STANDARD

DNV-ST-0145

Edition October 2020
Amended September 2021

Offshore substations

DNV AS

FOREWORD

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

Any comments may be sent by e-mail to *rules@dnv.com*

CHANGES – CURRENT

This standard supersedes the April 2016 edition of DNVGL-ST-0145.
The numbering and/or title of items containing changes is highlighted in red.

Amendments September 2021

Topic	*Reference*	*Description*
Abnormal environmental actions	[4.4.6.2]	Provide the possibility for specifying return period < 10 000 years for unmanned offshore substations when the defined preconditions are fulfilled and the consequences of higher risk are taken into consideration.
Rebranding to DNV	All	This document has been revised due to the rebranding of DNV GL to DNV. The following have been updated: the company name, material and certificate designations, and references to other documents in the DNV portfolio. Some of the documents referred to may not yet have been rebranded. If so, please see the relevant DNV GL document.

Changes October 2020

Reference	*Change*	*Reason for the change*
General	Updated to reference most recent standards, e.g. replacement of DNV-OS-H standards and GL ND guidelines.	References to current standards are updated.
General	The term 'wind farm' is changed to 'wind power plant' the terms 'platform' and 'installation' are changed to 'offshore substation'.	Consistency with DNV-SE-0190.
General	Replace 'should' by 'shall' and 'shall' by 'should', where relevant.	Distinguish between requirements and advice.
[1.6.2]	Removed terms manned/unmanned installation and replaced by substation type A, B and C.	Implement consistent approach throughout the standard using substation type A, B and C.
[1.6.2]	Definitions for 'fire damper' and 'smoke damper' added.	Alignment with SOLAS requirements.
[2.2.2]	Section has been revised to highlight that novel concept may be used and that prescriptive requirements shall not necessarily be fulfilled as long as the safety target of prescriptive requirements are fulfilled in the novel concept.	Open up for new methods and novel concepts.
[3.3.2]	Updated to further differentiate between type A, B and C substations. Type A, B and C are now also used in other sections of the standard.	Consistent use of definitions for type A, B and C substations.

Reference	*Change*	*Reason for the change*
[3.3.2]	Changed to: persons are only expected to be present for inspection and maintenance activities without overnight stays between working shifts. If habitability services are provided, they are limited and intended solely for the use during the working shift not facilitating for overnight stay.	Type A substations (normally unmanned) may be manned for inspection not only during daylight, but also at other times. The requirement shall be that overnight stays are allowed but the work shifts shall not necessarily take place during daylight only.
[3.4.1]	The section was completely revised.	Focus in this section is put on segregation of hazardous and dangerous areas. Aspects of separation by passive fire protection are moved to [6.4.2.2].
[3.4.3]	Added in first bullet point: (...) as well as areas used as storage for gas bottles of fire extinguishing systems.	Further definition of dangerous areas.
[3.5.2]	Requirement for having two main transformers on a AC substation is removed.	Availability of high voltage equipment is not in main focus of the standard and the certification by DNV GL.
[3.5.4]	Added at the end of the section: if a laydown area or part of laydown area is used as temporary or permanent storage, it shall be considered in total substation design weight and shall not restrict any escape paths. The specified design weight for laydown areas shall be clearly marked and included in the substation structural design calculations. During active lifting where an item is lowered to a laydown area before moved to next location, it is allowed to block escape paths during the operation if adequate risk mitigation has been performed.	Requirement to make sure that escape routes are not blocked and that the design weight of topside will not be exceeded.
[3.5.8.1], [3.5.8.2], [3.5.8.3]	Requirements for lifebuoys and lifejackets regarding arrangement and design added.	Requirements for lifebuoys, lifejackets and immersion suits added for filling gap in former standard.
[4.1], [4.2.1], [4.2.2.2], [4.3.2], [4.3.3], [4.4.5]	Content removed which is already covered in DNV-OS-C101 or other DNV GL documents, or where the content has no added value.	Remove unnecessary or double content.
[4.2.3]	Requirements for content of design basis added.	Requirements for content of design basis which before was part of DNV-SE-0073. At the same time the list was removed from DNV-SE-0073 to avoid double content and contradictions.
[4.2.3]	Guidance note added: It is considered beneficial to extend the design basis requirements covering also descriptions of the main design methodologies. For this purpose it is distinguished between 'design basis' and 'design briefs'. The intention with a design brief is to present design methodologies early in the design process.	Based on experience from verification of offshore structures, it is seen that lack of planning represents risks to develop inadequate load bearing structures. Nonconformities might not be discovered or revealed late and even after the fabrication is completed. From a structural standpoint, it is considered beneficial to extend the design basis requirements covering also descriptions of the main design methodologies.

Reference	*Change*	*Reason for the change*
[4.2.4]	Deleted: alternative design methods, further described in DNV-OS-C101, include: - design assisted by testing - full probability-based design.	Double content to Sec.2.
[4.3.2]	Definition of LRFD design method aligned with DNV-OS-C101.	Harmonization of DNV GL documents.
[4.3.3]	For ALS added: for the ALS load combination for damaged structure, the representative load effect is determined as the most probable annual maximum value.	Requirement for post-damage scenario formulated based on DNV-OS-C101.
[4.4.2]	Table 4-1 updated to be in line with DNV-OS-C101 Ch.2 Sec.2 Table 2	Alignment with other DNV GL standard.
[4.4.4]	Added: -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. - Secondary structural parts such as boat landings and ladders shall not suffer from damage leading to loss of their respective functions.	Boat landing structures are in generally considered as structural category primary (primary = structural parts where failure will have substantial consequences according to DNV-OS-C101 Ch.2 Sec.3 Table 1 .
[4.4.4]	Reference to DNV-OS-C101 for considering of live loads in primary and global design added: variable functional loads on deck areas which shall be considered in primary and global design are specified in DNV-OS-C101.	Clarification on live loads in primary and global design needed. The update is reflecting current industry practice.
[4.4.4]	Guidance note 2 is extended: depending on the access concept other scenarions should be evaulated such as the gangway on a service operation vessel (SOV) causing damage to access platform, handrails or similar.	Covering of other access means such as walk-to-work.
[4.4.5]	Requirement regarding transport fatigue added: Depending on the stress levels, the type of details in the main components and the duration of transport routes from fabrication yard to installation site, transport fatigue of the main components (mainly support structure or topside structure) may become an issue. Therefore, transport fatigue analyses shall be performed to determine the fatigue damage of the structure during transport (including possible waiting time at sea). If location of hot spots for transport is the same as for in-place conditions the fatigue damage of transport and in-place shall be added together. See guidance notes in DNV-ST-N001 [5.9.4] and DNV-ST-N001 [11.9.12].	Transport routes from fabrication yard to installtion yard are getting longer and therefore the relevance for transport fatigue is increasing.

Reference	*Change*	*Reason for the change*
[4.4.6]	More details and guidance note regarding air gap requirement and abnormal wave event added.	Clarification added that the 10, 000 year wave shall be taken into account for ALS. This may also be done by assuring that the wave passes underneath the structure. The guidance note advises that loss of certain elements may be tolerated. The update is reflecting current industry practice.
[4.4.6]	Based on DNV-RP-C205 the following sentence is added: Global wind loads on structures shall be determined using a time-averaged design wind speed in the form of a sustained wind speed. Wind speed averaged over one (1) minute is often referred to as sustained wind speed. See also DNV-RP-C205 Sec.2 and DNV-RP-C205 Sec.5.	Clear guidance regarding averaging period for wind loads were missing in this standard and other DNV GL documents.
[4.4.6]	The second guidance note in [4.4.6] is removed.	The information in this guidance note is already implicitly part of the standard.
[4.4.6.4]	Requirement regarding vesel impact speed is slightly modified: The speed of the drifting vessel (impact speed) shall be assessed in each case. Unless a lower impact speed can be justified it shall be assumed to be not less than 2 m/s.	Lower impact speed can be justified, which often will be the case for SOV operation.
[4.4.6.5]	Removed: where accommodation areas, temporary refuge or shelter areas can be exposed to a heat load, A60 passive fire protection shall be foreseen.	Avoid double content as this is covered in section 6.
[4.5.2]	Last sentence in the section is modified as follows: The material factor γ_m for the ALS shall be taken as 1.0 for steel structures. Material factors for ALS for concrete structures shall be chosen as per DNV-ST-C502 and for grouted connections according DNV-ST-0126. The material factor γ_m for the SLS shall be taken as 1.0.	Safety level in DNV-ST-C502 is 'high' as is the same as in DNVGL-ST-0145. Therefore, the safety factors shall be taken directly from DNV-ST-C502.
[4.6]	For steel in the submerged zone that is subject to cathodic protection the diametral effects of such type of protection should be considered in the selection of steel material in accordance with DNV-RP-B401 [5.5].	Inclusion of clear link to DNV-RP-B401 for sake of convenience.
[4.6.2]	Deleted the reference to DNV-OS-C401. The sentence below Table 4-6 should read "Material certificates are required as specified in [10.3]." (i.e. "...and DNV-OS-C401" should be deleted).	In the context, material certificates for e.g. WPQT is deemed not relevant.

Reference	*Change*	*Reason for the change*
[4.6.2]	Table 4-4, Table 4-5 and Table 4-6 updated to consider updated EN 10225-series. S355N/S355M added as substitute for VL D36 in Table 4-4 and Table 4-5. Option to use S275 and S235 for secondary structures included in Table 4-6.	Updated according external standard.
[4.6.2]	Guidance note regarding structural categorization added.	Until now the guidance in this matter was not sufficient. The guidance note is now aligned with DNV-ST-0126.
[4.6.4]	Requirements regarding type approval certificates for strcutural grout added. Furthermore, new paragraph for qualification of Ordinary Portland Cement added.	Aspects of grout certification and qualification was not properly covered in previous version of the standard.
[4.8.2]	Added: design of plated structures such as stiffened panels shall be done according to Part 1 of DNV-RP-C201.	Clarification of applicability of DNV-RP-C201.
[4.8.4]	Include option to use NORSOK N-004 Annex K for jacket-pile sleeve designs. following sentence is added in [4.8.4]: For grouted connections for which the geometry complies with NORSOK N-004 Annex K, such grouted connections may be designed according to NORSOK N-004 Annex K.	NORSOK N-004 Annex K is applied for previous substations according to DNV-OS-J201 and for Oil & Gas jacket structures.
[4.8.4]	First sentence in this section is changed: Grouted connections shall be designed according to the requirements given in DNV-ST-0126 Sec.6. Material factors shall be chosen as stated in [4.5.2].	Alignment with other DNV GL standards
[4.8.6]	Added: the air gap shall fulfil the below requirements (whichever is the larger) and be applied to the 100-year wave crest.	Clarification on air gap requirement added to avoid any doubt.
Sec.5	Section completely restructured.	Increase of readability, aligned with other DNV GL standards.
Sec.5	Content regarding maintenance and commissioning moved to Sec.10. Content regarding in-service moved to Sec.11.	Compile contents in relevant sections.
[5.3.1.1]	More precise definition of 'normal operational condition'.	Increase of readability.
[5.3.1.2]	More precise definition of '(N-1) operational condition' added.	Increase of readability.
[5.3.1.3]	More precise definition of 'islanded condition' added.	Increase of readability.
[5.3.1.4]	More precise definition of 'emergency condition'.	Increase of readability.
[5.3.1.5]	New operational condition 'black substation' added.	Demand for clear definition of earlier used term 'dead unit'.

Reference	*Change*	*Reason for the change*
[5.4.9], [5.4.10]	Clarification added regarding use of high voltage cables and cable trays with respect to material and heat resistance.	Mixing of 'should', 'shall', 'preferably' was confusing in previous version of the standard.
[5.4.9], [5.4.10]	Restructured for sake of more clarity and consistency with regards to differing requirements for high and low voltage cables.	Provide more clarity with respect to requirements for high and low voltage cables.
[5.5.2]	Connections to other substations able to supply power added as a main sources of power supply for auxiliary power system.	Update according to industry practice.
[5.5.3]	List of sources of emergency power supply updated.	Clarification of requirements.
[5.5.3.4]	Added at beginning of section: In the case of failure of the main source of auxiliary power (emergency operational condition), the emergency source of power shall automatically start electrical supply of the services listed in Table 5-2.	Clarification that emergency source of power shall automatically start electrical supply.
[5.5.4]	Section 'Meshed system' now renamed to 'Meshed power supply of auxiliary power system' and completely revised.	Describe performance criteria for meshed system and explain which services shall be available. Differentiation between substation type A and B/C.
[5.5.5]	Section on generator sets shortened and revised based on DNV-OS-D201.	Harmonization of DNV GL documents.
[5.5.6]	Completely revised based on DNV-OS-D201.	Harmonization of DNV GL documents.
[5.7]	Updated to consider requirements from revised standard IEC 61892-2.	Updated external standard.
Sec.6	Requirements from updated MODU Code and SOLAS are considered.	Alignment with external standards.
[6.2.5]	First paragraph is removed to avoid contradictions to the requirements given in Table 6-1.	Avoidance of contradictions.
[6.4]	Requirements for passive fire protection in Sec.6 were aligned to be consistent with SOLAS and MODU Code requirements.	Consideration of most recent SOLAS and MODU Code requirements.
[6.4.3]	Requirements are aligned with MODU Code.	Alignment with MODU Code.
[6.4.5], [6.4.6]	Sections completely revised to account for and harmonize with SOLAS and MODU Code requirements.	Alignment with SOLAS and MODU Code requirements.
[6.4.6], [6.4.7], [7.11.1]	Adaptation of SOLAS and MODU Code requirement for offshore substation application with respect to ventilation and penetrations.	Alignment with SOLAS and MODU Code requirements.
[6.5.5] [6.5.6] [6.5.8] [6.5.9]	References to FSS and IMO MSC are provided and minimum requirements are listed in [6.5.6.1].	Define minimum requirements specific for offshore substations. Relevant requirements in one document.

Reference	Change	Reason for the change
[6.5.6]	Added in [6.5.6.1]: Audible and visual alarms shall be provided in the protected space and additional visual alarms at each access to the space.	Requirement for warning before entering the room shall be provided.
Sec.7	Section re-structured and revised to be aligned with DNV-OS-D101, SOLAS and MODU Code.	Aligned with other DNV GL standards, SOLAS and MODU Code.
[7.2.2]	Environmental conditions are updated.	Aligned with DNV-OS-D101.
[7.3]	Section completely revised and aligned with DNV-OS-D101.	Alignment with other standards.
[7.4.2]	Revised to be aligned with DNV-OS-D101.	Alignment with DNV-OS-D101.
[7.6]	Completely revised and aligned with other DNV GL standards.	Alignment with other standards.
[8.4]	General design requirements regarding helicopter landing decks and winching areas removed and reference to local requirements and CAP 437 added. Requirements regarding fueling facilities and fire protection are maintained.	Requirements covered by reference to external standard.
Sec.9	Section updated to accommodate requirements from other DNV GL standards, LSA Code, MODU Code and SOLAS.	Unclear and insufficient requirements in previous version of the standard.
[10.3]	Reference to DNV-RP-0423 is added.	Reference do other DNV GL document for completeness.
[10.3.2]	Section completely revised to include requirements regarding factory acceptance tests (FAT), harbour acceptance tests (HAT), site acceptance tests (SAT).	Moved from Sec. 5.
[10.4.1]	Removal of guidance note.	Guidance no longer needed because all mentioned standards have been replace by N-001.
[11.4]	Section updated.	Section was incomplete before and safety systems have now been added.
App.C	New App.C included to describe operational conditions of the offshore substations by means of figures.	Provide more clarity by making use of figures.

Editorial corrections

In addition to the above stated changes, editorial corrections may have been made.

CONTENTS

SECTION 1 GENERAL

1.1 Introduction

This document is the DNV standard for the design of offshore substations. The standard is applicable for offshore substations associated with offshore renewable energy projects, see [1.4].

The performance-based approach promoted in this standard, complemented by prescriptive requirements and guidance, makes this document also relevant for novel designs and offshore substations beyond the proven concepts.

Topics covered by this standard are electrical design, safety aspects including system layout, fire and explosion protection and the response of the offshore substation in emergency situations. Furthermore arrangement and layout concept of the offshore substation as well as transfer and access to and from the substation is being addressed, see Figure 1-1. Structural design, geotechnics, material and fabrication is covered to the necessary and specific extent. Whenever necessary or relevant, references are made to the applicable DNV 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.

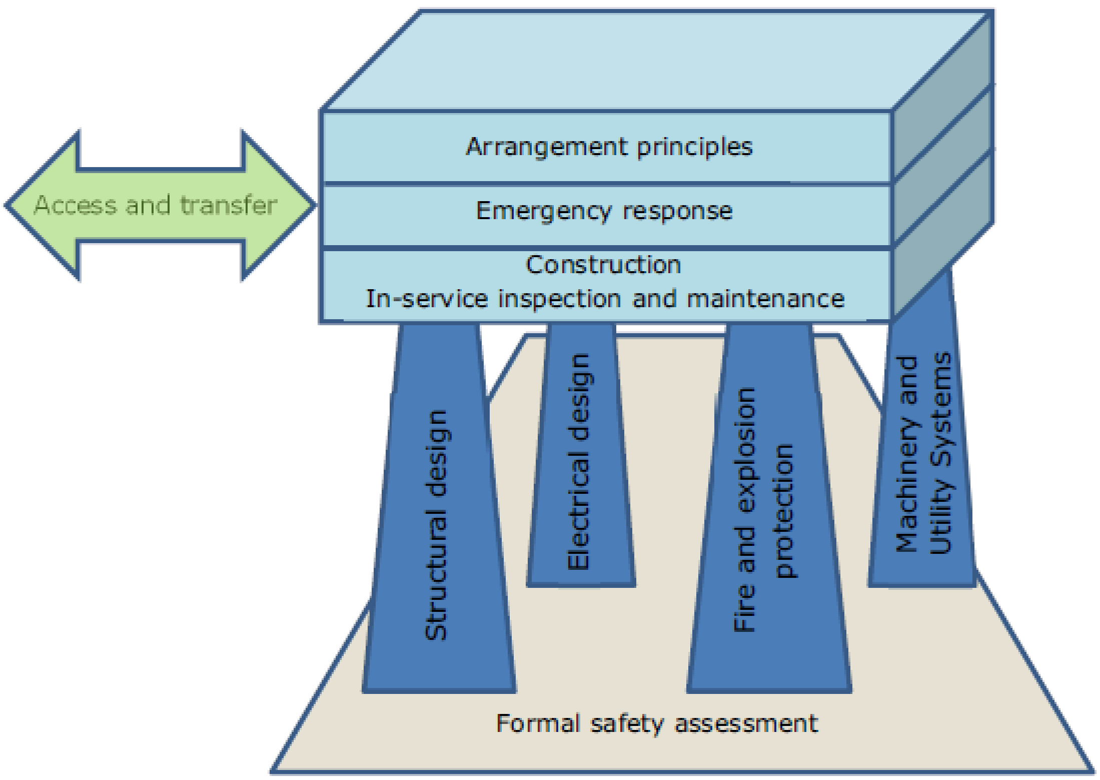

Figure 1-1 Content of this document

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

The certification scope is defined in the service specifications, among other:

— DNV-SE-0073 *Project certification of wind farms according to IEC 61400-22*
— DNV-SE-0190 *Project certification of wind power plants*
— IECRE OD-502 *IEC System for Certification to Standards relating to Equipment for use in Renewable Energy applications - Project Certification Scheme.*

1.2 Objective

The objectives of this standard are to:

— provide an internationally acceptable standard for safe design of offshore substations
— promote a holistic, performance and 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 substations subject to DNV verification and certification services.

1.3 Scope

This DNV standard for offshore substations may be applied for design, construction and in-service of bottom fixed installations, including foundation, support structure, topside structure and safety relevant systems.

This standard provides requirements for the following:

— safety assessment and arrangement principles
— structural design, including corrosion protection
— electrical design
— fire and explosion protection
— machinery and utility systems
— access, transfer and emergency response
— construction and in-service
— risk management and hazard identification.

In case this standard is applied for certification, the conformity assessment scope depends from the governing certification scheme, see [1.1].

If this standard is applied for verification, the verification scope shall be defined e.g. by the developer, regulator or other stakeholders and agreed with the verification body.

1.4 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 offshore substations 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. The application of local requirements shall be agreed in advance between the involved parties in a hierarchy of codes and standards.

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 shall be installed, in conjunction with this standard if such standards exist.

---e-n-d---o-f---g-u-i-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, see e.g. DNV-ST-0126
— subsea installations
— subsea cables (except for the termination point at the offshore substation), see DNV-ST-0359
— detailed procedures for operation or decommissioning of the offshore substation. For structural construction, see DNV-OS-C401.

Alternative solutions may be applied where demonstrated and documented to provide the same or a higher level of safety and reliability.

1.5 References

1.5.1 DNV documents

1.5.1.1 Normative DNV documents

This standard includes normative references to other DNV documents and recognised codes and standards which, through reference in the text, constitute provisions of this standard.

The latest revision of the standards in Table 1-1 applies.

Table 1-1 Normative DNV documents

Document code	*Title*
DNV-OS-B101	Metallic materials
DNV-OS-C101	Design of offshore steel structures, general - LRFD method
DNV-OS-C401	Fabrication and testing of offshore structures
DNV-ST-C502	Offshore concrete structures
DNV-ST-0126	Support structures for wind turbines
DNV-ST-0437	Loads and site conditions for wind turbines

1.5.1.2 Informative DNV documents

The informative references listed in Table 1-2 are referenced in the text of this document, and may be used as a source of supplementary guidance and information.

The latest revision of the documents in Table 1-2 applies.

Table 1-2 Informative DNV documents

Document code	*Title*
DNV-RP-C201	Buckling strength of plated structures
DNV-OS-A101	Safety principles and arrangements
DNV-OS-A301	Human comfort
DNV-OS-C301	Stability and watertight integrity
DNV-OS-D101	Marine and machinery systems and equipment
DNV-OS-D201	Electrical installations
DNV-OS-D202	Automation, safety and telecommunication systems
DNV-OS-D301	Fire protection
DNV-OS-E401	Helicopter decks
DNV-RP-0360	Subsea power cables in shallow water
DNV-RP-0416	Corrosion protection for wind turbines
DNV-RP-0419	Analysis of grouted connections using the finite element method
DNV-RP-0423	Manufacturing and commissioning of offshore substations
DNV-RP-A203	Technology qualification
DNV-RP-B401	Cathodic protection design
DNV-RP-C204	Structural design against accidental loads
DNV-RP-C205	Environmental conditions and environmental loads
DNV-RP-C210	Probabilistic methods for planning of inspection for fatigue cracks in offshore structures
DNV-RP-C212	Offshore soil mechanics and geotechnical engineering
DNV-RU-SHIP Pt.4 Ch.6	Piping systems
DNV-RU-SHIP Pt.6 Ch.5	Equipment and design features
DNV-SE-0073	Project certification of wind farms according to IEC 61400-22
DNV-SE-0160	Technology qualification management and verification
DNV-SE-0190	Project certification of wind power plants
DNV-SE-0295	Verification and certification of offshore concrete and grout structures
DNV-SE-0420	Certification of meteorological masts
DNV-SE-0474	Risk based verification
DNV-ST-0359	Subsea power cables for wind power plants
DNV-ST-0377	Shipboard lifting appliances

Document code	Title
DNV-ST-0378	Offshore and platform lifting appliances
DNV-ST-N001	Marine operations and marine warranty
DNV-ST-N002	Site specific assessment of mobile offshore units for marine warranty

1.5.2 External documents

The following standards and other relevant publications are referenced in this standard, see Table 1-3. The latest revision (unless otherwise agreed) of the documents in Table 1-3 applies. The listed standards include acceptable, but not mandatory methods, which may be applied provided it is shown that they meet or exceed the level of safety of this standard.

