of active fire protection for some typical areas. The actual choice of active fire protection should be based on the platform type, manned versus unmanned, the actual equipment in the considered room, potential fire loads etc. In addition CCTV system can be an option for a quick confirmation of a triggered alarm on an unmanned platform.

Table 6-3 Active fire protection

<table>
<thead>
<tr>
<th>Area</th>
<th>Suitable AFP</th>
</tr>
</thead>
<tbody>
<tr>
<td>all</td>
<td>portable fire extinguishers, various types(^1)</td>
</tr>
<tr>
<td>shunt reactor rooms, main transformer and auxiliary transformers</td>
<td>water-based systems (water spraying, water mist or deluge system). For dry type transformers gas system can be used.</td>
</tr>
<tr>
<td>diesel generator rooms</td>
<td>water-based systems (water spraying, water mist or deluge system), gas or high expansion foam system</td>
</tr>
<tr>
<td>mechanically ventilated utility areas, control rooms, switchgear</td>
<td>gas or water mist system</td>
</tr>
<tr>
<td>rooms, battery rooms, local equipment rooms, HVAC rooms, UPS rooms,</td>
<td></td>
</tr>
<tr>
<td>electrically driven crane engine rooms, LV and HV rooms,</td>
<td></td>
</tr>
<tr>
<td>telecommunication or public address rooms</td>
<td></td>
</tr>
<tr>
<td>accommodation spaces, locker room, public room</td>
<td>sprinkler system or portable fire extinguisher(^3)</td>
</tr>
<tr>
<td>diesel tank area, rooms containing gas bottles filled with</td>
<td>water-based systems (water spraying, water mist or deluge system), high expansion foam system</td>
</tr>
<tr>
<td>flammable gas, fire water pump rooms</td>
<td></td>
</tr>
<tr>
<td>rooms containing gas bottles (filled with non-flammable gas,</td>
<td>portable fire extinguishers</td>
</tr>
<tr>
<td>typically inert gas for fire suppression system)</td>
<td></td>
</tr>
<tr>
<td>helideck</td>
<td>water monitors or foam system(^2) and dual-purpose nozzle and hoses.</td>
</tr>
</tbody>
</table>

\(^1\) All areas should be equipped with the proper type and size of portable extinguishers.
\(^2\) Reference is given to CAP 437.
\(^3\) For manned installations a sprinkler system should be required.

Halogenated hydrocarbon systems shall not be used on new installations.

Fixed water mist, gas or deluge systems shall be installed to cover the following areas and equipment as applicable:

- HV equipment such as main transformer(s), switchgear, semiconductor converters: water mist, gas system or foam
- emergency generator: water mist or gas system
- areas of storage of cylinders with compressed gas (oxygen, acetylene, etc.): deluge system. Inert gas storage areas do not need fire protection if there is pressure relief built into the inert gas system
- helicopter deck: foam system.

The quantity of water supplied to areas requiring active protection shall be sufficient to provide exposure protection to equipment within that area. Addition of a film-forming agent (foam concentrate) can improve the effectiveness of water-based firefighting with respect to quantity of extinguishing medium to be applied as well as time of firefighting. The systems shall comply with the recognised standards, see \([6.5.3]\), \([6.5.4]\) and \([6.5.5]\).

Fixed water-based firefighting systems may consist of automatic deluge or water monitors or a combination of both. Water monitors are only considered suitable for protection of equipment in open areas. The layout is to ensure that all protected surfaces are wetted in all weather conditions.

6.5.2 Fire main systems

The fire main system represents a system distributing the water via piping (the main) throughout the offshore substation with the purpose of water supply to the discharge points (fire hydrants, hoses, nozzles). Fire main system can constitute the backbone of other water-based fire fighting systems.

At least two independently driven power pumps should be provided, each arranged to draw directly from the sea and discharge into a fixed fire main. However, in units with high suction lifts, booster pumps and storage tanks may be installed, provided such arrangements will satisfy the requirements.

(MODU Code 9.7.1)
At least one of the required pumps should be dedicated for fire-fighting duties and be available for such duties at all times.

(MODU Code 9.7.2)

The arrangements of the pumps, sea suctions and sources of power should be such as to ensure that a fire in any one space would not put both the required pumps out of action.

(MODU Code 9.7.3)

Centrifugal fire pumps shall be self-priming or hydrostatica pressurised.

Guidance note:
Fire pump unit installed in a self-contained enclosure on open deck should be insulated to A-60 standard.

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The capacity of the required pumps should be appropriate to the fire-fighting services supplied from the fire main.

(MODU Code 9.7.4)

Each pump should be capable of delivering at least one jet simultaneously from each of any two fire hydrants, hoses and 19 mm nozzles while maintaining a minimum pressure of 0.35 N/mm² at any hydrant. In addition, where a foam system is provided for protection of the helicopter deck, the pump should be capable of maintaining a pressure of 0.7 N/mm² at the foam installation. If the water consumption for any other fire protection or fire-fighting purpose should exceed the rate of the helicopter deck foam installation, this consumption should be the determining factor in calculating the required capacity of the fire pumps.

(MODU Code 9.7.5)

Where either of the required pumps is located in a space not normally manned and, in the opinion of the Administration, is relatively far removed from working areas, suitable provision should be made for remote start-up of that pump and remote operation of associated suction and discharge valves.

(MODU Code 9.7.6)

Every centrifugal pump which is connected to the fire main should be fitted with a non-return valve.

(MODU Code 9.7.8)

Relief valves should be provided in conjunction with all pumps connected to the fire main if the pumps are capable of developing a pressure exceeding the design pressure of the fire main, hydrants and hoses. Such valves should be so placed and adjusted as to prevent excessive pressure in the fire main system.

(MODU Code 9.7.9)

Water treatment may be necessary to prevent marine growth from impairing fire main system performance. Inlet strainers shall be installed to prevent damage of the pump. Water treatment must not damage the pump, components or pipe.

For manned installations a fixed fire main should be provided and be so equipped and arranged as to meet the specified requirements.

The diameter of the fire main and water service pipes should be sufficient for the effective distribution of the maximum required discharge from the required fire pumps operating simultaneously.

(MODU Code 9.7.11)

The fire main should, where practicable, be routed clear of hazardous areas and be arranged in such a manner as to make maximum use of any thermal shielding or physical protection afforded by the structure of the unit.

(MODU Code 9.7.13)

The fire main should be provided with isolating valves located so as to permit optimum utilisation in the event of physical damage to any part of the main.

(MODU Code 9.7.14)

The fire main should not have connections other than those necessary for fire fighting purposes.

(MODU Code 9.7.15)
All practical precautions consistent with having water readily available should be taken to protect the fire main against freezing.

(MODU Code 9.7.16)

Materials readily rendered ineffective by heat should not be used for fire mains and hydrants unless adequately protected. The pipes and hydrants should be so placed that the fire hoses may be easily coupled to them.

(MODU Code 9.7.17)

For use of fibre-reinforced plastic (FRP) material in firewater ring main, reference is made to DNV-OS-D101 Ch.2 Sec.2 [2.5].

A cock or valve should be fitted to serve each fire hose so that any fire hose may be removed while the fire pumps are operating.

(MODU Code 9.7.18)

The isolating valves shall be provided for easy access of operation. Where the isolation valves are remotely operated, manual operation shall be possible locally.

6.5.3 Deluge systems

The water pressure available at the inlet to the system or an individual section shall be sufficient for the efficient operation of all nozzles in that system or section under design flow conditions.

Release of the deluge systems shall be possible both locally and remotely at the control station where the operating status of the systems is monitored.

The piping for a deluge system shall be designed to be robust and adequately secured and supported.

The nozzle type, location and orientation shall be suitable for the possible fire events and the environmental conditions. It should be ensured that the required quantity of water or foam will impinge on the surfaces to be protected. Due account is to be taken to the effects of obstructions.

Provisions for flushing of the distribution pipework shall be provided.

Water supply shall be so arranged that damage to any single section of the main due to fire within a protected area is not to disrupt water supply to an adjacent area.

Two separate supplies to the deluge firewater distribution pipework shall be provided, the main supply being from the deluge valve. The secondary supply shall preferably be from another section of the fire main, i.e. there shall preferably be an isolation valve in the fire main between the two supply locations. The secondary supply may be manually activated.

Deluge valves shall be located to provide safe access from the emergency control station on the installation, and shall be located outside the fire zone they protect.

The deluge valve system shall be designed to allow isolation and maintenance without isolation of the ring main.

6.5.4 Automatic sprinkler systems

Automatic sprinkler systems shall comply with FSS code Ch.8.

Guidance note:

Automatic sprinkler systems are typically used in areas where fires are expected to involve cellulosic fuels, and where slow fire growth is expected. A typical use is in accommodation areas.

Reference is made to:
— NFPA 13 Standard for the Installation of Sprinkler Systems

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6.5.5 Fixed pressure water-spraying and water mist extinguishing systems

Fixed pressure water-spraying and water mist systems shall comply with FSS code Ch. 7.

**Guidance note:**
Further guidance can be found in:
- SOLAS regulation II-2/5,
- ISO 13702 "Petroleum and natural gas industries -- Control and mitigation of fires and explosions on offshore production installations -- Requirements and guidelines",
- IMO MSC/Circ.1165 amended by MSC./1/Circ.1386 "Revised guideline for the approval of equivalent water-based fire-extinguishing systems for machinery spaces and cargo pump-rooms",
- IMO MSC/Circ.913 partly superseded by MSC.1/Circ.1387 "Revised guidelines for the approval of fixed water -based local application fire-fighting systems for use in category A machinery spaces",
- NFPA 750 "Standard on Water Mist Fire Protection Systems",
- VdS 2109 "Sprühwasser-Löschanlagen - Planung und Einbau".

---end---of---guide---note---

6.5.6 Fixed gas fire extinguishing systems

Fixed gas fire extinguishing systems shall comply with FSS code Ch.5.

**Guidance note:**
Further guidance can be found in:
- SOLAS regulation II-2/10,
- ISO 13702 "Petroleum and natural gas industries - Control and mitigation of fires and explosions on offshore production installations - Requirements and guidelines",
- IMO MSC/Circ.884 "Revised guidelines for the approval of equivalent fixed gas fire-extinguishing systems, as referred to in SOLAS 74, for machinery spaces and cargo pump rooms",
- NFPA 2001 "Standard for Clean Agent Fire Extinguishing Systems"
- VdS 2380 "Feuerlöschanlagen mit nicht verflüssigten Inertgasen Planung und Einbau".

---end---of---guide---note---

6.5.7 Fixed high expansion foam systems

Fixed high expansion foam systems intended for total flooding shall comply with FSS code Ch.6.

**Guidance note:**
Further guidance can be found in:
- SOLAS regulation II-2/5,
- ISO 13702 "Petroleum and natural gas industries - Control and mitigation of fires and explosions on offshore production installations - Requirements and guidelines",
- NFPA 11 "Standard for Low-, Medium-, and High-Expansion Foam"

---end---of---guide---note---

6.5.8 Portable extinguishers

The accommodation, service and working spaces and control stations shall be provided with portable fire extinguishers of approved types and designs.

Each powder or carbon dioxide extinguisher shall have a capacity of at least 5 kg and each foam extinguisher shall have a capacity of at least 9 l. The mass of all portable fire extinguishers shall not exceed 23 kg and they shall have a fire-extinguishing capability at least equivalent to that of a 9 l fluid extinguisher. (FSS code Ch.4 3.1.1.1)

The fire extinguishing medium in the extinguishers shall be suitable for the potential fire hazards in the protected spaces.

Only refills approved for the fire extinguisher in question shall be used for recharging. (FSS code Ch.4 3.1.2).
One of the portable fire extinguishers intended for use in any space shall be stowed near the entrance to that space.

**Guidance note:**
Portable fire extinguishers should be located so that they can be reached within a distance of 15 m.

In general powder should be avoided as medium close to electrical equipment as massive damages can be the consequence.

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Portable fire extinguishers do not need to be installed in rooms where persons cannot enter during operation e.g. on HV/DC platforms. During maintenance procedures shall be established to ensure that sufficient firefighting equipment is placed in the room during maintenance.

### 6.6 Explosion protection

#### 6.6.1 General

The objectives of explosion protection are to:

- reduce the probability of explosions
- reduce the explosion loads
- reduce the probability of escalation.

Explosion events offshore include release of physical energy (e.g. pressure energy in gas) and chemical energy (chemical reaction). Explosion loads are characterised by temporal and spatial pressure distribution with rise time, maximum pressure and pulse duration being the most important parameters. For components and sub-structures the explosion pressure should normally be considered uniformly distributed. On a global level the temporal and spatial distribution of pressure is generally non-uniform.

Where possible, the severity of an explosion should be lowered by reducing the degree of congestion and by increasing the availability of venting.

The response to explosion loads may either be determined by nonlinear dynamic finite element analysis or by simple calculation models based on Single Degree Of Freedom (SDOF) analogies and elastic-plastic methods of analysis, see DNV-RP-C204.

The load bearing function of the installation shall remain intact with the damages imposed by the explosion loads.

#### 6.6.2 Blast protection

Blast protection of main transformers and adjoining equipment can be made by means of enclosures, specially designed to withstand and give the necessary deflection during a blast. The blast structure (wall, roof) should be made of materials preserving technical integrity and with low maintenance requirements of the structure, taken the harsh environment into consideration. The protection structure should be designed according to the actual hazards and identified fire scenario in the area concerned.

Areas of escape for persons, attached to the blast protected area, shall be protected properly to ensure persons can escape from an even seriously damaged explosion area. The escape area/route shall be designed in a well-arranged way, to give the best possibilities to keep the overview in an emergency situation.

Any blast structures shall be able to withstand loads from a blast, and any design wind and snow loads as well.

#### 6.6.3 Explosion venting

Blast relief vents shall be mounted in walls or in the roof of the blast structure, to prevent overpressure build-up. The necessary area of relief vents shall be calculated in accordance with the design explosions.
6.7 Fire and gas detection systems

6.7.1 General
The fire and gas detection systems shall be designed to allow testing without interrupting other systems onboard.

The relevant requirements of DNVGL-OS-D202 apply to the fire and gas detection systems.

If shutdown actions are performed by the fire and gas detection systems, the requirements for the shutdown system apply.

6.7.2 Fire detection system
Any required fixed fire detection and fire alarm system with manually operated call points shall be capable of immediate operation at all times.

(FSS Code Ch.9.2.1)

The fire detection system shall have continuous availability.

Power supplies and electric circuits necessary for the operation of the system shall be monitored for loss of power and other fault conditions as appropriate including:

— a single open or power break fault caused by a broken wire
— a single ground fault caused by the contact of a wiring conductor to a metal component
— a single wire-to-wire fault caused by the contact of two or more wiring conductors.

Occurrence of a fault condition shall initiate a visual and audible fault signal at the control panel which shall be distinct from a fire signal.

(FSS Code Ch.9.2.5.1.5)

There shall be not less than two sources of power supply for the electrical equipment used in the operation of the fire detection and fire alarm system, one of which shall be an emergency source. The supply shall be provided by separate feeders reserved solely for that purpose. Such feeders shall run to an automatic change-over switch situated in or adjacent to the control panel for the fire detection system. The main (respective emergency) feeder shall run from the main (respective emergency) switchboard to the change-over switch without passing through any other distributing switchboard.

(FSS Code Ch.9.2.2.1)

This requirement is considered to be fulfilled in the case of use of automatic changeover to a stand-by uninterruptible power supply.

Detectors and manually operated call points shall be grouped into sections. The activation of any detector or manually operated call point shall initiate a visual and audible fire signal at the control panel and indicating units. If the signals have not been acknowledged within 2 minutes an audible alarm shall be automatically sounded throughout the crew accommodation and service spaces, control stations and machinery spaces of category A. This alarm sounder system need not be an integral part of the detection system.

(FSS Code Ch.9.2.4.1.1 and FSS Code Ch.9.2.5.1.4)

On manned installations the fire detection central shall be located outside the main area of fire hazard and in a location permanently attended by authorised personnel.

On manned installations indicating units shall, as a minimum, denote the section in which a detector has activated or manually operated call point has operated.

For unmanned installations indicating units may only present at the control panel and the operator station (onshore and offshore).

Clear information shall be displayed on or adjacent to each indicating unit about the spaces covered and the location of the sections.

(FSS Code Ch.9.2.5.1.4)
Where the fixed fire detection and fire alarm system does not include means of remotely identifying each detector individually, no section covering more than one deck within accommodation, service and control stations shall normally be permitted except a section which covers an enclosed stairway. In order to avoid delay in identifying the source of fire, the number of enclosed spaces included in each section shall be limited as determined by the Administration. If the detection system is fitted with remotely and individually identifiable fire detectors, the sections may cover several decks and serve any number of enclosed spaces.

(FSS Code Ch.9.2.4.1.3)

A section of fire detectors which covers a control station, a service space or an accommodation space shall not include a machinery space of category A. For fixed fire detection systems with remotely and individually identifiable fire detectors, a section covering fire detectors in accommodation spaces, service spaces and control stations shall not include fire detectors in machinery spaces of category A.

(FSS Code Ch.9.2.4.1.2)

Detectors shall be operated by heat, smoke or other products of combustion, flame, or any combination of these factors. Detectors operated by other factors indicative of incipient fires may be used provided that they are no less sensitive than such detectors.

(FSS Code Ch.9.2.3.1.1)

Guidance note:
The table below provides a guideline for the choice of detectors for some typical areas. In addition, CCTV images can provide valuable information.

Table 6-4 Choice of detectors

<table>
<thead>
<tr>
<th>Area</th>
<th>Detection principle</th>
</tr>
</thead>
<tbody>
<tr>
<td>mechanically ventilated utility areas, control rooms, switchgear rooms, HV capacitor rooms, battery rooms*, instrument rooms, local equipment rooms, telecommunication or public address rooms, HVAC rooms, electrically driven crane engine rooms, UPS room, LV and HV rooms</td>
<td>smoke</td>
</tr>
<tr>
<td>main transformer / reactor rooms, auxiliary transformer rooms (units filled with mineral oil, synthetic ester or dry insulated)**</td>
<td>smoke and heat (around transformer)</td>
</tr>
<tr>
<td>diesel generator or generator rooms</td>
<td>flame or smoke</td>
</tr>
<tr>
<td>rooms containing gas bottles (typically inert gas for fire suppression system)</td>
<td>smoke</td>
</tr>
<tr>
<td>firewater pump rooms</td>
<td>smoke and/or flame</td>
</tr>
<tr>
<td>storage area, workshops</td>
<td>smoke or heat</td>
</tr>
<tr>
<td>paint store</td>
<td>heat or flame</td>
</tr>
<tr>
<td>fuel oil storage, diesel engine room</td>
<td>flame</td>
</tr>
<tr>
<td>accommodation: cabins, corridors, staircases, public rooms, radio room, laundry</td>
<td>smoke (and possibly flame)</td>
</tr>
<tr>
<td>accommodation: galley, galley hood or duct, washrooms, toilets</td>
<td>heat or smoke</td>
</tr>
<tr>
<td>void spaces above ceiling with height exceeding 0.4 m</td>
<td>smoke</td>
</tr>
<tr>
<td>open decks and areas subject to high air speeds</td>
<td>flame</td>
</tr>
</tbody>
</table>

Detectors may offer more than one detection principle in the same device.

*) Battery room may require H2 detection depending on the battery type.

**) Smoke should be avoided in rooms with high degree of natural ventilation.

Suitable instructions and component spares for testing and maintenance shall be provided. Detectors shall be periodically tested using equipment suitable for the types of fires to which the detector is designed to respond.

(FSS Code Ch.9.2.5.2)

The fire detection system shall be designed to:

1) control and monitor input signals from all connected fire and smoke detectors and manual call points
2) provide output signals to the navigation bridge, continuously manned central control station or onboard safety centre to notify the crew of fire and fault conditions
3) monitor power supplies and circuits necessary for the operation of the system for loss of power and fault conditions
4) the system may be arranged with output signals to other fire safety systems including:
   a) paging systems, fire alarm or public address systems
   b) fan stops
   c) fire doors
   d) fire dampers
   e) sprinkler systems
   f) smoke extraction systems
   g) low-location lighting systems
   h) fixed local application fire-extinguishing systems
   i) closed circuit television (CCTV) systems
   j) other fire safety systems.

(FSS Code Ch.9.2.1.2)

When fire detectors are provided with the means to adjust their sensitivity, necessary arrangements shall be ensured to fix and identify the set point.

When it is intended that a particular section or detector shall be temporarily switched off, this state shall be clearly indicated. Reactivation of the section or detector shall be performed automatically after a pre-set time.

A loop of fire detection systems with a zone address identification capability shall not be damaged at more than one point by a fire.

Fixed fire detection and fire alarm systems with individually identifiable fire detectors shall be so arranged that:

1) means are provided to ensure that any fault (e.g. power break, short circuit, earth, etc.) occurring in the section will not prevent the continued individual identification of the remainder of the connected detectors in the section
2) all arrangements are made to enable the initial configuration of the system to be restored in the event of failure (e.g. electrical, electronic, informatics, etc.)
3) the first initiated fire alarm will not prevent any other detector from initiating further alarms
4) no section will pass through a space twice. When this is not practical (e.g. for large public spaces), the part of the section which by necessity passes through the space for a second time shall be installed at the maximum possible distance from the other parts of the section.

(FSS Code Ch.9.2.1.6)

Failure in the fire detection central or in the detector circuits shall activate failure alarm.

6.7.3 Design

The system and equipment shall be suitably designed to withstand supply voltage variation and transients, ambient temperature changes, vibration, humidity, shock, impact and corrosion normally encountered at offshore substations.

(FSS Code Ch.9.2.1.5)

Smoke detectors required in all stairways, corridors and escape routes within accommodation spaces shall be certified to operate before the smoke density exceeds 12.5% obscuration per metre, but not until the smoke density exceeds 2% obscuration per metre, when tested according to standards EN 54:2001 and IEC 60092-504. Alternative testing standards may be used as determined by the Administration. Smoke detectors to be installed in other spaces shall operate within sensitivity limits to the satisfaction of the Administration having regard to the avoidance of detector insensitivity or oversensitivity.

(FSS Code Ch.9.2.3.1.2)
Heat detectors shall be certified to operate before the temperature exceeds +78°C but not until the temperature exceeds +54°C, when the temperature is raised to those limits at a rate less than 1°C per minute, when tested according to standards EN 54 and IEC 60092-505. Alternative testing standards may be used provided they have similar requirements. At higher rates of temperature rise, the heat detector shall operate within temperature limits to the satisfaction of the Administration having regard to the avoidance of detector insensitivity or over-sensitivity.

(FSS Code Ch.9.2.3.1.3)

### 6.7.4 Installation

An automatic fire detection and alarm system should be provided in all accommodation and service spaces. Accommodation spaces should be fitted with smoke detectors.