Table 1-3 External documents

Document code	Title
API RP 2X	Recommended Practice for Ultrasonic and Magnetic Examination of Offshore Structural Fabrication and Guidelines for Qualification of Technicians
API RP 75	Safety and Environmental Management System for Offshore Operations and Assets
API Spec 2W	Specification for Steel Plates for Offshore Structures, Produced by Thermo-Mechanical Control Processing (TMCP)
API Spec 2Y	Specification for Steel Plates, Quenched-and-Tempered, for Offshore Structures
ASTM E1529	Standard Test Methods for Determining Effects of Large Hydrocarbon Pool Fires on Structural Members and Assemblies
CAP 437	Standards for offshore helicopter landing areas
CIGRE Technical Brochure 483	Guidelines for the Design and Construction of AC Offshore Substations for Wind Power Plants
CIGRE Technical Brochure 502	High-Voltage On-Site Testing with Partial Discharge Measurement
CIGRE Technical Brochure 537	Guide for Transformer Fire Safety Practices
DIN 50930-6	Corrosion of metals - Corrosion of metallic materials under corrosion load by water inside of pipes, tanks and apparatus - Part 6: Evaluation process and requirements regarding the hygienic suitability in contact with drinking water
EN 54-series	Fire detection and fire alarm systems
EN 353-1	Personal fall protection equipment - Guided type fall arresters including an anchor line - Part 1: Guided type fall arresters including a rigid anchor line
EN 353-2	Personal protective equipment against falls from a height - Part 2: Guided type fall arresters including a flexible anchor line
EN 1090-2	Execution of steel structures and aluminium structures - Part 2: Technical requirements for steel structures
EN 1363-2	Fire resistance tests - Part 2: Alternative and additional procedures
EN 1993-1-series	Eurocode 3: Design of steel structures

Document code	*Title*
EN 10025-series	Hot rolled products of structural steels
EN 10160	Ultrasonic testing of steel flat product of thickness equal or greater than 6 mm (reflection method)
EN 10204	Metallic products - Types of inspection documents
EN 10210-series	Hot finished structural hollow sections
EN 10219	Cold formed welded steel structural hollow sections
EN 10225-series	Weldable structural steels for fixed offshore structures
EN 12097	Ventilation for Buildings - Ductwork - Requirements for ductwork components to facilitate maintenance of ductwork systems
EN 12599	Ventilation for buildings - Test procedures and measurement methods to hand over air conditioning and ventilation systems
EN 14986	Design of fans working in potentially explosive atmospheres
EN 50272-2	Safety requirements for secondary batteries and battery installations - Part 2: Stationary batteries
EN 50499	Procedure for the assessment of the exposure of workers to electromagnetic fields
EN 50522	Earthing of power installations exceeding 1 kV a.c
FSS Code	International Code for Fire Safety Systems
FTP Code	International Code for Application of Fire Test Procedures
IACS UI SC241	Manually operated call points (SOLAS II-2/7.7)
IACS UR D8	Hazardous areas
IACS UR D11	Safety features
IACS UR E15	Electrical services required to be operable under fire conditions and fire resistant cables
IACS UR F29	Non-sparking fans
IACS UR P1	Rules for pipes
IEC 60076-series	Power transformers
IEC 60079-10-1	Explosive atmospheres - Part 10-1: Classification of areas - Explosive gas atmospheres
IEC 60079-14	Explosive atmospheres - Part 14: Electrical installations design, selection and erection
IEC 60092-series	Electrical installations in ships
IEC 60099-series	Surge arresters - Part 4
IEC 60331-series	Tests for electric cables under fire conditions. Circuit integrity
IEC 60332-3-series	Tests on electric and optical fibre cables under fire conditions
IEC 60364-7-701	Low-voltage electrical installations - Part 7: Requirements for special installations or locations
IEC 60364-series	Low-voltage electrical installations
IEC 60376	Specification of technical grade sulphur hexafluoride (SF6) and complementary gases to be used in its mixtures for use in electrical equipment

Document code	Title
IEC 60502-2	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)
IEC 60598-series	Luminaires
IEC 60700-1	Thyristor valves for high voltage direct current (HVDC) power transmission - Part 1: Electrical testing
IEC 60812	Failure modes and effects analysis (FMEA and FMECA)
IEC 60840	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
IEC 60865-1	Short-circuit currents - Calculation of effects - Part 1: Definitions and calculation methods
IEC 60871-series	Shunt capacitors for a.c. power systems having a rated voltage above 1 000 V
IEC 61000-series	Electromagnetic compatibility (EMC)
IEC 61025	Fault tree analysis (FTA)
IEC 61071	Capacitors for power electronics
IEC 61400-3-1	Wind energy generation systems - Part 3-1: Design requirements for fixed offshore wind turbines
IEC 61643-11	Low-voltage surge protective devices - Part 11: Surge protective devices connected to low-voltage power systems - Requirements and test methods
IEC 61643-21	Low-voltage surge protective devices- Part 21: Surge protective devices connected to telecommunications and signaling networks - Performance requirements and testing methods
IEC 61869-series	Instrument transformers
IEC 61892-series	Mobile and fixed offshore units - Electrical installations
IEC 61936-1	Power installation exceeding 1 kVa.c. - Part 1: common rules
IEC 62067	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
IEC 62271-series	High-voltage switchgear and control gear
IEC 62305-1	Protection against lightning - Part 1: General principles
IEC 62305-3	Protection against lightning - Part 3: Physical damage to structures and life hazard
IEC 62305-4	Protection against lightning - Part 4: Electrical and electronic systems within structures
IEC 62485-series	Safety requirements for secondary batteries and battery installations
IEC 62501	Voltage sourced converter (VSC) valves for high-voltage direct current (HVDC) power transmission - Electrical testing
IEC TR 62001-series	High-voltage direct current (HVDC) systems - Guidance to the specification and design evaluation of AC filters
IECRE OD-502	IEC System for Certification to Standards relating to Equipment for use in Renewable Energy applications
ISO 1716	Reaction to fire tests for products — Determination of the gross heat of combustion (calorific value)

Document code	*Title*
ISO 7547	Ships and marine technology — Air-conditioning and ventilation of accommodation spaces — 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 9001	Quality management systems - Requirements
ISO 9943	Shipbuilding - Ventilation and air treatment of galleys and pantries with cooking appliances
ISO 12944 series	Paints and varnishes - Corrosion protection of steel structures by protective paint systems
ISO 14122-series	Safety of machinery - Permanent means of access to machinery
ISO 14224	Petroleum, petrochemical and natural gas industries - Collection and exchange of reliability and maintenance data for equipment
ISO 14520-1	Gaseous fire-extinguishing systems — Physical properties and system design — Part 1: General requirements
ISO 15138	Petroleum and natural gas industries - Offshore production installations. Heating, ventilation and air-conditioning
ISO/IEC 17025	General requirements for the competence of testing and calibration laboratories
ISO 17631	Ships and marine technology - Shipboard plans for fire protection, life-saving appliances and means of escape
ISO 19900	Petroleum and natural gas industries - General requirements for offshore structures
ISO 19901-2	Petroleum and natural gas industries - Specific requirements for offshore structures
ISO 19902	Petroleum and natural gas industries - Fixed steel offshore structures
ISO 20902-1	Fire test procedures for divisional elements that are typically used in oil, gas and petrochemical industries — Part 1: General requirements
LSA Code	International Life-Saving Appliance (LSA) Code
MARPOL 73/78	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
MODU Code	Code for the Construction and Equipment of Mobile Offshore Drilling Units
NFPA 11	Standard for Low-, Medium-, and High-Expansion Foam
NFPA 13	Standard for the Installation of Sprinkler Systems
NFPA 15	Standard for Water Spray Fixed Systems for Fire Protection
NFPA 16	Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems
NFPA 20	Standard for the Installation of Stationary Pumps for Fire Protection
NFPA 750	Standard on Water Mist Fire Protection Systems
NFPA 2001	Standard for Clean Agent Fire Extinguishing Systems
NORSOK C-001	Living quater area

Document code	*Title*
NORSOK C-002	Architectural components and equipment
NORSOK H-003	Heating, ventilation and air conditioning (HVAC) and sanitary systems
NORSOK M-501	Surface preparation and protective coating
NORSOK N-004	Design of steel structures
NORSOK S-002	Working environment
SOLAS	International Convention for the Safety of Life at Sea
VDI 6023	Hygiene in drinking-water installations - Requirements for planning, execution, operation and maintenance
Vds 2109	VdS Guidelines for Water Spray Systems - Planning and Installation
Vds 2380	VdS Guidelines for Fire Extinguishing Systems - Fire Extinguishing Systems Using Non-liquefied Inert Gases - Planning and Installation
VDS 2381	VdS Guidelines for fire extinguishing systems - Fire Extinguishing Systems using Halocarbon Gases - Planning and Installation

1.6 Definitions and abbreviations

1.6.1 Definition of verbal forms

Table 1-4 Definition of verbal forms

Term	*Definition*
shall	verbal form used to indicate requirements strictly to be followed in order to conform to the document
should	verbal form used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others
may	verbal form used to indicate a course of action permissible within the limits of the document

1.6.2 Definition of terms

Table 1-5 Definition of terms

Term	*Description*
accommodation area	space used for cabins, offices, lavatories, public spaces, corridors, hospitals, game and hobby rooms, pantries containing no cooking appliances and similar spaces

Term	*Description*
A class division	divisions formed by bulkheads and decks which comply with the following: 1) they shall be constructed of steel or other equivalent material 2) they shall be suitably stiffened 3) they shall be so constructed as to be capable of preventing the passage of smoke and flame to the end of the one-hour standard fire test 4) they shall be insulated with approved non-combustible materials such that the average temperature of the unexposed side will not rise more than 140°C above the original temperature, nor will the temperature, at any one point, including any joint, rise more than 180°C above the original temperature, within the time listed below: — class 'A-60' 60 minutes — class 'A-30' 30 minutes — class 'A-15' 15 minutes — class 'A-0' 0 minute 5) a test of a prototype division is required to ensure that it meets the requirements for integrity and temperature rise. (see SOLAS Reg. II-2/3.2)
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
as low as reasonably practicable	principle of reducing risks to 'as low as reasonably practicable'. This means that once risks are considered to be tolerable, further risk reduction measures are balanced against the cost, time or trouble of implementing such measures. The emphasis is to implement improvements unless they can clearly be shown to be 'not reasonably practicable', i.e. cost of implementation is unacceptable and disproportionate to safety benefit.
atmospheric zone	external surfaces of the installation above the splash zone
B class division	divisions formed by bulkheads, decks, ceilings or linings which comply with the following: 1) they shall be so constructed to be capable of preventing the passage of flame to the end of the first half hour of the standard fire test 2) they shall have an insulation value such that the average temperature of the unexposed side will not rise more than 140°C above the original temperature, nor will the temperature, at any one point, including any joint, rise more than 225°C above the original temperature, within the time listed below: — class 'B-15' 15 minutes — class 'B-0' 0 minute 3) they shall be constructed of recognised non-combustible materials and all materials entering into the construction and erection of 'B' class divisions shall be noncombustible, with the exception that combustible veneers may be permitted provided they meet other requirements of this chapter 4) a test of a prototype division is required to ensure that it meets the requirements for integrity and temperature rise. (see SOLAS Reg. II-2/3.4)

Term	*Description*
black substation condition	offshore substation is in black substation condition when the auxiliary power supply system is out of operation and the services required for the restoration of the auxiliary power supply system are not available. Batteries and/or pressure vessels for starting of all generator sets are considered discharged.
C class divisions	divisions constructed of approved non-combustible materials. They need meet neither requirements relative to the passage of smoke and flame nor limitations relative to the temperature rise. Combustible veneers are permitted provided they meet other requirements of this chapter. (see SOLAS Reg. II-2/3.10)
characteristic load	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	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	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	representative value associated with a prescribed probability of not being unfavourably exceeded or fallen below of (as relevant) during the applicable reference period
combustible material	any material other than a non-combustible material
continuous 'B' class ceilings or linings	'B' class ceilings or linings which terminate at an 'A' or 'B' class division
control station or control room	spaces with equipment performing control functions essential for operational and emergency services e.g. spaces containing: — operational control systems — emergency source of power (however, for purposes of the application of Sec.6, the space where the emergency source of power is located is not considered as being a control station) — fire control equipment — fire extinguishing equipment serving various locations. (see MODU Code Sec. 1.3.13)
corridor	long hall onto which several rooms open, including lobbies
corrosion allowance	extra wall thickness added during design to compensate for any anticipated reduction in thickness during the operation
davit crane	crane that projects over the side of an installation for moving cargo
deluge system	system to apply firewater through an array of open spray nozzles by operation of a valve on the inlet to the system. The system will discharge through all nozzles served by the deluge valve.
ductility	property of a steel or concrete member to sustain large deformations without failure
earthing	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
emergency condition	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 system as a consequence of a malfunction or an accidental event including fire, flooding, extreme waves and similar

Term	*Description*
emergency response	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.
emergency services	services essential for safety in an emergency condition
environmental state	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
escape	act of persons moving away from a hazardous event to a safer place
essential services	services required to maintain offshore substation in a defined state of readiness and habitation for a period defined by the user for situations other than normal operation and without recourse to the emergency source of power except than in an emergency situation (see IEC 61892-1)
evacuation	planned and controlled method of leaving the installation without directly entering the sea
fatigue	degradation of material caused by cyclic (mechanical) loading
failure mode and effect analysis	systematic procedure for the analysis of a system to identify the potential failure modes, their causes on the system performance (see IEC 60812). Note that additional techniques may be required if dealing with simultaneous multiple failures.
fault tree analysis	deductive (top down) method of analysis aimed at pinpointing the causes or combinations of causes that can lead to the defined top event (see IEC 61025)
fire area	area divided from other areas by horizontal and vertical fire divisions, of at least A-0 rating
fire damper	device installed in a ventilation duct, which under normal conditions, remains open allowing flow in the duct, and is closed during a fire, preventing the flow in the duct to restrict the passage of fire. In using the above definition the following terms may be associated: 1) automatic fire damper is a fire damper that closes independently in response to exposure to fire products 2) manual fire damper is a fire damper that is intended to be opened or closed by the crew by hand at the damper itself 3) remotely operated fire damper is a fire damper that is closed by the crew through a control located at a distance away from the controlled damper. (see SOLAS Reg. II-2/3.54)
fixed offshore structure	non-buoyant construction that is bottom founded at a particular offshore location, transferring all actions on it to the seabed
forced ventilation system	any ventilation system driven by hydraulic, pneumatic or electric motors
foundation	means for transfer of loads from a support structure to the seabed soils
flame retardant	property of a substance or treatment applied to a material to substantially suppress, reduce or delay the propagation of a flame
grout	preblended cementitious material including the constituent materials: cement, aggregates and water. Structural grout may also include admixtures and additions
guidance note	information in the standard given to increase the understanding of the statements

Term	Description
H class division	divisions formed by bulkheads and decks which comply with the following: 1) they shall be constructed of steel or other equivalent material 2) they shall be suitably stiffened 3) they shall be constructed as to be capable of preventing the passage of smoke and flames up to the end of the two-hour standard fire test 4) they shall be insulated with approved non-combustible materials or equivalent passive fire protection such that the average and maximum temperature of the unexposed side will not rise to more than 140°C and 180°C respectively above the original temperature, within the time listed below: — class 'H-120' 120 minutes — class 'H-60' 60 minutes — class 'H-0' 0 minute 5) atest of a prototype division is required to ensure that it meets the requirements for integrity and temperature rise. When tested according to the fire test procedures code, the furnace control temperature curve was replaced with the furnace control temperature curve for hydrocarbon fires defined in national or international standards.[1)] [1)] Refer to national standards such as: BS EN 1363-2:1999 *Fire resistance tests. Alternative and additional procedures*, or ASTM 1529-14a *Standard Test Methods for Determining Effects of Large Hydrocarbon Pool Fires on Structural Members and Assemblies*, or ISO/DIS 20902 1 *Fire test procedures for divisional elements that are typically used in oil, gas and petrochemical industries - Part 1: General requirements*. (see MODU Code Sec. 1.3.26)
hazard	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.
hazardous areas	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
insulation	non-conductive material surrounding or supporting a conductor
integrity	ability of the installation to remain safe and stable to safeguard personnel and facilities on board Integrity is generally taken to mean structural soundness, strength and stability required to fulfil these actions
islanded conditions	offshore substation is in islanded condition when the electrical connection with the external grid is not available
J-tube	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 J
legionella	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
limit states	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)
load effect	effect of a single design load or combination of loads on the equipment or system, such as stress, strain, deformation, displacement, motion, etc.

Term	*Description*
low flame spread	the surface thus described will adequately restrict the spread of flame, this being determined in accordance with the fire test procedures code
machinery spaces	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 (see MODU Code 1.3.33)
machinery spaces of category A	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 (see MODU Code 1.3.34)
mean time between failure	the mean time between two consecutive failures (see ISO 14224)
mean time to repair	the mean time before the item is repaired (see ISO 14224)
meshed power supply	two independent self-contained power sources and provides reliable backup power to emergency services through its fully redundant setup. The arrangement of components and the way of interconnecting switchboards provides sufficient flexibility that equals a system with dedicated main and emergency sources of power of auxiliary power system.
muster area	area for persons to muster safely in an emergency
(N-1) operational condition	the rule according to which the elements remaining in operation within the main power system and substations auxiliary power supply system after occurrence of a contingency are capable of accommodating the new operational situation without violating limits securing normal and habitable operational conditions on the offshore substation
natural ventilation systems	systems in which the air movement is caused solely by pressure differences caused by temperature differences or wind
non-combustible material	material which neither burns nor releases flammable vapours in sufficient quantity for self-ignition when heated to approximately 750ºC, this being determined in accordance with the fire test procedures code
normal operational and habitable conditions	condition under which the substation, as a whole, is in working order and functioning normally
offshore installation	collective term to cover any structure, buoyant or non-buoyant, designed and built for installation at a particular offshore location
offshore substation	collective term for high voltage AC (transformer) and high voltage DC (converter) substations, as well as associated accommodation platforms located offshore
open deck	open deck spaces and enclosed promenades clear of lifeboat and liferaft embarkation and lowering stations. To be considered in this category, enclosed promenades shall have no significant fire risk, meaning that furnishings shall be restricted to deck furniture. In addition, such spaces shall be naturally ventilated by permanent openings. Air spaces (the space outside superstructures and deckhouses). (see SOLAS II-2 Reg. 9.2.2.3.2 (5))

Term	*Description*
operational services	services that shall 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
partial safety factor method	method for the design where uncertainties in loads are represented by a load factor and uncertainties in strength are represented by a material factor
passive fire protection	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
place of safety	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
point of common coupling	cables terminations connecting the substation to the subsea cables that export the power to the grid
prevailing wind	wind direction which has the highest probability of occurrence.
primary muster area	area provided to protect personnel from the effects of an emergency, which is beyond immediate control Area and protection shall be sufficient to allow controlled muster, emergency assessment, incident evaluation, implementation of control emergency procedures as well as evacuation. The primary muster area should be provided with adequate command communication facilities to address an emergency and organise safe evacuation if necessary.
public address system	internal audible system which generates general announcements which may be combined with (e.g. fire alarm and/or General Alarm) specific area announcements
risk	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.
safety systems	systems, which are provided to prevent, detect, control or mitigate the effects of an accidental event. Failure of a safety system could lead to the development or escalation of an accidental event.
smoke damper	device installed in a ventilation duct, which under normal conditions remains open allowing flow in the duct, and is closed during a fire, preventing the flow in the duct to restrict the passage of smoke and hot gases. A smoke damper is not expected to contribute to the integrity of a fire rated division penetrated by a ventilation duct. In using the above definition the following terms may be associated: 1) automatic smoke damper is a smoke damper that closes independently in response to exposure to smoke or hot gases 2) manual smoke damper is a smoke damper intended to be opened or closed by the crew by hand at the damper itself 3) remotely operated smoke damper is a smoke damper that is closed by the crew through a control located at a distance away from the controlled damper. (see SOLAS Reg. II-2/3.55)
splash zone	the external surfaces of the installation that are affected by wave action periodically in and out of the water. The determination of the splash zone includes evaluation of all relevant effects including influence of waves, tidal variations, settlements, subsidence and vertical motions.

Term	Description
sprinkler system	system to apply firewater through nozzles by heat exposure of frangible bulb. The system is charged with pressurised firewater up to the nozzle (may also be pressurized air). Only fire exposed nozzles will discharge firewater. The system normally also include a control valve and a device for actuating alarm when system operates.
steel or other equivalent material	any non-combustible material which by itself or due to insulation provided, has structural and integrity properties equivalent to steel at the end of the applicable exposure to the standard fire test (e.g. aluminium alloy with appropriate insulation)
submerged zone	the part of the installation which is below the splash zone, including buried parts
substation	see offshore substation
substation control room	room where operators are stationed to carry out centralized control, monitoring and administrative responsibilities on offshore substations of type B and C
substation structure	comprises all structural parts of the substation, including the support structure and the topside structure
target safety level	nominal acceptable probability of failure
temporary refuge or shelter area	area provided to protect personnel from the effects of an emergency, which is beyond immediate control Protection shall be of sufficient duration to allow controlled muster, emergency assessment, incident evaluation, implementation of control emergency procedures as well as evacuation. The temporary refuge should be provided with adequate command communication facilities to address an emergency and organise safe evacuation if necessary. Accommodation area is often used as the safe haven or temporary refuge.
topsides	structures and equipment placed on a supporting structure to provide some or all of an offshore substation's function
type A substation	unmanned substation containing main power system as defined in [5.4.1.1]. Persons are only expected to be present for inspection and maintenance activities without overnight stays between working shifts. If habitability services are provided they are limited and intended solely for the use during the working shift not facilitating for overnight stay.
type B substation	temporarily (i.e. overnight stays between working shifts are assumed to take place, even if irregularly) or permanently manned substation containing main power system as defined in [5.4.1.1] and accommodation spaces. On departure of personnel from the substation all systems shall be returned to a safe and unmanned state, without adding additional hazards such as legionella developing in water systems.
type C substation	separate accommodation platform or an accommodation platform connected to another substation by a bridge

1.6.3 Abbreviations

Table 1-6 Abbreviations

Abbreviation	Description
AC	alternating current
ADG	auxiliary diesel generator
AIS	automatic identification system

Abbreviation	*Description*
ALARP	as low as reasonably practicable
ALS	accidental limit state
ATR	automatic target recognition
AVR	automatic voltage regulator
CAA	civil aviation authority
CCTV	closed circuit television
CDM	construction (design and management) regulations
CFD	computational fluid dynamics
CO_2	carbon dioxide
CoF	consequence of failure
COLREG	collision regulations
CSP	commissioning switching program
DB	distribution board
DC	direct current
DFF	design fatigue factor
DIFFS	deck integrated firefighting system
D&ID	ducting and instrumentation diagrams
EERA	emergency, escape and rescue assessment
EDB	emergency distribution board
EDG	emergency diesel generator
EHV	extra high voltage (> 230 kV)
EMC	electromagnetic compatibility
EMF	electromagnetic field
EN	European norm
ERRV	emergency response and rescue vessel
ESB	emergency switch board
ETA	event tree analysis
FAT	factory acceptance test
FEM	finite element method
FERA	fire and explosion risk assessment
FLS	fatigue limit state
FMEA	failure mode and effects analysis
FMECA	failure mode, effects and criticality analysis

Abbreviation	*Description*
FRA	frequency response analysis
FRC	fast rescue craft
FRP	fibre reinforced plastics
FTA	fault tree analysis
FW	fresh water
GDG	grid diesel generator
GIS	gas insulated switchgear
GIT	gas insulated transformer
GPS	global positioning system
HAT	harbour acceptance test
HAZID	hazard identification
HAZOP	Hazard and operability study
HCA	helideck certification agency
HSE	health safety and environment
HV	high voltage (≥ 1 kV and ≤ 230 kV)
HVAC	heating, ventilation and air conditioning (system)
HVDC	high-voltage direct current
ICAO	International Civil Aviation Organisation
IEC	International Electrotechnical Commission
IMO	International Maritime Organisation
ISO	International Organisation of Standardisation
LPL	lightning protection level
LPZ	lightning protection zone
LRFD	load and resistance factor design
LSA	life saving appliances
LV	low voltage (< 1 kV)
MAC	manual alarm callpoint
MIC	microbiologically induced corrosion
MSB	main switch board
NDE	non-destructive examination
NFPA	National Fire Protection Association
O&M	operation and maintenance
OLTC	on load tap changer

Abbreviation	*Description*
OPC	Ordinary Portland Cement (a cement slurry consisting of Ordinary Portland Cement and water)
OS	offshore standard
OSS	offshore substation
PA	public address system
PCC	point of common coupling
PFEER	offshore installations (prevention of fire and explosion, and emergency response) regulations
PLL	potential loss of life
POB	persons on board
PoF	probability of failure
PLB	personal locator beacon
PPE	personal protective equipment
QRA	quantitative risk assessment
RACON	radar beacon
RP	recommended practice
SAR	search and rescue
SAT	site acceptance test
SCADA	supervisory control and data acquisition
SCE	safety critical elements
SDOF	single degree of freedom
SE	service specification
SF_6	sulphur hexafluoride
SLS	serviceability limit state
SOLAS	safety of life at sea
SOV	service operation vessel
SPD	surge protection device
SPMT	self-propelled modular transporters
ST	standard
STATCOM	static synchronous compensator
TEMPSC	totally enclosed motor propelled survival craft
ULS	ultimate limit state
UPS	uninterruptible power supply
VdS	VdS Schadenverhütung GmbH
VRLA battery	valve regulated lead acid battery

Abbreviation	Description
WPT	welding production test

1.7 Procedural requirements

1.7.1 Certification requirements

Certification principles and procedures related to certification services for offshore renewable energy installations are specified in relevant service specifications, see [1.1].

Other recognised standards than those listed in [1.5.1.1] may be used provided it can be demonstrated that these meet or exceed the requirements of the normative DNV documents.

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.

SECTION 2 FORMAL SAFETY ASSESSMENT

2.1 Introduction

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 concept

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 concept 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 offshore substation related to one wind power plant or a part of the wind power plant, 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 performance- and risk-based approach shall be followed, while satisfying the given overall safety target of the prescriptive requirements. This can be applied for an entire substation, parts thereof or particular systems by providing a clear and convincing demonstration through technical rationale that the proposed alternative approach provides a level of safety equivalent to the requirement it would replace. The performance- and risk-based approach imposes a higher burden of proof than showing compliance with a prescriptive requirement. Depending on the extent of the novel solution, quantitative evaluation of the performance by means of quantitative risk assessment (QRA) may become necessary.

When proposing novel or alternative designs, the substitution of design measures to reduce risk with operational or procedural measures to claim equivalent safety shall be thoroughly examined and special care shall be taken in order to confirm that design measures take priority over operational or procedural measures.

In order to qualify alternative or novel design and for general guidance on the implementation of a risk based approach, see the following DNV service documents:

— DNV-SE-0160 *Technology qualification management and verification*
— DNV-RP-A203 *Technology qualification*
— DNV-SE-0474 *Risk based verification*

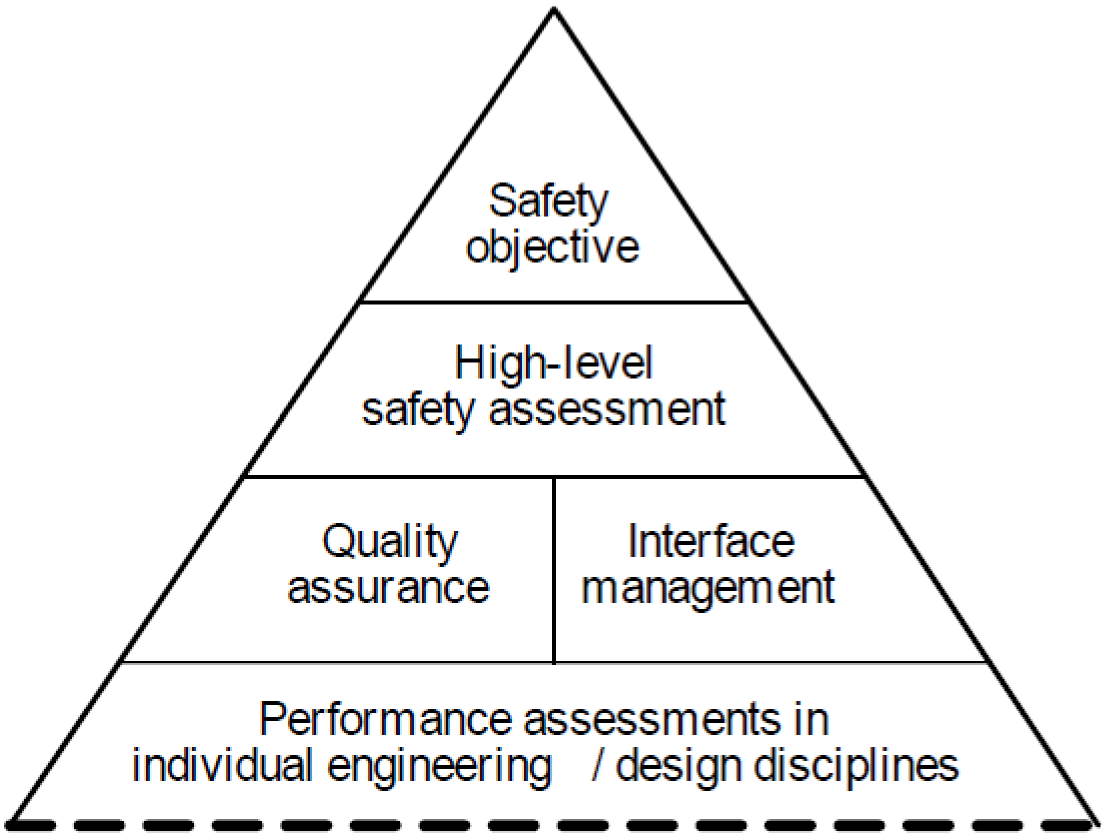

Figure 2-1 Safety concept structure

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 concept 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 or equivalent. 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

Safety critical interfaces shall be analysed, documented and updated throughout the project.

Coordination procedures between data providers and the various designing, manufacturing, transporting, installing and other relevant parties shall be defined, in particular when information shall be exchanged between different contractors, including:

— responsibilities
— data requirements covering all necessary aspects over the lifetime of the substation
— data format
— data schedule.

2.3 High-level safety assessment process

2.3.1 General

An offshore substation structure 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.

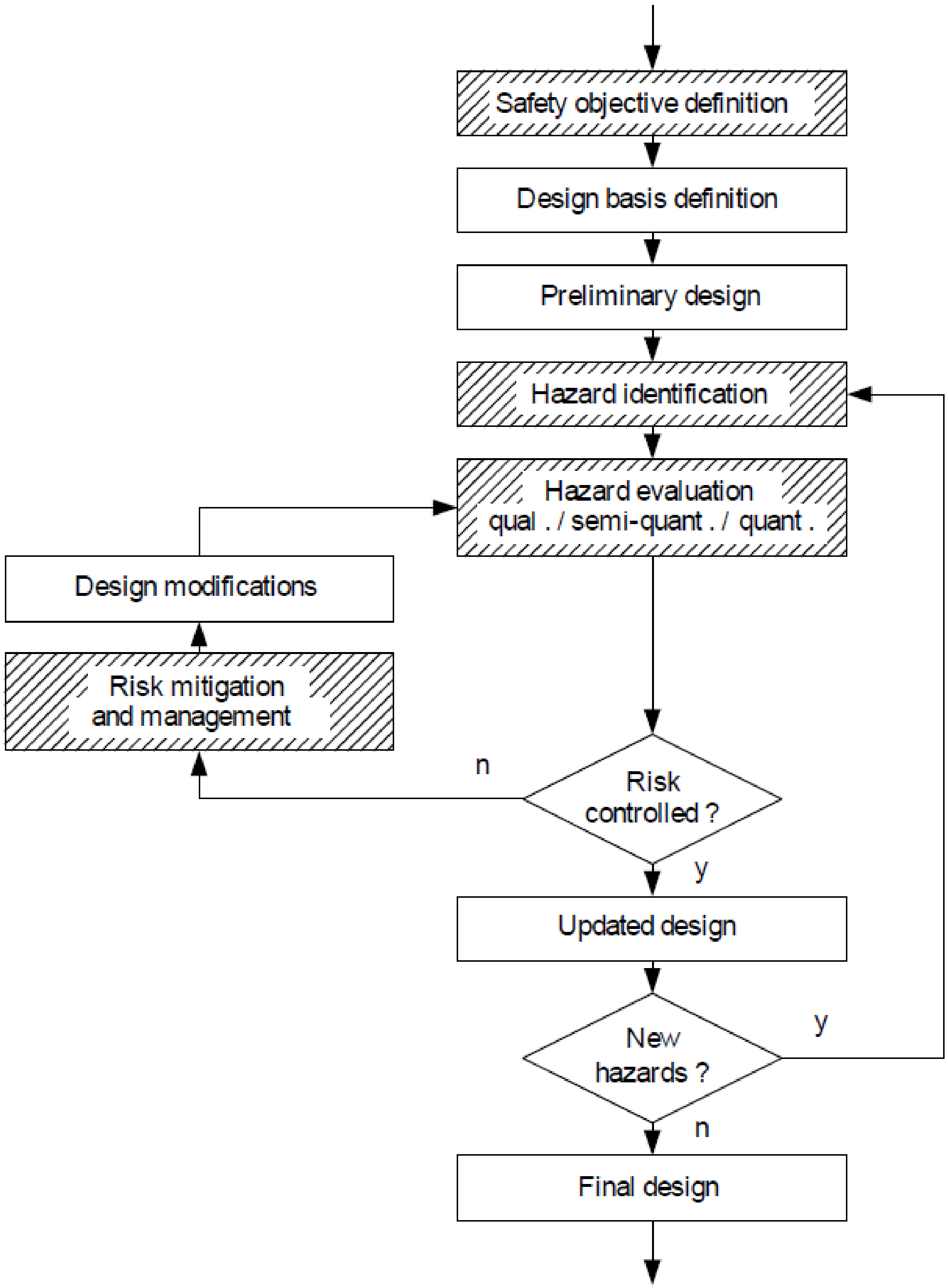

Figure 2-2 Safety assessment in the design process

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.

Based on the listed items above the process includes considering the arrangement of equipment, physical and chemical properties of fluids being handled and operating and maintenace 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
— 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.

In addition 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 substations associated with wind power plants are covered by standards to varying depth, depending on the field of engineering.

Design of offshore substations 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 substations. 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 shall be achieved or demonstrated; this is part of the verification plan.

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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.

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SECTION 3 ARRANGEMENT PRINCIPLES

3.1 Introduction

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*
— [8.4] *Helicopter access and transfer*
— [8.5] *Ascending and descending*.

For further information on general arrangement principles for offshore units and installations, see DNV-OS-A101. National and local requirements should be followed if available.

3.2 Safety concept 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 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, including injured personnel
— meet additional requirements due to its function as an offshore substation.

3.2.2 Safety criteria and evaluation

The layout and configuration of the substation shall be such that risks to persons on it are reduced to the lowest acceptable level, see App.A.

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 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 substation which shall be considered include, but are not limited to:

— environmental and oceanographic conditions
— substation 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), substation size, the risks (probability and consequence) including accidental events and shall be documented in basis of design documentation.

3.3 Offshore substation arrangement

3.3.1 Offshore substation location

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

— other fixed or floating installations
— electrical infrastructure (subsea cabling and pipelines)
— 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 power plant 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 offshore substation

Depending on manning principles,offshore substations are divided into the following types:

— Type A: unmanned substation containing main power system as defined in [5.4.1.1]. Persons are only expected to be present for inspection and maintenance activities without overnight stays between working shifts. If habitability services are provided, they are limited and intended solely for the use during the working shift not facilitating for overnight stay.
— Type B: temporarily (i.e. overnight stays between working shifts are assumed to take place, even if irregularly) or permanently manned substation containing main power system as defined in [5.4.1.1] and accommodation spaces. On departure of personnel from the substation all systems shall be returned to a safe and unmanned state, without adding additional hazards such as legionella developing in water systems.
— Type C: a separate accommodation platform or an accommodation platform connected to another substation by a bridge.

Guidance note:

During the installation, commissioning, run-in phase or extensive repair campaign of an offshore substation and associated wind power plant, the substation is commonly manned during daytime for extended periods, normally for up to several months. Adequate provisions should be made for this period at the design stage. For such temporary phases - not counted to routine operation and regular maintenance - specific escape, evacuation, auxiliary power supply concepts should be developed.

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

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Minimum and maximum number of persons expected to be on the substation at any time (and for whom accommodation shall 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 in manned state, i.e. persons are present on the substation
— means of communication.

3.4 Segregation of areas

3.4.1 General

The substation shall be divided into different areas according to the type of activities that will be carried out and the associated hazard potential.

Areas of high risk potential shall be segregated from areas of low risk potential, and from areas containing important safety functions. Incident escalation between areas shall be avoided.

Accommodation spaces, service spaces, control stations as well as spaces containing equipment, sudden failure of which may result in hazardous situations (e.g. fire pumps, emergency sources of power, and other operational or safety systems), should not be located adjacent to hazardous areas.

(see MODU Code Sec. 9.3.1)

Requirements concerning passive fire protection are addressed in [6.4].

3.4.2 Hazardous areas

The following fluids shall be considered as substances requiring area classification:

a) flammable gas or vapour
b) flammable and/or combustible liquids which are handled at or above their flashpoint, or which could be heated to the flashpoint after release
c) flammable and/or combustible liquids that could form a flammable mist
d) fluids which satisfy the criteria in a), b) or c), and which are present periodically within the plant for 100 hours per year or more (e.g. during start-up)
e) unclassified, flammable and/or combustible liquids containing residual, volatile materials and which are stored under confined, heated conditions give rise to limited area classification.

Area classification shall be carried out to a suitable standard, see [6.6.4.1].

Guidance note:

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.

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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:

Ventilation systems for hazardous areas should be separate from ventilation systems for non-hazardous areas, ref. [7.11.2.4]. 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.

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

3.4.3 Dangerous areas

Areas where 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. Besides, the following areas shall be assessed on demand of access restriction, oxigen concentration monitoring, measurement before entrance, other safety measures:

— enclosed spaces with risk of low oxygen content due to leakage e.g. areas used as storage for gas bottles of fire extinguishing systems, GIS rooms
— enclosed spaces where oxygen can be consumed by corrosion, or where toxic gases (H_2S) can be produced by anaerobic bacterial action.

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

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

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.

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

3.5.2 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 DNV-ST-0359 and DNV-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 are required to be shielded against dropping burning materials in case of a fire. See [9.5].

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3.5.3 Emergency power

The location of the emergency source of power [5.5.3], the transitional source of emergency power [5.5.3.3] and emergency switchboard [5.5.3.2] shall be such as to ensure that a fire or other casualty in the space containing main sources of power supply for auxiliary power system [5.5.2.1] will not interfere with the supply or distribution of emergency power supply.

As far as practical, the space containing the emergency source of power, the transitional source of emergency power and the emergency switchboard shall not be contiguous to boundaries of those spaces containing main sources of power supply for auxiliary power system.

Where the emergency source of power, the transitional source of emergency power, and the emergency switchboard are contiguous to those spaces containing main sources of power supply for auxiliary power system, the contiguous boundaries shall be in compliance with [6.4].

(see MODU Code Sec. 5.4.3)

3.5.4 Load-handling and laydown areas

Offshore substations shall be fitted with load-handling equipment (e.g. cranes) with a capacity and reach suitable for foreseeable load-handling operations 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 the offshore substation and from service vessel decks should be considered. The lifting equipment could also include man-riding capability for personnel transfer operations.

All equipment, spares and supplies that may need material handling during the lifetime of the offshore substation should be identified by size, weight, location, access and method of material handling.

Lifting and transport zones and routes should be identified.

Obstruction free and clear view of load and handling areas during operation of lifting devices should be considered in layout design.

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Cranes and laydown 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.

Laydown areas should 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.

Laydown 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.

If a laydown area or part of laydown area is used as temporary or permanent storage, it shall be considered in total substation design weight and shall not restrict any escape paths. The specified design weight for laydown areas shall be clearly marked and included in the substation structural design calculations. During active lifting where an item is lowered to a laydown area before moved to next location, it is allowed to block escape paths during the operation if adequate risk mitigation has been performed.

Requirements for certification and verification of offshore and platform cranes are provided in DNV-ST-0378.

3.5.5 Meteorological mast

Where used, the meteorological mast shall be located in an area of the substation 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 DNV-ST-0126 and DNV-SE-0420.

3.5.6 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.

Bunded areas, drain systems and spill trays shall be designed to meet maximum foreseeable fluid volumes. Drain from rooms shall be sized so that bunded 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 shall be taken into account.

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In the rooms where pressure rise can occur due to accidental events (explosion, gas leakage, fire extinguishing gas release), necessity of openings shall be analysed.

3.5.7 Safety systems

Safety systems including required utilities are provided to prevent, detect and warn of an accidental event/abnormal conditions and/or mitigate its effects.

It is relevant for (but not limited to) the following systems and services:

— fire and gas detection system
— fire and general alarm system
— fire extinguishing systems
— emergency communication system/public address 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 and escape lighting
— remote emergency stop/shutdown arrangements for systems which may support the propagation of fire and or explosion, see IACS UR E 15.

Safety systems shall be located such that they can remain operational during the defined accidental events. Controls for safety systems shall be located where they are accessible and available for safe, simultaneous use during an accidental event/abnormal condition.

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

(see DNV-OS-A101 Ch.2 Sec.2 [3.1.1])

Operational principles of the safety systems are further described in the following sections:

— Sec.6 *Fire protection*
— Sec.9 *Emergency response*.

3.5.8 Life-saving appliances and personal protective equipment

Life-saving appliances and personal protective equipment shall be approved, provided, stored and maintained in accordance with local/national requirements.

Personal protective equipment shall be available in a suitable location for any person transferring to or from the substation.

Guidance note:

Life-saving appliances and personal protective equipment typically include:

— lifejacket
— immersion/survival suit, depending on water temperature
— 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.

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The substation 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. Lifejackets corresponding to number of POB should be located at the primary and secondary muster areas.

Where helicopter decks are used, the required rescue equipment shall be appropriately stored so that it is ready for use.

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.

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Further requirements in relation to life-saving applicanes are provided in Sec.9.

3.5.8.1 Lifebuoys

Lifebuoys shall be so distributed as to be readily available on open decks of the substation.

At least one lifebuoy on each side of the substation shall be fitted with a buoyant lifeline equal in length to not less than twice the height at which it is stowed above the waterline in the lightest seagoing condition, or 30 m, whichever is the greater.

Not less than one half of the total number of lifebuoys shall be provided with lifebuoy self-igniting lights; not less than two of these shall also be provided with lifebuoy self-activating smoke signals; lifebuoys with lights and those with lights and smoke signals shall be equally distributed on both sides of the substation and shall not be the lifebuoys provided with lifelines.

(see SOLAS Ch. III Reg. 7.1)

3.5.8.2 Lifejackets

A lifejacket shall be provided for every person on the substation.

Lifejackets shall be so placed as to be readily accessible and their position shall be plainly indicated.

The lifejackets used in totally enclosed lifeboats, except free-fall lifeboats, shall not impede entry into the lifeboat or seating, including operation of the seat belts in the lifeboat.

Lifejackets selected for free-fall lifeboats, and the manner in which they are carried or worn, shall not interfere with entry into the lifeboat, occupant safety or operation of the lifeboat.

(see SOLAS Ch. III Reg. 7.2)

3.5.8.3 Immersion suits and anti-exposure suits

An immersion suit or an anti-exposure suit of an appropriate size, shall be provided for every person. If the substation is installed in warm climates where thermal protection is unnecessary, this protective clothing is not required to be provided.

(see SOLAS Ch. III Reg. 7.3 and 32.3)

3.5.9 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.

3.6 Workplaces

3.6.1 General

Workplaces are places on an offshore substation mainly for the performance of work and for rest, including substation control room, workshops, storages, accomodation areas (and excluding areas infrequently occupied solely to carry out inspection or maintenance tasks).

All offshore substations should 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.

National requirements shall be observed.

Workplaces 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, see [3.4.1].

Workplaces 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 substation, except in designated areas.

3.6.2 Substation control room

Substation control room, where operators are stationed to carry out centralised control, monitoring and administrative responsibilities on offshore substations of type B and C, shall be designed and constructed considering safety. Ergonomic principles shall be considered.

Provisions should be made for work at computers as required. Storage facilities for documentation such as drawings and manuals should be provided.

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 areas

For substations of type B and C 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 in accordance with the national requirements.

Accommodation as well as temporary refuge or shelter areas shall have adequate ventilation, heating and lighting and protection from vibration, noise, electromagnetic fields, fumes and inclement weather. Further guidance is provided in DNV-OS-A301 *Human comfort*.

Guidance note:

For HVDC substations 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 substation necessitate space for relaxation during breaks. National legislation and requirements for separate sanitary and sleeping facilities for men and women may apply.

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

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 ducting diagrams.

The standards, design specifications and assumptions on which the design work is based shall be presented in the basis of design documentation.

Guidance note:

Guidance on required documents can be found in the following document:

— DNV-SE-0190 App.A *List of documents offshore substation*

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SECTION 4 STRUCTURAL DESIGN

4.1 Introduction

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

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*.

The design of the substructure and the topside shall among other cover the following phases: SPMT transport, load-out, sea transportation, lifting, set-down, operation and de-commissioning.

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 concept 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 this section and also in DNV-RP-C204 *Structural 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 stucutural integrity during removal of particular items (e.g. replacement of main transformer) and de-commissioning of the offshore substation
— take account of manufacturing, installation and removal issues.

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 power plants, 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 may 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:

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 three-dimensional effects cause additional restraints in deformations, or when there are sudden changes in section properties.

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

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 shall be described by at least the following:

- offshore substation location and main functionalities
- general description of substation layout
- project co-ordinate system and vertical reference levels including project datum
- general description, main dimensions and water depth
- type of substructure and foundation
- applicable codes, standards, regulations etc.
- structural analysis concept including safety factors
- service life of offshore substation
- quality management system
- transport and installation methods and requirements
- operation and maintenance methods and requirements
- decommissioning methods and requirements.

The meteorological and oceanographic conditions shall be described by at least the following characteristics, or include requirements or limitations to:

- 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 1:

For normal environmental conditions, see DNV-ST-0437.

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The geotechnical conditions shall be described by at least the following characteristics, or include requirements or limitations to:

— extent and relevance of geotechnical investigation programme
— sea bed and soil description
— characteristic soil data, e.g. shear strength, unit weight, friction angle, etc.
— stability, initial and long-term settlements and inclination, subsidence
— driveability/constructability
— sand waves and moving sand banks
— scour.

The elements of the steel structure shall be described by at least the following characteristics, or include requirements or limitations to:

— categorisation of structural components (special/primary/secondary, for determination of structural category see DNV-OS-C101 Ch.2 Sec.3 [3.2.2]
— materials including required certification
— welding
— bolting, including preloading
— fabrication tolerances
— non-destructive examination (extent, methods and acceptance criteria) at fabrication
— corrosion protection strategy/corrosion control concept, e.g. alignment with fatigue design requirements
— manufacturing requirements, e.g. application of coatings, allocation of anodes and storage methods.

The substructure should be described by at least the following characteristics, or include requirements or limitations to:

— height, water levels, interface at sea bed level, elevation of cable/cellar deck
— structural interface between piles and jacket or monopile and transition piece
— overall geometry and weight
— access and escape routes (number and position of boatlandings, platforms, access to topside, etc.)
— number and layout of J-tubes.