(MODU Code 9.10.1)

Sufficient manual fire alarm stations should be installed at suitable locations throughout the unit.

(MODU Code 9.10.2)

Detectors shall be located for optimum performance. Positions near beams and ventilation ducts or other positions where patterns of air flow could adversely affect performance and positions where impact or physical damage is likely, shall be avoided. In general, detectors which are located on the overhead shall be a minimum distance of 0.5 m away from walls.

(FSS Code Ch.9.2.4.2.1)

Manually operated call points shall be installed throughout the accommodation spaces, service spaces and control stations. One manually operated call point shall be located at each exit. Manually operated call points shall be readily accessible in the corridors of each deck such that no part of the corridor is more than 20 m from a manually operated call point.

Smoke detectors shall be installed in all cabins, stairways, corridors and escape routes within accommodation spaces. Consideration shall be given to the installation of special purpose smoke detectors within ventilation ducting.

The maximum spacing of detectors shall be in accordance with Table 6-5 below:

**Table 6-5 Maximum spacing of detectors**

<table>
<thead>
<tr>
<th>Type of detector</th>
<th>Maximum floor area per detector</th>
<th>Maximum distance between detectors</th>
<th>Maximum distance away from walls</th>
</tr>
</thead>
<tbody>
<tr>
<td>heat</td>
<td>37 m²</td>
<td>9 m</td>
<td>4.5 m</td>
</tr>
<tr>
<td>smoke</td>
<td>74 m²</td>
<td>11 m</td>
<td>5.5 m</td>
</tr>
</tbody>
</table>

The Administration may require or permit other spacing based upon test data which demonstrate the characteristics of the detectors.

(FSS Code Ch.9.2.4.2.2)

**Guidance note:**

Normally more than one sensor should be installed in one room to allow for confirmation of a fire case by a second sensor.

Performance of heat and smoke detectors shall be in accordance with a recognised standard, e.g. EN 54-5 and 54-7.

Cables which form part of the system shall be so arranged as to avoid galleys, machinery spaces of category A, and other enclosed spaces of high fire risk except where it is necessary to provide for fire detection or fire alarm in such spaces or to connect to the appropriate power supply.

(FSS Code Ch.9.2.4.3.1)

Fire detection systems will normally not be required for spaces protected by an automatic sprinkler system provided that an alarm is given upon release of the sprinkler system.

Manual activation of fire alarm shall be possible from all passageways and from the control stations.

Fire detectors shall be fitted such that all potential fire outbreak points are effectively guarded.
6.7.5 Gas detection

A fixed automatic gas detection and alarm system shall be provided and arranged as to monitor continuously all enclosed areas of the unit in which an accumulation of flammable and toxic gas may be expected to occur and capable of indicating at the main control point by aural and visual means the presence and location of an accumulation.

**Guidance note 1:**
If pressure monitoring is installed on the GIS equipment, for detection of a potential SF6 gas release external gas detection may be omitted in the GIS room.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

The gas detection system shall have continuous availability.

**Guidance note 2:**
Continuous detection of hazardous gases should be considered in locations such as:

- battery room (H2 generation)
- switchgear room (SF6 leakage)
- hazardous areas, except in zone 0 according to IEC 60079-10 and areas mechanically ventilated
- ventilation outlets from hazardous areas having mechanical ventilation
- intakes for ventilation air.

On units and installations where the sources of leakage of flammable and toxic gases are concentrated in a small area, gas detectors in the air inlets of mechanically ventilated areas may be omitted provided that the ventilation systems are shut down automatically in the event of gas detection anywhere, and that gas detectors are located in all zone 1 and 2 areas according to IEC 60079-10. CO detection should be considered for improved fire protection.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

6.8 Marking

6.8.1 General

All active fire protection systems shall be marked with easy to understand operating instructions. Additional marking may be needed as per local requirements.

**Guidance note:**
Local requirements:
UK: Compared to DNVGL-OS-D301, additional labelling is required.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

A fire control plan complying with SOLAS regulation II-2/15.2.4 should be permanently exhibited.

(MODU Code 9.18)

In all units/installations general arrangement plans shall be permanently exhibited, showing clearly for each deck the control stations, the various fire sections enclosed by “A” class divisions, the sections enclosed by “B” class divisions together with particulars of the fire detection and fire alarm systems, the sprinkler installation, the fire-extinguishing appliances, means of access to different compartments, decks, etc. and the ventilating system including particulars of the fan control positions, the position of dampers and identification numbers of the ventilating fans serving each section. Alternatively, at the discretion of the operator, the aforementioned details may be set out in a booklet, a copy of which shall be supplied to each responsible, and one copy shall at all times be available in an accessible position. Plans and booklets shall be kept up to date, any alterations being recorded thereon as soon as practicable. In addition, instructions concerning the maintenance and operation of all the equipment and installations on board for the fighting and containment of fire shall be kept under one cover, readily available in an accessible position.
SECTION 7  MACHINERY AND UTILITY SYSTEMS

7.1  General
All machinery, associated piping systems, fittings and wiring shall be of a design and construction adequate for the service for which they are intended and shall be so installed and protected as to reduce to a minimum any danger to the personnel to the lowest practicable level, due regard being paid to moving parts, hot surfaces and other hazards. The design shall have regard to materials used in construction, and to marine and industrial purposes for which the equipment is intended, the working conditions and the environmental conditions to which it will be subjected.

Guidance note:
Further details of design and manufacture are provided in DNVGL-OS-D101 Marine and Machinery Systems and Equipment. The application of type approved components and systems is recommended.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

Consideration shall be given to the consequence of the failure of the system and equipment essential to the safety of the installation/unit.

National regulations shall be observed.

7.1.1  Design and manufacturing

7.1.1.1  Design principles
All parts shall be capable of withstanding the stresses and loads relevant to the service, e.g. due to movements, vibrations, corrosion, temperatures and wave impact, and have to be dimensioned in accordance with the requirements set out in the Design Basis for installation design and the present chapter and with relevant codes and standards as agreed for the specific project.

Parts of systems designed for different forces, pressure and temperatures (stresses), must be limited to safe loading of the parts with lower design capability, or alternatively safety devices are to be fitted which prevent the over-stressing of the system or plant item designed for the lower design parameters with an acceptable reliability.

7.1.1.2  Materials
All components subject to these requirements shall comply with the rules in Sec. 4 or in special cases with the relevant codes and standards agreed for the specific project.

7.1.1.3  Welding
The fabrication of welded components, the approval of manufacturing companies and the testing of welders are subject to the requirements outlined in Sec. 10 or in special cases to the relevant codes and standards agreed for the specific project.

7.1.1.4  Tests
Machinery and its component parts are subject to constructional and material tests, pressure and leakage tests and functional tests.

After installation of the machinery for auxiliary and emergency power supply the operational functioning of the machinery including the associated ancillary utility systems is to be verified. All safety equipment is to be tested, unless adequate testing has already been performed at the manufacturer’s works, e.g. during FAT.

The final installation on the platform is to include testing to complement commissioning to prove correct functioning and integration with other systems as relevant under the intended service conditions.

7.1.1.5  Markings, identification
In order to avoid operating and switching errors all parts of the machinery and utility systems whose function is not immediately apparent are to be adequately marked and labeled.
7.1.1.6 Fuels

Oil fuels with a flash point of less than 60°C (closed cup) are not permitted, except for the following:

- units or installations certified for restricted service within areas having climate ensuring that ambient temperatures of spaces where such fuel oil is stored will not rise to temperatures within 10°C below the flash point of the fuel, may use fuel oil with flash point below 60°C but not less than 43°C.
- installation specially approved for the use of heavy fuel oil.

Requirements for storage and transfer systems for liquids with flashpoint below 60°C (e.g. helicopter fuel) shall be fulfilled, see DNVGL-OS-D101 Ch.2 [3.7].

7.1.1.7 Corrosion protection

Parts which are exposed to corrosion are to be safeguarded by being manufactured of corrosion-resistant materials, provided with sufficient corrosion allowance or provided with effective corrosion protection.

The selection of suitable materials and adequate corrosion protection shall be defined in the design documentation.

7.1.1.8 Control and regulating equipment

Machinery shall be so arranged and equipped that it can be controlled in accordance with operating requirements in such a way that the service conditions prescribed by the manufacturer can be met.

In the event of

- failure or fluctuations of the supply of electrical, pneumatic or hydraulic power to control systems
- exceedance of acceptable values
- failure in a control loop.

steps shall be taken to ensure that:

- the appliances remain at their present operational setting or, if necessary, are changed to a setting which will have the minimum adverse effect on operation (fail-safe condition)
- the power output or engine speed of the machinery being controlled or governed is not in-creased
- no unintentional start-up sequences are initiated.

Alarms shall be generated with local as well as remote indication, see [9.3].

7.1.1.9 Availability of machinery

The machinery is to be so arranged and equipped that it can be brought into operation from the black-out conditions with the means available on the board.

7.1.2 Protective measures

Machinery and utility systems are to be installed and safeguarded in such a way that the risk of accidents is reduced to an acceptable level.

Besides national regulations particular attention is to be paid to the following:

a) Moving or rotating parts, chain and belt drives, linkages and other components which could constitute an accident hazard for the operating personnel are to be fitted with guards to prevent contact. The same applies to hot machine parts, pipes and walls for which no thermal insulation is provided, e.g. pressure lines to air compressors.

b) Drainage facilities are to be designed in such a way that the discharged medium is safely drained off.

c) In operating spaces, anti-skid floor plates and floor coverings shall be used, as well as insulating (rubber) mats near switchboards and electrical distribution boards.

d) Service gangways, operating platforms, stairways and other areas open to access during operation are to be safeguarded by guard rails. The outside edges of platforms and floor areas are to be fitted with coamings unless some other means are adopted to prevent objects, tools, etc. from sliding off and potentially endangering people below. Fixed steps, stairs or platforms shall be fitted where necessary and arranged to avoid risk from dropped objects.

e) Safety valves and manual valves and shut offs shall be easily accessible. Safety valves are to be installed to prevent the occurrence of excessive operating pressures.
7.1.3 Ambient parameters

The selection, layout and arrangement of all machinery and equipment shall be such as to ensure faultless continuous operation under the general ambient conditions specified in Table 7-1 or as provided in the basis of design.

For installations of unusual static and dynamic behavior and intended for operation only in specified areas, deviating ambient conditions based on metocean data for the location of the installation can be agreed for the specific project.

<table>
<thead>
<tr>
<th>Table 7-1</th>
<th>General temperatures and humidity conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>ambient temperature or suction air</td>
<td>enclosed spaces</td>
</tr>
<tr>
<td>relative humidity</td>
<td>generally</td>
</tr>
<tr>
<td>in specially protected areas</td>
<td>80%</td>
</tr>
<tr>
<td>for internal combustion engines</td>
<td>60%</td>
</tr>
<tr>
<td>seawater temperature</td>
<td>generally</td>
</tr>
</tbody>
</table>

7.1.3.1 Vibrations

Machinery, utility systems and supporting structures can be normally subjected to vibrations excitation. Design, construction and installation shall take account of the resulting effects by avoiding resonance conditions, by suitable isolation from excitation source, by adequate robustness of design, etc. The long-term service of individual components shall not be endangered by vibration effects including torsional vibrations in machinery drives.

For vibrations generated by an engine or other device, the intensity shall be defined in order that instrumentation and equipment mounted on the unit will not be subject to excessive vibration levels.

7.2 Combustion engines

7.2.1 General

The requirements contained in this section are valid for combustion engines driving auxiliary, emergency generators or GDG.

The rated power shall meet the requirements and standards as agreed for the specific project.

Guidance note:

It is considered good practice to rate the main power supply for auxiliary system to allow for an additional load of 15% to cover future increase. For emergency generators normal load should be based on the loads from all emergency services as per [5.6.2.9].

---e-n-d-o-f-g-u-i-d-a-n-c-e-n-o-t-e---

Engines are to be so arranged that all the access openings and inspection ports provided by the engine manufacturer for inspections and maintenance are accessible. A change of components, as far as practicable at the unit, shall be possible. Requirements related to space and construction have to be considered for the installation of the engines. For the location of combustion engines see [3.5.4].

7.2.2 Starting equipment

Engine starting equipment shall enable engines to be started up from the shutdown condition using only the means available on the substation.

Means are to be provided to ensure that auxiliary and emergency diesel engines can be started after blackout and “dead-unit” condition. This is to be considered especially for electronically controlled engines.

7.2.2.1 Compressed air starting equipment

Starting air systems are to be equipped with at least two starting air compressors. Air compressors shall be driven independently of the engines.

The total capacity of the starting air compressors is to be such that the starting air receivers designed in accordance with below requirements, as applicable, can be charged from atmospheric pressure to their final pressure within one hour.
Compressors of equal capacity should be installed.

If the auxiliary engine is started with compressed air, the available starting air is to be divided between at least two starting air receivers of approximately equal size which can be used independently of each other.

The total capacity of air receivers is to be sufficient to provide, without their being replenished, not less than three starts.

With multi-engine installations the number of start-up operations per engine may be reduced according to the concept of the power plant.

Consumers with high air consumption shall be provided with a separate air supply. If starting air systems are used for supplying pneumatically operated controls, instrument air or tyfon alarm sound emitters, due attention is to be paid to the air consumption of this equipment during calculation of the capacity of the main starting air receivers.

If starting air systems of different engines are fed by one receiver it is to be ensured that the receiver air pressure cannot fall below the highest of the different systems minimum starting air pressure.

7.2.2.2 Electrical starting equipment

Where engines are provided with electric start, two mutually independent starter batteries are to be installed. The batteries are to be so arranged that they cannot be connected in parallel with each other. Each battery shall enable the engine to be started from cold. Requirements of [5.6.2.5] shall be fulfilled.

7.2.3 Control Equipment

For auxiliary engines and emergency application engines the controls according to Table 7-2 are to be provided.

The presentation of alarms and indicators should be clear, distinctive, unambiguous and consistent.

(Ref. IMO A.1021(26), sec. 4.1)

Acknowledgement of visual signals should be separate for each signal or common for a limited group of signals. Acknowledgement should only be possible when the user has visual information on the alarm condition for the signal or all signals in a group.

Local equipment audible alarm for equipment connected to the automation and safety system, should be suppressed when localized in the same workplace as the user interface for the automation and safety system.

Permanent blocking of alarm units shall not be possible. Manual blocking of separate alarms is acceptable when this is clearly indicated.

Sufficient information shall be provided to ensure optimal alarm handling. The presence of active alarms shall be continuously indicated and all alarm text shall be easily understood.

**Table 7-2 Alarms and indicators**

<table>
<thead>
<tr>
<th>Description</th>
<th>Auxiliary engines</th>
<th>Emergency engines</th>
</tr>
</thead>
<tbody>
<tr>
<td>engine overspeed</td>
<td>A, S</td>
<td>A, S</td>
</tr>
<tr>
<td>lubricating oil pressure at engine inlet</td>
<td>I, L, S</td>
<td>I, L</td>
</tr>
<tr>
<td>lubricating oil temperature at engine inlet</td>
<td>I, H</td>
<td>I, H</td>
</tr>
<tr>
<td>fuel oil pressure at engine inlet</td>
<td>I</td>
<td></td>
</tr>
<tr>
<td>fuel oil leakage from high pressure pipes</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>cylinder cooling water pressure or flow at engine inlet</td>
<td>I, L</td>
<td>I, L</td>
</tr>
<tr>
<td>cylinder cooling water temperature at engine outlet</td>
<td>I, H</td>
<td>I, H</td>
</tr>
<tr>
<td>starting air pressure (if applicable)</td>
<td>I, L</td>
<td>I, L</td>
</tr>
<tr>
<td>oil mist concentration in crankcase or alternative monitoring system</td>
<td>I, H</td>
<td>I, H</td>
</tr>
</tbody>
</table>

I : Indicator
A : Alarm
H : Alarm for upper limit
L : Alarm for lower limit
S : Shut down with alarm for shut-down
7.3 Storage tanks for liquid fuels, lube and hydraulic oils

7.3.1 General safety precautions for liquid fuels
Tanks and fuel pipes shall be so located and equipped that fuel cannot spread either inside the installation/unit or on deck and cannot be ignited by hot surfaces or electrical equipment. To prevent excessive pressure in case of overfilling, tanks shall be fitted with vents at the top and overflow pipes.

7.3.2 Distribution, location and capacity of fuel tanks

7.3.2.1 Arrangement of fuel tanks
The fuel supply shall be stored in several tanks so that, even in the event of damage to one of the tanks, the fuel supply will be available.

It is assumed that only diesel will be used on offshore substations and not heavy oil and blended oils. Heavy oils and blended oils have flash points below 60 °C and thus require assessing storage areas and rooms with piping with flange connections to be assessed for hazardous area Zone 1 or Zone 2.

If heavy oil or intermediate oils are used, provision shall be made to ensure that internal combustion engines can operate temporarily on fuel which does not need to be preheated.

Fuel tanks shall be separated from tanks containing lubricating, hydraulic, oil, drinking water. This does not apply to waste oil collected for disposal.

Fuel oil tanks adjacent to lubricating oil circulating tanks are not permitted.

If fuel, including helicopter fuel, is stored in separate containers, the following shall apply:

— location of container to be compatible with the platform structure including substructure, fastening and earthing
— fixed piping for filling and suction as well as air, overflow and sounding pipes. Flexible hoses shall be accepted on case by case basis
— tank gauges
— drains with self-closing appliances as well as
— fire load in the area containing fuel tanks to be considered
— pressure test considering the pressure vessel rating of the tank to be carried out.

7.3.2.2 Location of fuel tanks
Fuel tanks or fuel oil pipe flanges located above engines, and other equipment with a high surface temperature (above 220°C) must be provided with adequate spill trays or shielding. Such tanks and pipes must also be protected against heat radiation.

Equipment with surface temperatures above 220°C shall be insulated. If risk of personnel touching the hot surfaces than insulation should be provided to reduce surface temperature to below 60°C.

An independent fuel supply shall be provided for the prime movers of the emergency source of electrical power.

The fuel supply shall be sufficient for at least 18 hours operation.

If the fuel tank for the emergency diesel generator may be subject to ambient temperatures that may affect the quality of the fuel, arrangements shall be considered to maintain adequate fuel condition.

7.3.3 Fuel tank fittings and mountings
For fuel filling and suction lines, air, overflow and sounding pipes, see [7.7].

Fuel service tanks shall be so arranged that water and residues can settle out. Fuel tanks shall be fitted with water drains with self-closing shut-off valves.

The fuel oil supply line from the tank shall be provided with a remotely operated quick closing valve close to the tank.
7.3.3.1 Tank gauges
The following tank gauges are permitted:
— sounding pipes
— oil level indicating devices
— oil level gauges with flat glasses and self-closing shut-off valves at the connections to the tank and protected against external damage.

Sounding pipes need not be fitted to tanks equipped with oil level indicating devices.
Installations intended for unmanned periods should have systems for remote fuel storage tank oil level indication.
Fuel service tanks shall be fitted with oil level indicating devices or oil-level gauges.
Sight glasses and oil gauges fitted directly on the side of the tank and cylindrical glass oil gauges are not permitted.
Sounding pipes of fuel tanks may not terminate in accommodation spaces, nor shall they terminate in spaces where the risk of ignition of spillage from the sounding pipes might arise.
Sounding pipes should terminate outside machinery spaces. Where this is not possible, the following requirements are to be met:
— oil-level gauges are to be provided in addition to the sounding pipes
— sounding pipes are either to terminate in locations remote from ignition hazards or they are to be effectively screened to prevent that spillage may come into contact with the source of ignition
— the sounding pipes are to be fitted with self-closing shut-off devices and self-closing test cock.

7.3.3.2 Fastening of appliances and fittings on fuel tanks inside machinery spaces
Appliances, mountings and fittings not forming part of the fuel tank equipment may be fitted to tank walls only by means of intermediate supports.
Only components forming part of the tank equipment may be fitted to free-standing tanks.
Valves and pipe connections shall be attached to doubler flanges welded to the tank walls. Holes for stud bolts are not permitted drilled in the tank walls.
Instead of doubler flanges, short, thick walled pipe stubs with flange connections may be welded to the tank walls.

7.3.4 Storage of lubricating and hydraulic oils
Oil drain tanks shall be sufficiently large to ensure that the residence time of the oil is long enough for the expulsion of air bubbles, the settling out of residues, etc. The tanks shall be large enough to hold at least the oil contained in the entire circulation systems, including the contents of gravity tanks and considering the possibility of inadvertent overfilling of tanks. The safety margin shall be at least 15%.
Oil drain tanks shall be equipped with sufficiently dimensioned vents.

7.3.5 Storage of oil residues
7.3.5.1 Tank heating system
To ensure the pump ability of the oil residues a tank heating system in accordance with international rules is to be provided, if considered necessary.
Sludge tanks are generally to be fitted with means of heating which are to be so designed, that the content of the sludge tank may be heated up to 60°C.

7.3.5.2 Sludge tanks
The capacity of sludge tanks shall be adequate to hold the accumulated residues arising from the operation of the installation having regard to the maximum duration between offshore supply services.
7.3.6 Testing for tightness
Testing of tanks for fuel oil, lubricating, hydraulic and thermal oil as well for water is to be effected by a combination of a leak test by means of air pressure and an operational test by means of water or the liquid for which the tank is intended to be used.

The air pressure is not to exceed 0.2 bar gauge. The increased risk of accident while the tanks are subjected to the air pressure is to be observed.

Butt welds made by approved automatic or semiautomatic processes on erection welds need not be tested, provided that these welds are carefully visually examined and are free of repairs. The results of the non-destructive examinations made at random shall not reveal significant defects. If there is evidence of problems from inspection results of these welds an increase in the extent of the leak testing should be considered.

Water testing after application of a coating should be avoided. The test head shall correspond to a head of water of 2.5 m above the top of tank or to the top of overflow or air pipe, whichever is the greater.

The operational test may be carried out in the fabrication yard. For all tanks the proper functioning of filling and suction lines and of the valves as well as functioning and tightness of the vent, sounding and overflow pipes are to be tested.

7.3.7 Drip trays
Drip trays shall be installed under equipment where leakages may occur.

Oil filled electrical equipment like transformers shall be fitted with drip trays or bunding to contain minimum the volume of oil content, but also considering the volume from rain and fire water. Fire retardant grating at the entrance to the drain pipe and a flame trap in the drain pipe should be provided. Influence of the fire retardant grating and the flame trap on drainage performance shall be considered.

7.4 Bunker stations

7.4.1 Bunker lines
Bunker lines, if present, for fuel, oily sludge, water, sanitary sludge and other fluids shall lead to a bunker station.

The bunkering of oil fuels shall be performed by means of permanently installed lines either from the open deck or from bunkering stations located below deck which shall be isolated from other spaces.