The topsides should be described by at least the following characteristics, or include requirements or limitations to:

— 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, etc.)
— crane coverage (including crane capacity, crane reach and load spectrum)
— corrosion protection strategy/corrosion control concept
— additional functionalities required for topsides walls and decks for explosion and/or fire resistance, see Sec.6, including availability of suitably approved penetrations for fire rating of ventilation ducts, piping and electrical cables
— tightness requirements to barriers around areas protected by fire gas flooding systems, or oxygen reduction fire prevention systems
— strength and tightness for watertight barriers as relevant.

Guidance note 2:

It is considered beneficial to extend the design basis requirements covering also descriptions of the main design methodologies. For this purpose it is distinguished between 'design basis' and 'design briefs'. The intention with a design brief is to present design methodologies early in the design process.

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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].

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 ultimate resistance for carrying loads
— fatigue limit states (FLS) correspond to the possibility of failure due to the effect of cyclic loading
— accidental limit states (ALS) correspond to damage to components due to an accidental event or operational failure
— serviceability limit states (SLS) correspond to the criteria applicable to normal 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 (in some cases reduced by repeated 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 due to repeated loads.
— Accidental limit states (ALS):
    — structural damage caused by accidental loads
    — ultimate resistance of damaged structures (post damaged analysis)
    — maintain 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, see DNV-OS-A301, 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 offshore substation
    — temperature-induced deformations.

4.3.2 Design by LRFD method

Design by the LRFD 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 reference values of the basic variables. The basic variables are, in this context, defined as:

— loads acting on the structure
— resistance of the structure or resistance of materials in the structure.

The target safety level is achieved by using deterministic factors representing the variation in load and resistance and the reduced probabilities that various loads will act simultaneously at their characteristic values.

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

$$S_d \leq R_d$$

The equation: $S_d = R_d$, defines a limit state.

A design load is obtained by multiplying the characteristic load by a given load factor:

$$F_d = \gamma_f F_k$$

where:

F_d = design load
γ_f = load factor
F_k = characteristic load, see DNV-OS-C101 Ch.2 Sec.2.

The load factors and combinations for ULS, ALS, FLS and SLS shall be applied according to DNV-OS-C101 Ch.2 Sec.1 [4.3] to DNV-OS-C101 Ch.2 Sec.1 [4.7].

A design load effect is the most unfavourable combined load effect derived from the design loads, and may, if expressed by one single quantity, be expressed by:

$$S_d = q\left(F_{dl}, ..., F_{dn}\right)$$

where:

S_d = design load effect
q = load effect function.

If the relationship between the load and the load effect is linear, the design load effect may be determined by multiplying the characteristic load effects by the corresponding load factors:

$$S_d = \sum_{i=1}^{n} \gamma_{fi} S_{ki}$$

where:

S_{ki} = characteristic load effect.

The resistance for a particular load effect is, in general, a function of parameters such as structural geometry, material properties, environment and load effects (interaction effects).

The design resistance (R_d) is determined as follows:

$$R_d = \varphi R_k$$

where:

R_k = characteristic resistance
φ = resistance factor.

The resistance factor relate to the material factor γ_M as follows:

$$\varphi = \frac{l}{\gamma_M}$$

where:

γ_M = material factor.

R_k may be calculated on the basis of characteristic values of the relevant parameters or determined by testing. Characteristic values should be based on the fifth percentile of the test results.

Load factors account for:

— possible unfavourable deviations of the loads from the characteristic values
— the reduced probability that various loads acting together will act simultaneously at their characteristic value
— 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 values
— possible reduced resistance of the materials in the structure, as a whole, as compared with the characteristic values deduced from test specimens.

4.3.3 Characteristic load effect

The representative values for the different groups of limit states in the operating design conditions are defined as follows:

— For load combinations relevant for design against the ULS, the characteristic value of the resulting loadeffect 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 ALS, the characteristic load effect is a specified value, dependent on operational requirements. For the ALS load combination for damaged structure, the representative load effect is determined as the most probable annual maximum value.
— For load combinations relevant for design against the SLS, the characteristic load effect is a specified value, dependent on operational requirements.

For temporary design conditions, the characteristic value 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 DNV-OS-C101 for steel structures and in DNV-ST-C502 for concrete structures and in DNV-ST-0126 for pile/soil interaction. For aluminium alloys see DNV-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, erection, 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-ST-N001.

For the operational design conditions, the basis for selection of characteristic loads and load effects are specified in Table 4-1.

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

Load category	*ULS*	*FLS*	*ALS intact structure*	*ALS damaged structure*	*SLS*
Permanent (G)	Expected value				
Variable (Q)	Specified value				
Environmental (E)	Annual probability[2)] being exceeded = 10^{-2} (100 year return period)	Expected load or load effect history	n/a	Load or load effect with return period not less than 1 year[1)]	Specified value
Accidental (A)			Specified value, see also [4.4.6]		
Deformation (D)	Expected extreme value				
[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.					
[2)] The joint probability of exceedance applies, see DNV-OS-C101 Ch.2 Sec.2 [6].					

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 fully appear in any load combination for design of primary structures and foundations. Variable functional loads on deck areas which shall be considered in primary and global design are specified in DNV-OS-C101. Variable functional loads on platform areas shall be determined in accordance with DNV-ST-0126 [3.7.2] or DNV-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 see DNV-RP-0360 covering specifications for cable handling.

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Loads and dynamic factors from maintenance and service cranes on structures shall be determined in accordance with requirements given in DNV-ST-0377 and DNV-ST-0378.

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

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 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.

Further guidance regarding ship impact can be found in DNV-ST-0437 [4.2.10] and DNV-RP-C204 Sec.3.

Depending on the access concept other scenarions should be evaulated such as the gangway on a service operation vessel (SOV) causing damage to access platform, handrails or similar.

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

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

For operational helideck loads, see DNV-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
— marine growth
— snow, hail and ice.

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.

The air gap is defined as the vertical clearance between the lowest deck of 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 DNV-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 DNV-ST-0126 or ISO 19901-2.

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 DNV-ST-0126, DNV-RP-C205.

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 DNV-ST-0126 and in DNV-RP-C212.

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.

Depending on the stress levels, the type of details in the main components and the duration of transport routes from fabrication yard to installation site, transport fatigue of the main components (mainly support structure or topside structure) may become an issue. Therefore, transport fatigue analyses shall be performed to determine the fatigue damage of the structure during transport (including possible waiting time at sea). If location of hot spots for transport is the same as for in-place conditions, the fatigue damage of transport and in-place shall be added together. See guidance notes as shown in DNV-ST-N001 [5.9.4] and DNV-ST-N001 [11.9.12].

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 service documents relevant parts of DNV-ST-N001 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 DNV-OS-C101 Ch.2 Sec.2 [6].

Global wind loads on structures shall be determined using a time-averaged design wind speed in the form of a sustained wind speed. Wind speed averaged over 1 minute is often referred to as sustained wind speed. See also DNV-RP-C205 Sec.2 and DNV-RP-C205 Sec.5.

4.4.6 Accidental loads (A)

4.4.6.1 General

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:

— abnormal environmental actions
— 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 concept 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.

4.4.6.2 Abnormal environmental actions

For ALS design, the basis for selecting the abnormal environmental actions shall be taken as events whose return periods are 10 000 years. The types of relevant abnormal environmental actions to be considered in the design shall be determined by a project-specific evaluation or risk assessment. In any case, the ALS wave event shall be considered.

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 may be calculated according to DNV-RP-C205.

The still water level shall be taken as the highest possible water level in extreme weather whose return period is 10 000 years, however possibly with consideration of the correlation between the water level and significant wave height in cases where this can be properly justified, see DNV-RP-C205 [4.2.4] and DNV-RP-C205 [4.2.5].

When establishing the ALS wave event, a lower resulting safety level for the structural design may be acceptable for substations which are unmanned during ALS wave events. An evaluation shall demonstrate that the consequences of a reduced return period for the abnormal environmental event applied in design will not entail:

— increased risk to life-safety
— threat to surrounding infrastructure
— unacceptable loss of power production of connected wind farm or grid stability

— significant pollution
— financial consequences in excess of what is found acceptable by the project based on a project-specific risk evaluation.

If these criteria are fulfilled, the ALS design may be performed using abnormal environmental actions based on events with return periods shorter than 10 000 years but no less than 1 000 years provided unmanning of the platform is carried out prior to the event under the assumption that the event can be forecasted.

The project shall, in case this approach is adopted, clearly specify the approach taken and document the associated evaluation in the project documentation and finally include the implied limitations in the operational manual. A substation may be categorized as unmanned during abnormal environmental events if the probability of personnel being on the substation simultaneously with the occurrence of environmental actions damaging main safety functions is less than 10^{-4} per year. When establishing the ALS design criteria, uncertainties including installation tolerances, settlement, sea-level rise, etc. will impact the final results. Therefore, care shall be taken when combining these effects to obtain a representative conservative combination that will not further reduce the safety level.

Guidance note:

Specifying abnormal environmental events with return periods shorter than 10 000 years will lead to an effective reduction in the obtained structural safety level which requires involvement and awareness of all relevant stakeholders in the project. Therefore, the above-mentioned evaluations which aim to mitigate and quantify consequences of the reduced structural safety level should at least consider the following:

— The egress and evacuation procedures should include requirements for timely unmanning of personnel on the substation in case abnormal environmental events are forecasted. The requirements should account for possible limitations for operation of helicopter and vessels imposed by the approaching weather conditions. Furthermore, the warning time in advance of the occurrence of extreme weather should be considered in the planning for unmanning. Further guidance on establishing of unmanning criteria and procedures are given in NORSOK N-006. These procedures and requirements for unmanning should be included in the project documentation.
— Evaluations and risk assessment should be performed and documented to evaluate the effect of potential substation failure impacting surrounding infrastructure (e.g. in case of mother/daughter platform concept).
— Failure of the substation may entail grid instability or entire loss of power supplied to the grid. Likely scenarios should be evaluated together with the grid operator.
— Pollution to the environment such as oil spill should be evaluated and should as a minimum comply with local requirements.
— Financial consequences of losing the asset should be included in the risk assessment and it should be considered that loss of the substation will lead to the loss of the entire wind farm production.

The risk assessment may be based on the principles defined in App.A.

In addition, potential damage to reputation of all affected parties should be considered, including e.g. developer/owner, operator, designer and the renewable industry in general.

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4.4.6.3 Dropped objects

For accidental loads from dropped objects, it is assumed that lifting arrangements comply with DNV-ST-0378 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 from drop of objects, please see DNV-RP-C204.

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 equipment.

4.4.6.4 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 (impact speed) shall be assessed in each case. Unless a lower impact speed can be justified it shall be assumed to be not 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:

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

where:

m	=	displacement of vessel, in t
a	=	added mass of vessel, normally assumed 0.4 of vessel mass for sideway and 0.1 m for bow or stern collision
v	=	impact speed, in m/s.

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.

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4.4.6.5 Fire

Critical items shall be designed to withstand anticipated heat loads, including:

— passive fire protection
— structures of which the collapse can potentially block escape ways or impede evacuation
— 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.

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4.4.6.6 Explosion

Evaluation of explosion loads on offshore substations shall consider the following sources and events:

— 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, see guidance note in [5.4.4.3]
— overpressure of liquid-immersed equipment caused by short circuit

— overpressure in high voltage switchgear caused by short circuit.

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:

— main structure
— structures of which the collapse can potentially block escape ways or impede evacuation
— safety systems.

Regarding explosion protection see [6.6].

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 4-2 Load factors γ_f for the ultimate limit states

Load factor set	*Load category*			
	G	*Q*	*E*	*D*
(a)	1.3	1.3	0.7	1.0
(b)	ψ	ψ	1.3	1.0

Load factor set	Load category			
	G	Q	E	D
For values of ψ, 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 ψ = 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 ψ = 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 ψ = 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.

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

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 γ_f in the FLS is 1.0 for all load categories.

For design against the SLS, the load factor γ_f is 1.0 for all load categories, both for temporary and operational design conditions.

For design against the ALS, the load factor γ_f is 1.0.

4.5.2 Resistance factors

Material factors for the ULS are given in the relevant sections of DNV-OS-C101 for steel structures, in the relevant sections of DNV-ST-C502 for concrete structures and in DNV-ST-0126 Sec.6 for grouted connections. Resistance factors for geotechnical design shall be taken from DNV-OS-C101.

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 against the FLS is given in Table 4-3. The material factor γ_m for design of grouted connections against the FLS is given in DNV-ST-0126 [6.4.1] and for concrete structures in DNV-ST-C502 [6.13].

The material factor γ_m for the ALS shall be taken as 1.0 for steel structures. Material factors for ALS for concrete structures shall be chosen as per DNV-ST-C502 and for grouted connections according DNV-ST-0126. The material factor γ_m for the SLS shall be taken as 1.0.

Table 4-3 Design fatigue factor for steel structures

No access for inspection and repair	*Accessible[1)] location in the submerged zone[2)]*	*Accessible[1)] location above the splash zone*
10.0	3.3	2.0

No access for inspection and repair	*Accessible[1] location in the submerged zone[2]*	*Accessible[1] location above the splash zone*
[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, see DNV-RP-C210. 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 DNV-ST-0126.		

The material factor γ_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, DNV-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 shall be according to the flow chart in Figure 4-1.

Selection of equivalent steel grades shall consider the following parameters:

— chemical composition especially CEV and sulfur-value
— mechanical properties including impact properties
— service temperature
— location and orientation of impact test pieces
— other relevant steel manufacturing parameters.

Guidance note 1:

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 of certain grades and of larger thickness are specified and tested for ductile properties not only at subsurface position or one fourth of the plates' thickness but additionally also at mid thickness. In this way it is assured that minimum impact properties are met through thickness.

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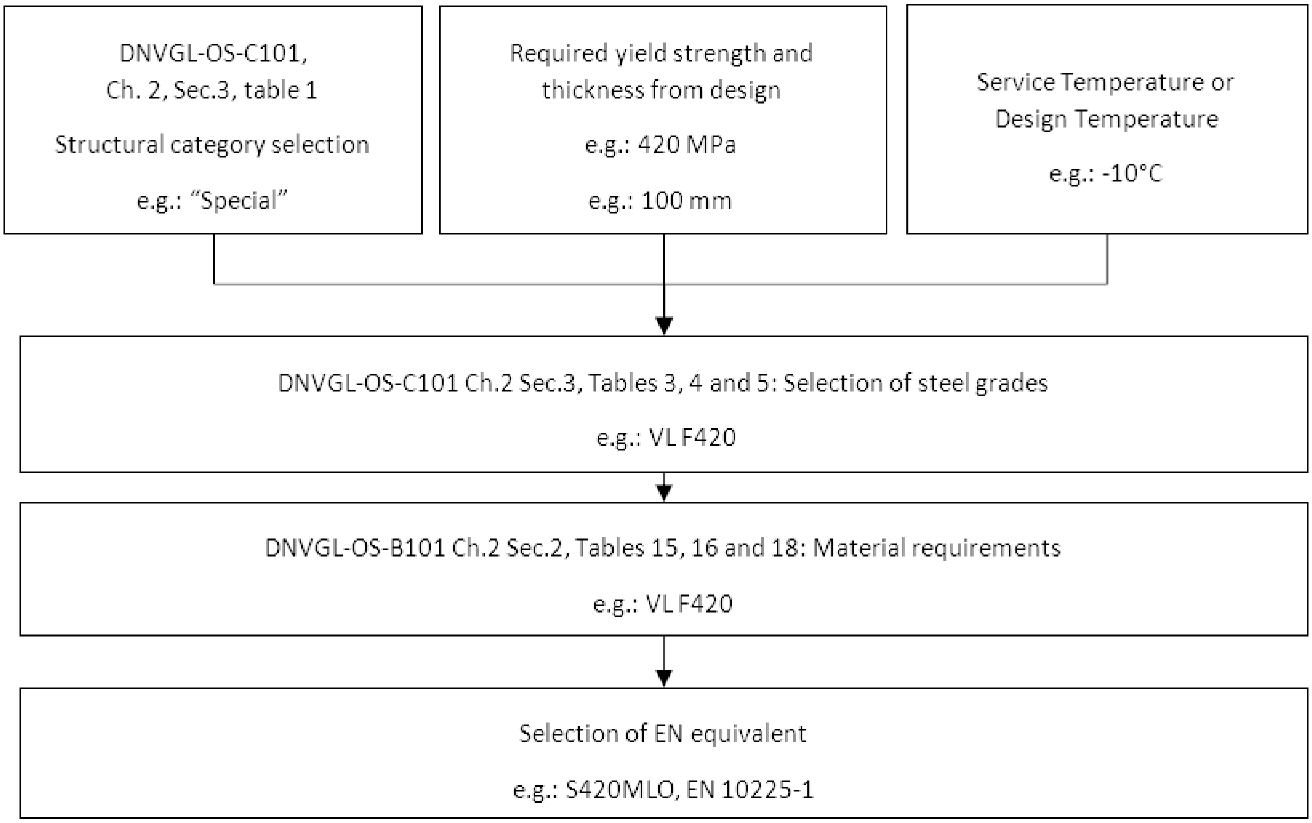

Figure 4-1 Selection of equivalent steel grades

For the DNV NV 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

DNV steel grade	*Steel grade*	*Steel grade*	*Product type*	*≥ +10°C*	*0°C*	*-10°C*	*-20°C*	*-25°C*	*-30°C*
NV A36 [3)] / AW36	S355J2 [3)], EN 10025-2; S355J2H [3)], EN 10210		Plates/ sections Hot finished tubes	15	10	N.A.	N.A.	N.A.	N.A.
NV D36 [3)] / DW36	S355K2 [3)], EN 10025-2; S355K2H [3)], EN 10210; S355N/ M [3)], EN 10025-3/-4		Plates/ sections Hot finished tubes	30	25	20	15	12.5	10

DNV steel grade	Steel grade	Steel grade	Product type	≥ +10°C	0°C	-10°C	-20°C	-25°C	-30°C
NV E36 3) / EW36				60	50	40	30	25	20
NV F36 3)				120	100	80	60	50	40
	S355NLHHO/ QLHHO 3)4) , EN 10225-3		Seamless tubes	65	65	65	65	65	65
	S355NL10 3)4) , EN 10225-2		Rolled sections	63	63	63	63	63	63
	S355MLO 3)4), EN 10225-1		Plates	120	120	120	120	120	120
	S355NLO 3)4) , EN 10225-1	50 (+M) 1)2) API Spec 2Y/2W	Plates	200	200	200	200	200	200
NV A420 3)	S420M 3), EN 10025-4; S420MH 3) , EN 10219	S420N 3), EN 10025-3; S420NH 3), EN 10210	Plates/ sections Cold formed tubes Hot finished tubes	20	15	10	N.A.	N.A.	N.A.
NV D420 3) / DW420	S420ML 3), EN 10025-4; S420 MLH 3), EN 10219	S420NL 3) ,EN 10025-3; S420NLH 3), EN 10210	Plates/ sections Cold formed tubes Hot finished tubes	35	30	25	20	17.5	15
NV E420 3) / EW420				70	60	50	40	35	30
NV F420 3)				150	150	100	80	70	60
	S420QLHHO 3)4) , EN 10225-3		Seamless tubes	65	65	65	65	65	65
	S420ML10 3)4) , EN 10225-2		Rolled sections	63	63	63	63	63	63
	S420MLO/ QLO 3) 4) . EN 10225-1	60 (+QT/M) 1)2) API Spec 2Y/2W	Plates	120/150	120/150	120/150	120/150	120/150	120/150

DNV steel grade	Steel grade	Steel grade	Product type	≥ +10°C	0°C	-10°C	-20°C	-25°C	-30°C
NV A460 3)	S460M 3), EN 10025-4; S460MH 3), EN 10219-1	S460N 3), EN 10025-3; S460NH 3), EN 10210-1	Plates/ sections Cold formed tubes Hot finished tubes	20	15	10	N.A.	N.A.	N.A.
NV D460 3) / DW460	S460ML 3) EN 10025-4S460MLH 3), EN 10219-1	S460NL 3), EN 10025-3; S460NLH 3), EN 10210-1	Plates/ sections Cold formed tubes Hot finished tubes	35	30	25	20	17.5	15
NV E460 3) / EW460				70	60	50	40	35	30
NV F460 3)				150	150	100	80	70	60
	S460ML10 3)4), EN 10225-2		Rolled sections	63	63	63	63	63	63
	S460MLO/ QLO 3) 4), EN 10225-1		Plates	120/150	120/150	120/150	120/150	120/150	120/150

1) Test temperature -60°C, option S2.

2) Z30, option S4 or Smax ≤ 0.006, option S5.

3) Z35, option according to the relevant product standard. Plates shall be ultrasonic tested and as a minimum meet the requirements according EN 10160, class S1/E1.

4) For design temperature below -10°C prequalification and test temperatures for arctic areas shall be observed, see EN 10225 parts 1 to 4.

5) For service temperature below -20°C the upper limit for use of this grade shall be specially considered.

Table 4-5 Thickness limitation (mm) of equivalent steel grades for primary structural category and service temperatures

DNV steel grade	Steel grade	Steel Grade	Product type	≥ +10°C	0°C	-10°C	-20°C	-25°C	-30°C
NV A36 / AW36	S355J2, EN 10025-2; S355J2H, EN 10210-1		Plates/ sections Hot finished tubes	30	25	20	15	12.5	10

DNV steel grade	*Steel grade*	*Steel Grade*	*Product type*	*≥ +10°C*	*0°C*	*-10°C*	*-20°C*	*-25°C*	*-30°C*
NV D36 / DW36	S355K2, EN 10025-2; S355K2H, EN 10210-1; S355N/M, EN 10025-3/-4		Plates/ sections Hot finished tubes	60	50	40	30	25	20
NV E36 / EW36				120	100	80	60	50	40
NV F36				150	150	150	150	5)	5)
	S355NLHHO/ QLHHO 4), EN 10225-3		Seamless tubes	65	65	65	65	65	65
	S355NLO/ MLO 4), EN 10225-2		Rolled sections	63	63	63	63	63	63
	S355MLO 4) , EN 10225-1		Plates	120	120	120	120	120	120
	S355NLO 4), EN 10225-1	50 (+M) 1) , API Spec 2Y/2W	Plates	200	200	200	200	200	200
NV A420	S420M, EN 10025-4; S420MH, EN 10219-1	S420N, EN 10025-3; S420NH, EN 10210	Plates/ sections Cold formed tubes Hot finished tubes	35	30	25	20	17.5	15
NV D420 / DW420	S420ML, EN 10025-4	S420NL, EN 10025-3	Plates/ sections	70	60	50	40	35	30
	S420MLH, EN 10219-1		Cold formed tubes	40	40	40	40	35	30
		S420NLH, EN 10210	Hot finished tubes	65	60	50	40	35	30
NV E420 / EW420				150	150	100	80	70	60
NV F420				150	150	150	150	5)	5)
	S420MLO 4), EN 10225-2		Rolled sections	63	63	63	63	63	63

DNV steel grade	Steel grade	Steel Grade	Product type	≥ +10°C	0°C	-10°C	-20°C	-25°C	-30°C
	S420MLO/ QLO [4] , EN 10225-1	60 (+QT/M) [1] API Spec 2Y/2W	Plates	120/150	120/150	120/150	120/150	120/150	120/150
NV A460	S460M, EN 10025-4 S460MH, EN 10219-1	S460N, EN 10025-3; S460NH, EN 10210	Plates/ sections Cold formed tubes Hot finished tubes	35	30	25	20	17.5	15
NV D460/ DW460	S460ML, EN 10025-4	S460NL, EN 10025-3	Plates/ sections	70	60	50	40	35	30
	S460MLH, EN 10219-1		Cold formed tubes	40	40	40	40	35	30
		S460NLH, EN 10210	Hot finished tubes	65	60	50	40	35	30
NV E460/ EW460				150	150	100	80	70	60
NV F460				150	150	150	150	[5]	[5]
	S460MLO [4], EN 10225-2		Rolled sections	63	63	63	63	63	63
	S460MLO/ QLO [4] , EN 10225-1		Plates	120/150	120/150	120/150	120/150	120/150	120/150

[1] Test temperature -60°C, option S2.