The bunkering lines are to be fitted with blind flanges and a quick closing valve on deck.

7.4.2 Arrangement
Bunker stations are to be arranged so that the bunkering with a supply vessel can be performed from at least one side of the installation without danger.

Drip trays or bunding shall be installed around the bunker area. Bunkering instructions has to be provided.

7.4.3 Standard discharge connection
Discharge pipelines for residues from machinery bilges and oil sludge tank shall be fitted with standard discharge connections.

7.5 Water systems

7.5.1 Drinking water systems
National Regulations are to be considered as relevant, in particular choice of material for the complete drinking water system.

7.5.1.1 Drinking water tanks
Drinking water tanks shall not have any walls in common with tanks containing substances other than feed water or distillate.
Pipes not carrying drinking water shall not be led through drinking water tanks.

Drinking water tanks located at the installations shell or outside are to be provided with means for tank heating to prevent freezing.

### 7.5.1.2 Drinking water tank connections

Filling connections shall be located sufficiently high above deck and shall be fitted with a closing device.

Filling connections shall not be fitted to air pipes.

Air/overflow pipes shall be protected against the entry of insects by a fine mesh screen.

Sounding pipes shall terminate sufficiently high above tank.

### 7.5.1.3 Drinking water pipe lines

Drinking water piping shall not be connected to pipes carrying other media.

Drinking water pipes lines are not to be laid through tanks which do not contain drinking water.

Drinking water supply to tanks or systems which do not contain drinking water (e.g. expansion tanks of the fresh water cooling system) shall be made by means of an open funnel or with means of preventing flow back.

### 7.5.1.4 Drinking water pumps

Separate drinking water pumps shall be provided for drinking water systems.

The pressure lines of the pumps of drinking water pressure tanks shall be fitted with screw-down non-return valves.

### 7.5.1.5 Drinking water generation

Where the distillate produced by the installation’s own evaporator is used for the drinking water supply, the treatment of the distillate has to comply with the requirements of National Health Authorities.

### 7.5.2 Sanitary systems

National Regulations are to be considered as relevant.

#### 7.5.2.1 General arrangement

Units are to be fitted with the following equipment:

- a sewage treatment plant approved according to IMO Resolution MEPC 159(55), or
- a holding tank.

A pipeline for the discharge of sewage to a Bunker station is to be arranged. The piping is to be provided with a standard discharge connection and a screw-down non-return valve.

Scuppers in sufficient numbers and sizes to provide effective drainage considering precipitation rates and/or fire water in case of fire extinguishing shall be fitted in all decks; hazardous and safe areas shall have separate drainage.

Sanitary discharge pipes located in operational areas shall be specially protected. Individual sanitary discharge pipes shall be connected to common discharge pipes.

For discharge lines the following pipes may be used:

- steel pipes
- pipes having smaller thickness when specially protected against corrosion, on special approval
- special types of pipes according to recognized standards, e.g. socket pipes, on special approval.

Penetrations of pipes of smaller thickness, pipes of special types and plastic pipes through bulkheads shall be of type A class, see [6.4.3].

#### 7.5.2.2 Sewage tanks and sewage treatment systems

Vent pipes shall be lead to an open deck, consideration should be given to prevent smell disturbance.

Sewage tanks are to be fitted with a filling connection, a flushing connection and a level alarm.

Bilge pumps may not be used for emptying sewage tanks.
7.5.3 Seawater cooling and supply systems

7.5.3.1 Sea suctions
At least two sea suctions are to be provided.
For service in tidal waters, it is recommended that the end of the suction line is under water at each level.
This equipment may be integrated into the legs/jackets or a special suction tower may be installed.

7.5.3.2 Strainer
The suction lines of the seawater pumps are to be fitted with strainers.
The strainers are to be so arranged (duplicated) that they can be cleaned while the platform is operating.

7.5.3.3 Pumps
Submersible seawater lift pumps on fixed installations shall be inserted in, or attached to, the suction tubing to allow easy removal for control and maintenance.

7.5.3.4 Cooling water supply for auxiliary engines
Where a common cooling water pump is provided to serve more than one auxiliary engine or plant, an independent stand-by cooling water pump with the same capacity is to be fitted.
If each auxiliary engine or plant is equipped with a dedicated cooling water pump, stand-by cooling water pumps need not to be provided.

7.5.4 Freshwater cooling systems

7.5.4.1 General
Fresh water cooling systems are to be so arranged that the engines and plants can be sufficiently cooled under all operating conditions.
Depending on the requirements of the engine and component plants, the following fresh water cooling systems are allowed:
— a single cooling circuit for the entire plant
— separate cooling circuits for the main and the auxiliary plants
— several independent cooling circuits for the main components which need cooling and for the auxiliary plants
— separate cooling circuits for various temperature ranges.
The cooling circuits are to be so divided that, should one part of the system fail, operation of the auxiliary systems can be maintained.
Change-over arrangements are to be provided for this purpose, as relevant.
As far as possible, the temperature controls of main and auxiliary plants as well as of different circuits are to be independent of each other.
Where, in automated plants, heat exchangers for fuel, lubricating or cooling oil are incorporated in one system, the entire cooling water system is to be monitored for fuel and oil leakage.
Common cooling water systems for main and auxiliary plants are to be fitted with shut-off valves to enable repairs to be performed without taking the entire plant out of service.

7.5.4.2 Heat exchangers, coolers
The construction and equipment of heat exchangers should be made to recognized standards.
The coolers of cooling water systems, engines and equipment are to be so designed as to ensure that the specified cooling water temperatures can be maintained under all operating conditions.
It is to be ensured that auxiliary machinery can be maintained in operation while repairing the main coolers.
If necessary, means are to be provided for changing over to other heat exchangers, machinery or equipment through which a temporary heat transfer can be achieved.
Shut-off valves shall be provided at the inlet and outlet of all heat exchangers.
7.5.4.3 Expansion tanks
Expansion tanks shall be arranged at sufficient height for each cooling water circuit.

Different cooling circuits may only be connected to one common expansion tank, if they do not interfere with each other. Care shall be taken here to ensure that damage to or faults in one system cannot affect the other system.

Expansion tanks shall be fitted with filling connections, aeration/de-aeration devices, water level indicators and a drain arrangement.

7.5.4.4 Fresh water cooling pumps
Main and stand-by cooling water pumps are to be provided for each fresh water cooling system.

Stand-by cooling water pumps are to have the same capacity as main cooling water pumps.

A stand-by cooling water pump of a cooling water system may be used as a stand-by pump for another system provided that the necessary pipe connections are arranged. The shut-off valves in these connections are to be secured against unintended operation.

Equipment providing emergency cooling from another system can be approved if the plant and the system are suitable for this purpose.

7.5.4.5 Temperature control
Cooling water circuits shall be provided with temperature control and alarms. Control devices, whose failure may impair the functional reliability of the machinery, shall be equipped with means for manual operation.

Means shall be provided for preheating fresh cooling water.

7.5.4.6 Emergency generator units
Internal combustion engines driving emergency generators or fire pumps shall be fitted with independent cooling systems.

Such cooling systems shall be protected from freezing, where necessary.

7.6 Drain and separator systems

7.6.1 Drains
Weather decks (i.e. open decks exposed to the sky) are to be fitted with drains sufficient in number and size to provide effective drainage of the peak rainfall. These drains may be led outside directly to the sea.

Areas with oily leakage shall be fitted with bunding or coamings.

Drains for these areas should be led to the oily drain holding tank or to be emptied manually.

The assumptions like the expected maximum flow of rainwater, the estimated maximum peak rain intensity and the considered average velocity in pipes as well as the relevant codes and standards have to be agreed for the specific project.

Internal decks are to be drained to the bilge tank. Clean drains could be led directly to the sea.

Drains for spaces with oily leakage are to be connected to pipes to an oily drain holding tank and are to be well protected.

Fire traps in the pipes or drain pots shall be installed in every fire area to prevent a back flash in case of fire.

The pipes for discharge fluids shall have an adequate capacity.

Oily drain holding tanks shall be dimensioned for the largest amount of oil, deluge water and firewater coming from an oil filled equipment during the greatest incident plus spare capacity (15% recommended).

Oily drain water is to be disposed by a supply vessel or shall be led to an oily water separator.

Helicopter deck drain shall be led in a safe way directly to sea without any spill to the outside of the helideck or to other parts of the installation.

Drain systems in hazardous areas shall be completely separated from drains in non-hazardous areas.
7.6.2 Oily water separator
Offshore substations shall be provided with an oily water separator or filter plant for the separation of water/oil mixtures or a sufficiently dimensioned oily drain holding tank for transportation ashore. National and international requirements shall be observed. Reference is made to MARPOL 73/78.

7.7 Piping systems

7.7.1 General
The following requirements apply to piping systems, fittings, and flexible hoses on fixed offshore units. Each piping system will have to be designed according to the service and operating conditions as well as the relevant environmental conditions. The piping design is to be carried out to a recognized code for the specific type of service and conditions.

7.7.2 Materials and testing
Materials to be used for pipe systems including valves and fittings shall be suitable for the intended application and shall comply with the standards specific to the project. In case of especially corrosive media, special requirements on the material used shall be observed.

7.7.2.1 Material manufacturers
Pipes, elbows, fittings, valve casings, flanges and semi-finished products intended to be used are to be manufactured according recognized standard.

7.7.2.2 Pipes, valves and other fittings of steel
Pipes shall be seamless drawn steel pipes or pipes fabricated in accordance with an appropriate welding procedure to be equivalent to seamless pipes. In general, carbon and carbon-manganese steel pipes, valves and other fittings shall not be employed for temperatures above 400°C. For applications above 400°C the suitability shall be demonstrated.

7.7.2.3 Pipes, valves and fittings of copper and copper alloys
Pipes of copper and copper alloys shall be of seamless drawn material or fabricated according to approved methods. The use is to be limited to auxiliary and utility services if the following requirements are observed. In general, copper and copper alloy pipe lines shall not be used for media having temperatures above the following limits:
- copper and aluminium brass 200°C
- copper nickel alloys 300°C
- high-temperature bronze 260°C.

7.7.2.4 Grey cast iron pipes and fittings
The use of grey cast iron is not allowed:
- for pipes and fittings for media having temperatures above 220°C and for pipes subject to water hammer, severe stresses or vibrations
- for valves on fuel and oil tanks subject to static head.

The use of grey cast iron for other purposes and operating conditions shall be subject to specific agreements.

7.7.2.5 Plastic pipe systems
Risks coupled with the use of plastic piping systems shall be observed. Among others, three different levels of fire endurance for plastic pipe systems are to be distinguished (see IMO Resolution A.753(18), Appendix 1 and 2) depending on the location of installation and the medium.
It shall be ensured that pipes and fittings are produced with consistent and uniform mechanical and physical properties.
Each pipe and fitting is to be tested by the manufacturer at a hydrostatic pressure not less than 1.5 times the nominal pressure. Alternatively, for pipes and fittings not employing hand lay-up techniques, the hydrostatic pressure test may be carried out in accordance with the hydrostatic testing requirements stipulated in the recognized national or international standard to which the pipe or fittings are manufactured, provided that there is an effective quality system in place.

Piping and fittings are to be permanently marked with identification. Identification is to include pressure ratings, the design standards that the pipe or fitting is manufactured in accordance with, and the material of which the pipe or fitting is made.

Depending upon the intended application the pressure testing of each pipe and/or fitting may be required.

The selection and spacing of pipe supports are to take into account pipe dimensions, mechanical and physical properties of the pipe material, mass of pipe and contained fluid, external pressure, operating temperature, thermal expansion effects, loads due to external forces, thrust forces, water hammer, vibrations, maximum accelerations to which the system may be subjected. Combination of loads is to be considered.

Heavy components such as valves and expansion joints are to be independently supported.

When calculating the thermal expansions, account is to be taken of the difference between the operating temperature of the system and the ambient temperature during installation.

Pipes are to be protected during installation and service from mechanical damage where necessary.

In piping systems for fluid with conductivity less than 1000 picoSiemens per metre [pS/m] such as refined products and distillates use is to be made of conductive pipes.

Regardless of the medium, electrically conductive plastic piping is to be used if the piping passes through hazardous areas. The resistance to earth from any point in the piping system is not to exceed $1 \times 10^6$ Ohm. It is preferred that pipes and fittings be homogeneously conductive. Pipes and fittings having conductive layers are to be protected against a possibility of spark damage to the pipe wall. Satisfactory earthing is to be provided.

After completion of the installation, the resistance to earth is to be verified. Earthing connections are to be arranged in a way accessible for inspection.

To meet the fire endurance the pipes and fittings may be provided with flame protection covers, coatings or isolations.

The installation instructions of the manufacturer have to be considered.

Pipe penetrations through fire divisions shall be subject to specific approvals.

Piping systems for essential services are to be subjected to a pressure test with a pressure of 1.5 times the design pressure (or nominal pressure) but at minimum to 4 bar.

Piping systems for non-essential services are to be checked for leakage under operational conditions.

For piping required to be electrically conductive, earthing is to be checked and random resistance testing is to be conducted.

### 7.7.2.6 Aluminium and aluminium alloys

Aluminium and aluminium alloys may in individual cases be used for temperatures up to 200°C. They are not acceptable for use in pipes for fire extinguishing purposes.

Aluminium and aluminium alloys shall not be used in hydrocarbon piping systems.

Tests shall be carried out in accordance with applicable recognized standards.

### 7.7.3 Calculation of wall thickness and elasticity

#### 7.7.3.1 Wall thickness

Tests to determine the minimum wall thickness and calculations of the pipe wall thickness shall be carried out in accordance to applicable standards.
7.7.3.2 Corrosion allowance
The corrosion allowance shall be provided depending on the application of the pipe and in accordance with recognized standards.

7.7.4 Principles for the construction of piping systems

7.7.4.1 General
Piping systems shall be constructed and manufactured on the basis of recognized standards.
Piping intended for use at elevated temperatures has to be rated according to the temperature limitation of respective standards or specifications.
Welding shall be done according to qualified procedures and with qualified welders.
Welded joints rather than detachable couplings shall be used for all hydrocarbon services, for piping carrying toxic media or flammable liquefied gases.
Expansion in piping systems due to heating and shifting of their suspensions caused by deformations of the adjacent structure shall be compensated by bends, compensators and flexible pipe connections.
The arrangement of suitable fixed points shall be taken into consideration.
Where pipes are protected against corrosion by special protective coatings, e.g. hot dip galvanising, rubber lining, etc., it is to be ensured that the protective coating will not be damaged during installation.

7.7.4.2 Types of pipe connections
The following pipe connections may be used:
— full penetration butt welds with/without provision to improve the quality of the root
— socket welds with suitable fillet weld thickness and in accordance with recognized standards
— steel flanges may be used in accordance with the permitted pressures and temperatures specified in recognized standards
— mechanical joints (e.g. pipe unions, pipe couplings, press fittings) of an approved type.
The use of welded pipe connections shall be in accordance with recognized standards.

7.7.4.3 Flange pipe connections
Dimensions of flanges and bolting shall comply with recognized standards.
Gaskets are to be suitable for the intended media under design pressure and temperature conditions and their dimensions and construction shall be in accordance with recognized standards.
Steel flanges may be used in accordance with the permitted pressures and temperatures specified in the relevant standards.
Flanges made of non-ferrous metals may be used in accordance with the relevant standards and within the limits laid down in the approvals.

7.7.4.4 Welded socket pipe connections
Welded socket connections shall be in accordance with recognized standards. The following conditions are to be observed:
— the thickness of the sockets is to be at least equal to the thickness of the pipe
— the clearance between the pipes and the socket is to be as small as possible
— the use of welded socket connections in systems of pipe class II may be accepted only under the condition that in the systems no excessive stress, erosion and corrosion are expected.

7.7.4.5 Screwed socket pipe connections
Screwed socket connections with parallel and tapered threads shall comply with requirements of recognized national or international standards.
Screwed socket connections with parallel threads are permitted for pipes with an outside diameter ≤ 60.3 mm as well as for selected systems (e.g. sanitary and hot water heating systems). They are not permitted for systems for flammable media.
Screwed socket connections with tapered threads are permitted for the following:

— class I, outside diameter not more than 33.7 mm
— class II and class III, outside diameter not more than 60.3 mm.

Screwed socket connections with tapered threads are not permitted for piping systems conveying toxic or flammable media or services where fatigue, severe erosion or crevice corrosion is expected to occur.

7.7.4.6 Brazed pipe connections
Brazed connections may be used. Risks in conjunction with their design and manufacturing shall be observed.

7.7.4.7 Mechanical joints
Mechanical joints in piping which is essential to safety shall be fire resistant.

Mechanical joints are not to be used in piping sections directly connected to sea openings or tanks containing flammable liquids.

The use of slip-on joints should be limited only to cases with no risks for humans and environment.

7.7.4.8 Pipe layout, marking and installation
Piping systems shall be adequately identified according to their purpose. Valves are to be permanently and clearly marked.

Pipe penetrations leading through bulkheads/decks and tank walls shall be water and oil tight. Bolts through bulkheads are not permitted.

Holes for fastening screws shall not be drilled in the tank walls.

Sealing systems for pipes penetrating through watertight bulkheads and decks as well as through fire divisions shall comply with requirements of [6.4.3].

Piping close to electrical switchboards shall be so installed or protected that a leakage cannot damage the electrical installation.

Piping systems are to be so arranged that they can be completely emptied, drained and vented.

Piping systems in which the accumulation of liquids during operation could cause damage shall be equipped with special drain arrangements.

7.7.4.9 Shut-off devices
For the requirements of shut-off devices including remote control of valves see [7.3].

7.7.4.10 Hose assemblies and compensators

a) Scope:
The following requirements are applicable for hose assemblies and compensators made of non-metallic and metallic materials.

Hose assemblies and compensators made of non-metallic and metallic materials may be used according to their suitability in fuel-, lubricating oil-, hydraulic oil-, bilge-, ballast-, fresh water cooling-, sea water cooling-, compressed air-, exhaust gas and thermal oil systems as well as in secondary piping systems.

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Table 7-3 Pipe connections

<table>
<thead>
<tr>
<th>Types of connections</th>
<th>Pipe class</th>
<th>Outside diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>welded butt-joints with special provisions for root side</td>
<td>I, II, III</td>
<td>all</td>
</tr>
<tr>
<td>welded butt-joints without special provisions for root side</td>
<td>II, III</td>
<td>≤ 60.3 mm</td>
</tr>
<tr>
<td>socket weld</td>
<td>III</td>
<td></td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>≤ 60.3 mm</td>
</tr>
</tbody>
</table>
Hose assemblies and compensators made of non-metallic materials are not permitted in permanently pressurized starting air lines. Furthermore it is not permitted to use hose assemblies and compensators in fuel injection piping systems of combustion engines.

b) Requirements:
Hoses and compensators used in the systems mentioned under item a) above are to be of an approved type.
Manufacturers of hose assemblies and compensators shall be recognized by DNV GL.
Hose assemblies and compensators including their couplings are to be suitable for media, pressures and temperatures they are designed for.
The selection of hose assemblies and compensators is to be based on the maximum allowable working pressure of the system concerned. A pressure of 5 bar is to be considered as the minimum working pressure.
Hose assemblies and compensators for the use in fuel-, lubricating oil-, hydraulic oil-, bilge- and sea water systems are to be fire-resistant.

c) Installations:
Hose assemblies and compensators shall only be used at locations where they are required for compensation of relative movements. They shall be kept as short as possible under consideration of the installation instructions of the hose manufacturer.
The number of hose assemblies and compensators is to be kept to minimum.
The minimum bending radius of installed hose assemblies shall not be less than specified by the manufacturers.
Non-metallic hose assemblies and compensators are to be located at visible and accessible positions.
In fresh water systems with a working pressure of $\leq$ 5 bar and in charging and scavenging air lines, hoses may be fastened to the pipe ends with double clips.
Where hose assemblies and compensators are installed in the vicinity of hot components they shall be provided with approved heat-resistant sleeves.
Hose assemblies and compensators conveying flammable liquids that are in close proximity of heated surfaces are to be provided with screens or other similar protection to avoid the risk of ignition due to failure at the hose assembly or compensator.

d) Test:
Hose assemblies and compensators are to be subjected in the manufacturer's works to a pressure test.
For compensators intended to be used in exhaust gas pipes the pressure test may be omitted.

e) Marking:
Hose assemblies and compensators shall be permanently marked with the following particulars:

- manufacturer's mark or symbol
- date of manufacturing
- type
- nominal diameter
- maximum allowable working pressure respectively nominal pressure
- test certificate number and identification code.

7.7.4.11 Protection of piping systems against overpressure
The following piping systems shall be fitted with safety valves to avoid destructive overpressures:

- piping systems and valves in which liquids can be blocked in and heated
- piping systems which may be exposed to service pressures in excess of the design pressure.

Safety valves shall be capable of discharging at a maximum pressure increase 10% above the maximum
allowable overpressure and have to fulfil the requirements of the Pressure Equipment Directive (2014/68/EU) and other relevant national rules and standards. Safety valves shall be fitted on the low pressure side of reducing valves.

7.7.4.12 Protection of piping systems against vibrations
Protective means shall be included to reduce the stress on piping caused by reciprocating machines through use of adequate flexibility and strength of pipe connections.

7.7.5 Fuel oil systems

7.7.5.1 Bunker lines
The bunkering of oil fuels shall be performed by means of permanently installed lines either from the open deck or from bunkering stations located below deck which shall be isolated from other spaces.

Bunker stations are to be arranged that the bunkering can be performed from at least one side of the installation without danger. The bunkering lines are to be fitted with blind flanges on deck and a remotely controlled shut-off valve.

7.7.5.2 Tank filling and suction lines
Filling and suction lines from storage, settling and service tanks with a risk of leaking in case of damage or fire, are to be provided with shut-off devices fitted directly on the tanks capable of being closed from a safe position outside the space concerned.

On normally manned installations, shut-off devices on fuel oil tanks having a capacity of less than 500 L need not be provided with remote control.

Filling lines are to extend to the bottom of the tank. Short filling lines directed to the side of the tank may be admissible.

Storage tank suction lines may also be used as filling lines.

Where filling lines are led through the tank top and end below the maximum oil level in the tank, a non-return valve at the tank top is to be arranged.

The inlet connections of suction lines are to be arranged far enough from the drains in the tank so that water and impurities which have settled out will not enter the suctions.

The remotely operated shut-off devices shall be capable to be manually operated from outside the concerned spaces.

7.7.5.3 Pipe layout
Fuel lines may not pass through tanks containing feed water, drinking water, lubricating oil or thermal oil.

Fuel lines may not be laid directly above or in the vicinity of appliances or equipment with high surface temperatures (over 220°C) or in way of other sources of ignition.

Flanged and screwed socket connections in fuel oil lines shall be screened or otherwise suitably protected to avoid, as far as practicable, oil spray or oil leakages onto hot surfaces, into machinery air intakes, or other sources of ignition.

The number of detachable pipe connections is to be limited. In general, flanged connections according to recognized standards shall be used.

Flanged and screwed socket connections in fuel oil lines which run directly above hot surfaces or other sources of ignition are to be screened and provided with drainage arrangements.

Flanged and screwed socket connections in fuel oil lines with a maximum allowable working pressure of more than 0.18 N/mm² and within about 3 m from hot surfaces or other sources of ignition and direct sight of line shall be screened. Drainage arrangements need not to be provided. This type of connections shall also be assessed individually taking into account working pressure, type of coupling and possibility of failure.

Flanged and screwed socket connections in fuel oil lines with a maximum allowable working pressure of more than 1.6 N/mm² need normally to be screened.

Pipes running below engine room floor need normally not to be screened.
Shut-off valves in fuel lines in the machinery spaces shall be operable from above the floor plates.

Glass and plastic components are not permitted in fuel systems. Sight glasses made of glass located in vertical overflow pipes may be permitted.

Fuel pumps shall be capable of being isolated from the piping system by shut-off valves.

**7.7.5.4 Fuel transfer, feed and booster pumps**

Fuel transfer, feed and booster pumps shall be designed for the intended operating temperature of the medium.

A fuel transfer pump shall be provided. Other service pumps may be used if they are suitable for this purpose.

At least two means of oil fuel transfer shall be provided for filling the service tanks.

Where a feed or booster pump is required to supply fuel to auxiliary engines, a standby pumps shall be provided.

Fuel supply units for auxiliary diesel engines are to be designed such that the auxiliary engines start without aid from the emergency generator within 30 seconds.

Guidance note:

To fulfill the above requirements for example the following measures could be a possibility:

- service pump
- gravity tank
- service (daily) tank in the vicinity of each auxiliary diesel engine.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

For plants with more than one engine, complete spare feed or booster pumps stored on offshore substation may be accepted instead of stand-by pumps, provided that the feed or booster pumps are so arranged that they can be replaced with the means available on the offshore substation.

**7.7.5.5 Fuel and injection lines of combustion engines**

Only pipe connections with metal sealing surfaces or equivalent pipe connections of approved design may be used for fuel injection lines.

All components of the fuel system are to be designed to withstand the maximum peak pressures which will be expected in the system.

If fuel oil reservoirs, dampers or instruments with a limited life cycle are fitted in the fuel oil system the life cycle together with overhaul instructions is to be specified by the engine manufacturer in the corresponding manuals.

Oil fuel lines are not to be located immediately above or near units of high temperature, exhaust manifolds, silencers or other equipment required to be insulated, see [7.7.9.4]. As far as practicable, oil fuel lines are to be arranged far apart from hot surfaces, electrical installations or other potential sources of ignition and are to be screened or otherwise suitably protected to avoid oil spray or oil leakage onto the sources of ignition. The number of joints in such piping systems is to be kept to a minimum.

Regardless of the intended use and location of internal combustion engines, all external fuel injection lines (high pressure lines between injection pumps and injection valves) are to be shielded by jacket pipes in such a way that any leaking fuel is:

- safely collected
- drained away unpressurized
- efficiently monitored and alarmed.

**7.7.5.6 Shut-off devices**

Shut-off devices isolating the fuel supply to any engine shall be provided. These shut-off valves shall be under the control of the shut-down system, see [9.4.3].

These valves shall be operable from a position not rendered inaccessible by a fire on any of the engines. Instead of shut-off devices in the return/recirculation lines check valves may be fitted.
**7.7.5.7 Filters**
Fuel oil filters are to be fitted in the delivery line of the fuel priming pumps.
Mesh size and filter capacity are to be in accordance with the requirements of the manufacturer of the engine.
Uninterrupted supply of filtered fuel has to be ensured during cleaning of the filtering equipment. In case of automatic back-flushing filters it is to be ensured that a failure of the automatic back-flushing will not lead to a total loss of filtration.
Back-flushing intervals of automatic back-flushing filters are to be monitored.
Fuel oil filters are to be fitted with differential pressure monitoring.
Engines for the exclusive operation of emergency generators and emergency fire pumps may be fitted with simplex filters.
Fuel transfer units are to be fitted with a simplex filter on the suction side.
Fuel and lubricating oil filters which are to be mounted directly on the engine are not to be located above rotating parts or in the immediate proximity of hot components. Where such arrangement is not feasible, the rotating parts and the hot components shall be sufficiently shielded.
Filters have to be so arranged that fluid residues can be collected by adequate means. The same applies to lubricating oil filters if oil can escape when the filter is opened.
Change-over filters with two or more chambers are to be equipped with means enabling a safe pressure release before opening and a proper venting before re-starting of any chamber. Normally, shut-off devices are to be used. It shall be clearly visible, which chamber is in and which is out of operation.
Oil filters fitted in parallel for the purpose of enabling cleaning without disturbing oil supply to engines (e.g. duplex filters) are to be provided with arrangements that will minimize the possibility of a filter under pressure being opened by mistake. Filters/filter chambers shall be provided with suitable means for:
- venting when put into operation
- depressurizing before being opened.
Valves or cocks with drain pipes led to a safe location shall be used for this purpose.

**7.7.5.8 Purifiers**
Where a fuel purifier may exceptionally be used to purify lubricating oil, the purifier supply and discharge lines are to be fitted with a change-over arrangement which prevents the possibility of fuel and lubricating oils being mixed.
Suitable equipment is also to be provided to prevent such mixing occurring over control and compression lines.
The sludge tanks of purifiers are to be fitted with a level alarm which ensures that the level in the sludge tank cannot interfere with the operation of the purifier.

**7.7.5.9 Storage and service tanks**
Capacity of the storage and service (daily) tanks shall be sufficient to ensure fuel supply
- for auxiliary power supply: in accordance with requirements of [5.6.2.1],
- for emergency services: in accordance with requirements of Table 5-2.

**7.7.5.10 Fuel leak drainage**
Appropriate design measures are to be introduced to ensure generally that leaking fuel is drained efficiently and cannot enter into the engine lube oil system.

**7.7.5.11 Heat tracing, thermal insulation, recirculation**
Fuel lines, including fuel injection lines, to engines which are operated with preheated fuel are to be insulated against heat losses and, as far as necessary, provided with heat tracing.
Means for fuel circulation are also to be provided.
7.7.6  Lubricating oil systems

Lubricating oil systems are to be in accordance with the requirements of the manufacturer of the engines respectively the complete generator sets (generator with combustion engine) and to be specified by the engine manufacturer in the corresponding manuals.

7.7.7  Air and overflow pipes

7.7.7.1  Arrangement

All tanks shall be fitted at their highest position with air pipes or overflow pipes. Air pipes shall normally terminate at the open deck.

Air and overflow pipes passing through operating areas shall be protected against damage.

Air pipes from unheated leakage oil tanks and lubricating oil tanks may terminate at clearly visible positions in the room where the engine is positioned. It shall be ensured that no leaking oil can spread onto heated surfaces where it may ignite.

Air pipes from lubricating oil tanks and leakage oil tanks which terminate in the room of the engine are to be provided with funnels and pipes for safe drainage in the event of possible overflow.

Air pipes for lubricating and fuel oil tanks which terminate on open deck are to be arranged such that in the event of a broken air pipe this shall not directly lead to the risk of rain water ingress.

Wherever possible, the air pipes of feed water and distillate tanks should not extend into the open.

Where fuel service tanks are fitted with change-over overflow pipes, the change-over devices are to be so arranged that the overflow is led to one of the storage tanks.

The overflow pipes of changeable tanks shall be capable of being separated from the fuel overflow system.

The air and overflow pipes of lubricating oil and fuel tanks shall not be led to a common line.

For the cross-sectional area of air pipes and air/overflow pipes, see Table 7-4.

**Table 7-4  Cross-sectional area of air and overflow pipes**

<table>
<thead>
<tr>
<th>Tank filling systems</th>
<th>Cross-sectional areas of air and overflow pipes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Air pipe</td>
</tr>
<tr>
<td>filling mode</td>
<td>by gravity</td>
</tr>
<tr>
<td></td>
<td>by pumping</td>
</tr>
</tbody>
</table>

Explanatory note:

f  : cross-sectional area of tank filling pipe

1  1.25 f as the total cross-sectional areas is sufficient if it can be proved that the resistance to flow of the air and overflow pipes including the air pipe closing devices at the proposed flow rate cannot cause unacceptable high pressures in the tanks in the event of overflow.

7.7.7.2  Number of air and overflow pipes

The number and arrangement of the air pipes is to be such that the tanks can be aerated and deaerated without exceeding the tank design over- or under-pressure.

Air and overflow pipes terminating above the open deck are to be fitted with air pipe gooseneck heads. Vent pipes for oil tanks should be fitted with a flame screen.

7.7.7.3  Overflow systems

The overflow collecting manifolds of fuel tanks are to be led at a sufficient gradient to an over- flow tank of sufficient capacity.

The overflow tank is to be fitted with a level alarm which operates when the tank is about 1/3 full.

The use of a fuel storage tank as overflow tank is permissible but requires the installation of a high level alarm and an air pipe with 1.25 times the cross-sectional area of the main bunkering line.

Air and overflow pipes shall have an outside diameter of at least 60.3 mm. The minimum wall thickness of air and overflow pipes are to be in accordance with regulations.

The pipe materials are to be selected according to the regulations.
7.7.8 Sounding pipes

7.7.8.1 General
Sounding pipes shall be provided for tanks.
As far as possible, sounding pipes shall be straight and shall extend near to the bottom of the tank.
All sounding pipes shall be extended to the open deck. The sounding pipe openings must always be accessible and fitted with watertight closures.
Sounding pipes of tanks shall be provided close to the top of the tank with holes for equalizing the pressure.
Sounding pipes passing through operational areas are to be laid in protected spaces or protected against damage.

7.7.8.2 Sounding pipes for fuel and lubricating oil tanks
Sounding pipes which terminate below the open deck shall be provided with self-closing devices as well as with self-closing test valves.
Sounding pipes shall not be located in the vicinity of fired plants, machine components with high surface temperatures or electrical equipment.
Sounding pipes shall not terminate in accommodation or service spaces.
Sounding pipes shall not be used as filling pipes.

7.7.8.3 Cross section of pipes
Sounding pipes shall have a nominal inside diameter of at least 32 mm.
The nominal diameter of sounding pipes, which pass through refrigerated holds at temperatures below 0°C, shall be increased to an inside diameter of 50 mm.
The minimum wall thicknesses and materials of sounding pipes are to be in accordance with a recognized standard.

7.7.9 Exhaust gas ducts

7.7.9.1 Duct layout
Exhaust gas ducts from engines shall be installed separately from each other with regard to passive fire protection in a separate funnel.
Account is to be taken of thermal expansion in arrangement and support of the ducts.
Exhaust gas outlets to consider possible adverse effects on helicopter operations and to people on the substation.

7.7.9.2 Silencers
Engine exhaust pipes shall be fitted with effective silencers or other suitable means are to be provided.
Silencers shall be provided with an inspection opening.

7.7.9.3 Water drains
Exhaust lines and silencers shall be provided with suitable drains of adequate size.

7.7.9.4 Insulation
Exhaust gas lines, silencers and exhaust gas boilers shall be effectively insulated to prevent the ignition of combustible materials on their hot surfaces. Surface temperature shall be limited to 220°C at any point.
Exhaust gas ducts, other equipment and piping systems carrying hot gases or hot fluids or gases are to be effectively insulated with a maximum 60°C surface temperature in areas with risk of injuries of persons.
Insulating materials shall be non-combustible. Points at which combustible liquids or moisture can penetrate into the insulation shall be suitably protected, e.g. by means of shielding.
Insulating materials have to be incombustible and to resist absorbing oil.
Exhaust gas lines inside engine rooms shall be provided with metal sheathing or other approved type of hard sheathing.
7.7.9.5 Precautions against sparks exhaust gases
Exhaust gases shall be discharged to the atmosphere at a sufficient height. Exhaust lines shall be fitted with spark arrestors.
Spark arrestors shall be provided with ample space for the deposit of soot particles and with readily accessible openings for cleaning, fitted with easily opened gastight covers and drains.
For other technical design, construction and installation requirements not defined in this section please refer to the regulations.

7.7.10 Compressed air lines
7.7.10.1 General
Pressure lines connected to air compressors are to be fitted with non-return valves at the compressor outlet.
A water trap and a cooler have to be provided after the final stage of all compressors.
Starting air lines may not be used as filling lines for air receivers.
Only hose assemblies made of metallic materials to a recognized standard may be used in starting air lines of diesel engines which are permanently kept under pressure.
The starting air line to each engine is to be fitted with a non-return valve and a drain.
A safety valve is to be fitted behind each pressure-reducing valve.
Pressure water tanks and other tanks connected to the compressed air system are to be considered as pressure vessels and shall comply with a recognized standard.
The provisions for compressed air supply to pneumatically operated valves and quick-closing valves have to be agreed with DNV GL.
Requirements for starting engines with compressed air, see [7.2].

7.7.10.2 Control air systems
Control air systems for essential consumers are to be provided with the necessary means of air treatment, in particular filtering and dryness of air being used for systems subject to ambient conditions.
Pressure reducing valves in the control air system for engines are to be provided with a redundant arrangement.

7.8 Heating, ventilation and air conditioning system
7.8.1 General
National rules or regulations may have to be considered in addition to DNV GL service documents.
For design and construction of HVAC-systems the following international standards are recommended as guidance. The last edition of each standard should be applied.

— ISO 7547, Shipbuilding – Air-conditioning and ventilation of accommodation spaces on board ships – Design conditions and basis of calculations
— ISO 8861, Shipbuilding – Engine room ventilation in diesel-engined ships – Design requirements and basis of calculations
— ISO 8862, Air-conditioning and ventilation of machinery control rooms on board ships – Design conditions and basis of calculations
— ISO 9943, Shipbuilding – Ventilation and air treatment of galleys and pantries with cooking appliances
— NORSOK H-001, Heating, Ventilation and Air-Conditioning
— NORSOK H-003, HVAC and Sanitary Systems
— ISO 15138, Petroleum and natural gas industries - Offshore production installations. Heating, ventilation and air-conditioning
— EN ISO 13351, Industrial fans – Dimensions
— EN 12907, Ventilation for Buildings - Ductwork - Requirements for ductwork components to facilitate maintenance of ductwork systems
The ventilation systems for machinery spaces of category A, galleys, shall, in general, be separated from each other and from the ventilation systems serving other spaces.

Where necessary, main intakes and outlets shall be fitted with gratings to prevent fouling.

Where a fixed gas fire-extinguishing system is fitted, ventilation openings of these spaces shall be capable of being closed from outside the protected space. If the closures are not fitted directly at the external bulkhead the duct between bulkhead, and closing device shall be constructed of steel having a thickness of at least 3 mm and flange joints are to be sealed by non-combustible material.

Where individual rooms have separate arrangements for flooding by fixed gas fire-extinguishing system 2, the ventilating system must also be separate. Provision is to be made to remove gas after flooding of these spaces.

Electrical machinery and installations (switch cabinets, etc.) are to be protected such that water particles penetrating into the air ducts will not cause disturbances. Risks of this kind shall be minimized by appropriate arrangement (water traps) of ducts and air in/outlets.

7.8.2 Requirements for particular spaces

7.8.2.1 Accommodation spaces and workplaces
National requirements should be observed as relevant concerning primary data of air condition system and air change rates.

7.8.2.2 Galleys
Each exhaust duct shall be fitted with:

- a grease trap readily removable for cleaning
- a fire damper located in the lower end of the duct and, in addition, a fire damper in the upper end of the duct
- arrangements, operable from within the galley near exit, for shutting off the exhaust fan
- fixed means for extinguishing a fire within the duct.

7.8.2.3 Control stations
In case a control station is served by a common ventilation system, which serves also other spaces, effective local closing arrangements shall be provided. Effective local closing arrangements mean that the provided ventilation systems shall be fitted with fire dampers or smoke dampers which could be closed easily within the control station in order to maintain the absence of smoke in the event of fire.

Alternative and separate means of air supply shall be provided; air inlets of the two sources of supply shall be so disposed that the risk of both inlets drawing in smoke simultaneously is minimized. Such requirements need not be applied to control stations situated on, and opening on to, an open deck and where local closing arrangements would be equally effective.

Alternative and separate means of air supply may be provided also by combination of a mechanical supply duct and a natural exhaust duct or vice versa provided that the fan is reversible.

7.8.2.4 Hazardous areas
Hazardous areas are to be provided with arrangements according to DNVGL-OS-A101 Ch.2 Sec.3.

7.8.2.5 Machinery space ventilation
The ventilation systems for machinery spaces shall be separate from the ventilation systems serving other spaces and shall be in general of the supply type.
Other modes of operation may be applied upon special approval.
Machinery spaces of category A shall be adequately ventilated appropriate for the purpose of that machinery space.

The positions of air inlets and air outlets are to be such as to prevent short-circuiting of air.
In general the unit machinery, equipment and appliances in machinery spaces are to be designed for continuous operation at maximum engine room air temperature as required.

For the determination of the ventilation capacity the heat radiation of the equipment in the space and the required combustion air are to be considered.
The capacity and arrangement of ventilation systems/ducts is to ensure that accumulation of oil vapor is avoided under normal conditions.

**Guidance note:**
The capacity requirements mentioned in this section are in general deemed to be according to ISO Standard 8861 in the latest version.

Air ducts close to electrical switchboards must be so installed and fitted with drains, where necessary, that condensed water cannot enter the electrical installation.

### 7.8.2.6 Electrical machines
Reference is made to Sec.5 above.
If external forced ventilation for electrical machines is fitted with air ducts leading to the upper deck, the fan motors shall be provided with an emergency disconnecting switch outside the engine room, connected to the shut-down system as relevant. A failure of external forced ventilation shall cause an alarm.
For high voltage areas reference is made to [3.5.2].

### 7.8.2.7 Refrigerating machinery rooms
Refrigerating machinery spaces shall be provided with a suitably arranged forced ventilation system as relevant.

### 7.8.2.8 Spaces containing batteries
Requirements of [5.6.3] shall be fulfilled.

### 7.8.2.9 Emergency generator rooms
The ventilation system serving the emergency generator room has to ensure a sufficient supply of combustion and cooling air for the equipment installed.

The ventilation openings need not be fitted with fire closures, unless a fixed gas firefighting system for the emergency generator space is fitted.

Adequate drain is to be provided in the air inlet ducting to avoid heavy rainfalls causing flooding of the stationary engine.
If the emergency generator starts automatically it is to be ensured that the fire closures dampers or inlet louvers are open.
In case the fire dampers do not open automatically or under remote control, a warning plate is to be provided stating that they are to be kept open all the time.
SECTION 8  ACCESS AND TRANSFER

8.1  Introduction
This section provides design and management principles, requirements and guidance for safe and controlled access and transfer of personnel to and from the offshore substation.

Sections of this standard containing important information related to access and transfer include:

— Sec.3, arrangement principles
— Sec.9, emergency response
— Sec.11, inspection and maintenance planning.

Requirements for helicopter design and operation are not included in this standard. The use of twin main rotor helicopters for substation access is not considered.

8.2  Safety philosophy and design principles

8.2.1  General
The objective of this section is to describe adequate and effective facilities including:

— equipment and areas for safe docking or landing of vessels or helicopters
— equipment for safe transfer of personnel and cargo onto an installation
— methods of transfer from docking or landing areas to accommodation areas
— access and egress including rescue of injured personnel.

A performance-based approach should be used to develop concepts for accessing the installation and transferring personnel and cargo to and from the installation (Figure 8-1). The concept study shall consider construction, operation and maintenance as well as de-commissioning phases of the installation and the plans associated with these. Based on the access and transfer concepts a design shall be developed. It shall be assessed against the safety criteria and improved until the evaluation is satisfactory. For safety criteria see [8.2.2].

![Figure 8-1 Performance-based access and transfer concept design](image)

The access and transfer concept is likely to utilise more than one access and transfer method depending on each operational requirement and the safe operating envelope of each method.
8.2.2 Safety criteria and evaluation

The access and transfer concept shall be evaluated regarding its suitability to meet the performance criteria specified for the installation.

Issues to consider when defining performance criteria for vessel access may include:

- meteorological and ocean condition operating window
- vessel suitability for intended operation, personnel or cargo transfer
- vessel crew training and competence for intended operation
- vessel station holding capability and operating stability
- baggage hoist and crane suitability
- potential for slips, trips, crushing and falls into the sea
- accessibility for mariners in distress.

Issues to consider when defining performance criteria for helicopter access may include:

- severity of turbulence that can occur in the helicopter flight path
- estimate for the likely helicopter deck operational downtime
- efficiency of the deck’s active fire protection system.

Issues to consider when defining performance criteria for ascending and descending may include:

- meteorological and ocean condition operating window
- potential for slips, trips and falls
- suitability for physical capability of workforce
- ability to rescue casualties, including a person on a stretcher, and transfer them from the installation
- prevention of unauthorised access.

8.2.3 Design basis

Site conditions to be considered should include, for instance:

- meteorological and ocean conditions at the installation site and along the travel routes, in particular wind, waves, tidal currents and levels, water depth and ice
- weather windows for safe access and transfer
- hours of daylight, visibility, low clouds and fog.

Arrangement information shall include, for instance:

- platform location, general arrangement and structural capacity
- location, vulnerability and interference of J-tubes, pipework, cables, vents, drains and similar objects
- crane access, lay-down and potential for dropped objects.

Means of transport shall be considered including:

- vessel options, size, capabilities and requirements; ports; installation docking systems
- helicopter options, size, capabilities and requirements; heliports; installation helicopter and heli-hoist decks
- distances and travel times.

Health and safety related considerations include, for instance:

- proximity of communication and alarm devices
- hazardous areas to be passed
- access, ladders and fall arrest system
- medical evacuation
- emergency escape and evacuation
- proximity of other installations and emergency services.
8.2.4 Design process
Based on the access and transfer concept and the boundary conditions described in the design basis a preliminary design shall be developed. Specific consideration shall be given to the following:

— helicopters should not be the only means of access and egress
— vessel design and access system shall be compatible.

Detailed design review shall include:

— full failure mode, effects and criticality analysis (FMECA)
— structural, wind and wave loading analysis meeting DNVGL-OS-C101
— access system review demonstrating that the particular system chosen ensures risks are as low as reasonably practicable (ALARP).

8.2.5 Minimum requirements
Sub-section [8.3] outlines minimum requirements and options applicable to transfer of persons and cargo to and from a vessel. An offshore substation shall have a means of transferring persons and cargo between vessel and installation where each activity shall be carried out within defined meteorological and oceanographic conditions.