[2] Z30, option S4 or Smax ≤ 0.006, option S5.

[3] Z35, option according to the relevant product standard. Plates shall be ultrasonic tested and as a minimum meet the requirements according EN 10160, class S1/E1.

[4] For design temperature below -10°C prequalification and test temperatures for arctic areas shall be observed, see EN 10225 parts 1 to 4.

[5] For service temperature below -20°C the upper limit for use of this grade shall be specially considered.

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

DNV steel grade	Steel grade	Steel Grade	Product type	≥ +10°C	0°C	-10°C	-20°C	-25°C	-30°C
NV A	S235JR, EN 10025-2		Plates/ sections	35	30	25	20	15	10
NV B	S235J0, EN 10025-2		Plates/ sections	70	60	50	40	30	20

DNV steel grade	*Steel grade*	*Steel Grade*	*Product type*	*≥ +10°C*	*0°C*	*-10°C*	*-20°C*	*-25°C*	*-30°C*
NV D	S235J2+N, EN 10025-2		Plates/ sections	150	150	100	80	70	60
NV A27S	S275J0, EN 10025-2;		Plates/ sections	60	50	40	30	20	15
NV D27S	S275J2+N, EN 10025-2; S275N/M, EN 10025-3/-4;		Plates/ sections	120	100	80	60	50	40
NV A36 / AW36	S355J2, EN 10025-2; S355J2H, EN 10210-1		Plates/ sections Hot finished tubes	60	50	40	30	20	15
NV D36 / DW36	S355K2, EN 10025-2; S355K2H, EN 10210-1; S355N/M, EN 10025-3/-4		Plates/ sections Hot finished tubes	120	100	80	60	50	40
NV E36 / EW36				150	150	150	150	120	100
NV F36				150	150	150	150	5)	5)
	S355NLHHO/ QLHHO 4), EN 10225-3		Seamless tubes	65	65	65	65	65	65
	S355NLO/ MLO 4), EN 10225-2		Rolled sections	63	63	63	63	63	63
	S355MLO 4), EN 10225-1		Plates	120	120	120	120	120	120
	S355NLO 4), EN 10225-1	50 (+QT/M) 1), API Spec 2Y/2W		200	200	200	200	200	200
NV A420	S420M, EN 10025-4; S420MH, EN 10219-1	S420N, EN 10025-3	Plates/ sections Cold formed tubes	70	60	50	40	30	20
		S420NH, EN 10210	Hot finished tubes	65	60	50	40	30	20
NV D420 / DW420	S420ML, EN 10025-4		Plates/ sections	150	150	100	80	70	60

DNV steel grade	Steel grade	Steel Grade	Product type	≥ +10°C	0°C	-10°C	-20°C	-25°C	-30°C
	S420MLH, EN 10219-1		Cold formed tubes	40	40	40	40	35	30
NV E420 / EW420				150	150	150	150	120	100
NV F420				150	150	150	150	[5]	[5]
	S420MLO [4], EN 10225-2		Rolled sections	63	63	63	63	63	63
	S420MLO/ QLO [4],, EN 10225-1	60 (+QT/M) [1] API Spec 2Y/2W	Plates	120/150	120/150	120/150	120/150	120/150	120/150
NV A460	S460M, EN 10025-4	S460N, EN 10025-3	Plates/ sections	70	60	50	40	30	20
	S460MH, EN 10219-1		Cold formed tubes	40	40	40	40	30	20
		S460NH, EN 10210	Hot finished tubes	65	60	50	40	30	20
NV D460/ DW460	S460ML, EN 10025-4	S460NL, EN 10025-3	Plates/ sections	150	150	100	80	70	60
	S460 MLH, EN 10219-1		Cold formed tubes	40	40	40	40	35	30
		S460NLH, EN 10210	Hot finished tubes	65	65	65	65	65	60
NV E460/ EW460				150	150	150	150	120	100
NV F460				150	150	150	150	[5]	[5]
	S460MLO [4], EN 10225-2		Rolled sections	63	63	63	63	63	63
	S460MLO/ QLO [4], EN 10225-1		Plates	120/150	120/150	120/150	120/150	120/150	120/150

[1] Test temperature -60°C, option S2.

[2] Z30, option S4 or Smax ≤ 0.006, option S5.

[3] Z35, option according to the relevant product standard. Plates shall be ultrasonic tested and as a minimum meet the requirements according EN 10160, class S1/E1.

[4] For design temperature below -10°C prequalification and test temperatures for arctic areas shall be observed, see EN 10225 parts 1 to 4.

[5] For service temperature below -20°C the upper limit for use of this grade shall be specially considered.

Material certificates are required as specified in [10.3].

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

Guidance note 2:

Tubular joints are categorised as special due to their biaxial or tri-axial stress patterns and risk of brittle fracture. Likewise, flanged connections in primary structures are in general categorised as special due to their irregular stress pattern and loading in through-thickness direction.

Monopile structures including the uniaxially-loaded parts of their transition pieces are categorised as primary.

J-tubes shall be considered as primary structures as they are critical elements in terms of availability, see [4.8.7].

The main topside structure is generally categorised as primary structure.

Structural items such as ladders, stairs, walkways and railings are categorised as secondary structure.

If the structural categorisation according to Eurocode is performed, tubular joints are categorised as EXC4 due to their biaxial or tri-axial stress patterns and risk of brittle fracture. This will influence the thickness limitations.

Members in jacket structures as well as monopile structures are normally categorised as EXC3, because they are non-redundant structures whose stress pattern is primarily uniaxial and whose risk of brittle fracture is negligible.

J-tubes shall be considered as EXC3 as they are critical elements in terms of availability, see [4.8.7].

The topside structure is typically categorised as EXC2 except for certain members as crane pedestal and interface legs to the support structure which should be classified EXC3.

Structural items such as ladders, stairs, walkways and railings are normally categorised as EXC2.

Execution classes (EXC) are defined according to EN 1993-1-1 and EN 1090-2.

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For steel in the submerged zone that is subject to cathodic protection the detrimental effects of such type of protection shall be considered in the selection of steel material in accordance with DNV-RP-B401 [5.5].

4.6.3 Concrete materials

For selection of structural concrete materials, DNV-ST-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-ST-C502 Sec.4 *Materials*. The properties of structural grout shall be documented on a type approval certificate as defined in DNV-SE-0295 *Verification and certification of offshore concrete and grout structures*.

If Ordinary Portland Cement (OPC) is used instead of blended grout material, special attention shall be taken to the material properties of OPC. The application of OPC shall be aligned at an early stage of the project with DNV. The suitability and performance of the OPC shall be qualified on a project specific basis, accounting for:

— specification of cement / cement supplier
— control of incoming raw material
— material testing
— appropriate validation testing, including a full or reduced scale mock-up test (equipment, personnel, method and material)
— procedures for production, installation and quality control testing offshore
— traceability of raw and produced materials.

The scope of the tests for OPC shall be analogous to the requirements in DNV-ST-C502 App.H and DNV-ST-C502 App.J.

4.6.5 Aluminium materials

For selection of aluminium materials DNV-OS-B101 Ch.2 Sec.6 shall apply.

4.7 Structural analysis

4.7.1 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 shall 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 power plants.

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.

4.7.2 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.

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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 DNV-ST-N001 should be applied. Further references are provided in [10.4].

Roll to be combined with heave; pitch to be combined with heave. Roll and pitch not to be combined.

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

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Requirements to lift operations are given in DNV-ST-N001.

4.7.3 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 offshore substation 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 DNV-OS-C101, DNV-ST-C502 and DNV-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 DNV-OS-C101. For design against failure in the FLS, the requirements to the DFF given in [4.5.2] overrule those given in DNV-OS-C101.

Design of plated structures such as stiffened panels shall be done according to Part 1 of DNV-RP-C201.

4.8.3 Concrete structures

Concrete structures shall be designed according to the requirements given in DNV-ST-C502, see [4.5.2].

4.8.4 Grouted connections

Grouted connections shall be designed according to the requirements given in DNV-ST-0126 Sec.6. Material factors shall be chosen as stated in [4.5.2].

For grouted connections for which the geometry complies with NORSOK N-004 Annex K, such grouted connections may be designed according to NORSOK N-004 Annex K.

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 DNV-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.

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4.8.5 Foundations

Geotechnical design of foundations shall be carried out in accordance with DNV-OS-C101. Safety factors for geotechncial design shall be taken from DNV-OS-C101. Guidance for geotechnical design can be found in DNV-RP-C212.

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 (whichever is the larger) and be applied to the 100-year wave crest:

— 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.

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 offshore substation for the loads from such run-up.

In addition to the above, unless it is demonstrated that the air gap is sufficient to avoid wave in deck impact from ALS events as described in [4.4.6.2], relevant deck impact analysis shall be performed, and therefore a larger deck height than required to fulfil the air gap criterion above may be needed to avoid adverse effects.

Guidance note:

Sufficient air gap is necessary in order to avoid slamming forces on the substation. 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.

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4.8.7 Auxiliaries

Auxiliary components such as J-tubes, sling platforms and boat landing fenders shall be designed in accordance with DNV-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 DNV-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 DNV-RP-0416 [4.3]. 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 DNV-OS-C101 Ch.2 Sec.9 or DNV-RP-0416.

Steel structure components in the splash zone shall be protected in accordance with requirements given in DNV-OS-C101 Ch.2 Sec.9 or DNV-RP-0416.

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 DNV-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 to be applied in the splash zone shall be based on manufacturer specific materials that have been pre-qualified for the actual coating system by proven experience or relevant testing (e.g. according to NORSOK M-501, ISO 12944).

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 12944-9. Guidance regarding coating systems can also be found in DNV-RP-0416.

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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, see DNV-ST-0126 [5.10].

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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, see DNV-SE-0176.

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.

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SECTION 5 ELECTRICAL DESIGN

5.1 Introduction

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

— [4.2.3] *Design basis*
— Sec.11 *In-service inspection and maintenance*.

The requirements of this section are based on standards DNV-OS-D201 and IEC 61892. Where discrepancy occurs, the present standard shall prevail.

5.2 Applicability and design process

5.2.1 General

This subsection 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 HVDC substations, between HV cable terminations AC and cable termination (excluded) of the HVDC transmission system.

Evaluation and certification of grid code compliance is not part of this standard. Further information on this topic can be found in DNV-ST-0125, as well in relating grid codes or similar applicable national and international rules and requirements.

5.2.2 Electrical infrastructure

Electrical installations shall be designed so that:

— the maintaining of normal operational and habitable conditions is ensured without recourse to the emergency source of electrical power
— the availability of emergency services is ensured under various defined accidental events and for the specified lifetime
— the safety of personnel and units/installations from electrical hazards is ensured and risks of injury to human life will be reduced to a minimum.

5.3 Common definitions and requirements

5.3.1 Operational conditions

5.3.1.1 Normal operational condition

Normal operational condition is a condition under which the substation, as a whole, is in working order and functioning normally. Operational and emergency services, see [5.3.2], during normal operational condition shall be available.

Services designed for the habitable condition on substations of type B and type C including cooking, heating, domestic refrigeration, mechanical ventilation, sanitary facilities and fresh water shall be available.

A schematic presentation of the normal operational condition is given in App.C.

5.3.1.2 (N-1) operational condition

(N-1) operational condition is an operational condition following a failure of a single component in:

— main power system, see [5.4]

— auxiliary power system, see [5.5]

without influence on the system availability.

Guidance note:

In order to increase the availability of the system in (N-1) operational conditions, the potential failures should be assessed and analysed at the basic design stage of the project. The target is to minimise the probability of failure of the complete system by means of component redundancy and adequate interconnection of systems.

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5.3.1.3 Islanded condition

An offshore substation is in islanded condition when the electrical connection with the external grid is not available.

Consideration of islanded condition is mandatory for offshore substations of type B and C, see [3.3.2]. For offshore substations of type A, see [3.3.2], the same requirement applies unless it is assured that evacuation of personnel on board can be initiated immediately upon the occurrence of islanded condition. Possibility of immediate evacuation presumes availability of primary means of evacuation on or in direct vicinity of the offshore substation. Evaluated evacuation time shall in no case exceed 30 minutes.

Emergency services shall be available during islanded condition.

An islanded condition is not regarded as emergency, see [5.3.1.4]. Operational services required during the islanded condition shall be defined at the basic design stage of the project. The demand on such operational services during the islanded condition shall be duly assessed and analysed.

Guidance note:

Special attention should be paid to the availability of the following essential services ensuring reliable operation and maintaining substation operation within operational limitations during islanded conditions:

- power automation system
- SCADA
- ventilation and heating systems - to avoid unwanted atmospheric processes and to maintain environmental conditions for the installed equipment
- sanitary systems, potable water system to maintain health and hygienic requirements
- tracing/heating of pipes laid outside to avoid freezing of liquids or to maintain the viscosity
- seawater pumps
- load handling equipment (cranes, winches)
- main lighting system
- power supply of the wind turbines during standstill periods.

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For the substations of type B and type C, services designed for the habitable condition shall be available as well.

Assumed duration of the islanded condition shall be at least seven days. Hence, auxiliary power supply shall have a capacity to maintain supply for this duration.

A schematic presentation of the islanded condition is given in App.C.

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 order due to a failure of the main source of auxiliary power system as a consequence of a malfunction or an accidental event including fire, flooding, extreme waves and similar. Worst case scenarios and necessary emergency services and procedures shall be considered during the design process.

At least the emergency power consumers given in Table 5-2 shall be available during emergency condition.

A schematic presentation of the emergency condition is given in App.C.

5.3.1.5 Black substation condition

'Black substation' condition is understood to mean that the auxiliary power supply system is out of operation and that services required for the restoration of the auxiliary power supply system are not available. Batteries and/or pressure vessels for starting of all generator sets are considered discharged.

Means for the restoration of the auxiliary power supply upon 'black substation' condition shall be foreseen.

Guidance note:

A temporary generator set may be required to be brought onto the substation for the restoration of the auxiliary power supply.

Following aspects are essential for the consideration in respect of the restoration of auxiliary power system during 'black substation' condition:

— transportation of the portable source of power (e.g. temporary generator) onto the substation
— precautions and safety measures during the step-over onto the substation, among other due to the unavailability of detection, alarm systems and lighting
— restoration of auxiliary power supply
— alarms clearance and re-activation of the systems.

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5.3.2 Services

5.3.2.1 Operational services

Operational services are those services that need to be supplied to maintain continuous operation of all 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 as well as to maintain habitable conditions where applicable. Operational services maintain the substation operation within desired normal operational limits.

5.3.2.2 Emergency services

Emergency services are those services that are essential for safety in an emergency condition.

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
— equipment and systems for starting and control of emergency generator sets
— equipment and systems for starting and control of diesel engines for emergency fire-fighting pumps, if any.

Requirements for emergency services are given in [5.5.3].

5.3.3 Power systems

5.3.3.1 Main and auxiliary power

The substation electrical installation shall be divided in two functional subsystems:

— [5.4] *Main power system*
— [5.5] *Auxiliary power system.*

The main power system comprises all the high voltage and medium voltage equipment necessary to:

— collect and transform the power produced by the wind power plant 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).

The auxiliary power system comprises equipment necessary to operate the main power system and to safely keep the substation within the designed operational and habitable conditions.

5.3.4 Boundary conditions

5.3.4.1 Environmental conditions for outdoor installations

Equipment located outdoors will be subject to the actual site ambient conditions, which shall 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 km^2 per year]
— monthly average daily total solar radiation on horizontal surface [MJ/m^2]
— electromagnetic interference e.g. from aerials or high frequency parts of the installation.

The design of the electrical equipment foreseen for outdoor installation shall also take into account environmental conditions characterised by UV radiation exposure, high salinity and corrosiveness of the air. Unless otherwise stated and justified by site-specific met-ocean data, an ambient temperature range of -25°C to +45°C, relative humidity of up to 95% and sun radiation of 1000 W/m^2 shall be assumed as design basis.

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

The design of the electrical equipment foreseen for outdoor installation shall observe penetration of moisture, salinity and dust, see DNV-OS-D201 Ch.2 Sec.10 [2.2].

5.3.4.2 Environmental conditions for indoor installations

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

   — equipment temperature range [°C]
   — relative humidity (not condensing) [%]
   — electromagentic interference.

b) The design of the electrical equipment foreseen for indoor installation shall observe possibility of alteration of environment-controlled conditions as well as penetration of moisture, salinity and dust, see DNV-OS-D201 Ch.2 Sec.3 [4.5] *Enclosures ingress protection*.

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 of the substation in high wave conditions shall be investigated.

5.3.4.3 Electrical conditions

a) The substation main power system is connected to the wind power plant through the array cabling system. The characteristics of the collected power are depending on the wind turbines power quality and inter-array cables, and information in this regard shall be available at the design stage.

   Guidance note:
   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 network (AC grid connected or HVDC connected). As a minimum the following network characteristics shall be observed:

— 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]
— any other requirement of the applicable grid code.

Guidance note:

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

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5.3.4.4 Other conditions

Space limitations, if any, shall be defined.

Seismicity at the installation location and vibrations (acceleration, deflection) of the offshore substation 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.

EMC aspects of the offshore substation shall be considered thoroughly for both, normal operation of the electrical system as well as during fault conditions. The methodology and principles how to design for EMC are describes in the IEC 61000 series and shall be applied accordingly.

5.3.5 Design principles

5.3.5.1 Basic design principles and performance criteria

a) Electrical installations shall be designed in such a way 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 shall include at least:

— fire and explosion risk
— risk of electric shock
— exposure of personnel to electromagnetic fields
— reliability and availability
— electromagnetic compatibility of equipment.

5.4 Main power system

5.4.1 General

5.4.1.1 Description of main power system

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 array cabling system, when the substation is under islanded conditions.

5.4.2 Design requirements

5.4.2.1 Electrical design

For substations of type A, remote control of main power system shall, as far as practicable, enable the users to perform switching, reset and testing procedures from the onshore control center.

The electrical design of the equipment in the main power system shall ensure correct operation under all environmental and electrical operating conditions specified in [5.3.4].

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 shall be such that the stresses resulting from external electrical fault events do not lead to permanent deformation, fracture, or buckling of the materials. This shall 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 substation, adequate separation between panel compartments and e.g. spark chutes for circuit breakers shall be assessed to avoid flash-over events from break-down of air insulation properties by ionised air.

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

5.4.2.3 Neutral arrangement

a) The neutral arrangement of the 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. A neutral point may 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 shall 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 comply with IEC 61936-1, where applicable.

5.4.3.2 Arrangement within rooms containing main power electrical equipment

General installation requirements for bunded areas are given in [3.5.6].

Arrangement of main power equipment:

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 the vicinity of the switchgear. This shall be supported by internal fault testing.
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 Passageways for high voltage switchboards

	Width of front passage		*Width of passage behind (only if applicable)*	
System	*Unobstructed*	*With doors open or switchgear drawn out*	*Minimum free passage*	*Minimum free passage at frame*
Switchgear with nominal voltage above 1000 V	1.0 m	0.5 m	1.0 m	0.6 m

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

5.4.4 Main power transformers

5.4.4.1 Reference

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

5.4.4.2 Electrical design requirements

a) 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.

b) 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 shall be agreed with the grid operator. Some national grid codes explicitly state these parameters.

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c) 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 [5.3.4.1] and [5.3.4.2].

d) 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.

e) The transformer shall have reliable design, also for transient conditions (voltage transients, frequency transients).

5.4.4.3 Mechanical design requirements

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.

Guidance note:

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

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

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

— 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.

— The mechanical assessment of the transformer should include measures to contain the effects of a possible short-circuit in the oil-filled transformer.

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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 ½ cycle, consisting mainly of a mix of hydrogen and acetylene, i.e. about 1 m^3 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.

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

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 or Cx 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 while it shall be included in the substations operating and maintenance manual:

— 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 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

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

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) Transport of pressurized switchgear shall be duly evaluated and confirmed upfront.
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

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 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 61869-series series.

5.4.9 High voltage cables

High voltage cables shall not run through the accommodation area.

Cables with rated voltage higher than 1 kV shall be designed and tested according to following standards depending on their rated voltage:

— IEC 60502-2
— IEC 60840
— IEC 62067.

Care shall be taken when routing and fixing HV cables. Appropriate cable clamps, fixing components, trays shall be used in consideration of:

— personal safety during escape and evacuation, see [9.5] to [9.7]
— personal safety during normal operation in terms of mechanical forces applied
— safety of the environment.

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

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

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

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

Forces resulting from electromagnetic interaction of cables during short-circuit events shall be estimated by applying calculations of IEC 60865-1.

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

Escape routes shall be protected from dropping and burning materials in case of fire of high voltage cables.

5.4.10 Low voltage cables

5.4.10.1 General

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 60332-3-series, 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 60331.
d) Cables manufactured in accordance with the relevant recommendations of IEC 60092-350, 60092-360, 60092-352, 60092-353, 60092-354, 60092-360, 60092-376, 60092-376, 60092-376 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.

5.4.10.2 Cable laying for circuits

a) For single-phase and three-phase AC systems, multi-core cables shall 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) In relation of intrinsically safe circuit wiring and termination, provisions of DNV-OS-D201 Ch.2 Sec.11 [4.2.7] shall be observed.

5.4.10.3 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 shall 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 by DNV and may 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 shall 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 shall 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.

5.4.10.4 Fastening of cables and wires

a) To meet the requirements of [9.5] to [9.7], relevant cable trays and cableways shall be made of heat resistant materials, preferably metallic, which are protected against corrosion. Cables and wires shall be fastened with corrosion-resistant, flame retardant clips, ties or bindings. Exceptions are made for cables which are laid in pipes, cable ducts or similar means of protection. 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 shall be made of copper alloy if they are in electrical contact with the latter.
c) Single-core cables shall 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) When plastic cable trays are used above escape routes, metal supporting shall be used, together with the cables, to prevent obstruction of the escape routes in case of fire. Cables routed above escape routes shall be shielded against dropping burning materials in case of a fire.
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.

5.4.10.5 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-series, category A/F
— suitable measures have been taken during installation, e.g. the providing of fire stops or the application of flame-proof coatings.

5.4.10.6 Application of fire-resistant cables

a) Cables for safety systems, see [3.5.7], and emergency services, see [5.3.2.2], required to be operable under fire conditions shall be of a fire-resistant type, where they pass through machinery spaces of category A and other high fire risk areas other than those which they serve, and be supported by steel cable trays.
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) 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.

(see IACS Unified Requirements E15)

5.4.11 Power automation system

5.4.11.1 General

The main purpose of power automation system is to supervise, control and manage the operation of the substation main 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 lifetime.

Beside this, it shall also assure the maximum possible availability of the substation through a selectivity achieved by proper parameters setting of relays, sensors and PLCs.

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

Main transformers shall be provided with a back-up protection.

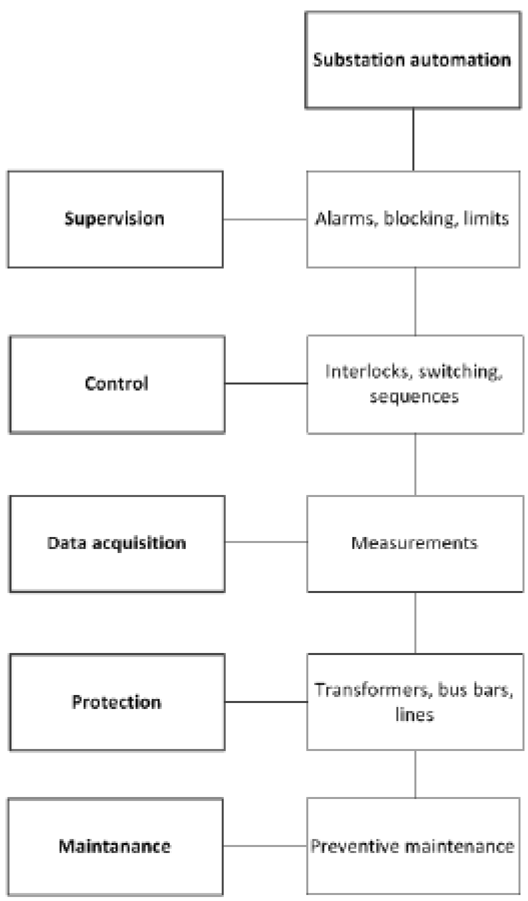

Figure 5-1 Automation system functions overview (informative)

5.4.11.2 Power supply to substation automation system

All the automation system consumers are fed by the main power supply. Backup shall be supplied by e.g. 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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5.4.11.3 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.