Sub-section [8.4] outlines requirements applicable to helicopter transfer. As a minimum, a designated deck area shall be established from which persons and cargo can be hoisted into a helicopter.

For helicopter decks that cannot fully comply with the requirements in [8.4], a system of compensating operational limitations shall be imposed to ensure that the safety level to flights is not compromised.

8.3 Vessel access and transfer
8.3.1 Fendering systems
During fendering operations a vessel docks or pushes against an installation leg to allow persons to step over to a ladder. Fendering the vessel may also permit transfer of cargo with a suitable crane and available deck space. Where fendering operations are to be used, the criteria outlines in the below sub-sections should be applied.

Guidance note:
It should be observed that fendering operations are considered to be more risky than the access and transfer operations described in sub-sections [8.3.2] and [8.3.3]. Therefore, whenever this type of access and transfer system is taken into consideration, it is highly recommended that this decision is based on carefully weighing up of alternatives.

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8.3.1.1 Design
a) The leg of the installation shall be designed to withstand loads and impacts from the largest expected force from the maximum authorised service vessel.
b) Design loads for the fendering system shall be designed for the loads given in [3.7.4] of DNVGL-ST-0126.
c) Two access ladders should be considered, appropriately positioned to accommodate for prevailing wind, wave and tidal conditions.
d) Fenders shall be installed at either side of ladders and access or landing platforms capable of withstanding vessel impact.
e) Where alternatives are available, no J-tubes, umbilicals, cables or risers shall be positioned on or within legs where fendering operations are expected. Where alternatives are not available (e.g. on monopiles), vulnerable items shall be located sufficiently away and protected from collisions with the transfer vessel.
8.3.1.2 Operational considerations

a) As a minimum, all personnel shall be provided with appropriate personal protection equipment including safety harness, head protection and a high visibility lifejacket. A survival suit shall always be available for use.

b) Cargo, tools and baggage shall only be carried by personnel where suitable backpacks are used allowing free movement and use of both hands.

Guidance note:
Each backpack and its contents should weigh no more than 5 kg.

8.3.2 Gangway docking systems

Gangway docking type operations consist of a vessel mounted gangway which is connected directly or indirectly to the installation. Where gangway docking operations are to be used, the criteria in [8.3.2.1] and [8.3.2.2] shall be applied.

8.3.2.1 Design

a) The leg of the installation, the landing platform, the gangway and the docking arrangement shall be designed to withstand loads and impacts from the maximum authorised service vessel.


c) A 'weak link' or automated emergency release mechanisms shall be integral to the design which prevents excess stresses and loads on the installation structure. These devices shall be provided with warning systems for excessive movements and when auto-disconnection is imminent.

d) The vessel shall have a dynamic positioning system where deemed necessary following a formal safety assessment.

e) Maximum safe working load and maximum number of people allowed on the gangway at any one time shall be clearly marked.

f) The docking system shall be certified by an independent verifying body.

Guidance note:
Criteria and guidance for certification and verification of the design, materials, fabrication, installation, testing and commissioning of gangways used offshore can be found in the DNV GL Standard DNVGL-ST-0358 Certification of offshore gangways for personnel transfer.

8.3.2.2 Operational considerations

a) During personnel transfers a rescue craft shall be available for recovering personnel from the water. A transfer vessel may be used as a rescue vessel if it meets the requirements of [9.8.2].

b) At a minimum, all personnel shall be provided with head protection and a high visibility lifejacket. A survival suit shall always be available for use.

c) Cargo, tools and baggage shall normally be transferred by use of crane or hoist and only be carried by personnel where suitable backpacks are used allowing free movement and use of both hands.

Guidance note:
In some countries use of backpack is not allowed.

8.3.3 Personnel carriers

Crane transfer of persons (in approved man-riding carriers such as baskets, cages or cradles) and cargo can be performed with the vessel positioned in a standoff location, not directly in contact with the installation, or fendered. Where crane transfer operations are to be used, the criteria below shall be applied.
8.3.3.1 Design

a) Lifting structures shall be designed to permit safe vertical lift with consideration for load swing and minimal potential for impact with vessel or installation.

b) Man-riding cranes shall comply with applicable regulations and marked with the safe working load, the maximum number of people that can be carried and “Suitable for lifting people” or “Suitable for man-riding”. A certificate or report shall be provided to demonstrate that the man-riding equipment is functional.

c) Personnel carriers should be designed to protect users from lateral and vertical impacts that might arise during the defined operating envelope. The design shall incorporate suitable standing and handhold arrangements and should provide an arrangement for holding hand luggage or backpacks.

d) A double safety load line assembly composed of a main support line constructed of a galvanised steel wire rope sling and a secondary stabilising rig line rated for the expected load should be provided.

e) Landing areas on vessel and installation should:
   — be adequate to allow a safe landing tolerance
   — be adequate for entry and exit of persons
   — clearly marked
   — free from obstructions.

Guidance note:
Local requirements for equipment selection, installation and operation of equipment should be observed such as:
— Europe: European Use for Work Equipment Directive 89/655/EEC

8.3.3.2 Operational considerations

a) At a minimum, all persons to be transferred shall be provided with head protection and a high visibility lifejacket. Survival suits shall always be available for use.

b) Cargo should be transferred by crane.

8.3.4 Other marine access methods

Other access methods such as novel concepts may be used, provided that it can be demonstrated that the associated risks are as low as reasonably practicable (ALARP).

Swing ropes, cargo nets, cargo containers and rope ladders shall not be used for transfer of personnel.

8.4 Helicopter access and transfer

8.4.1 General

8.4.1.1 Deck areas

a) Helicopter decks and heli-hoist decks used for transfer of personnel and cargo by helicopter shall be fit for purpose.

Guidance note 1:
Local requirements for approval of helicopter decks:
— Denmark: Civil Aviation Administration (CAA)
— Germany: Federal Ministry of Transport, Building and Urban Development
— UK: Helideck Certification Agency (HCA Civil Aviation Administration (CAA))

b) Decks shall be located with a view to minimising hazards from obstructions, turbulence or vents, whilst providing a good approach path during prevailing weather conditions. The helicopter shall not be required to cross the unit or installation during such approaches.
Guidance note 2:
Turbulence around platform installations can be a large source of disturbance and present a significant safety risk to flight operations. Turbulence generators and, where applicable, engine, turbine or boiler exhausts should be taken into consideration and deck helicopter landing areas should be located upwind of major obstructions. Airflow studies may include wind tunnel testing and CFD analyses.

c) The diameter of the helicopter deck or landing area for single main rotor helicopters shall not be less than the overall length of helicopter including main and tail rotors running.

Guidance note 3:
Typical helicopter data are given in Chapter 3 Table 1 of CAP 437, Edition February 2013.

8.4.1.2 Communication

a) Helicopter and installation shall communicate through a VHF installation, maritime or aero mobile.

Guidance note:
An aero mobile VHF should be installed and licensed by the aviation authority of the coastal state for helicopter decks with frequent landings.

b) A portable VHF apparatus with earphones shall be available. Three-way communication between helicopter, helicopter deck and installation control room shall be possible.

8.4.1.3 Operation

a) For manned installations a competent person shall be appointed for control of helicopter deck operations on the installation.

b) To operate safely in varying offshore conditions at all times helicopters shall be afforded sufficient space. Helicopter performance depends on:
   — total helicopter mass
   — ambient temperature and barometric pressure
   — effective wind speed and direction
   — physical, thermal and airflow characteristics of the deck and its surroundings
   — operating technique.

Guidance note:
Limitations commonly apply to specific wind speeds and directions and may include restrictions to helicopter weight or suspension of flying. Well-designed helicopter decks result in effective and cost-efficient operations.

c) Wind speed and direction, air temperature and barometric pressure, visibility, cloud cover and, for floating installations, roll, pitch and heave shall be recorded and communicated to the helicopter before approaching. Simple instruments for this purpose shall be available.

d) When large vessels or crane barges operate close to the offshore substation, horizontal and vertical obstacle requirements set out in [8.4.2] and [8.4.3] may not be met, which can result in operating restrictions for the helicopter access and transfer. Crane work at the installation shall cease when helicopter movements take place.

e) Winching operations shall be conducted in accordance with procedures agreed by the helicopter operator and the local national civil aviation authority:
   — It shall be demonstrated that the risk is as low as reasonably practicable (ALARP).
   — Only twin engine helicopters of performance class 1 with a sufficient one-engine-inoperative hover capability for minimum 30 seconds shall be used for winching.
   — Night time and low visibility winching should be for emergency purposes only (e.g. for medical evacuation which cannot wait or impending loss of installation structural integrity).
8.4.2 Helicopter decks

8.4.2.1 Arrangement

a) Helicopter decks shall be designed for the largest and heaviest helicopter which is expected to land and take off (Figure 8-2).

![Figure 8-2 Helicopter deck layout](image)

b) Helicopter decks shall:
- be placed at or above the highest point of the main structure of the installation
- be preferably located in a corner of the installation with as large overhang as possible
- have an air gap under the deck large enough to facilitate a linear and clean air flow
- have a minimum of 2 access/egress routes and be oriented so that embarking or disembarking passengers do not have to pass around the tail rotor.

**Guidance note 1:**
A recommended overhang for large structures is such that the centre of the deck is above or outboard of the installation's topsides.
For shallow topsides an air gap of 1 m may be sufficient; very tall structures could require 3 to 5 m.
Vertical component of airflow should not exceed ±0.9 m/s for horizontal wind velocities up to 25 m/s over the landing area at main rotor height.
Where heat sources on the installation cause a temperature rise in air exceeding 2 K, operational restrictions may apply.

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C) The helicopter deck shall be located such that the obstacle free approach and take-off sector, 210° normally being required, gets the most efficient direction in connection to the prevailing wind conditions. This is in order to ensure that the approach and take-off sector and the landing area are as little as possible affected by turbulence from the structures. The level of turbulence for different wind conditions shall be evaluated. Where applicable, high temperature exhausts or vents shall be minimised and remain acceptable for all wind directions.
d) There shall be a clear zone below the landing area level over at least 180° with an origin at the centre of the D circle and with a falling gradient of 5 in 1 from the edges of the landing area to the surface of the sea. Ideally this gradient should clearly cover the whole of the 210° obstacle free sector and extend outwards for 1 km.

**Guidance note 2:**
The falling gradient may, for practical purposes, be defined from the outboard edge of the helicopter deck safety net.

e) Steel or other solid construction at perimeter may extend 50 mm above deck level.

f) In the approach sector, on and outside of the perimeter, only aids essential to helicopter operations are allowed to extend above the deck level, e.g. landing lights, floodlights, foam monitors and the outer edge of safety net.

**Guidance note 3:**
The maximum height above deck level should be according to governing regulations. For instance, part 6 chapter 1 of the DNV Rules for Classification of Ships, Edition January 2013, specifies 250 mm, while the 2009 MODU Code specifies 25 mm.

g) Within the limited obstacle sector of 150° height restrictions shall apply according to Figure 8-2.

h) Escape routes from the helicopter deck shall be arranged on the embarkation side and the rear side. The strength of stairways and walkways shall comply with the standard for walkways to and from the unit.

**Guidance note 4:**
Some authorities, such as the Norwegian CAA, require a third route for escape.

8.4.2.2 Structure

a) The design of structural elements shall be based on the most unfavourable of landing and stowed (helicopter lashed on deck) conditions. Both the normal operational and any identifiable accidental conditions shall be considered including loads such as:
  
  — landing impact forces (undercarriage with wheels, skids)
  — gravity and inertia forces of the helicopter in stowed position
  — wind, vortex shedding, snow, ice
  — personnel, cargo, fuelling equipment.

b) Helicopter decks shall be constructed in steel or aluminium and shall meet strength requirements given in Offshore Standard DNVGL-OS-E401, Helicopter Decks.

c) Landing platforms and landing areas in exposed positions shall be bordered by an about 50 mm high coaming to prevent personnel, helicopter or equipment from sliding off the helicopter deck. The border coaming shall not impede good drainage of water and any fuel.

d) The deck shall be surrounded by a gutter for collecting and draining fuel spills (including burning fuel) leaking out following an accident. The gutter shall be made of steel, see also [7.6].

8.4.2.3 Deck surface

a) The landing area should be as flush as possible to avoid damage on skids, wheels or pontoon.

b) The surface of the helicopter decks and landing areas shall be of such a nature or so equipped that the static coefficient of friction between the helicopter’s landing gear and the surface will be satisfactory in any weather condition. Deck coating and surface markings shall be made with non-slip material.

c) To prevent sliding in cold weather where there is a danger of icing, the surface shall either have a grid of ribs (for wheel helicopters) or shall be arranged for fitting a rope net, which shall be kept on the installation.

d) The rope net shall have a size at least as given in Figure 8-1. The rope net shall be secured at every 1.5 m around. Mesh size and tightening shall be such as to avoid hooking of helicopter substructure.
8.4.2.4 Tie-down points

a) Helicopter decks shall have tie-down points for lashing of the helicopter. The tie-down points shall not protrude above the level of the helicopter deck.

Guidance note:
Helicopter operators and national aviation authorities can advise on correct tie-down point configurations. A particular problem may be on how to prevent them filling up with ice without having drain holes providing leak paths to lower areas of the installation.

b) The breaking load of the tie-down points for helicopters calling at the installation should be confirmed by the helicopter operator or manufacturer.

8.4.2.5 Safety net

a) Landing platforms and landing areas in exposed positions shall be surrounded by a safety net not less than 1.5 m wide (in the horizontal plane). The safety net shall have an upward and outboard slope of about 10° from deck level or just below to slightly above the level of the landing area, but by not more than 250 mm.

b) The netting shall be flexible and of a non-flammable material. The flexibility and tightening of the safety net shall be chosen to avoid rebounding. The number and shape of rails and bracket shall be chosen to minimise injuries.

c) The test load for safety net and safety net supporting structure surrounding a helicopter deck shall not be taken less than 75 kg dropped from 1 m height.

Guidance note:
Local requirements for safety net strength:
— UK: The net should be strong enough to withstand and contain a 100 kg load dropped from 1 m.

8.4.2.6 Marking

a) The helicopter deck shall be marked with the installation identification.

b) The perimeter of the helicopter deck shall be marked with a white line, the width of which shall comply with local requirements. Preferred colours of the deck within the perimeter line are dark grey and dark green.

c) An aiming circle that shall be a 1 m wide yellow line with inner diameter 0.5 D shall be painted in a location specified by national authorities. D denotes the diameter of the helicopter deck.

Guidance note:
Local requirements for aiming circle placement:
— Denmark: 0 to 0.1 D from centre towards outboard edge
— Norway: In deck centre
— UK: 0.1 D from centre towards outboard edge, except for a mid-installation cross flight channel.

d) A letter “H” shall be painted 4 × 3 m of 750 mm white lines located in the centre of the aiming circle with the mid-bar of the H located along the midline of the approach sector.

e) Maximum gross mass on the deck should be provided as a non-ambiguous value.

The advised information differs locally. It will generally consist of the mass in tons expressed in two or three figures and followed by the letter “t”.

### Table 8-1 Net size

<table>
<thead>
<tr>
<th>Deck diameter (m)</th>
<th>Net size (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>below 14</td>
<td>6 × 9</td>
</tr>
<tr>
<td>14 to 17</td>
<td>9 × 9</td>
</tr>
<tr>
<td>17 to 22</td>
<td>12 × 12</td>
</tr>
<tr>
<td>above 22</td>
<td>15 × 15</td>
</tr>
</tbody>
</table>
f) The maximum helicopter D value in m, used for the approval, shall be inserted in the perimeter at mid-line of approach sector and 90° to each side in a contrasting colour to the deck.

g) Obstacles that the helicopter operator should be especially aware of, e.g. lattice tower structures and crane booms close to helicopter decks, shall be attention painted in diagonal stripes of contrasting colour.

The requirements by national aviation authorities shall be observed.

8.4.2.7 Night operation marking and lighting

a) A floodlight should be arranged for night operations, with care not to dazzle the pilot.

b) Lights should be fitted on the perimeter line, maximum 3 m apart. The intensity of lighting should be 25 candela (cd) (when fitted with necessary filters and shades). The lighting should not be visible below the helicopter deck level.

   Guidance note:
   Lighting colour should be according to governing regulations. Green perimeter lighting should be used.

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c) Floodlight and perimeter lights should be connected to the emergency power system.

d) All significant obstacles shall be indicated by red obstruction lights visible from all directions or floodlighting or a combination of both.

8.4.2.8 Fuelling facility

Where a fuelling facility is planned, the following should be considered. General requirements for fuel tanks see [7.3].

a) A designated area should be provided for the storage of fuel tanks which should be:
   1. as remote as is practicable from accommodation spaces, escape routes and embarkation stations
   2. isolated from areas containing a source of vapour ignition.

   (2009 MODU Code 9.16.6.1)

   Guidance note:
   Helicopter fuel with a flash point (closed cup method) of more than 10°C above maximum ambient temperature for the installation may be treated as not giving rise to hazardous areas.

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b) The fuel storage area should be provided with arrangements whereby fuel spillage may be collected and drained to a safe location.

   (2009 MODU Code 9.16.6.2)

c) Tanks and associated equipment should be protected against physical damage and from a fire in an adjacent space or area.

   (2009 MODU Code 9.16.6.3)

d) Where portable fuel storage tanks are used, special attention should be given to:
   1. design of the tank for its intended purpose
   2. mounting and securing arrangements
   3. electrical bonding
   4. inspection procedures.

   (2009 MODU Code 9.16.6.4)

e) Storage tank fuel pumps should be provided with means which permit shutdown from a safe remote location in the event of a fire. Where a gravity-fuelling system is installed, equivalent closing arrangements should be provided to isolate the fuel source.

   (2009 MODU Code 9.16.6.5)
f) The fuel pumping unit should be connected to one tank at a time. The piping between the tank and the pumping unit should be of steel or equivalent material, as short as possible and protected against damage.  
(2009 MODU Code 9.16.6.6)

g) Electrical fuel pumping units and associated control equipment should be of a type suitable for the location and potential hazard. 
(2009 MODU Code 9.16.6.7)

h) Fuel pumping units should incorporate a device which will prevent over-pressurisation of the delivery or filling hose.  
(MODU Code 9.16.6.8)

i) The procedures and precautions to be followed during refuelling operations should be in accordance with recognised safe practices and contained in the operations manual. 
j) (2009 MODU Code 14.2.2) All equipment used in refuelling operations shall be properly electrically bonded and earthed.  
(Interpretation of 2009 MODU Code 9.16.6.9)

8.4.2.9 Fire protection

a) The construction of the helidecks should be of steel or other equivalent materials. If the helideck forms the deckhead of a deckhouse or superstructure, it should be insulated to A-60 class standard, as defined in [1.4]. If aluminium or other low melting point metal construction that is not made equivalent to steel is used and the helideck is located above a deckhouse or similar structure, the following provisions should be satisfied:

a. the deckhouse top and bulkheads under the helideck should have no openings
b. windows under the helideck should be provided with steel shutters.  
(Interpretation of 2009 MODU Code 9.16.2)

b) A helideck should be provided with both a main and an emergency means of escape and access for firefighting and rescue personnel. These should be located as far apart from each other as is practicable and preferably on opposite sides of the helideck.  
(Interpretation of 2009 MODU Code 9.16.3)

c) In close proximity to the helideck, the following fire-fighting appliances should be provided and stored near the means of access to that helideck:

1) at least two dry powder extinguishers having a total capacity of not less than 45 kg but not less than 9 kg each
2) carbon dioxide extinguishers of a total capacity of not less than 18 kg or equivalent
3) a foam application system consisting of monitors or foam-making branch pipes capable of delivering foam to all parts of the helideck in all weather conditions in which the helideck is intended to be available for helicopter operations. The minimum capacity of the foam production system will depend upon the size of the area to be protected, the foam application rate, the discharge rates of installed equipment and the expected duration of application:
   a. a minimum application rate of 6 l/m² within a circle having a diameter equal to the D-value
   b. a minimum of 5 min discharge capability should be provided
   c. foam delivery at the minimum application rate should start within 30 s after system activation.
4) the principal agent should be suitable for use with salt water and conform to performance standards not inferior to those acceptable to the Organization¹

¹ Refer to the International Civil Aviation Organization Airport Services Manual, part 1, Rescue and Fire Fighting, chapter 8, Extinguishing Agent Characteristics, paragraph 8.1.5, Foam Specifications table 8-1, level ‘B’.
5) at least two nozzles of an approved dual-purpose type (jet/spray) and hoses sufficient to reach any part of the helideck.  
(Interpretation of 2009 MODU Code 9.16.4.1-5)
Guidance note:
A deck integrated firefighting system (DIFFS) for spray distribution of foam is an alternative to fixed monitor systems and particularly useful for normally unmanned installations.

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d) Drainage facilities in way of helidecks should be:

1) constructed of steel or other arrangements providing equivalent fire safety
2) lead directly overboard overboard independent of any other system
3) designed so that drainage does not fall onto any part of the unit.
(2009 MODU Code 9.16.5)

8.4.2.10 Rescue equipment

Necessary rescue tools/equipment shall be provided in proximity of the helicopter deck. It is recommended that at least one set of the following equipment is available. Size of equipment should be appropriate for the types of helicopter expected to use the facility. Required tools should include:

— adjustable wrench
— large rescue axe (non-wedge or aircraft type)
— crowbar
— bolt cutters, 600 mm
— large crowbar
— grab or salving hook
— hacksaw heavy duty complete with 6 spare blades
— fire resistant blanket
— ladder for access to casualties in an aircraft on its side
— side cutting pliers
— set of assorted screwdrivers
— harness knife complete with sheath (*)
— fire resistant gloves (*)
— self-contained breathing apparatus (complete)
— power cutting tool (for helicopters with an overall length of 24 m and upwards)
— lift line 5 mm diameter and 30 m in length
— protective equipment in accordance with [3.6] (*).

(*) required for each helicopter deck crew member.

8.4.2.11 Additional requirements for not permanently manned installations

In addition to the provisions given above, the following should be considered for installations which are not permanently manned:

— helicopter ‘wave-off lights’ to provide visual warning to a helicopter pilot that the installation is in an alarm condition
— a passive fire-retarding surface in combination with an automatically activated fixed monitor system or a deck integrated firefighting system (DIFFS)
— perimeter and floodlighting which should remain permanently on or be controlled by a light sensitive switch with a manual override facility operable locally and remote where flights at night are foreseeable (including for evacuation purposes)
— regular monitoring for the degradation of lighting, markings, safety nets.
8.4.3 Heli-hoist decks

8.4.3.1 Arrangement
Winch areas shall comply with the following (Figure 8-3):

— An ‘outer manoeuvring zone’ with a minimum diameter of $2 \times D$ shall be provided, where $D$ denotes the diameter of the winch manoeuvring zone.
— There should be no obstructions higher than 6 m within the manoeuvring zone.
— Within the manoeuvring zone, a ‘clear area’ should be centred. This clear area should be at least 5 m in diameter and should be a solid surface.
— There should be a ‘inner manoeuvring zone’ centred within the manoeuvring zone with a minimum diameter of $1.5 \times D$ where no obstructions higher than 3 m are present.
— Part of the manoeuvring zone, outside the clear zone, may be located beyond the installation’s boundary, but should comply with the obstruction requirements shown in Figure 8-3.
— Thermal radiation and air turbulence caused by the installation shall be considered when designing and locating winch-only helidecks.