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b) In case of fire detection system activation, relevant provision shall be implemented as per [9.4].
c) In case of fire a response plan shall be followed, including automatic disconnection of relevant systems.

5.4.12 HVDC offshore substations

5.4.12.1 General

This section provides technical provisions specific for HVDC offshore substations, in addition to the requirements in Sec.5.

For HVDC offshore substations dedicated equipment is required for the conversion from AC to DC voltage or vice versa. HVDC substations are connected to one or more offshore wind power plants via HV submarine cable on the one side. In the other direction, these substations are connected to the onshore grid via DC submarine cables. Depending on the transmitted electrical power and the distance to the onshore converter substation, the DC voltage may vary between ±150 kV DC and ± 525 kV DC. This section covers the specific equipment which is installed on HVDC substations, which are mainly:

— high power semiconductor converter valves
— the HVDC converter transformers
— converter reactors and 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., provisions for fire detection and fire protection facilities shall be considered as per [2.4.2] or [2.4.3]. 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.

5.4.12.2 Power transformers and reactors on HVDC offshore substations

a) Converter substation power transformers, smoothing reactors or shunt reactors shall comply with the respective requirements as per standard series IEC 60076.
b) Transformers shall be designed for both, rectification and inversion, when not specified otherwise.
c) Specific requirements resulting from their operationshall 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 in consideration of a defined field of distribution of the harmonics expected at site.
   Type and routine tests shall be in compliance with the requirements of IEC/IEEE 60076-57-129.
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/IEEE 60076-57-129.
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 HVDC 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 converter cooling shall not be adversely affected in case of disturbance of the main power system. Any hazards or severe damage of the converter valves (e.g. as a result of failure of the cooling system) shall be prevented by appropriate mitigation measures.

5.4.12.3 Power semiconductors and protection

a) Insulated gate bipolar transistors 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.

5.4.12.4 Testing

Testing of the HVDC converter stations shall be based on applicable international standards. A test specification shall be issued and provided for approval. At least following tests should be carried out depending on their applicability:

— 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-series and related parts.

5.5 Auxiliary power system

5.5.1 General

Auxiliary power system comprises electrical power equipment ensuring:

— operation of the main power system of the offshore substation
— power supply of offshore wind turbines as far as required during standstill periods in an islanded condition
— power supply of further operational services as per [5.3.2.1]
— power supply of emergency services as per [5.3.2.2].

Guidance note:

Electrical power demanded for offshore wind turbines during an islanded condition is typically covered either by the dedicated grid diesel generator(s) (GDG) installed on the offshore substation or by a source of energy outside of the offshore substation, i.e. by the diesel generators installed on the offshore wind turbines.

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The substation auxiliary power system shall satisfy the redundancy criteria for availability by providing either

1) two mutually independent electric power supply systems:
   — main power supply of auxiliary power system, [5.5.2], enabling safe, normal and habitable operation of the substation within the specified boundary conditions
   — emergency power supply of auxiliary power system, [5.5.3], supplying the emergency services if the main power supply for auxiliary power systems fails

   or

2) a meshed power supply, [5.5.4].

5.5.2 Main power supply of auxiliary power system

5.5.2.1 Components of main power supply system

The main power supply for the substation auxiliary power system is built 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.

All associated control systems and services that must be in operation for the above-mentioned systems shall be considered as part of the main power supply for auxiliary power system.

The main sources of the substation auxiliary power system are the sources 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 substations of type B and C, the main source of power has also the purpose to maintain the substation in habitable condition.

Main sources of power supply for auxiliary power system are:

— external grid (supplying electric power through the substation main and auxiliary transformers)
— dedicated generator set(s) (auxiliary diesel generator(s), GDG)
— connections to other substations able to supply power.

On offshore substations of type B and C, main source of power supply for auxiliary power system required for islanded condition shall be dedicated generator set(s) located on the offshore substation.

The generator sets used as main source of power during islanded condition shall fulfil the following requirements:

— All generators shall be equipped with automatic load shedding or other automatic means to prevent sustained overload of any generator.
— It shall be possible to start the generator sets without recourse to energy sources located outside of the machinery space where the generator sets are installed.
— Batteries for starting of the generator sets shall be installed near the engine, so as to minimize the voltage drop in the power lines.
— Electric starting arrangement for a generator set shall have a separate battery. When the starting arrangement serves two or more generator sets, there shall at least be two separate batteries.
— Each starting battery shall have sufficient capacity for at least three start attempts of each of the generator sets. The duration of each starting shall be taken as minimum 10 seconds.
— Starting and connection to the main switchboard shall be preferably within 30 seconds, but in any case not more than 45 seconds after external grid loss.

5.5.2.2 Distribution system of main power supply

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 substation services.

A distribution board (DB) is any switchboard utilised for distribution to electrical consumers, but which is not considered as a main switchboard.

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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The main switchboard shall be located as close as is practicable to the main auxiliary generator set(s), but not in the same room.

Regarding the auxiliary power distribution system following sections of DNV-OS-D201 shall be applied, where applicable:

— DNV-OS-D201 Ch.2 Sec.2 [6] *Electric power distribution*
— DNV-OS-D201 Ch.2 Sec.2 [9.1.2] *Arrangement of power generation and distribution systems*
— DNV-OS-D201 Ch.2 Sec.2 [9.2] *Switchboard arrangement*.

5.5.2.3 Capacity of main source of power

The main power supply shall have the capacity to supply power to all services necessary for maintaining the offshore substation in normal operational and habitable condition without recourse to the emergency source of power, see [5.3.1.3].

The start of the largest auxiliary consumer shall not cause exceedance of the transient voltage and frequency variations limits specified in DNV-OS-D201 Ch.2 Sec.2 [1.2].

In islanded condition the capacity of main power supply for auxiliary power system shall be in accordance with [5.3.1.3].

5.5.3 Emergency power supply of auxiliary power system

5.5.3.1 Emergency electric power supply

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
— transitional source of emergency power
— emergency switchboards (ESB)

— emergency distribution boards (EDB)
— all cables from the emergency source of electrical power to the final consumers.

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

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.

Emergency sources of electrical power are:

— emergency generator(s)
— battery system(s).

The emergency source of power shall fulfil the following requirements:

— It shall be a self-contained source of electrical power.
— It shall be located in a safe location, separated from the main auxiliary power supply system and be readily accessible. This is related to associate transforming equipment, emergency switchboard, emergency lighting switchboard and transitional source of emergency power.
— 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 seconds supply at least the services required in Table 5-2 upon loss of main power 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 substation. Exceptionally, and for short periods, the emergency source of power may be used to supply non-emergency circuits, 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.
— Batteries for starting of the emergency generator set shall be installed near the engine, so as to minimize the voltage drop in the power lines.
— Each emergency generator set required to be capable of automatic starting, shall be equipped with a starting system to an acceptable standard and the capacity of which shall be sufficient for at least three consecutive starts. The duration of each starting shall be minimum 10 seconds.
— 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.
— An emergency generator set shall be capable of being readily started in its cold condition at a temperature of 0°C. If this is impracticable, or the offshore substation is intended for operation at lower ambient temperatures, provisions shall be made for heating arrangements to ensure ready starting of the generating sets.

Guidance note:

For floating installations the emergency generator should follow 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. The emergency generator should to be able to operate up to the maximum damage condition heel and meet the inclination design requirements of DNV-OS-D101 Ch.2 Sec.1 [2.2.1].

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5.5.3.2 Distribution system of emergency power supply

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.

Switchboards not being directly supplied by the emergency source of power may be considered as emergency switchboards when this is found relevant from a system and operational point of view.

An emergency distribution board (EDB) is any switchboard utilised for distribution to electrical consumers, but which is not considered as an emergency switchboard.

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 are considered as emergency switchboards (ESBs), i.e. at least one level of switchboards for each voltage level used.

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

The emergency switchboard shall fulfil the following requirements:

a) It shall be arranged as near as is practicable to the emergency source of power, but away from the main source of auxiliary power, and where the emergency source of power is a generator, the emergency switchboard shall preferably be located in the same space.
b) The emergency switchboard shall be supplied from the main switchboard during normal operation 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.
c) 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.

Technical requirements for functionality and construction of main switchboards apply also to emergency switchboards, see DNV-OS-D201 Ch.1 Sec.1 [1.6.9.1].

5.5.3.3 Transitional source of emergency electrical power

A transitional source of power is considered to be part of the emergency electric power supply, mainly to cover potential delays in start of the emergency generator for consumers needing continuous supply.

If the emergency source of electrical power is a generator, a transitional source of power is required.

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.

The battery source shall be able to operate, without recharging, while maintaining adequate voltage for the consumers throughout the discharge period. The capacity of the transitional source of power shall be sufficient to automatically supply at least the services required by Table 5-2.

5.5.3.4 Capacity of emergency source of power

In the case of failure of the main source of auxiliary power (emergency operational condition), the emergency source of power shall automatically start electrical supply of emergency services as listed in Table 5-2.

The electrical power available shall be sufficient to supply all services essential for safety in an emergency, with due regard being paid to such services as may be operated simultaneously, also taking into account starting currents and transitory nature of certain loads.

When non-emergency consumers are supplied by the emergency source of power, it shall either be possible to supply all operational required consumers simultaneously, or automatic disconnection of non-emergency consumers shall be arranged.

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

Service	*Emergency power consumers*	*Duration of emergency power [h]*	*Duration of transitional power [h]*
Emergency lighting	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.	18	0.5 $^{1)}$

Service	*Emergency power consumers*	*Duration of emergency power [h]*	*Duration of transitional power [h]*
	In all service and accommodation corridors, stairways and exits, personnel lift cars and personnel lift trunks.	18	0.5 [1)]
	In machinery spaces.	18	0.5 [1)]
	In all control stations / 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.	18	0.5 [1)]
	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.	18	0.5 [1)]
	At all stowage positions for firemen's outfits.	18	0.5 [1)]
	At the fire pump referred to in this table and its starting position.	18	0.5 [1)]
	At the sprinkler pump and its starting position.	18	0.5 [1)]
	Floodlight and perimeter lights on helicopter landing decks.	18	0.5 [1)]
Navigation lights	The navigation lights and other lights required by the National and International Regulations for Preventing Collisions at Sea in force.	96	0.5 [1)]
Structure marking	Any signalling lights or sound signals that may be required for marking of offshore structures.	96	0.5 [1)]
Active fire protection	Fire pumps and other firefighting equipment dependent on the emergency source of electrical power.	18	
Lifeboat	Secondary means of launching of free fall lifeboat.	[2)]	
Control and communication	Internal and external communication equipment required in an emergency.	18	0.5 [1)]
	Maritime and aeronautical radio systems for communication to ships and helicopters, where required by national authorities or by SOLAS Convention.	18	0.5 [1)]
	All control equipment required under abnormal conditions, see [9.4].	18	0.5 [1)]
Alarm systems	Fire and gas detection systems.	18	0.5 [1)]
	Alarm systems.	18	0.5 [1)]
	Manual fire alarms and all internal signals that are required in an emergency.	18	0.5 [1)]

[1)] Unless such services have an automatically charged battery with adequate capacity, suitably located for use in an emergency.

[2)] Power for launching of the lifeboat, where required, shall be available on demand with duration of 10 minutes for each lifeboat.

5.5.4 Meshed power supply of auxiliary power system

A meshed power supply for auxiliary power system represents an auxiliary power system for which a distinction between main and emergency power supply is not assumed.

An overview of a substation electrical system realised according to the design principles is shown in App.C.

A meshed power supply system shall provide the proper redundancy and flexibility of the substation distribution network in order to assure the uninterrupted operation / availability of operational and emergency services.

Failure of redundant component of meshed power supply shall not impair availability and rating of services required by [5.3.1.3].

Guidance note:

An offshore substation built in accordance with this section will not have any dedicated emergency power supply, since redundant main power supply of auxiliary power system during islanded condition is considered to ensure power supply to emergency consumers at all times. Compliance with [5.5.10.4] is not required.

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The following requirements shall be observed for meshed power supply:

— The main sources of electrical power shall be located in two or more spaces which have their own power distribution and control systems, completely independent of the systems in the other spaces.
— A fire or other accident in any space shall not affect the power supply from the others.
— Meshed power supply shall be fed by at least two self-contained generator sets. Each generator set shall meet the requirements in [5.5.2].
— Power to all required emergency services as listed in Table 5-2 supplied from main switchboards and sub distributions shall be automatically available within 45 seconds when power is automatically restored after external grid loss.
— Transitional source of power shall be provided as required in [5.5.3.3].
— Auxiliary systems of generator sets, e.g. cooling system, ventilation and lubrication, shall operate independently.
— Bus tie breakers between the spaces shall have short circuit protection providing discrimination.

5.5.5 Generator sets

DNV-OS-D201 Ch.2 Sec.5 *Rotating machines* shall be applied, where relevant.

Dimensioning of the diesel generator and their associated fuel tank(s) shall be based on the site characteristics i.e. type of substation, distance from the shore, site conditions and electricity demand.

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.

Requirements for the control, see [5.5.2], [5.5.3] and [5.5.9.3], [5.5.9.4], and protection, see [5.5.10.3], [5.5.10.4] and [7.4.3], of the generator sets shall be observed.

5.5.6 Battery system

5.5.6.1 Battery powered systems

Battery powered systems foreseen for parallel operations shall be provided with output synchronisation.

Every battery system shall have its own dedicated charging device (i.e. in order to constitute a battery system).

Battery systems shall be so rated that they can supply the consumers for the required period, in accordance with the energy balance, when charged to 80% of their rated capacity.

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

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 shall be automatic. If manual boost charge is provided, then the charger is to revert to normal charge automatically.

The type of UPS unit employed, whether off-line or on-line, shall be appropriate to the power supply requirements of the connected load.

5.5.6.2 Battery monitoring

An alarm shall be given at substation control room if the charging of a battery fails, alternatively an alarm shall be given if the battery is being discharged.

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.

UPS units used as emergency source of power or transitional source of emergency power, shall in addition have alarm for power supply failure (voltage and frequency) to the connected load. Alarms shall be given to substation control room.

5.5.6.3 Arrangement

a) Requirements of [6.6] shall be fulfilled for electrical equipment installed in battery rooms, lockers or boxes.
b) Accumulator batteries shall be suitably housed and compartments shall be properly constructed and efficiently ventilated.
c) Batteries shall be so located that their ambient temperature remains within the manufacturer’s specification at all times.
d) Battery cells shall be placed so that they are accessible for maintenance and replacement.
e) Batteries shall be so installed that battery poles are covered/protected such that a short circuit is prevented in case of falling objects or other incidents.
f) Batteries shall not be located in sleeping quarters. Exemptions shall be justified and shall be specially considered.
g) Batteries shall 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 conditions that the box is white in colour, are provided with ventilation and heating, and that the charger is provided with temperature compensation capability.
h) Extract fan(s) shall be interlocked with the battery charger if the batteries are known to produce hazardous levels of explosive gas during boost charging, so that loss of extract ventilation prevents charger operation.
i) Requirements to ventilation of spaces containing batteries are based on the possible gassing of batteries. The amount of gassing depends on charging power and type of battery.

5.5.6.4 Ventilation of battery spaces

a) Forced ventilation is required in battery spaces on offshore substations.

b) Calculations of ventilation rate shall be based on the following calculations:
Calculation of battery charging power (P):

$$P = U \cdot I$$

where:

P = calculated battery charging power [W]
U = rated battery voltage [V]
I = charging current [A]
= $I = 8 \cdot K/100$ for lead acid batteries
= $I = 16 \cdot K/100$ for NiCd- batteries
K = battery capacity [Ah].

If several battery sets are used, the sum of charging power shall be calculated.

Calculation of required ventilation flow rate (Q):

Q = $f \cdot 0.25\, I \cdot n$
Q = ventilation flow rate [m^3/h]
n = number of battery cells in series connection
f = 0.03 for VRLA (valve-regulated lead-acid battery) batteries
f = 0.11 for vented batteries.

If several battery sets are installed in one room, the sum of ventilation flow rate shall be calculated.

Calculation of required cross section of ventilation ducts (A) - assuming an air speed of 0.5 m/s

A = $5.6 \cdot Q$
A = cross-section [cm^2].

c) The ventilation system shall be independent of the ventilation systems serving other rooms, see [3.4.2].
d) Ventilation inlet and outlet openings shall be so arranged to ensure efficient ventilation of the free air volume. The air inlet openings shall be arranged in the lower part and air outlet openings shall be arranged in the upper part, so that the total free air volume is ventilated.
e) For forced ventilation the air speed should not exceed 4 m/s.
f) The inclination of air ducts for natural ventilation shall not exceed 45° from vertical. Where lockers are provided for batteries, the duct shall terminate not less than 0.9 m above the top of the battery enclosure.
g) Where a battery room ventilation duct is fitted with a closing device, then a warning notice, stating for example: 'This closing device shall be kept open and only closed in the event of fire or other emergency - EXPLOSIVE GAS', shall be provided at the closing device.
h) Exhaust fans handling air from hazardous locations or installed in hazardous locations shall be of non-sparking construction (see IACS UR F29). The fan motors shall be either certified safe type with a degree of protection for gas group IIC and temperature class T1 or be located in a non-hazardous area.

5.5.6.5 VRLA batteries installed in switchboards with calculated battery charging power up to 0.2 kW

Such batteries may be installed in switchboards without separation to switchgear and without any additional ventilation, if:

— the switchboards are not closed completely (IP 2X is suitable)

— the charger is regulated automatically by an IU- controller with a maximum continuous charging voltage of 2.3 V/cell.

5.5.6.6 Batteries installed in spaces with calculated battery charging power up to 2 kW for vented batteries and 8 kW for VRLA batteries

Such batteries shall be installed in ventilated cabinets or containers arranged in ventilated spaces. The free air volume of the space shall be larger than required volume calculated as follows:

$V = 2.5 \cdot Q$

V = free air volume in the room [m^3]

Q = ventilation flow rate [m^3/h].

If the space free air volume is not sufficient or the ventilation duct does not have the required cross-section, mechanical ventilation shall be provided. The air quantity Q shall be calculated, and the air speed should not exceed 4 m/s. Wherever possible exhaust fans shall be used.

5.5.6.7 Batteries installed in spaces with calculated battery charging power more than 2 kW for vented batteries and 8 kW for VRLA batteries

Such batteries shall be installed in closed cabinets, containers or battery rooms with mechanical exhaust to open deck area.

Vented lead acid batteries up to 3 kW calculated charging power may be ventilated by natural ventilation to open deck area.

5.5.6.8 Charging station for battery powered fork lift

Specific consideration shall be given to accumulation of flammable gas and ignition sources in the arrangement of charging stations for battery powered fork lifts.

1) A charging station is defined as a separate room, only used for this purpose, or a part of a large room based on the area occupied by the fork lift plus 1 m on all sides.
2) Socket outlets shall have at least enclosure IP 44 or IP 56, depending upon the location. In general, no other electrical equipment, except explosion protected equipment as specified for battery rooms may be installed.
3) Charging stations shall generally be arranged as battery rooms with charging power in accordance with the battery capacity of the fork lift. For charging stations having mechanical overpressure ventilation, an alternative arrangement shall provide a natural ventilation outlet duct of sufficient capacity from the upper part of the charging station to free air.

5.5.7 Auxiliary transformer

Auxiliary transformers shall comply with DNV-OS-D201 Ch.2 Sec.6 [1].

5.5.8 Auxiliary power system cables

[5.4.9] and [5.4.10] shall be applied.

5.5.9 Auxiliary systems control

5.5.9.1 General

For the substations of type A, remote control of the auxiliary power system as well as of the operational and emergency services shall, as far as practicable, enable the users to perform start-up, activation, shutdown, switching, reset and testing procedures from the onshore control.

5.5.9.2 Control of duplicated consumers

a) Control circuits for duplicated safety and essential equipment shall be kept separated from each other, and not located in the same enclosure.
b) Control gear for duplicated equipment shall be mutually independent and shall be divided between two motor control centres or distribution boards having separate supplies from different sides of the main switchboard and/or the emergency switchboard.
c) Where switchboards are fitted with bus ties or bus links, the duplicated circuits shall be fed from different sides of the bus tie.
d) Duplicated equipment shall not be dependent on any common circuits such as e.g. contactors for emergency stop.

5.5.9.3 Control of auxiliary generator sets

a) Where a switchboard is arranged for operation from an automation system, the switchboard shall in addition be arranged for local operation at the front of the switchboard or at a dedicated control position within the space where it is installed. This local operation shall be independent of remote parts of the automation system.
b) The following alarms shall be arranged at the substation control room, see [3.6.2]:
   - power failure to the control system
   - high and low frequency on the main busbars
   - high and low voltage on the main busbars.

All generator prime movers and generator circuit breakers shall have means for manual operation.

Automatic control of start, stop and load sharing between generators shall be adequate to ensure proper availability and functionality.

Where start, stop and/or load sharing between generators are controlled by an automation system the following apply:

- The following alarms should be arranged at the substation control room:
  1) starting failure of prime mover
  2) difference in loads (kVA or alternatively both kW and kVAr) taken by the generators, with the necessary time delay, when in symmetrical load sharing mode.
- Automatic starting attempts which fail should be limited to restrict consumption of starting energy.
- The generator circuit breaker should be provided with automatic wind up of the closing spring of the breaker.
- Simultaneous connection of generators on to the same bus shall not be possible.
- Automatic connection of generator shall not take effect before the voltage of the generator is stable and at normal level.

At any control position for manual operation of a generator breaker, including operator stations, the following information and control signals shall be easily and simultaneously observed by the operator:

- control and indication of breaker open and breaker close
- generator power [kW]
- generator current. Three separate simultaneous readings or alternatively one reading with a changeover switch for connection to all phases. If changeover switch is used, the current reading shall be supplied by separate current transformers, not used for protection. At an operating station one reading is sufficient.
- generator voltage
- generator frequency
- busbar voltage
- busbar frequency.

5.5.9.4 Control of emergency generator sets

a) Alarms shall be arranged at the substation control room for the case if emergency generator failed to start due to any reason including power failure to the control system.
b) The emergency generator set shall have means for manual operation. The generator circuit breaker shall be provided with automatic charging of the closing spring of the circuit breaker.
c) Automatic connection of the generator during blackout shall only be possible when auxiliary contacts on the incoming feeder circuit breaker show directly that all power supply is disconnected from the emergency switchboard.
d) Automatic connection of generator shall not take effect before the voltage of the generator is stable and at normal level.
e) Any casualty within one compartment of the emergency switchboard should not render both the incoming feeder circuit breaker and the generator's circuit breaker, nor their instrumentation and signals, inoperative.
f) For emergency generators, a trip of a control circuit protection shall not lead to uncontrolled closing of the generator circuit breaker against a live bus bar.
g) A disconnection signal shall be sent to the generator circuit breaker when the generator prime mover is stopped or shut down.

At the control position for manual operation of the generator circuit breaker, the following information and control signals shall be easily and simultaneously observed by the operator:

— control and indication of circuit breaker open and circuit breaker close
— generator power [kW]
— generator current. Three separate simultaneous readings or alternatively one reading with a changeover switch for connection to all phases. If changeover switch is used, the current reading shall be supplied by separate current transformers, not used for protection. At an operating station one reading is sufficient.
— generator voltage
— generator frequency
— busbar voltage
— busbar frequency.

5.5.9.5 Operation of switchgear and control gear

a) Switchboards that are arranged for supply by two (or more) alternative circuits shall be provided with interlock or instructions for correct operation by signboard on the switchboard. Positive indication of which of the circuits is feeding the switchboard shall be provided.
b) When a secondary distribution switchboard has two or more supplies, each supply circuit shall be provided with multipole switchgear.
c) In high voltage installations, the incoming feeders in the low voltage main switchboards shall be equipped with voltmeters and ampere-meters. It shall be possible to display the currents and voltages of all three phases. Where instrumentation switches for voltage or ampere meter are used it shall be ensured that a failure in measuring circuit doesn't impair or disable any protection function of this circuit.
d) Parallel operation of high voltage service transformers is only permissible for load transfer in maximum 10 s, if also the high voltage sides of the transformers are connected. A forced splitting, independent of the automation system shall be provided.
e) Switchboards supplied from low voltage power transformers shall be arranged with interlock or signboard as in a) unless the power transformers are designed for parallel operation.
f) Interlocking arrangements shall be such that a fault in this interlocking system cannot put more than one circuit out of operation.
g) In the case where a secondary distribution system is supplied by parallel operated power transformers, supplied by different non-synchronous systems, necessary interlocks shall be arranged to preclude parallel operation of the transformers when the primary sides are not connected.
h) Transformers shall not be energised from the secondary side, unless accepted by the manufacturer. For high voltage transformers, secondary side switchgear shall generally be interlocked with the switchgear on the primary side. This is to ensure that the transformer will not be energised from the secondary

side when the primary switchgear is opened. If backfeeding through transformers is arranged, special warning signs shall be fitted on the primary side switchgear. Different generators shall not feed the different sides of transformers simultaneously to avoid locking of generators in synchronism via a transformer.

5.5.10 Auxiliary systems protections

5.5.10.1 System protection

Selection, arrangement and performance of the system protection shall provide complete and co-ordinated automatic protection in order to obtain continuity of supply and elimination of the effects of faults to reduce damage to the system and the hazard of fire as much as possible. See IEC 61892-2.

Load shedding or other equivalent automatic arrangements shall be provided to protect the generators, required by this standard, against sustained active/reactive overload.

Each insulated or high resistance earthed primary or secondary distribution system shall have a device or devices to continuously monitor electrical insulation to earth.

In case of abnormally low insulation values an alarm at substation control room shall be given (i.e. both visual and audible signal).

At overvoltage an alarm shall be given at substation control room. Settings shall not be higher than 130% of nominal voltage with a time delay less than 5 s.

The electric distribution system and electrical consumers shall be fitted with short circuit, overcurrent and earth fault protection.

The short circuit, overcurrent and earth fault protection of essential and important equipment shall be selective and shall ensure that only the switching device nearest to the fault initiates disconnection of the faulty circuit.

5.5.10.2 Circuit protection

Each separate circuit shall be protected against short circuit with the protection in the feeding end. For generators smaller than 1500 kVA, the protection may be at the switchboard side of the cables.

Each circuit shall be protected against overcurrent.

All consumers shall be separately protected except as noted below.

Loss of control voltage to protective functions shall lead to a disconnection of the corresponding equipment or give an alarm on a manned control position, unless other specific requirements apply.

No fuse, switch or breaker shall be inserted in earthing connections or conductors. Earthed neutrals may only be disconnected provided the complete circuit is disconnected at the same time by means of multipole switch or breaker.

The circuit breaker control shall be such that pumping (i.e. automatically repeated breaking and making) cannot occur.

Circuits for heating cables, tapes, pads, etc. should be supplied through a circuit breaker with earth fault protection (residual-current device, RCD).

Exceptions:

— For emergency generator sets.
— Circuit supplying multiple socket outlets, multiple lighting fittings or other multiple non-important consumers is accepted when rated maximum 16 A in 230 V systems, or 30 A in 110 V systems.
— Non-important motors rated less than 1 kW, and other non-important consumers, rated less than 16 A, do not need separate protection.
— Separate short circuit protection may be omitted for consumers serving non-important services. Each motor shall have separate overcurrent protection and controlgear.
— Common short circuit protection for more than one consumer is acceptable for non-important consumers, and for important consumers constituting a functional service group (i.e. when the important function cannot be ensured by a single consumer of the group).

- Common overload or overcurrent protection for more than one consumer is acceptable when the protection system adequately detects overload/overcurrent or other malfunction origin at individual consumer. Cables connected to individual consumer shall be sized to settings adjusted at the common protection.
- Separate short circuit protection may be omitted at the battery or busbar end of short circuit proof installed cables.

5.5.10.3 Auxiliary generator sets protection

Generators shall be fitted with short circuit and overcurrent protection as well as undervoltage release.

The overcurrent protection shall normally be set so that the generator breaker trips at 110% to 125% of nominal current, with a time delay of 20 s to 120 s. Other settings may be accepted after confirmation of discrimination.

The short circuit trip shall be set at a lower value than the generator's steady state short circuit current and with a time delay of maximum 1 s.

The undervoltage release shall have a time delay longer than the respective short circuit setting.

Each generator arranged for parallel operation shall be provided with reverse-power protection with settings in accordance with engine manufacturer's recommendation. If no manufacturer's recommendation is provided, setting values shall be:

- time delay between 3 s and 10 s
- tripping the generator circuit breaker at
  - maximum 15% of the rated power for generators driven by prime movers

The release power shall not depart from the set point by more than 50% at voltage variations down to 60% of the rated voltage, and on AC installations at any power factor variation.

Reverse power protection may be omitted when power supplied from the main switchboard to the generator is impossible.

When the incoming circuits for generators are controlled by circuit breakers, these shall be fitted with undervoltage release so that re-connection to a dead busbar by another source of power is not impeded. This undervoltage release shall trip the breaker when the generator voltage drops within the range 70% to 35% of its rated voltage.

The undervoltage protection shall allow the breaker to be closed when the voltage and frequency are 85% to 110% of the nominal value.

The undervoltage protection shall have a time delay allowing for correct operation of the short circuit protection (i.e. longer time delay than the short circuit protection).

For prime mover [7.4.3] shall be observed.

5.5.10.4 Emergency generator sets protection

The protective shutdown functions associated with emergency generator sets shall be limited to those necessary to prevent immediate machinery breakdowns i.e. short circuit. If overcurrent protection release is implemented, the setting of this release shall be so high that under no circumstances the supply to emergency consumers is impaired.

Generator circuit breaker shall have undervoltage release with a time delay longer than the respective short circuit time delay and clearance time.

A shut down or stop signal to the prime mover shall cause disconnection signal to the generator circuit breaker if a generator runs in parallel with any other source of power.

Other protective functions such as overcurrent, high temperature etc. shall, if installed, give alarm only.

For prime mover [7.2.3] shall be observed.

5.5.10.5 Battery protection

Circuits connected to batteries above 12 V or above 1 Ah capacity shall have short circuit and overcurrent protection. Protection may also be required for smaller batteries capable of posing a fire risk. Short circuit protection shall be located as close as is practical to the batteries, but not inside battery rooms, lockers, boxes or close to ventilation holes.

5.5.11 Miscellaneous equipment

Sockets, lighting equipment, heating equipment, cooking and other galley equipment shall comply with DNV-OS-D201 Ch.2 Sec.8, where applicable. National requirements shall be observed.

5.5.12 Arrangement of electrical rooms

Passages in front of switchboards shall have a height of minimum 2 m. The same applies to passages behind switchboards having parts that require operation from the rear.

The width of the front passage shall be as given in Table 5-3.

Where switchgear needs passage behind for installation and maintenance work the free passage behind the switchgear shall be as given in Table 5-3.

The free passageway in front of, or behind the switchboard, shall give unobstructed access to a door for easy escape in case of an emergency situation occurring in the space.

Table 5-3 Passageways for low voltage switchboards

	Width of free passage [m]		*Width of passage behind [m]*	
System voltage [V]	*Unobstructed*	*With doors open or switchgear drawn out*	*Minimum free passage*	*Minimum free passage of frames*
Below 500	0.8 ≤	0.4	0.6	0.5
500 V ≤ and ≤ 1000	0.8	0.4	0.8	0.6

5.6 Lightning protection and earthing

5.6.1 References

5.6.1.1 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.

5.6.1.2 Basic design criteria

5.6.1.2.1 Lightning protection level (LPL)

The offshore substation 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 shall be found in IEC 62305- 1, Table 5 and 6.

5.6.1.2.2 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 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 shall 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 0_A and LPZ 0_B 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 shall be taken for a further reduction in the effects of electromagnetic fields and over-voltages, especially for sensitive electronic systems.

5.6.1.2.3 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.

5.6.1.2.4 Electrical systems and installations

Electrical systems and installations shall 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.

5.6.1.2.5 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-voltagepower distribution systems – Requirements and tests for power systems*
— IEC 61643-11 .

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 60099-4 .

5.6.1.2.6 Earthing system

Solid and durable earthing of the offshore substation 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 IEC 61936-1 and IEC 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.

Unintential potential transfer between the earthing system of the offshore substation and others like, e.g., the earthing system of the wind turbines shall be considered and avoided. Containers installed on the offshore substation 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 mm^2 per conductor.

5.6.1.2.7 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, shall 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).

5.7 Lighting systems

5.7.1 Main lighting

The main lighting system shall be 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 comply with IEC 61892-2, Annex G *Illumination level*. National/local requirements shall be observed.

A lighting calculation and a lighting layout shall be prepared for the main lighting.

For installation of light fittings or switches in bathrooms and shower rooms, see IEC 60364-7-701.

5.7.2 Emergency lighting

An emergency lighting system shall be provided. 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 inoperative.

The emergency lighting e.g. in control or machinery spaces shall be so dimensioned to facilitate the recovery of the substation operation by personnel on board from the emergency condition.

The emergency lighting system shall be switched on automatically in case of a failure of the main power supply of auxiliary system, [5.5.2], when the substation is in manned state.

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. National/local requirements shall be observed.

A lighting calculation and a lighting layout shall be prepared for the emergency lighting.

5.7.3 Escape lighting

Escape lighting shall be provided to ensure that the means of escape, see [9.5] can be effectively identified and safely used.

The escape lighting shall be operational immediately after main power failure to facilitate a safe escape of personnel, when the offshore substation is in manned state. It shall have a power supply with a backup time of minimum 30 minutes supplied either by integrated batteries or centralised by emergency power supply system, see [5.5.3].

The lighting level of the escape lighting shall comply with IEC 61892-2, Annex G *Illumination level*. National/local requirements shall be also observed.

A lighting calculation and a lighting layout shall be established for the escape lighting.

5.7.4 Design of light fittings

Luminaries, floodlights and searchlights shall be conform to IEC 60598 and IEC 60092-306.

Specific environmental conditions, e.g. strong electromagnetic radiation and high temperatures at ceilings in HVDC converter rooms shall be considered for lighting fixtures installed in such areas.

The surface temperature of easily touchable parts of light fittings shall not exceed 60°C.

High-power lights with higher surface temperatures shall 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 mm^2. A cross section of at least 1.5 mm^2 shall be used for through wiring. Heat-resistant wires shall 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.

Guidance note:

Service and maintenance of the light system should be taken into consideration when designing the light system. Work at height and above guardrails should be avoided.

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5.7.5 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.

5.7.6 Lighting circuits

The maximum permissible fused current of lighting circuits is 16 A.

The number of lighting points (lamps) connected to one 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 lighting circuits in systems insulated on all poles is permitted only in the accommodation area.

At least in the spaces listed below the lighting shall be supplied by at least two separate protected circuits:

— passageways, stairs and other escapes (indoor and outdoor)
— galleys
— machinery spaces, service spaces and control rooms
— messes, accommodation and day rooms for the personnel
— boat landing, helicopter landing and winching area.

It is not permitted to supply all the lighting circuits exclusively from only one source of power. The light fittings shall be so arranged that adequate illumination is maintained should any circuit fail.

A fire zone shall be treated equivalent to spaces as listed above.

5.8 Marking

Marking of the electrical equipment shall be in accordance with DNV-OS-D201 Ch.2 Sec.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 further important information related to fire and explosion protection include:

— [3.5.7] *Safety systems*
— [4.4.6.4] *Explosion*
— [5.5] *Auxiliary power system*
— [8.4.2] *Helicopter decks*
— Sec.9 *Emergency response*
— [11.4.4] *Safety systems*.

6.2 Safety concept 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.

Sec.6 of this standard summarizes minimum prescriptive requirements to achieve these objectives.

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.

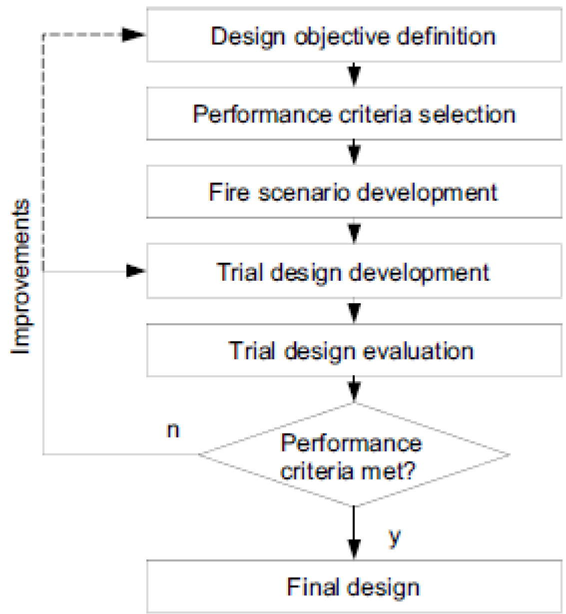

Figure 6-1 Performance-based fire protection design

6.2.2 Safety criteria and evaluation

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 or explosion.

See also [4.4.6.5] and [4.4.6.6].

Performance criteria related to health and safety of persons shall be evaluated. The criteria are valid during the waiting time in a temporary safe area or during an evacuation process.

6.2.3 Design basis

Fire and explosion analysis shall be based on information such as:

— applicable regulations and standards
— layout of the installation and arrangement of equipment
— geometry, ventilation conditions and thermal inertia of the enclosures
— nature and risk of fires, fire escalation and explosions
— fluids handled and their properties including substances that can catch fire
— manning concept, distribution of persons, human factors.

6.2.4 Design process

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.

Selection of relevant fire scenarios follows. Relatively large number of initial fire scenarios are reduced to a number of selected scenarios, see [6.3.1].

Following typical fire scenarios shall as a minimum be evaluated:

- 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 substation control room or social areas due to smoking, unattended electrical devices, poor housekeeping.

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
- 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.

6.2.5 Minimum requirements

Minimum requirements for passive fire protection are described in [6.4].

Active firefighting systems shall be foreseen in accordance with [6.5].

Portable fire extinguishing equipment is required on all substations according to [6.5.9].

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 and, where required, gas detection systems, shall be foreseen in accordance with [6.7].

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 probability to occur
— fires having a severe consequence.

Guidance note:

It is often enough to select four (4) to six (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.

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

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:

$$\dot{Q}_b = \dot{m}'' \cdot \Delta H_c \cdot \chi \cdot A_f$$

where:

$\dot{Q}_b$ = combustion controlled value of energy release rate, in MW
$\dot{m}''$ = burning rate, in kg s^{-1} m^{-2}
ΔH_c = heat of combustion, in MJ/kg
X = combustion coefficient
A_f = burning area, in m^2.

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:

$\dot{Q}_v$ = ventilation controlled value of energy release rate, in MW
A_0 = area of openings (vents) in fire room, in m^2
H_0 = weighted mean height of openings, in m.

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 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 exposure) and make escape and evacuation possible
— protect systems and equipment essential for safety
— maintain structural integrity for the required period of time.

Substations of all types shall be subdivided into spaces by thermal and structural divisions having regard to the fire risks of the space, see Table 6-1 and Table 6-2.

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.

These provisions have been formulated principally for the substations having their structural bulkheads, decks and deckhouses constructed of steel. Units constructed of other materials may be accepted, if they provide an equivalent standard of safety.

(see MODU Code Sec. [9.2.1] and [9.2.2])

Structural fire protection details, materials and methods of construction shall be in accordance with the FTP Code, as applicable, and SOLAS regulations II-2/5.3 and II-2/6, as applied to cargo ships.

(see MODU Code Sec. [9.2.3])

The Table 6-1 and Table 6-2 are interpretations of MODU Code tables 9-1 and 9-2 adapted for offshore substation purposes.

6.4.2.1 General selection principles

For well proven designs the prescriptive requirements given in Table 6-1 and Table 6-2 may be applied directly under due consideration of requirements for specific spaces in [6.4.2.2] having priority.

For the determination of the fire integrity of bulkheads and decks between adjacent spaces, such spaces shall be classified according to their fire risk, as shown in categories (1) to (11) below. Definitions of spaces see also in [1.6.2]. 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 Table 6-1 and Table 6-2:

— (1) 'control stations' are spaces with equipment performing control functions essential for operational and emergency services, e.g. spaces containing:
  — operational control systems
  — fire control equipment
  — 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 similar spaces.
— (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 lockers, storerooms 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, 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.

Table 6-1 Fire integrity of walls separating adjacent spaces

Space	*Typical spaces on an offshore substation*	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*
(1) control stations	control and communication room, UPS, emergency diesel generator, SCADA and control room	A-0	A-0	A-60	A-0	A-15	A-60	A-15	A-60	A-60	*	A-0
(2) corridors			C	B-0	B-0 A-0	B-0	A-60	A-0	A-0	A-0	*	B-0
(3) accommodation spaces	public room, locker room			C	B-0 A-0	B-0	A-60	A-0	A-0	A-0	*	C
(4) stairways					B-0 A-0	B-0 A-0	A-60	A-0	A-0	A-0	*	B-0 A-0
(5) service spaces (low risk)	workshop, storage					C	A-60	A-0	A-0	A-0	*	B-0
(6) machinery spaces of category A	diesel generator room (> 375 kW), HV transformer room						*	A-60	A-60	A-60	*	A-0

Space	*Typical spaces on an offshore substation*	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*
(7) other machinery spaces	diesel generator room (< 375 kW), rooms for LV HV							A-0 a)	A-0	A-0	*	A-0
(8) hazardous areas	heli fuel skid, diesel tanks								-	A-0	-	A-0
(9) service spaces (high risk)										A-0 a)	*	A-0
(10) open decks	walkways										-	*
(11) sanitary and similar spaces												C

a) Where spaces are of the same numerical category and superscript 'a' 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.

* The divisions should be of steel or equivalent material, but are not required to be of A class standard. However, where a division 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 division.

Table 6-2 Fire integrity of decks separating adjacent spaces

Spaces above → *below* ↓	*Typical spaces on an offshore substation*	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*
(1) control stations	control and communication room, UPS, emergency diesel generator, SCADA and control room	A-0	A-0	A-0	A-0	A-0	A-60	A-0	A-0	A-0	*	A-0
(2) corridors		A-0	*	*	A-0	*	A-60	A-0	A-0	A-0	*	*
(3) accommodation spaces	public room, locker room	A-60	A-0	*	A-0	*	A-60	A-0	A-0	A-0	*	*
(4) stairways		A-0	A-0	A-0	*	A-0	A-60	A-0	A-0	A-0	*	A-0

Spaces above → *below* ↓	*Typical spaces on an offshore substation*	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*
(5) service spaces (low risk)	workshop, storage	A-15	A-0	A-0	A-0	*	A-60	A-0	A-0	A-0	*	A-0
(6) machinery spaces of category A	diesel generator room (>375 kW) HV transformer room	A-60	A-60	A-60	A-60	A-60	*	A-60	A-60	A-60	*	A-0
(7) other machinery spaces	diesel generator room (<375 kW), rooms for LV, HV	A-15	A-0	A-0	A-0	A-0	A-0	*	A-0	A-0	*	A-0
(8) hazardous areas	heli fuel skid, diesel tanks	A-60	A-0	A-0	A-0	A-0	A-60	A-0	-	A-0	-	A-0
(9) service spaces (high risk)		A-60	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0 a)	*	A-0
(10) open decks	walkways	*	*	*	*	*	*	*	-	*	-	*
(11) sanitary and similar spaces		A-0	A-0	*	A-0	*	A-0	A-0	A-0	A-0	*	*
a) Where spaces are of the same numerical category and superscript 'a' 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.												
* The divisions should be of steel or equivalent material, but are not required to be of A class standard. However, where a division 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 division.												

6.4.2.2 Requirements for specific spaces

In areas where dimensioning fire loads exceeds 100 kW/m², 'H'-rated divisions shall be applied, see DNV-OS-A101 Ch.2 Sec.1 [3.6] *Heat loads*.

At least the following equipment of auxiliary power system shall be separated by an 'A-60' class division:

— main and emergency sources of auxiliary power supply system
— main and emergency switchboards
— redundant equipment of meshed power supply for auxiliary system.

Emergency source of power or components of an emergency power supply adjoining a space containing HV equipment shall be separated by an 'A-60' class division.

Provisions of [8.4.2.2] on 'A-60' insulation of the helidecks forming the deckhead of a deckhouse or superstructure shall be observed.

6.4.3 Fire protection materials

Except for insulation in refrigerated compartments, insulation material, pipe and vent duct lagging, ceilings, linings and bulkheads shall be of non-combustible material. Insulation of pipe fittings for cold service systems and vapour barriers and adhesives used in conjunction with insulation need not be non-combustible, but they shall be kept to a minimum, and their exposed surfaces shall have low flame spread characteristics. In spaces where penetration of oil products is possible, the surfaces of the insulation shall be impervious to oil or oil vapours.

(see MODU Code Sec. 9.3.7)

Guidance note:

In respect of the low-flame spread characteristics see *Recommendation on improved fire test procedures for surface flammability of bulkhead, ceiling and deck finish materials*, adopted by the Organization by resolution A.653(16), in conjunction with guidelines on the evaluation of fire hazard properties of materials, adopted by the Organization by resolution A.166(ES.IV) and Annex 1, Part 1 of the *International Code for Application of Fire Test Procedures (FTP Code)*.

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The framing, including grounds and the joint pieces of bulkheads, linings, ceilings and draught stops, shall be of non-combustible material.

(see MODU Code Sec. 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 shall have low flame spread characteristics. Exposed surfaces of ceilings in accommodation and service spaces and control stations shall have low flame spread characteristics.

(see MODU Code Sec. 9.3.9)

Walls, linings and ceilings may have combustible veneers provided that the thickness of such veneers does 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 shall have a calorific value not exceeding 45 MJ/m^2 of the area for the thickness used.

(see MODU Code Sec. 9.3.10)

Guidance note:

In respect of calorific value see ISO 1716 *Reaction to fire tests for products – Determination of the gross heat of combustion (calorific value)*.

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Primary deck coverings, if applied within accommodation and service spaces and control stations, shall be of approved material which will not readily ignite, this being determined in accordance with the FTP Code.

(see MODU Code Sec. 9.3.11)

Paints, varnishes and other finishes used on exposed interior surfaces shall not be capable of producing excessive quantities of smoke and toxic products, this being determined in accordance with the FTP Code.

(see MODU Code Sec. 9.3.12)

6.4.4 Structural elements

Bulkheads required to be 'B' class divisions shall extend from deck to deck and to the shell or other boundaries. Where a continuous 'B' class ceiling or lining is fitted on both sides of the bulkhead, the bulkhead may terminate at the continuous ceiling or lining.

(see SOLAS Ch. II-2 Reg. 9.2.3.2.1)

Continuous 'B' class ceilings or linings, in association with the relevant decks or bulkheads, may be accepted as contributing, wholly or in part, to the required insulation and integrity of a division.

(see SOLAS Ch. II-2 Reg. 9.2.3.3.3)

Stairways which penetrate only a single deck shall 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 shall be protected by 'A' class divisions. Stairways and lift trunks which penetrate more than a single deck shall be surrounded by 'A' class divisions and protected by self-closing doors at all levels. Self-closing doors shall not be fitted with hold-back hooks. Holdback arrangements incorporating remote release fittings of the fail-safe type may be utilized.