![Figure 8-3 Winching area layout (acc. CAP 437)](image)

8.4.3.2 Marking
a) All dominant obstacles within, or adjacent to the manoeuvring zone should be conspicuously marked.
b) Lighting shall be arranged for emergency operations at night, with care not to dazzle the pilot.
c) Areas shall be clearly marked “WINCH ONLY” in white writing so as to be clearly visible by the pilot.

8.5 Ascending and descending

8.5.1 General
The design of deck and platform surfaces, walkways, stairs, ladders, handrails and fenders shall be such that the potential for slips, trips, falls and trapped fingers is minimised. Drainage and easy cleaning, e.g. from oil contaminants, where relevant, shall be possible.

Where offshore substations have more than one deck, they should be equipped with suitably sized and positioned stairs.
Adequate lighting and emergency lighting shall be provided.

Measures against unauthorised access should be considered and balanced against the potential need for access in emergencies, e.g. by mariners in distress. Temporary barriers, locks, chains, mechanical clamps shall be considered for working areas.

8.5.2 Design

8.5.2.1 Working areas

a) Safe working areas shall be provided.

b) Working platforms and walkways shall be designed and constructed in accordance with ISO 14122-2.

c) Barriers shall be fitted at openings direct to sea, see also [5.6.3].

8.5.2.2 Stairs

Stairs should be preferred over ladders. Where stairs are used, they should be designed according to ISO 14122-3 and the following criteria shall be met:

— Spiral or helical stairs shall not be used due to the reduction in tread towards the centre of the stairway and the risks associated with emergency access and egress.

— Companion-way ladders with an inclination of between 65° and 75° shall not be used as a person may attempt to run down facing forward in panic conditions.

8.5.2.3 Retractable stairs

Where retractable stairs are used, the following criteria shall be met:

— Design of stairs, intermediate platforms and associated structures shall comply with ISO 14122.

— An alternative escape route shall be provided or emergency power supplies and/or a method of manually lowering the stairs in an emergency shall be provided.

8.5.2.4 Lifts

Powered personnel hoists (lifts) may be considered for large, multi-level installations. Where lifts are used, the following criteria shall be met:

— Either an alternative escape route shall be provided or emergency power supplies and/or a method of manually lowering oneself in an emergency shall be provided.

— The lift should be clearly marked at the operator's location with the maximum number of people it can carry.

— Any lift shall meet requirements of the local regulations and shall be inspected, tested and maintained in accordance with requirements in these regulations.

Guidance note:

Local requirements:

— Europe: European Use for Work Equipment Directive 89/655/EEC

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8.5.2.5 Ladders

Ladders and associated intermediate platforms or structures shall comply with ISO 14122 and should only be used where the following minimum criteria are met:

— It is demonstrated that stairs or a lift are not a reasonably practicable option.

— A maximum ladder height of 6 m shall be used where practicable. An intermediate or rest platform should be installed where ladder runs are higher than this and where they could not be impacted by a vessel during fendering and transfer operations. Where impracticable, it shall be demonstrated that a person can rest using a suitable fall arrest system without impacting its operability through such operations.
**Guidance note 1:**
Tidal variations may require single ladder heights in excess of 6 m. Where ladders longer than 9 m are required, a resting platform should be fitted. The platform should remain clear of the transfer vessel at the highest astronomical tide.

---end---of---guidance---note---

— At the upper part of the ladder either safety cages (hoops) with at least 5 vertical slats or a fall arrest system (meeting local requirements) with appropriate harness anchor points shall be installed.

**Guidance note 2:**
Local requirements for fall arrest systems:
— Europe: EN 353-1 and -2: Personal protective equipment against falls from a height. Guided type fall arresters including a rigid / flexible anchor line.

Some fall arrest systems deform when sufficient load is applied to them and as such would be unusable after one use.

---end---of---guidance---note---

— Ladder rungs should be square with an edge facing upwards to minimise the risk of slipping in wet, icy or fouled conditions.
— Self-closing gates which meet the requirements of ISO 14122-4 shall be used at the top of ladders. A “hatch open” lock should be fitted.

**8.5.2.6 Railings and barriers**

a) Railings and other barriers shall be designed with sufficient strength, height and arrangement such that personnel are protected from falling either overboard or more than 0.5 m to a lower deck level.

b) Guard-rails shall be designed and constructed in accordance with ISO 14122-3. They shall be installed when the height of the potential fall exceeds 0.5 m. Hand rails shall be at least 1.1 m high. At least one intermediate knee rail shall be no more than 0.5 m from the hand rail or the toe plate. The toe plate shall be 100 mm high and no more than 10 mm from the walking level and the edge of the platform.

**Guidance note:**
Reference is made to NORSOK-C-002 Section "Handrails, guardrails and barriers".

---end---of---guidance---note---

c) Handrails for access to helicopter decks may have to be retractable, collapsible or removable in order to satisfy the applicable height limitations.

**8.6 Marking**

**8.6.1 General**

Marine access systems shall be marked according to [8.3].

**Guidance note:**
The Standard Marking Schedule for Offshore Installations provides guidance for the size of markings. In general, markings which can be read from 20 m away in the most severe foreseeable weather and visibility conditions for personnel transfer are acceptable.

---end---of---guidance---note---

Helicopter decks shall be marked according to [8.4.2.6] and [8.4.2.7]. Heli-hoist decks shall be marked according to [8.4.3.2]. In addition, a wind direction indicator (windsock) shall be provided.

In fuel storage areas “NO SMOKING” signs should be displayed at appropriate locations.
SECTION 9  EMERGENCY RESPONSE

9.1  Introduction
This section provides principles, requirements and guidance for the design of adequate and effective facilities for safe and controlled emergency response during defined accidental events when the installation is manned. This includes:

— routes which allow personnel to escape from the immediate effects of a hazardous event to a muster area
— provision of muster area which will protect personnel from the effects of an emergency for the time required for incident assessment and controlled evacuation
— rescue of injured personnel
— safe evacuation of the unit or installation.

Sections of this standard containing important information related to access and transfer include:

— Sec.3, arrangement principles
— [8.3], vessel transfer
— [8.4], helicopter transfer
— [8.5], ascending and descending.

Requirements for emergency response strategy, rescue and evacuation means and safety equipment are not included in this standard. Relevant local requirements for flagged units and/or coastal state requirements shall be applied.

Guidance note:
Local requirements:
— UK: Prevention of Fire and Explosion and Emergency Response on offshore installations Regulations (PFEER) 1995, Health and Safety Executive Construction Design and Management (CDM) regulations

9.2  Design principles

9.2.1  General
The objective of emergency response planning is to ensure that systems and procedures are provided as suitable and effective to safeguard personnel and plant against hazardous events (see Appendix B) on the installation to:

— maintain the safety of persons in emergency situations
— provide temporary safe areas
— facilitate escape, evacuation, rescue and recovery of persons.

The emergency response planning should follow an iterative process as depicted in Figure 9-1. After defining the design objectives the performance criteria shall be established. Credible emergency scenarios shall be developed and an analysis shall determine whether the design meets the performance criteria. Deviations shall be addressed by design improvements.
9.2.2 Safety criteria and evaluation

Performance criteria for emergency response shall be aligned with those defined in the formal safety assessment. An important consideration is the time required to escape, muster and evacuate taking into consideration human factors and casualties. Acceptance criteria include, for instance:

— time for detection of an abnormal, hazardous situation
— time to escape and muster
— time for evacuation using primary and secondary methods
— time for rescue and recovery vessel or helicopter to arrive
— time a person may have to spend in water.

9.2.3 Design basis

Boundary conditions for emergency response measures which shall be considered to be included, but are not limited to:

— environmental and oceanographic conditions
— installation location and availability of emergency services
— layout of the installation and arrangement of equipment
— location of sources of hazardous events
— manning philosophy, distribution of persons and human factors
— normal means of access to and egress from the installation.

9.2.4 Design process

At the beginning of the design process applicable local regulations shall be clarified.

Activities that could lead to emergency situations shall be described, building on the safety assessment process described in [2.3], including, for instance:

— normal work activities
— installation or repair
— transportation, transfer and storage of explosive, flammable or toxic materials
— other hazardous activities.

All foreseeable emergency situations relevant for the offshore substation, the whole wind farm and conditions that might follow shall be considered for development of representative emergency scenarios, including, for instance:
— fire or explosion on the offshore substation, manned and unmanned, including the effects of radiated heat and smoke
— walking/stretcher casualties
— man overboard
— stranded by weather
— incapacitated support vessel.

Initial layout and arrangements of the installation and the performance of the emergency response facilities and procedures (including command and training) shall be subject to a structured review by means of an escape, evacuation and rescue analysis. In each of the representative scenarios the adequacy, availability and survivability of the systems shall be considered, taking redundancies into consideration. The electrical energy available to supply all services essential for safety in an emergency shall be assessed, due regard being paid to simultaneous operation of all services.

A smoke ingress analysis can be included in order to ensure that the temporary safe area can, for an adequate period, remain free of smoke.

Based on the findings, improvements and optimisations shall be made and the requirements for the following systems shall be fulfilled:
— emergency power supply, [5.6]
— alarms and communications, [9.3]
— shutdown, [9.4]
— escape routes (including bridge links to other installations if appropriate), [9.5]
— mustering facilities and temporary safe areas, [9.6]
— means of escape and evacuation such as helicopter, helicopter and heli-hoist deck operation, lifeboats, life rafts, crane transfer and escape chutes, [9.7]
— means of rescue and recovery such as emergency response and rescue vessel (ERRV), SAR helicopters and marine craft in the vicinity of the installation, [9.8].

A system for tracking (number of persons and which persons) all persons on an installation shall be established.

The tracking system is often a tally system, which does not have to be at the installation.

The requirements in [9.3] through [9.9] shall be considered as minimum requirements except where stated otherwise.

**9.3 Alarms and communications**

**9.3.1 General**

Communication and alarm systems shall be provided to alert all personnel on board, at any location, of an emergency. The systems shall be suitable to provide instructions for emergency response.

Alarms initiated from the following systems shall be provided where relevant:
— general emergency alarm or muster
— man overboard call point
— fire and gas detection
— fire extinguishing medium release (CO2 or other extinguishing gas flooding systems)
— power-operated watertight door closing (floating installations)
— major equipment fault detection or shutdown.

An alarm system comprises of the following as relevant:

— manual alarm input devices
— input lines from detector and shutdown systems
— alarm central unit receiving and evaluating input signals and creating output signals to alarm sounding devices
— alarm sounding devices such as bells, flashing lights and/or loudspeakers
— power supply.

Guidance note:
Requirements to public address, general alarm and two way voice communication systems are described in IMO document MSC/Circ.808, 30 June 1997.

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9.3.2 Requirements

An alarm philosophy shall be established ensuring that the alarms are simple and unambiguous. The philosophy shall define which alarms are broadcast to the entire installation and whether this should occur automatically or not.

The number of alarms during abnormal conditions shall be assessed and reduced as far as practicable by alarm processing and/or suppression techniques in order to have operator attention on the most critical alarms that require operator action.

All alarms shall be indicated visually and audibly in the control centre. The alarms shall be clearly audible at all locations on the installation, and shall be easily distinguishable. If noise in an area prevents the audible alarm being heard a visible means of alarm shall be provided. Installation alarms shall also be audible from the lowest access platform or ladder.

The installation shall be equipped with a public address system. The alarm system may be combined with the public address system, provided that:

— alarms automatically override any other input
— volume controls are automatically set for alarm sounding
— all parts of the public address system (e.g. amplifiers, signal cables and loudspeakers) are made redundant
— redundant parts are located or routed separately
— all loudspeakers are protected with fuses against short circuits.

Alarm to areas which are not regularly manned (e.g. cofferdams, tanks) may be covered by procedural precautions, e.g. using portable radios.

Activation of the general alarm shall be possible from the main control stations.

In addition to the alarm systems, a two-way communication system shall be provided for transmittal of alarm, instructions and information between those who may require them.

The alarm and communication system shall be powered in accordance with [5.6].

Requirements for alarms in connection with watertight doors and release of hazardous fire extinguishing medium are given in DNVGL-OS-C301 and DNVGL-OS-D301.

The alarm system shall be regularly tested.
9.3.3 External emergency communication

Appropriate arrangements and systems shall be provided for communication in all foreseeable emergency scenarios between:

- the installation and persons not on the installation, but engaged in activities in connection with the installation
- the installation and persons beyond the installation.

These arrangements and systems shall remain effective in an emergency.

At a minimum, at least two portable VHF radios shall be provided with spare batteries along with an additional method of communication such as mobile phones or a satellite phone with a backup power supply. Requirements of [5.6] shall be observed.

9.4 Shutdown

9.4.1 General

The shutdown system comprises:

- a control unit receiving and creating signals
- input devices and transfer lines
- output actuators (e.g. relays) and transfer lines
- interfaces towards other safety systems (e.g. fire detection, gas detection, alarm and communication systems, firefighting systems, ventilation systems).

The shutdown system shall be designed so that the risk of unintentional shutdown caused by malfunction or inadvertent operation is minimised. It shall allow testing without interrupting other systems on the installation. It shall be continuously available and fulfil the requirements of [5.6].

9.4.2 Shutdown philosophy

The shutdown philosophy shall comprise functional requirements for the safety systems upon detection of an abnormal condition.

The shutdown philosophy shall be focused on the following targets:

- limit the duration and severity of the incident, revert the process to a safe state
- protect personnel exposed to the incident
- limit environmental impact
- facilitate escape, muster and evacuation, as necessary
- prevent unintended startup of the process until the cause of the incident has been corrected.

Inter-relationships and requirements for other safety systems shall be addressed.

Upon failure of the shutdown system, all connected systems shall default to the safest condition for the installation (fail-safe functionality). The safest conditions for the systems shall be defined.

Failures to be considered for the shutdown system shall include broken connections and short circuits on input and output circuits, loss of power supply and if relevant loss of communication with other systems.

9.4.3 Shutdown logic

Shutdown shall be executed in a pre-determined, logical manner. Definition of the logic and required response time shall include consideration of interactions between systems and dynamic effects.

Shutdown logic shall implement the results of iterative design process described in [9.2].

Shutdown logic shall be implemented to determine the response to different degrees of emergency or upset condition and can comprise (but shall not be limited to) the following shutdown levels:

- total substation shutdown
— system shutdown
— equipment shutdown.

Total substation shutdown can be required in the case of catastrophic criticality of an incident e.g. in the case of HV transformer explosion.

Total substation shutdown
— can require disconnection of the offshore substation from the grid
— may not stop or impede the operation of emergency consumers (among others active fire protection, emergency lighting, navigation aids).

System shutdown can be required in the case of severe criticality of an incident e.g. in the case of fire in auxiliary generator room.

System shutdown
— should not disconnect the offshore substation from the grid
— shall isolate an entire unit or area involved in a fire or other emergency
— may not stop or impede the operation of emergency consumers (among others active fire protection, emergency lighting, navigation aids).

Equipment shutdown is required in the case of major to slight criticality of an incident e.g. in the case of exceedance of operating limits of centrifugal pumps, separators, diesel engines, electric motors, generators and similar subsystems.

Equipment shutdown shall serve to stop the affected equipment or subsystem and bring it to a safe state.

Depending on the shutdown level attributed to a particular incident, following actions or their combinations can be required to achieve the targets set in shutdown philosophy:
— shutdown of HV equipment
— disconnection of the offshore substation from the grid
— start-up of auxiliary power supply
— taking-over of emergency consumers by transmission/emergency source of power
— shutdown of diesel oil transfer system, activation of its shut-off valves
— shutdown of power ventilation
— stop of the batteries charging
— closure of doors and ventilation openings
— initiation of audible siren signalling, visual warning, automatic announcements
— automatic orientation of CCTV cameras to the incident location.

Shutdown shall not result in adverse cascade effects which depend on activation of other protection devices to maintain a substation in a safe condition. The shutdown system shall be designed to ensure that any ongoing operations can be terminated safely when a shutdown is activated.

Any shutdown level shall initiate an alarm at the (onshore) control station. The initiating device and operating status of devices affected by the shutdown action shall be indicated at the control station. Automatic reset shall be prohibited, local or remote reset is required.

Personnel lifts, work platforms and other man-riding equipment shall be designed to enable safe escape after an emergency shutdown, e.g. by controlled descent to an access point on a lower level.

Plants that are protected by automatic safety systems shall have pre-alarms to alert when operating parameters are exceeding normal levels.

The shutdown command shall not be automatically reset. Significant shutdown devices shall be reset locally following recognition and reset at the main control room.
9.4.4 Manual and automatic shutdown

Systems which are not permanently attended during operation, and which could endanger safety if they fail, shall be provided with automatic safety control, alert and alarm systems. Shutdowns shall normally be automatically initiated.

Manual activation of all levels of shutdown shall be possible at the main control station.

Other manual shutdown buttons shall be located at strategic points on the installation.

Manual shutdown buttons shall be protected against unintended activation and be provided with clear label describing the extent of the system being shut down.

The shutdown system shall contain provisions for testing functionality as well as input and output devices.

9.5 Escape routes

9.5.1 General

Safe, direct and unobstructed exits, access, and escape routes to muster areas and embarkation or evacuation points shall be provided from all areas needed to be temporary or regularly attended by personnel.

Guidance note 1:
Accommodation, offices, galleys, locker rooms, mess areas, control rooms, workshops, cranes and muster areas are generally considered to be normally manned. Telemetry cabins, battery rooms and areas which are generally occupied for less than 5% of the time that the installation is attended can be considered normally unmanned.

All areas temporary or regularly attended by personnel shall be provided with at least two exits and escape routes, separated as widely as practicable such that at least one exit and the connected escape route will be passable during an accidental event. Escape routes to muster areas should be provided on both sides of the unit or installation.

Single exists may be used for small rooms where personnel rarely spend time, but no dead ends may exceed 7m. Switchboards more than 7 m long shall not form dead end corridors; two escape routes shall be available.

Guidance note 2:
Dedicated escape routes need not necessarily apply to very infrequently manned areas, e.g. which are subject to structural inspection only, where suitable arrangements can be made with temporary access facilities (e.g. scaffolding). Single exits may be acceptable from small access platforms, rooms and cabins with low vulnerability.

Two means of escape shall be provided from every machinery space such as those containing major electrical equipment. Where the machinery space is below open deck level the means of escape shall be according to DNVGL-OS-A101 [5.2.4].

Guidance note 3:
The number of means of escape may be reduced based on a consideration of the nature and use of the space and the normal level of manning within the space (MODU Code 9.4.2).

Personnel shall be able to use the escape routes without being exposed to excessive toxic fumes, smoke or unacceptable heat loads, hot liquids or falling objects. Special consideration is to be given to routing of medium and high voltage cables in escape routes.

Guidance note 4:
Escape routes are normally considered to be impaired when personnel would not be able to pass along them in normal offshore clothing at a normal walking pace without risk of injury.

Escape routes shall be of suitable size to enable quick and efficient movement of the maximum number of personnel who may require using them, and for easy manoeuvring of fire-fighting equipment and use of stretchers.

Typical widths of escape routes are 1 m for main escape routes and 0.7 m for secondary escape routes, with consideration given to areas for manoeuvring a stretcher. Escape routes shall have adequate vertical clearance. The height shall be 2.2 m, but may locally be reduced to 2.0 m.
9.5.2 Doors, stairs, ladders and lifts

Any necessary changes in elevation along escape routes shall be by stairs. Ladders may only be accepted where it is clearly not practicable to install stairs, and only for use by a very limited number of persons in an emergency.

Lifts shall not be considered as an emergency means of escape.

All escape route doors shall be readily operable in the main direction of escape or be sliding doors and shall not be a hazard to personnel using the escape route outside. Doors from cabins and small offices are excluded from this requirement.

**Guidance note:**

For rooms where human activity is high when the platform is manned, it should be considered to equip the doors with vertical oriented push-door lever handles (i.e. possible to open doors also when crawling along the floor, typically if the room is full of smoke).

---end-of-guidance-note---

9.5.3 Emergency lighting

All areas temporary or regularly attended by personnel shall be equipped with emergency lighting, which is supplied from the emergency source of power. The illumination level shall be sufficient to ensure that necessary emergency response actions, including reading of signs and layouts, can take place efficiently.

Access routes, exit points, escape routes, muster areas, embarkation stations, launching areas and the sea below life-saving appliances shall be adequately illuminated by emergency lighting so they are readily identifiable in an emergency.

9.6 Muster areas

9.6.1 General

At least two easily accessible muster areas (primary and secondary) shall be clearly defined and separated from each other as widely as practicable on the unit or installation.

All muster areas shall be located close to arrangements for evacuation (embarkation stations, survival craft launching stations, helicopter deck). Direct and ready access to survival craft or other life-saving appliances shall be provided to enable a safe and efficient evacuation or escape from the installation.

All muster areas shall be suitably sized to enable efficient accounting of personnel and donning of personal protective equipment. Areas shall be suitably arranged to enable movement of stretchers.

**Guidance note 1:**

Each muster station should have sufficient clear deck space to accommodate all persons assigned to muster at that station, at least 0.35 m² per person and 0.7 m² or more being preferred.

---end-of-guidance-note---

Muster areas shall be provided with suitable protection and facilities, including lighting and communications, for use in identified accidental events.

**Guidance note 2:**

The suitable protection will depend of the risk exposure including PoB, distance to shore, manning frequency and duration etc.

---end-of-guidance-note---

9.6.2 Primary muster area

A primary muster area (sometimes called the temporary refuge, shelter area or safe haven) is provided to protect personnel from the effects of an emergency which is beyond immediate control. Protection (if required) shall be sufficient to allow controlled muster, emergency assessment, incident evaluation, and implementation of control emergency procedures and evacuation. The primary muster area should be provided with adequate command communication facilities to address an emergency and organise safe evacuation if necessary.

Primary muster areas for substation shall protect for all hazards determined using a formal safety assessment and shall include fire, smoke and ventilation protection hazards.

The primary muster area should remain unimpaired by excessive toxic fumes, smoke, unacceptable heat loads, hot liquids and falling objects for up to 30 minutes after all reasonably foreseeable incidents begin.
Guidance note:
Impairment of the primary muster area could be due to:
— loss of structural support or failure of walls allowing entry of fire and smoke
— deterioration of internal conditions due to external smoke, gas, heat, loss of oxygen, internal fumes or fire, when personnel would not be able to pass along them in normal offshore clothing at a normal walking pace without risk of injury
— loss of command functions necessary for monitoring and control of the incident and for organising evacuation.

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9.7 Evacuation

9.7.1 General
Arrangements shall be made, to the extent necessary, for provisions on the offshore substation or with suitable persons beyond, that will ensure, so far as is reasonably practicable, the safe evacuation of all personnel from the platform. Persons shall be taken to a place of safety or to a location from which they can be recovered and taken to such a place.

Means of evacuation offer protection from the hazard and have their own motive power to enable persons to move quickly away from the installation. Such means may include:
— davit launched or free fall lifeboat
— transfer or rescue vessel equipped with appropriate arrangements for personnel transfer operations
— helicopter.

Arrangements shall be made to ensure, so far as is reasonable practicable, the safe escape of all persons from the offshore substation in case evacuation arrangements fail. This may involve entering the sea.

Several locations on the installation should enable persons to escape to the sea. Means of escape which assist with descent to sea, such as davit launched or throw-over life rafts, lifebuoys, chute systems, doughnuts, cargo nets or ladders, shall be provided.

All offshore substations shall have at least one launchable life raft which can take the maximum number of persons on the installation. In addition, the following applies:
— unmanned installation: When the offshore substation is manned, an emergency response and rescue vessel (ERRV, [9.8.2]) shall be in the vicinity of the installation. The ERRV shall be equipped with fast rescue craft
— manned installation: At least one launchable lifeboat with the capacity of maximum manning shall be available. Should manning ever exceed the boat’s capacity, additional provisions shall be made.

Guidance note 1:
Life-saving appliances must be approved in accordance with local national legislation.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

Lifeboats should remain unimpaired by excessive toxic fumes, smoke, unacceptable heat loads, hot liquids and falling objects for up to 30 minutes after all reasonably foreseeable incidents begin.

Guidance note 2:
Lifeboats are normally considered to be impaired when personnel would not be able to board and launch them in normal offshore clothing without experiencing increased risk of accidents.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

9.8 Rescue and recovery

9.8.1 General
Arrangements shall be made to enable persons to be recovered or rescued from the sea or near the installation to a place of safety. Such arrangements are:
— facilities and services external to the installation, such as vessels, public sector and commercially provided search and rescue facilities
— facilities on the installation such as installation based fast rescue or man-overboard craft.
**Guidance note:**
A place of safety is defined as an onshore or safe offshore location or vessel where medical treatment and other facilities for the care of survivors are available. It must be available in all but exceptional weather and sea conditions and these exceptional conditions must be defined by the operator. Initial treatment of casualties must be provided for immersion (e.g. cold shock, hypothermia, near drowning). The conditions must be suitable to ensure a good prospect of recovery and survival of casualties.

---end---of---guide---note---

Incidents to be considered shall include a person falling overboard or a helicopter ditching on landing or take-off.

**Guidance note:**
Normally persons should be rescued from the water within less than 2 hours (depending on clothing, water temperatures, extent of injuries, etc.). In most cases, this means that ERRV arrangements should be in place if the installation is more than 10 nautical miles from a place of safety (e.g. the nearest manned installation or port).

---end---of---guide---note---

Arrangements for recovery and rescue should take into account:

— the number of persons who may need to be rescued or recovered
— the capacity, remoteness and response times of the rescue and recovery services
— potential limitations on availability, daytime, weather conditions and sea states
— the need to cover all stages of the operation
— the nature of work activities being carried out (e.g. over side/under deck work would require a dedicated rescue craft).

Arrangements shall be regarded as being effective if they secure a good prospect of persons being recovered, rescued and taken to a place of safety, onshore or offshore, where medical treatment and other facilities for care are available.

**Guidance note:**
"Good prospects" exist when arrangements yield a high probability in all but the most severe storm conditions and sea states, of rescuing and recovering persons and taking them to a place of safety.

---end---of---guide---note---

### 9.8.2 Emergency response and rescue vessels

The ERRV and its support fast rescue craft (FRC) should be staffed by an adequate number of competent, medically trained crew which is ready to carry out their full range of duties.

**Guidance note:**
A fast rescue craft (FRC) is a high speed, manoeuvrable craft which may have an enclosed cabin for crew and survivors, deployed from an ERRV for the purposes of rescue and recovery of survivors and marshalling or towing life rafts. As a minimum, an ERRV should be within 10 nautical miles or 1 hour of a place where casualties may need to be recovered. This may have to be reduced in adverse weather and sea states or low visibility.

---end---of---guide---note---

When a vessel is provided it should be maintained in a position most suitable for the rescue and recovery functions, taking into account on-going work activities. Such vessels may be shared between installations if this does not compromise the prospects of rescue and recovery.

The fast rescue craft shall be equipped with adequate means of communicating with the ERRV by radio and carry an adequate portable searchlight.

### 9.8.3 Transfer vessels

A vessel used for the transfer of personnel to and from an installation may be used as a means of rescue or recovery (e.g. as an ERRV) if requirements described in [9.8.2] can be met safely and efficiently without jeopardising the safety of those on board the vessel.

### 9.8.4 Helicopters

The local coastguard, armed forces or other authorities should be engaged where rescue and recovery to a helicopter from the water may be required. Search and rescue expertise and equipment is required, hence helicopters ordinarily used for personnel transfer shall not be used for these purposes.
9.9 Marking

9.9.1 Signs, marking and warnings

Signs and marking shall be provided along escape routes, showing exit points and the preferred direction to muster areas and, accordingly, to embarkation areas and means of escape to sea. Signs shall be provided in sufficient numbers to be visible from any temporary and regularly attended areas on the unit or installation.

Muster areas and escape routes shall be marked, painted or indicated by signs to make them conspicuously and avoid blockage by portable equipment and supplies.

Areas for storage of flammable, explosive or otherwise hazardous substances shall be marked with appropriate warning signboards.

Entrances to enclosed spaces where there is a danger of asphyxiating or toxic atmosphere shall be marked with appropriate warning signs.

Self-closing doors between areas with different area classification (if applicable) shall be fitted with signboards. See IEC 61892-7, paragraph 4.6.4 for details.

Warning signboards shall be fitted to doors and hatches which open directly to sea.

9.9.2 Safety plans

Orientation and safety plans shall be strategically located at major circulation points on the unit or installation (e.g. near the main stairways). The safety plans shall contain the following information:

- plan view of each level of the unit or installation
- escape routes and muster areas
- embarkation areas and means of evacuation
- means of escape, ladders, live-saving appliances, etc.
- location of personal protective equipment
- location of push-buttons for alarm and shutdown.

Guidance note:
Reference is made to ISO 17631 "Ships and marine technology — Shipboard plans for fire protection, life-saving appliances and means of escape".

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SECTION 10 CONSTRUCTION

10.1 Introduction
This section provides principles, requirements and guidance for the construction phase of the project which shall be considered and addressed at the design stage. The construction phase includes manufacturing, load-out, transport, installation and commissioning; de-commissioning shall also be taken into consideration.

Sections of this standard containing important information related to construction include:

— Sec.3, arrangement principles
— Sec.8, access and transfer.

10.2 Safety philosophy and design principles

10.2.1 General
The objectives of construction design are to:

— outline a realistic project programme with adequate time for planning and execution
— early identify and reduce risks
— minimise work required offshore by completing work onshore including (partial) commissioning and testing
— facilitate co-operation between parties involved in construction.

A risk based construction design shall be adopted in the design process considering safety, environmental consequences and total life cycle costs. The planning and design sequence is given in Figure 10-1.

10.2.2 Safety criteria and evaluation
The design shall be evaluated regarding its suitability to meet the performance criteria. Performance criteria for construction may, for instance, include lost time injuries.

Where offshore construction and commissioning times are minimised, the exposure of persons to risks is commonly reduced.

10.3 Manufacturing

10.3.1 General
During the design phase, consideration shall be given to all activities required for fabrication and construction onshore as well as load-out and transportation. Corresponding design requirements shall be established.
Unless otherwise agreed, onshore fabrication and construction shall comply with DNVGL-OS-C401 Fabrication and testing of offshore structures. For supplementary guidance, reference is made to EN 1090.

**Guidance note:**
The application of European and International standards can be agreed as long as the limits of their application are maintained and as long as design methods and fabrication specifications are mutually compliant in achieving the target structural safety.

NDT personnel who inspect tubular nodes which are accessible from the outside only need special qualified in accordance with API RP 2X. Welding procedure test and welding production test (WPT) for tubular nodes at varying angles should be performed, as also referred to in DNVGL-OS-C401.

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Steel materials and products shall be delivered with inspection documents as defined in EN 10204 or in an equivalent standard. Unless otherwise specified, material certificates according to Table 10-1 shall be presented.

**Table 10-1 Material certificates**

<table>
<thead>
<tr>
<th>Certification process</th>
<th>Material certificate (EN10204)</th>
<th>Structural category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test certificate as work certificate, inspection and tests witnessed and signed by an independent third party body</td>
<td>3.2 special</td>
<td></td>
</tr>
<tr>
<td>Work certificate test results of all specified tests from samples taken from the products supplied. Inspection and tests witnessed and signed by QA department</td>
<td>3.1 primary</td>
<td></td>
</tr>
<tr>
<td>Test report confirmation by the manufacturer that the supplied products fulfil the purchase specification, and test data from regular production, not necessarily from products supplied</td>
<td>2.2 secondary</td>
<td></td>
</tr>
</tbody>
</table>

For definition of structural categories DNVGL-OS-C101 Ch.2 Sec.3 Structural Categorisation, Material Selection and Inspection Principles shall apply. The structural categories as defined in Table 10-1 are directly related to inspection categories as defined in DNVGL-OS-C101 Ch.2 Sec.3. The extend and acceptance criteria stipulated in DNVGL-OS-C401 Ch.2 Sec.3 Table 1 shall be complied with.

### 10.4 Marine operations

#### 10.4.1 Planning of operations

The planning of the marine operations shall cover planning principles, risk evaluation and documentation. Operational prerequisites such as design criteria, weather forecast, organisation, marine operation manuals as well as preparation and testing should be covered.

The stability of the installation vessels shall be evaluated if possible at the time of design. This evaluation includes evaluation of stability during barge transports and load-out operations and applies to all vessels used during the installation, including special vessels such as floating cranes. Equipment including equipment used for towing of vessels and for mooring systems is also subject to evaluation.

Acceptable characteristics shall be documented for the handled object and all equipment, temporary or permanent structures, vessels, etc. involved in the operation.

All elements of the marine operation shall be documented. This also applies to elements such as onshore facilities, e.g. quays, soil, pullers and foundations.

Properties for object, equipment, structures, vessels, etc. may be documented with recognised certificates. The basis for the certification shall then be clearly stated, i.e. acceptance standard, basic assumptions, dynamics considered, etc. and shall comply with the philosophy and intentions of “DNV-OS-H series”.

**Guidance note:**

The "DNV-OS-H series" (also referred to as "VMO Standard") is replacing "DNV - Rules for Planning and Execution of Marine Operations". DNV-OS-H101, DNV-OS-H102 and DNV-OS-H201 through DNV-OS-H206, are called the "DNV-OS-H series". For sea transport operations, the following guidelines may be used:
Design analysis should typically consist of various levels with a global analysis at top level, and with strength calculations for details as a lowest level. Different types of analysis methods and tools may apply for different levels.

10.4.2 Loads, structural design and load transfer

*Design loads*

Characteristic conditions described in the design basis shall be used to derive characteristic loads and corresponding load factors which lead to design loads.

The load analysis shall take into account dynamic effects and nonlinear effects. Permanent loads, live loads, deformation loads, environmental loads as well as accidental loads shall be considered.

Further requirements are given in DNV-OS-H102 *Marine Operations, Design and Fabrication*.

*Structural design*

Prerequisites for structures involved in marine operations shall include design principles, strength criteria for limit state design, testing, material selection and fabrication.

Requirements and guidelines are given in DNV-OS-H102 *Marine Operations, Design and Fabrication*.

*Load transfer operations*

The load transfer operations cover load-out, float-out, lift-off, pile upending, on-bottom stability, pile-driving and mating operations.

Requirements to load transfer operations are given in DNV-OS-H201 *Load Transfer Operations*.

Specific requirements and guidelines for single-vessel and barge-towing operations are given in DNV-OS-H101 *Marine Operations, General*, Ch.2.

10.4.3 Offshore installation

Specific requirements and recommendations for offshore installation operations particularly applicable for fixed offshore structures are given in DNV-OS-H204 *Offshore Installation Operations*. Environmental loads and load cases to be considered are described as well as on-bottom stability requirements and requirements to structural strength.

Operational aspects for ballasting, pile installation and grouting shall be considered.

Guidance and recommendations for well controlled lifting operations, onshore, inshore and offshore are given in DNV-OS-H205 *Lifting Operations*. The chapter describes in detail the basic loads, dynamic loads, skew loads and load cases to be considered.

Design of slings, grommets and shackles as well as design of the lifting lugs/lifting eyes and the lifted object itself is covered. In addition, operational aspects such as clearances, monitoring of lift and cutting of sea fastening are described.

The requirements of the International Regulations for Prevention of Collision at Sea (COLREG) applicable to navigation lights and sound signals shall be complied with.

Subsea cable tie-in and connection (including fibre optic cables) shall be considered in the design phase, including, for instance, support of cable during installation and operation, location of pulling equipment and connection options like junction boxes.

10.4.4 Subsea operations

Subsea operations are relevant for tie-in of, for example, electrical cables. Planning, design and operational aspects for such installations are described in DNV-OS-H206 *Loadout, transport and installation of subsea objects*.

Diving operations shall be eliminated where practicable.
10.4.5 Warranty surveys
Warranty surveys are normally required by the owner or by insurance companies for insurance of the sea transport phase and the installation phase.

Warranty surveys shall be carried out in accordance with an internationally recognised scheme, e.g. DNV-OS-H series. Marine operations cover yard lift, load-out, sea transportation, offshore lift and installation operations.

10.5 Documentation

10.5.1 Marine operational procedures
Operational aspects shall be documented in the form of calculations, operation manuals and procedures. The documentation shall demonstrate that philosophies, principles and requirements of DNV-OS-H series are complied with.

Documentation for marine operations shall be self-contained or clearly refer to other relevant documents. The quality and details of the documentation shall be such that it allows for independent reviews of plans, procedures and calculations for all parts of the operation.

Guidance note:
A document plan describing the document hierarchy and scope of each document is recommended for major marine operations.

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Applicable input documentation such as:

- statutory requirements
- rules
- company specifications
- standards and codes
- concept descriptions
- basic engineering results (drawings, calculations, etc.)
- relevant contracts or parts of contracts

shall be identified before any design work is performed.

Necessary documentation shall be prepared to prove acceptable quality of the intended marine operation. Typically, output documentation consists of:

- planning documents including design briefs and design basis, schedules, concept evaluations, general arrangement drawings and specifications
- design documentation including load analysis, global strength analysis, local design strength calculations, stability and ballast calculations and structural drawings
- operational procedure including testing programme and procedure, operational plans and procedure, arrangement drawings, safety requirement and administrative procedures
- certificates, test reports, survey reports, NDE documentation, as built reports, etc.

All relevant documentation shall be available on site during execution of the operation.

Execution of marine operations shall be logged. Samples of planned recording forms shall be included in the marine operations manual.

10.5.2 As-built documentation
The structural as-built documentation shall comprise:

- quality records, material test certificates, approval documents
- construction procedures, method statements
- construction log
- inspection records, description of non-conformities
- as-built drawings, description of accepted changes.
SECTION 11 IN-SERVICE INSPECTION AND MAINTENANCE

11.1 Introduction
This section provides principles, requirements and guidance for the inspection and maintenance system to be considered at the design stage, covering the entire installation from support structure to the topsides and the subsea cable interfaces.

Sections of this standard containing important information related to inspection and maintenance to be carried out in-service include:

- Sec.3, accessibility for inspection and maintenance
- Sec.9, test of emergency response systems.

11.2 Safety philosophy and design principles

11.2.1 General
The objectives of inspection and maintenance design are to:

- ensure that the offshore substation remains suitable for its intended purpose throughout its lifetime
- outline requirements and recommendations for inspection, maintenance and condition monitoring of offshore substations
- indicate how these requirements and recommendations can be achieved.

A risk based inspection and maintenance programme shall be established as part of the design process considering safety, environmental consequences and total life cycle costs.

11.2.2 Design basis
Development of an inspection and maintenance programme shall be based on information such as:

- applicable codes and standards
- manufacturer required inspection and maintenance scope and frequency
- design lifetime of structure, systems and components
- site conditions, see [4.2.3]
- deterioration processes
- knowledge based on design and technology
- experience gained from similar installations; historical inspection and maintenance data
- access and transfer options, see Sec.8.

11.2.3 Design process
Risk based inspection and maintenance shall be based on the design life of the system and entails a comprehensive analysis of the system, planning of inspection and maintenance activities, execution and feedback for improvement.

The process involves screening of the system regarding its risks (Figure 11-1). Low risk items should be subject to corrective maintenance strategies. High risk components should be evaluated further based on their type. Risk based inspections should be chosen for items whose integrity is expected to gradually deteriorate. Safety critical equipment should be subject to safety based inspections and maintenance. Risk based maintenance addressing reliability should cover the remaining equipment and items.
Based on the system assessment, a long-term inspection and maintenance programme shall be established. The programme shall specify:

- scope and frequencies of work
- methods of work
- requirements for inspection (including methods of inspection) and maintenance manuals
- requirements for conditioning monitoring systems
- requirements with respect to personal safety.

Based on findings, historical data, experience and with a view to new knowledge and techniques, the programme scope and timing shall be periodically reviewed and updated. Special attention should be paid to deterioration mechanisms for the relevant materials and components such as:

- time-dependent effects
- mechanical/chemical attacks
- damage from accidents.

Guidance note:
In offshore wind farms the interval between inspections of critical items does normally not exceed one year. Inspection intervals for subsequent inspections are adjusted based on findings.

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Where necessary, inspection intervals shall be adjusted to comply with legal requirements and project conditions or to meet equipment manufacturers’ recommendations.

In addition the country specific statutory requirements shall be carried out.

11.3 Risk based inspection and maintenance

11.3.1 General
Personnel involved in inspection planning and condition assessment shall have relevant competence with respect to the offshore substation design, materials, construction and specific experience in the application of inspection and maintenance techniques. Service staff shall familiarise themselves with the primary design and operational aspects before conducting an inspection.

The first inspection and condition verification shall provide a comprehensive initial assessment. Thereafter, the activities shall be carried out periodically in accordance with the risk based maintenance programme.

Following the inspection and maintenance activities an evaluation of the condition shall be carried out. Trends indicating time-dependent deterioration processes shall be clearly identified and evaluated.

Inspection and maintenance activities shall be considered after direct exposure to extreme environmental events (e.g. waves) and accidental events (e.g. boat collision).

In the event of change of use, lifetime extension, modifications, deferred abandonment, damages or deterioration of the offshore substation or a notable change in the reliability data on which the inspection and maintenance scheme is based, measures shall be taken to maintain the substation integrity, safety and reliability. The programme shall be reviewed to determine the applicability to the changed conditions and shall be subjected to modification as required.

11.4 Scope of service

11.4.1 Types of service
Inspection and maintenance activities include:

— global and close visual inspection
— non-destructive inspection or non-destructive testing
— instrumentation based condition monitoring
— corrective maintenance.

11.4.2 Structural components
Structural surveys for components above water focus on:

— dents and deformation
— fatigue cracks
— bolt pretension
— corrosion

and include components such as:

— foundation structure
— platform decks, walls and appurtenances
— walkways, stairs, ladders
— J-tubes, fenders, pipework
— lifting appliances
— helicopter deck
— life boats.

Inspection of structures in the splash zone and below water focuses in addition on the corrosion protection systems (steel wall thickness, anodes, coating, etc.), marine growth and scour protection.
11.4.3 Electrical and control system
The following items shall be covered by the inspection:

— main and auxiliary transformer(s)
— emergency pushbuttons and shut down systems
— high and medium voltage switchgear
— emergency power generation equipment (diesel generator, batteries, UPS)
— auxiliary power supply, HVAC equipment and similar facilities
— cables
— earthing
— measurement, monitoring, control (parameters and settings) and protection systems.

Subsea cables connected at the offshore substation shall be inspected for proper fixing and signs of wear. Cable burial to design depth shall be verified.

11.4.4 Fire protection systems
Inspection, maintenance and tests of fire protection systems shall, at a minimum, be carried out in accordance with applicable regulations. Portable extinguishers commonly require annual inspections. National standards shall apply.

11.4.5 Helidecks
The helicopter deck shall be monitored and kept free from oil, grease, snow, ice, surface water and other contaminants such as guano which could degrade surface friction or compromise visibility of markings.

Further inspection shall be carried out for the following deck landing area components:

— landing net
— perimeter safety netting
— tie-down points
— wind indicator
— perimeter and flood lighting
— fuel system installation and earthing.

11.4.6 Safety and emergency response system
The following items shall be covered by the inspection:

— emergency lighting
— communication systems
— rescue equipment
— fall arrest systems
— personal safety and protection equipment
— markings, warnings, and identification panels.

11.5 Documentation

11.5.1 General
The O&M plan resulting from the risk based maintenance concept shall be documented.

The results of in-service inspections and maintenance shall be documented. The efficiency and integrity of the inspection and condition monitoring activities is dependent on the validity, timeliness, extent and accuracy of the available inspection data.

Up-to-date inspection and maintenance records and summaries shall be retained.
APPENDIX A RISK MANAGEMENT CONCEPTS

A.1 Hazards and risk

A.1.1 General

A hazard is a potential source of harm. Harm may be related to human injury, negative environmental impact, damage to property or a combination of these. An incident which occurs when a hazard is realised is a hazardous event or a failure.

Risk is the likelihood of a specified undesired event occurring within a specified period or in specified circumstances. It can be expressed as the combination of probability and consequence of that event.

A.2 Consequence of failure

A.2.1 General

Consequence of failure (CoF) is evaluated as the outcome of a failure based on the assumption that such a failure will occur.

Consequence of failure values or rankings should be presented separately depending on the consequence type:

— health and safety
— environmental impact
— economics
— loss of reputation.

The consequence scale is necessarily different for different types of consequence and should be selected to account for the full range of values.

A.2.2 Health and safety consequences

Safety consequence evaluation should take into account important factors such as:

— fires and explosions
— toxicity
— electrocution
— falling from heights
— man over board.

Safety consequences should consider the potential death and injury of personnel and are commonly expressed in terms of potential loss of life (PLL).

An example of a safety consequence scale is shown in Table A-1 with ranges from very low (LL) to very high (HH).

<table>
<thead>
<tr>
<th>Category</th>
<th>CoF (PLL)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HH</td>
<td>&gt; 1</td>
<td>multiple fatalities</td>
</tr>
<tr>
<td>M</td>
<td>1</td>
<td>single fatality</td>
</tr>
<tr>
<td>L</td>
<td>$10^{-1}$</td>
<td>major injury, permanent disability</td>
</tr>
<tr>
<td>LL</td>
<td>$10^{-2}$</td>
<td>minor injury</td>
</tr>
<tr>
<td></td>
<td>$10^{-3}$</td>
<td>slight injury</td>
</tr>
</tbody>
</table>

Table A-1 Safety consequence scale

When estimating safety consequence, the changes in manning levels that occur as a result of different phases of operation must be considered.
A.2.3 Environmental consequences

Environmental consequence analysis requires estimation of factors such as:

- pollution through discharge of liquids
- gas releases, also regarding greenhouse potential
- loss of highly toxic chemicals
- excessive noise.

Environmental consequences should be limited to local and global damage to the environment alone; not including safety and economic aspects.

An example for an environmental consequence scale is shown in Table A-2. The definition of units (monetary, volumetric) depends on the design philosophy.

<table>
<thead>
<tr>
<th>Category</th>
<th>CoF (litres of oil)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HH</td>
<td>&gt; 16 000</td>
<td>massive effect</td>
</tr>
<tr>
<td>H</td>
<td>10 000 - 16 000</td>
<td>major effect</td>
</tr>
<tr>
<td>M</td>
<td>1000 - 10 000</td>
<td>local effect</td>
</tr>
<tr>
<td>L</td>
<td>100 - 1000</td>
<td>minor effect</td>
</tr>
<tr>
<td>LL</td>
<td>&lt; 100</td>
<td>slight effect, negligible</td>
</tr>
</tbody>
</table>

A.2.4 Economic consequences

Economic consequence should include all matters financial in relation to a potential incident including:

- repair costs
- clean-up costs
- value of lost production
- fines.

Economic consequence should be expressed in monetary terms using appropriate currency units.

An example of an economic consequence scale is shown in Table A-3, assuming an installation value of 25 M€.

<table>
<thead>
<tr>
<th>Category</th>
<th>CoF (€)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HH</td>
<td>&gt; 5 M</td>
<td>massive effect</td>
</tr>
<tr>
<td>H</td>
<td>500 k - 5 M</td>
<td>major effect</td>
</tr>
<tr>
<td>M</td>
<td>50 k - 500 k</td>
<td>local effect</td>
</tr>
<tr>
<td>L</td>
<td>5 k - 50 k</td>
<td>minor effect</td>
</tr>
<tr>
<td>LL</td>
<td>&lt; 5 k</td>
<td>slight effect, negligible</td>
</tr>
</tbody>
</table>

The economic consequences of business interruption can be estimated from duration and extent of production downtime, multiplied by the value of production.

A.2.5 Reputation consequences

Failures might also lead to negative impact on the reputation of companies or organizations related to the failure.
A.3 Probability of failure

A.3.1 General
Probability of failure (PoF) is the probability of an event occurring per unit time (e.g. annual probability). An example of a probability of failure scale is shown in Table A-4.

<table>
<thead>
<tr>
<th>Category</th>
<th>PoF / year</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HH</td>
<td>&gt; 10^-2</td>
<td>failure expected</td>
</tr>
<tr>
<td>H</td>
<td>10^-3 to 10^-2</td>
<td>high probability of failure</td>
</tr>
<tr>
<td>M</td>
<td>10^-4 to 10^-3</td>
<td>Medium probability of failure</td>
</tr>
<tr>
<td>L</td>
<td>10^-5 to 10^-4</td>
<td>Low probability of failure</td>
</tr>
<tr>
<td>LL</td>
<td>&lt; 10^-5</td>
<td>failure not expected</td>
</tr>
</tbody>
</table>

A.4 Risk representation

A.4.1 General
Risk can conveniently be represented by means of a risk matrix. A separate matrix for each risk (consequence) category should be established.

The common risk matrices shall be harmonised and standardised at the beginning of the design process and used for all risk assessments related to the installation under review.

To achieve adequate resolution, a 5 × 5 matrix is recommended as shown in Figure A-1. All matrices should use the common probability scale on one (normally the vertical) axis and individual consequence scales on the other (normally the horizontal) axis.

The risk is commonly divided into three or four (pictured) categories which should be the same for safety, environmental and economic aspects:

— H: high risks are unacceptable and actions shall be taken to reduce the risk level
— M: medium risk can be further divided into tolerable (upper) and broadly acceptable (lower) regions to focus on efforts for risk control
  a) Risks are tolerable once all reasonably practicable actions have been taken to reduce them. Further reduction action is needed, unless the costs are grossly disproportionate to the benefits.
  b) Risks are broadly acceptable if most people would not be concerned by them. Further action is appropriate where cost-effective, or where needed to ensure risks do not increase.
— L: low, negligible risks do not require actions to be taken.

A matrix with three categories can be divided into H = unacceptable, M = tolerable with action required and L = broadly acceptable with no action required.
Figure A-1  Example of a risk matrix
APPENDIX B  HAZARD IDENTIFICATION

B.1  Potential offshore substation hazards

B.1.1  General
As described in Sec.2, no single failure will normally lead to life threatening situations for any person or to unacceptable damage to the environment or the installation. The purpose of this appendix is to provide an example of a typical approach used to: systematically identify hazards; assess the risks and consequences of those hazards being realised; and put in place suitable philosophies and design measures to prevent, control and mitigate the risks.

The following Figure B-1 illustrates the 5 step process to risk based design:

![Figure B-1  Five step process to risk based design](image)

Table B-1 provides examples for hazardous events which may be encountered on offshore substations, possible causes and consequences. Potential consequences are given for (P)eople, (E)nvironment and (A)sset.
**Table B-1  Hazard identification for offshore substations**

<table>
<thead>
<tr>
<th>Number</th>
<th>Hazardous event</th>
<th>Possible causes</th>
<th>Possible consequences</th>
</tr>
</thead>
</table>
| 1.1    | Structural damage                                 | Ship impact  
Transformer explosion  
Fire in sump tank  
Extreme weather  
Subsidence  
Scouring  
Earthquake  
Subsea/splash zone corrosion | Fatality (P)  
Platform collapse (A)                                                                                                                                   |
| 1.2    | Collision of vessel with platform                 | Loss of power  
Inappropriate approach procedure/design  
Human factors  
Adverse weather or sea state  
Lack of navigation aids  
Inadequate collision avoidance system  
Drifting vessel | Structural damage (A)                                                                                                                                 |
| 1.3    | Dropped object, swinging load                     | Inappropriate lifting  
Human error  
Adverse weather  
Sling whole or partial failure  
Mechanical failure | Injury, fatality (P)  
Damage (A)                                                                                                                                             |
| 2.1    | High voltage faults                               | Connection point  
Short circuit | Injury (P)                                                                                                                                             |
| 2.2    | Short circuit in electrical installations          | Poor maintenance  
Substandard components/cables  
Poor design | Fire, explosion (A)                                                                                                                                      |
| 2.3    | Release of SF6                                     | Fault operation  
System failure  
System design | Injury, narcosis, asphyxia (P)  
Greenhouse gas release (E)                                                                                                                               |
| 2.4    | Electrocution, electric shock                      | Maintenance activities  
Untrained personnel  
Touch voltages  
Lack of high voltage signage | Injury, fatality (P)                                                                                                                                      |
| 2.5    | Unattended electrical consumer                     | Failure to switch off electrical consumers | Fire (A)                                                                                                                                             |
| 2.6    | Failure of lightning protection                    | Inadequate earthing  
Incorrect design  
Poor maintenance | Fire, explosion (A)                                                                                                                                      |
| 2.7    | Electromagnetic compatibility problem              | Electromagnetic radiation from equipment | Health risk (P)  
Interference (A)                                                                                                                                     |
| 2.8    | Loss of emergency power                            | Start failure of generator  
Diesel shortage  
Battery or UPS failure | Shutdown of emergency consumers (A)                                                                                                                        |
| 2.9    | Fuel release from emergency generator, day tank or storage tank | Loss of containment  
Pipe, valve or hose failure  
Human error | Pollution (E)  
Fire (A)  
Loss of emergency power (A)                                                                                                                                |
| 2.10   | Hydrogen release from batteries                    | Collapse of cells  
Lack of ventilation  
Charging failure | Injury (P)  
Explosion (A)                                                                                                                                         |
| 2.11   | Battery leakage                                    | Structural failure  
Aged batteries  
Poor maintenance  
Charging failure | Injury (P)                                                                                                                                             |
<table>
<thead>
<tr>
<th>Number</th>
<th>Hazardous event</th>
<th>Possible causes</th>
<th>Possible consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Main transformer fire or explosion</td>
<td>Internal fault Short circuit Lack of cooling medium Oil degradation External fire Overload Poor layout or design Inadequate drainage</td>
<td>Injury, fatality (P) Release of burning oil (E) Downtime (A)</td>
</tr>
<tr>
<td>3.2</td>
<td>Utility transformer fire</td>
<td>Internal fault Short circuit Lack of cooling medium External fire Overload</td>
<td>Injury (P) Downtime (A)</td>
</tr>
<tr>
<td>3.3</td>
<td>HV switchgear fire or explosion</td>
<td>Lack of insulation gas (SF6) Earthing fault Short circuit Overload Malfunction of equipment Poor maintenance Lack of training Incorrect work procedures</td>
<td>Injury (P) Downtime (A)</td>
</tr>
<tr>
<td>3.4</td>
<td>LV equipment fire</td>
<td>Short circuit Overload Malfunction of equipment</td>
<td>Injury (P) Downtime (A)</td>
</tr>
<tr>
<td>3.5</td>
<td>Emergency generator fire</td>
<td>Internal fault Generator allowed to run out of fuel Fuel system leak Poor maintenance</td>
<td>Injury (P) Environmental pollution (E) Loss of emergency power (A)</td>
</tr>
<tr>
<td>3.6</td>
<td>Toxic smoke</td>
<td>Fire on transformer or electrical equipment Explosion Loss of containment</td>
<td>Injury (P) Damage (A)</td>
</tr>
<tr>
<td>3.7</td>
<td>Fire in accommodation</td>
<td>Kitchen or cabin use Smoking Poor housekeeping Unattended electrical equipment</td>
<td>Injury, fatality (P)</td>
</tr>
<tr>
<td>3.8</td>
<td>Fire or explosion at helicopter deck</td>
<td>Ignited leak or static discharge</td>
<td>Injury (P)</td>
</tr>
<tr>
<td>3.9</td>
<td>Fire or explosion in battery room</td>
<td>Ignited hydrogen leak</td>
<td>Injury (P) Damage (A)</td>
</tr>
<tr>
<td>3.10</td>
<td>Fire or explosion in paint store/chemical store</td>
<td>Ignited hazardous material</td>
<td>Injury (P) Damage (A)</td>
</tr>
<tr>
<td>3.11</td>
<td>Fire or explosion in hypochlorite package</td>
<td>Ignited hydrogen leak</td>
<td>Injury (P) Damage (A)</td>
</tr>
<tr>
<td>4.1</td>
<td>Marine transfer incident</td>
<td>Slips, falls caused by marine growth, ice Ladder failure caused by marine environment Lack of instruction and training</td>
<td>Injury (P)</td>
</tr>
<tr>
<td>4.2</td>
<td>Helicopter crash, ditching</td>
<td>Mechanical failure Pilot error Poor weather/visibility Loss of fuel Faulty Navigational Aids</td>
<td>Injury, fatality (P) Helicopter/installation damage (A)</td>
</tr>
<tr>
<td>Number</td>
<td>Hazardous event</td>
<td>Possible causes</td>
<td>Possible consequences</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------</td>
<td>-----------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>4.3</td>
<td>Helicopter rotor impact</td>
<td>Lack of training or control Poor housekeeping Lack of helideck protection (nets, lights, etc.) Adverse weather</td>
<td>Injury, fatality (P) Helicopter damage (A)</td>
</tr>
<tr>
<td>4.4</td>
<td>Helicopter winching incident</td>
<td>Poorly controlled winching Mechanical failure of winching system Poor weather</td>
<td>Injury, fall, fatality (P) Helicopter damage (A)</td>
</tr>
<tr>
<td>4.5</td>
<td>Unauthorised access to high risk area</td>
<td>Lack of locks, signage</td>
<td>Injury (P) Tampering with equipment (A) Release (E)</td>
</tr>
</tbody>
</table>

### 5 Emergency response incident

<table>
<thead>
<tr>
<th>Number</th>
<th>Hazardous event</th>
<th>Possible causes</th>
<th>Possible consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1</td>
<td>Man over board</td>
<td>Boat transfer Maintenance work Personnel working over water</td>
<td>Injury, fatality (P)</td>
</tr>
<tr>
<td>5.2</td>
<td>Loss of escape route or transfer back to shore</td>
<td>Inclement weather Nearby marine emergency No ERRV due to other work Mechanical problems with vessel Inappropriate or ill-equipped muster areas Poor design or inadequate sizing or location</td>
<td>Being stranded, injury (P)</td>
</tr>
<tr>
<td>5.3</td>
<td>Loss of communication to vessels or shore</td>
<td>Cable or equipment fault Onshore problem Loss of power Fire, explosion Maintenance activities</td>
<td>Delays (P)</td>
</tr>
<tr>
<td>5.4</td>
<td>Failure of flood lights, navigation aids</td>
<td>Loss of power</td>
<td>Unsafe operations (P, A)</td>
</tr>
<tr>
<td>5.5</td>
<td>Shortages in food and water supply</td>
<td>Poor planning Inclement weather</td>
<td>Discomfort, injury (P)</td>
</tr>
<tr>
<td>5.6</td>
<td>Uncoordinated search and rescue</td>
<td>Poor procedures Lack of equipment Lack of training Language</td>
<td>Delays, injury, fatality (P)</td>
</tr>
</tbody>
</table>

### 6 Other incidents

<table>
<thead>
<tr>
<th>Number</th>
<th>Hazardous event</th>
<th>Possible causes</th>
<th>Possible consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.1</td>
<td>Release from cooling oil system</td>
<td>Loss of containment</td>
<td>Injury (P) Contamination (E) Downtime (A)</td>
</tr>
<tr>
<td>6.2</td>
<td>Failure of HVAC system</td>
<td>Wrong design Malfunctioning of fire dampers Failure of detector</td>
<td>Smoke ingress into cabins (P) Feeding fire with oxygen (A)</td>
</tr>
<tr>
<td>6.3</td>
<td>Occupational hazards</td>
<td>Vessel movement Adverse weather and sea states</td>
<td>Injury (P)</td>
</tr>
<tr>
<td>6.4</td>
<td>Epidemic illness</td>
<td>Food poisoning Bio hazard Escherichia coli Legionnaires’ disease</td>
<td>Injury (P)</td>
</tr>
</tbody>
</table>
## B.2 Safety critical systems

### B.2.1 General

After the HAZID has been conducted it should be possible to create a table listing all barriers and systems which will be required to prevent an incident from occurring, or to detect, control and mitigate the consequences of an accident should one occur. Table B-2 below provides a table of typical safety critical systems relevant to offshore substation platforms.

**Table B-2** An example table of typical safety critical systems

<table>
<thead>
<tr>
<th>Barrier</th>
<th>Class</th>
<th>Critical function</th>
<th>#</th>
<th>System</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAFETY</td>
<td>S1</td>
<td>Safety</td>
<td>1</td>
<td>HAZID</td>
</tr>
<tr>
<td></td>
<td></td>
<td>See Sec.2 and Sec.3</td>
<td>2</td>
<td>HAZOP</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Safety concept/ basis of design</td>
<td>3</td>
<td>Safety philosophy (HSE)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Risk assessments (see note #1below)</td>
<td>5</td>
<td>ALARP studies</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Manning philosophy</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>PREVENTION</td>
<td>P1</td>
<td>Structural and stability integrity</td>
<td>1</td>
<td>Jacket</td>
</tr>
<tr>
<td></td>
<td></td>
<td>See Sec.4</td>
<td>2</td>
<td>Piles</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Foundations</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Topsides/ surface structures</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Crane structure/ pedestal</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Appurtenances and supports</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jacking mechanism</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Locking mechanism</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Helideck (impact/load)</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lifting/transit</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Collision protection (J-tubes)</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Accidental loads</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ship impact</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P2</td>
<td>Prevention of collisions/impacts</td>
<td>1</td>
<td>Collision avoidance system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>See Sec.3</td>
<td>2</td>
<td>Radar/ATR/RACON</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nav aids (marine warning lights)</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Warning lights (aviation)</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Automatic identification system (AIS)</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P3</td>
<td>Prevention of dropped/swinging object</td>
<td>1</td>
<td>Lifting equipment (EU directive/ LOLA)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>See [4.4.6]</td>
<td>2</td>
<td>Crane (offshore cert.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Crane safety devices (hook, cable, brake, CEC)</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dropped object/impact protection</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P4</td>
<td>Prevention of process hazards and mech failure</td>
<td>1</td>
<td>Electrical equipment safety and EMF (EU directives)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>See Sec.2 and Sec.3</td>
<td>2</td>
<td>Mechanical equipment safety (EU directives)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Process control system</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Barrier</td>
<td>Class</td>
<td>Critical function</td>
<td>#</td>
<td>System</td>
</tr>
<tr>
<td>---------------</td>
<td>-------</td>
<td>------------------------------------</td>
<td>----</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>P5</td>
<td></td>
<td>Prevention of Ignition</td>
<td>1</td>
<td>Hazardous area classification (flammable/explosive)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>See Sec.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>Heating, ventilation and air conditioning (HVAC)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>ATEX (EU directives)/certification of equipment</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4</td>
<td>Earth bonding and continuity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>Electrical isolation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6</td>
<td>Lightning protection</td>
</tr>
<tr>
<td>CONTROL</td>
<td>C1</td>
<td>Fire and gas detection</td>
<td>1</td>
<td>Fire detection systems</td>
</tr>
<tr>
<td></td>
<td></td>
<td>See [6.7]</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>Smoke detection systems</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>Hazardous gas detection systems (battery room, EDG)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4</td>
<td>Manual alarm callpoint (MAC’s)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>SF6 leak detection</td>
</tr>
<tr>
<td>MITIGATION*</td>
<td>M1</td>
<td>Explosion mitigation</td>
<td>1</td>
<td>Blast protection</td>
</tr>
<tr>
<td></td>
<td></td>
<td>See Sec.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>Blast walls/zones (transformer)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>Blast panels/pressure relief panels</td>
</tr>
<tr>
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<td></td>
<td>4</td>
<td>Firewalls</td>
</tr>
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<td>5</td>
<td>Fire pump systems</td>
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<td></td>
<td>6</td>
<td>Foam systems</td>
</tr>
<tr>
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<td></td>
<td></td>
<td>7</td>
<td>Liquid and gaseous extinguishing systems</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>8</td>
<td>Fire extinguisher (LSA)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>9</td>
<td>Drains (transformer oil, helideck, etc.)</td>
</tr>
<tr>
<td>EVACUATION and</td>
<td>E1</td>
<td>General alarm and emergency</td>
<td>1</td>
<td>General alarm systems (fire/collision)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>communications</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ESCAPE</td>
<td></td>
<td>See [9.3]</td>
<td>2</td>
<td>External communication and emergency response</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>VHF radios (marine/aviation)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4</td>
<td>Fire and gas detection</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>Smoke detection systems</td>
</tr>
<tr>
<td></td>
<td></td>
<td>See Sec.8 and [9.5], [9.6], [9.7]</td>
<td>2</td>
<td>Escape route lighting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and [9.8]</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>Skyscape/life rafts/TEMPSC/EERV/FRC</td>
</tr>
</tbody>
</table>
Table B-2  An example table of typical safety critical systems (Continued)

<table>
<thead>
<tr>
<th>Barrier</th>
<th>Class</th>
<th>Critical function</th>
<th>#</th>
<th>System</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>4  Temp. refuge/ muster areas (protection and sizing)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5  Emergency and Escape lighting</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>6  Emergency PPE (life jacket, suit, smoke hood, PLB)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>7  First aid room</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E3</td>
<td>Helideck</td>
<td>1  Layout and markings</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>See Sec. 8</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2  Emergency equipment</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3  Fire fighting (DIFFS)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4  Helicopter crash rescue equipment</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
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<td>5  Effects of airflows over Helideck</td>
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<td>E4</td>
<td>Emergency power supplies</td>
<td>1  Emergency generator</td>
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<td></td>
<td>See Sec. 9</td>
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<td>2  UPS</td>
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<tr>
<td>ENVIRONMENT</td>
<td>N1  Environmental</td>
<td>1  Leakage containment</td>
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<td>See [A.2.3]</td>
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<tr>
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<td></td>
<td>2  Water emissions</td>
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<td>3  Air emissions</td>
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<td>4  Bunded areas</td>
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<td>5  Acoustic protection</td>
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<td>6  Epidemic illness</td>
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</table>

* The electrical equipment itself should be specified such that fire and explosion risks are reduced following a performance-based design approach.

Note #1  Risk assessments would normally include:
- FERA – Fire and explosion risk assessment
- EERA – Emergency, Escape and Rescue assessment
- Ship Collision Analysis
- Dropped Objects Study

B.3  Defining philosophies and design objectives

B.3.1  General

After it has been established what barriers and mitigation methods are required, it should then be established what performance requirements or targets these barriers need in order to be effective for their designed role. This information should be documented in a system design philosophy. Where a number of systems can be grouped under a common discipline or title the project may wish to do so as to keep all design philosophy information pertaining to that system in one place.

Most safety critical systems will have applicable codes and standards pertinent to the location or global zone the substation is being installed. Such applied codes and standards should be referenced in the design philosophies and the minimum requirements noted. Code and standard minimum requirements should be evaluated during the development of the design philosophies to ensure that the requirements are adequate for the barrier to be effective.
B.4 Design document hierarchy

B.4.1 General

The design process should have a clear robust and traceable design document hierarchy which will enable anyone in the future to systematically find what the design specifications are and why. An example document structure can be seen below.

![Diagram of design document hierarchy](image)

B.5 Ensure design has not introduced new hazards

B.5.1 General

After the basic design has been completed a HAZID closeout should be conducted to ensure that the resulting risk is in an acceptable range and that the barriers imposed are adequate to prevent, detect, control and mitigate any foreseeable event. A HAZID closeout should also ensure that no new hazards are present due to the established design solutions.

Below is a table that can be used to trace and evaluate if all hazards have protective barriers and where those protective barriers have been realised.

![Table of design document hierarchy](image)
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