(see MODU Code Sec. 9.3.5 and Sec. 9.2.10)

Stairs shall be constructed of steel or equivalent material.

(see MODU Code Sec. 9.3.4)

Air spaces enclosed behind ceilings, paneling or linings shall 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., shall be closed at each deck.

(see MODU Code Sec. 9.3.6)

In cases where any part of the structure is of aluminium alloy, the following shall apply:

1) the insulation of aluminium alloy components of 'A' or 'B' class divisions, except structure which, in the opinion of the administration, is non-load-bearing, shall be such that the temperature of the structural core does not rise more than 200 degrees C above the ambient temperature at any time during the applicable fire exposure to the standard fire test
2) special attention shall be given to the insulation of aluminium alloy components of columns, stanchions and other structural members required to support lifeboat and liferaft stowage, launching and embarkation areas, and 'A' and 'B' class divisions to ensure:
   - that for such members supporting lifeboat and liferaft areas and 'A' class divisions, the temperature rise limitation specified in 1) shall apply at the end of one hour
   - that for such members required to support 'B' class divisions, the temperature rise limitation specified in 1) shall apply at the end of half an hour.

(see SOLAS Ch. II-2 Reg. 11.3)

6.4.5 Protection of openings in fire-rated divisions

6.4.5.1 General

Openings in fire rated divisions (doors, windows, sidescuttles, hatches) shall be arranged so as to maintain the fire rating of the divisions.

6.4.5.2 Doors

The fire resistance of doors shall be equivalent to that of the division in which they are fitted, this being determined in accordance with FTP Code. Doors and door frames in 'A' class divisions shall be constructed of steel. Doors in 'B' class divisions shall be non-combustible. Doors fitted in boundary bulkheads of machinery spaces of category A shall be reasonably gastight and self-closing. Doors approved as 'A' class without the sill being part of the frame shall be installed such that the gap under the door does not exceed 12 mm and a non-combustible sill shall be installed under the door such that floor coverings do not extend beneath the closed door. Doors approved as 'B' class without the sill being part of the frame shall be installed such that the gap under the door does not exceed 25 mm.

(see SOLAS Ch. II-2 Reg. 9.4.2.1)

Doors required to be self-closing shall not be fitted with hold-back hooks. However, hold-back arrangements fitted with remote release devices of the fail-safe type may be utilized.

(see SOLAS Ch. II-2 Reg. 9.4.2.2)

In corridor bulkheads ventilation openings may be permitted in and under the doors of cabins and public spaces. Ventilation openings are also permitted in 'B' class doors leading to lavatories, offices, pantries, lockers and store rooms. Except as permitted below, the openings shall be provided only in the lower half of a door. Where such an opening is in or under a door the total net area of any such opening or openings shall not exceed 0.05 m². Alternatively, a non-combustible air balance duct routed between the cabin and the corridor, and located below the sanitary unit is permitted where the cross-sectional area of the duct does not exceed 0.05 m². Ventilation openings, except those under the door, shall be fitted with a grille made of non-combustible material.

(see SOLAS Ch. II-2 Reg. 9.4.2.3)

6.4.5.3 Windows

Windows and sidescuttles in bulkheads within accommodation and service spaces and control stations other than those to which the provisions of Reg. 9.4.1.1.7 (see below), shall be so constructed as to preserve the integrity requirements of the type of bulkheads in which they are fitted, this being determined in accordance with the fire test procedures code.

(see SOLAS Ch. II-2 Reg. 9.4.1.3.1)

External boundaries which are required to be of steel or other equivalent material may be pierced for the fitting of windows and sidescuttles provided that there is no requirement for such boundaries to have 'A' class integrity. Similarly, in such boundaries which are not required to have 'A' class integrity, doors may be constructed of materials which are to the satisfaction of the administration.

(see SOLAS Ch. II-2 Reg. 9.2.3.3.4)

The requirements for 'A' class integrity of the outer boundaries of a substation shall not apply to glass partitions, windows and sidescuttles. The requirements for 'A' class integrity of the outer boundaries of the substations shall not apply to exterior doors, except for those in superstructures and deckhouses facing lifesaving appliances, embarkation and external assembly station areas, external stairs and open decks used for escape routes. Stairway enclosure doors does not need meet this requirement.

(see SOLAS Ch. II-2 Reg. 9.4.1.1.7)

Windows and sidescuttles shall be of the non-opening type. The administration may permit windows and sidescuttles outside hazardous areas to be of the opening type.

(see MODU Code Sec. 9.2.8)

6.4.6 Penetration in fire-rated divisions and prevention of heat transmission

6.4.6.1 Pipe, cable and duct penetrations

Penetrations for the passage of electric cables, pipes and ventilation ducts in fire rated divisions shall be arranged so as to maintain the fire rating of the divisions.

Where 'A' class divisions are penetrated, such penetrations shall be tested in accordance with the FTP Code. In the case of ventilation ducts, [6.4.7] apply. Where a pipe penetration is made of steel or equivalent material having a thickness of 3 mm or greater and a length of not less than 900 mm (preferably 450 mm on each side of the division), and no openings, testing is not required. Such penetrations shall be suitably insulated by extension of the insulation at the same level of the division.

(see SOLAS Ch. II-2 Reg. 9.3.1)

Where 'B' class divisions are penetrated for the passage of electric cables, pipes, trunks, lighting fixtures and similar devices, arrangements shall be made to ensure that the fire resistance is not impaired. Pipes other than steel or copper that penetrate 'B' class divisions shall be protected by either:

— A fire tested penetration device, suitable for the fire resistance of the division pierced and the type of pipe used.
— A steel sleeve, having a thickness of not less than 1.8 mm and a length of not less than 900 mm for pipe diameters of 150 mm or more and not less than 600 mm for pipe diameters of less than 150 mm (preferably equally divided to each side of the division). The pipe shall be connected to the ends of the sleeve by flanges or couplings, or the clearance between the sleeve and the pipe shall not exceed 2.5 mm, or any clearance between pipe and sleeve shall be made tight by means of non-combustible or other suitable material.

(see SOLAS Ch. II-2 Reg. 9.3.2)

Uninsulated metallic pipes penetrating 'A' or 'B' class divisions shall be of materials having a melting temperature which exceeds 950ºC for 'A-0' and 850ºC for 'B-0' class divisions.

(see SOLAS Ch. II-2 Reg. 9.3.3)

6.4.6.2 Prevention of heat transmission
The risk of heat transmission at intersections and terminal points of required thermal barriers shall be regarded. The insulation of a deck or bulkhead shall be carried past the penetration, intersection or terminal point for a distance of at least 450 mm in the case of steel and aluminium structures. If a space is divided with a deck or a bulkhead of 'A' class standard having insulation of different values, the insulation with the higher value shall continue on the deck or bulkhead with the insulation of the lesser value for a distance of at least 450 mm.

(see SOLAS Ch. II-2 Reg. 9.3.4)

6.4.7 Ventilation systems

6.4.7.1 Ventilation ducts and dampers
Ventilation ducts shall be of non-combustible material. Short ducts, however, not generally exceeding 2 m in length and with a cross-sectional area not exceeding 0.02 m^2 are not required to be non-combustible, subject to the following conditions:

1) these ducts shall be of a material which, in the opinion of the administration, has a low fire risk
2) they may only be used at the end of the ventilation device
3) they shall not be situated less than 600 mm, measured along the duct, from where it penetrates any 'A' or 'B' class division including continuous 'B' class ceilings.

(see MODU Code Sec. 9.3.13)

The following arrangements shall be tested in accordance with the FTP Code:

— fire dampers, including their relevant means of operation, however, the testing is not required for dampers located at the lower end of the duct in exhaust ducts for galley ranges, which must be of steel and capable of stopping the draught in the duct
— duct penetrations through 'A' class divisions. The test is not required where steel sleeves are directly joined to ventilation ducts by means of riveted or screwed connections or by welding.

(see SOLAS Ch. II-2 Reg. 9.7.1.2)

Fire dampers shall be easily accessible. Where they are placed behind ceilings or linings, these ceilings or linings shall be provided with an inspection hatch on which the identification number of the fire damper is marked. The fire damper identification number shall also be marked on any remote controls provided.

(see SOLAS Ch. II-2 Reg. 9.7.1.3)

Ventilation ducts shall be provided with hatches for inspection and cleaning. The hatches shall be located near the fire dampers.

(see SOLAS Ch. II-2 Reg. 9.7.1.4)

The main inlets and outlets of ventilation systems shall be capable of being closed from outside the spaces being ventilated. The means of closing shall be easily accessible as well as prominently and permanently marked and shall indicate the operating position of the closing device.

(see SOLAS Ch. II-2 Reg. 9.7.1.5)

Combustible gaskets in flanged ventilation duct connections are not permitted within 600 mm of openings in 'A' or 'B' class divisions and in ducts required to be of 'A' class construction.

(see SOLAS Ch. II-2 Reg. 9.7.1.6)

Ventilation openings or air balance ducts between two enclosed spaces shall not be provided except as permitted by paragraphs SOLAS Ch. II-2 Reg. 9.4.2.3, see above.

(see SOLAS Ch. II-2 Reg. 9.7.1.7)

6.4.7.2 Arrangement of ducts

Ventilation systems for machinery spaces of category A, galleys and hazardous areas shall be separated from each other and from the ventilation systems serving other spaces. Ducts serving hazardous areas shall not pass through accommodation spaces, service spaces, or control spaces. Ducts provided for the ventilation of machinery spaces of category A and galleys shall not pass through accommodation spaces, control stations or service spaces unless:

1) the ducts are constructed of steel having a thickness of at least 3 mm for ducts with a free cross-sectional area of less than 0.075 m^2, at least 4 mm for ducts with a free cross-sectional area of between 0.075 m^2 and 0.45 m^2, and at least 5 mm for ducts with a free cross-sectional area of over 0.45 m^2
2) the ducts are suitably supported and stiffened
3) the ducts are fitted with automatic fire dampers close to the boundaries penetrated
4) the ducts are insulated to 'A-60' class standard from the machinery spaces or galleys to a point at least 5 m beyond each fire damper,
   or
5) the ducts are constructed of steel in accordance with item 1 and 2 of this paragraph
6) the ducts are insulated to 'A-60' class standard throughout the accommodation spaces, service spaces or control stations.

(see MODU Code Sec. 9.3.15 and SOLAS Ch. II-2 Reg. 9.7.2.4)

Ducts provided for the ventilation of accommodation spaces, service spaces or control stations shall not pass through machinery spaces of category A, galleys or hazardous areas. However, the administration may permit a relaxation from these provisions, except for the ducts passing through hazardous areas, provided that:

1) the ducts where they pass through a machinery space of category A or a galley are constructed of steel in accordance with MODU Code Sec. 9.3.15 items 1 and 2 (see above)
2) automatic fire dampers are fitted close to the boundaries penetrated
3) the integrity of the machinery space or galley boundaries is maintained at the penetrations;
   or
4) the ducts where they pass through a machinery space of category A or a galley are constructed of steel in accordance with MODU Code Sec. 9.3.15 items 1 and 2 (see above)
5) are insulated to 'A-60' standard within the machinery space or galley.

(see MODU Code Sec. 9.3.16)

Ventilation ducts with a cross-sectional area exceeding 0.02 m^2 passing through 'B' class bulkheads shall be lined with steel sheet sleeves of 900 mm in length divided preferably into 450 mm on each side of the bulkhead unless the duct is of steel for this length.

(see MODU Code Sec. 9.3.17)

Where they pass through accommodation spaces or spaces containing combustible materials, the exhaust ducts from galley ranges shall be of equivalent fire integrity to 'A' class divisions.

(see MODU Code Sec. 9.3.18)

Each galley exhaust duct shall be fitted with:

1) a grease trap readily removable for cleaning
2) a fire damper located in the galley end of the duct which is automatically and remotely operated and, in addition a remotely operated fire damper located in the exhaust end of the duct
3) arrangements, operable from within the galley, for shutting off the exhaust fans
4) fixed means for extinguishing a fire within the duct.

(see MODU Code Sec. 9.3.19)

Power ventilation of accommodation spaces, service spaces, control stations, machinery spaces and hazardous areas shall 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 shall be specially considered. The means provided for stopping the power ventilation serving machinery spaces or hazardous areas shall be entirely separate from the means provided for stopping ventilation of other spaces.

(see MODU Code Sec. 9.3.21)

The ventilation of the accommodation spaces and control stations shall be arranged in such a way as to prevent the ingress of flammable, toxic or noxious gases, or smoke from surrounding areas.

(see MODU Code Sec. 9.3.23)

A duct, irrespective of its cross section, serving more than one deck on substations of type B and C shall be fitted, near the penetration of each deck served, with a fire or smoke damper.

(see SOLAS Ch. II-2 Reg. 9.7.4.4 and MSC/Circ. 1120)

6.4.7.3 Details of duct penetrations

Ducts passing through 'A' class divisions shall meet the following requirements:

1) Where a thin plated duct with a free cross sectional area equal to, or less than, 0.02 m^2 passes through 'A' class divisions, the opening shall be fitted with a steel sheet sleeve having a thickness of at least 3 mm and a length of at least 200 mm, divided preferably into 100 mm on each side of a bulkhead or, in the case of a deck, wholly laid on the lower side of the decks penetrated.
2) Where ventilation ducts with a free cross-sectional area exceeding 0.02 m^2, but not more than 0.075 m^2, pass through 'A' class divisions, the openings shall be lined with steel sheet sleeves. The ducts and sleeves shall have a thickness of at least 3 mm and a length of at least 900 mm. When passing through bulkheads, this length shall be divided preferably into 450 mm on each side of the bulkhead. These ducts, or sleeves lining such ducts, shall be provided with fire insulation. The insulation shall have at least the same fire integrity as the division through which the duct passes.
3) Automatic fire dampers shall be fitted in all ducts with a free cross-sectional area exceeding 0.075 m^2 that pass through 'A' class divisions. Each damper shall be fitted close to the division penetrated and the duct between the damper and the division penetrated shall be constructed of steel in accordance with [6.4.7.2]. The damper shall be fitted with a visible indicator which shows the operating position of the damper. 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 penetrate. A duct of cross-sectional area exceeding 0.075 m^2 shall not be divided into smaller ducts at the penetration of an 'A' class division and then recombined into the original duct once through the division to avoid installing the damper required by this provision.

(see SOLAS Ch. II-2 Reg. 9.7.3.1)

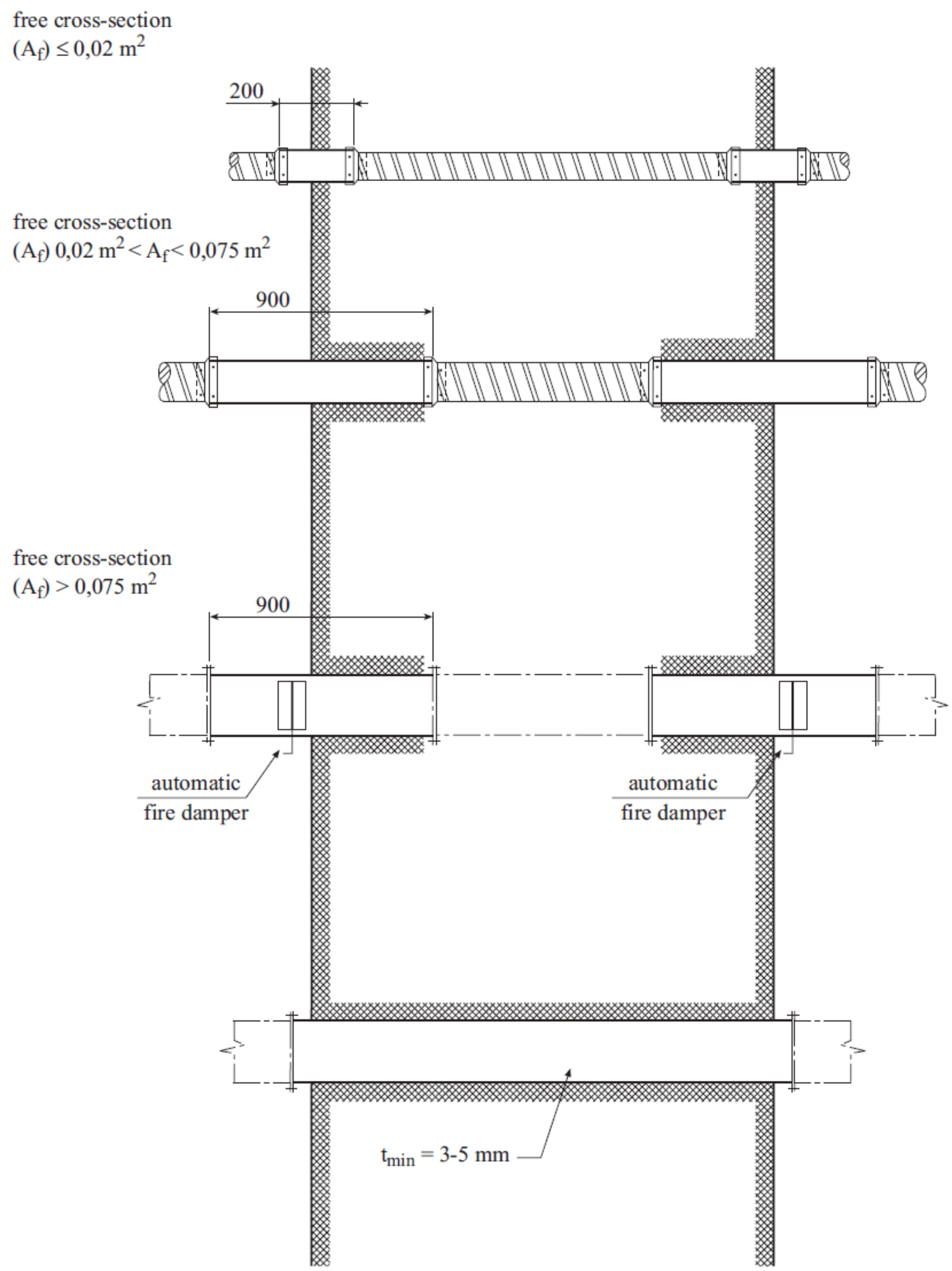

Figure 6-2 Details of duct penetrations through "A" class bulkheads (informative)

6.5 Active fire protection

6.5.1 General

The objectives of active fire protection 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 substation.

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 shall be provided on the substation. 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 selection of active fire protection for the typical areas of an offshore substation. The actual choice of active fire protection depends on the type of the substation, installed equipment in the considered space, potential fire loads and as per outcome of fire risk assessment.

Table 6-3 Active fire protection selection

Area	*Suitable active fire protection*
All	Portable fire extinguishers, various types [1)]
Shunt reactor rooms, main/auxiliary transformer rooms	Water-based systems[2)] (water spraying, water mist system), high expansion foam system.
Diesel generator rooms	Water-based systems (water spraying, water mist or deluge system), gas or high expansion foam system
Mechanically ventilated utility spaces, control rooms, switchgear rooms, battery rooms, local equipment rooms, HVAC rooms, UPS rooms, electrically driven crane engine rooms, LV and HV rooms, telecommunication or public address rooms	Gas or water mist system
Accommodation spaces, locker room, public room	Sprinkler system[3)] or portable fire extinguisher
Diesel tank area, rooms containing gas bottles filled with flammable gas (including oxygen), fire water pump rooms	Water-based systems (water spraying, water mist or deluge system), high expansion foam system
Rooms containing bottles with non-flammable gas (e.g. extinguishing medium)	Portable fire extinguishers
Helideck	Fixed foam application system [4)]
[1)] All areas should be equipped with the proper type and size of portable extinguishers. [2)] 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. [3)] On offshore substations of type B and C installation of the sprinkler system can be required by national regulations. [4)] Reference is given to CAP 437 Ch. 5, FSS Code Ch.17.	

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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.

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.

Active fire protection systems shall be designed in accordance with the applicable standards, see [6.5.2] to [6.5.9]. National/local requirements to active fire protection systems as well as their components approval shall be observed.

6.5.2 Fire main systems

6.5.2.1 Minimum requirements

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.

(see MODU Code Sec. 9.7.1)

At least one of the required pumps shall be dedicated for fire-fighting duties and be available for such duties at all times.

(see MODU Code Sec. 9.7.2)

The arrangements of the pumps, sea suctions and sources of power shall be such as to ensure that a fire in any one space would not put both the required pumps out of action.

(see MODU Code Sec. 9.7.3)

Centrifugal fire pumps shall be self-priming or hydrostatical pressurised.

The capacity of the required pumps shall be appropriate to the fire-fighting services supplied from the fire main.

(see MODU Code Sec. 9.7.4)

Each pump shall 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/mm^2 at any hydrant. In addition, where a foam system is provided for protection of the helicopter deck, the pump shall be capable of maintaining a pressure of 0.7 N/mm^2 at the foam installation. If the water consumption for any other fire protection or fire-fighting purpose shall exceed the rate of the helicopter deck foam installation, this consumption shall be the determining factor in calculating the required capacity of the fire pumps.

(see MODU Code Sec. 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 shall be made for remote start-up of that pump and remote operation of associated suction and discharge valves.

(see MODU Code Sec. 9.7.6)

Every centrifugal pump which is connected to the fire main shall be fitted with a non-return valve.

(see MODU Code Sec. 9.7.8)

Relief valves shall 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 shall be so placed and adjusted as to prevent excessive pressure in the fire main system.

(see MODU Code Sec. 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.

The diameter of the fire main and water service pipes shall be sufficient for the effective distribution of the maximum required discharge from the required fire pumps operating simultaneously.

(see MODU Code Sec. 9.7.11)

The fire main shall, 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.

(see MODU Code Sec. 9.7.13)

The fire main shall be provided with isolating valves located so as to permit optimum utilisation in the event of physical damage to any part of the main.

(see MODU Code Sec. 9.7.14)

Guidance note:

1) The isolation valves should include provisions for easy access of operation including clear marking. Where the isolation valves are remotely operated, manual operation should be possible locally.
2) Water main supply to deluge systems or water monitors should 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 deluge system or fire-fighting equipment in an adjacent area.
3) Two separate supplies to the deluge firewater distribution pipework should be provided, the main primary supply being from the deluge valve. The secondary supply should be from another section of the fire main by an isolation valve in the fire main between the two supply locations. The secondary supply may be manually activated.

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The fire main shall not have connections other than those necessary for fire fighting purposes.

(see MODU Code Sec. 9.7.15)

All practical precautions consistent with having water readily available shall be taken to protect the fire main against freezing.

(see MODU Code Sec. 9.7.16)

Materials readily rendered ineffective by heat shall not be used for fire mains and hydrants unless adequately protected. The pipes and hydrants shall be so placed that the fire hoses may be easily coupled to them.

(see MODU Code Sec. 9.7.17)

A cock or valve shall be fitted to serve each fire hose so that any fire hose may be removed while the fire pumps are operating.

(see MODU Code Sec. 9.7.18)

Guidance note:

Further guidance references:

— MODU Code Sec. 9.7 *Fire pumps, fire mains, hydrants and hoses*
— SOLAS Ch. II-2 Reg. 10 *Fire fighting*
— NFPA 20 *Standard for the Installation of Stationary Pumps for Fire Protection*'.

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6.5.3 Deluge systems

6.5.3.1 Minimum requirements

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.

It should be possible to manually actuate the deluge system in case of failure of the automatic release. The actuation should be possible both locally and remotely. The remote activation should be at the substation control room where the operating status of the systems is monitored. The local activation should have safe access from the emergency control station and located outside the fire zone protected by the actual system.

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 shall be ensured that the required quantity of water or foam will impinge on the surfaces to be protected. Due account shall be taken to the effects of obstructions.

Provisions for flushing of the distribution pipework shall be provided.

For the supply of the deluge system from fire main, see [6.5.2].

Guidance note:

Further guidance references:

- MSC.1/Circ.1430 *Revised guidelines for the design and approval of fixed water-based fire-fighting systems for ro-ro spaces and special category spaces*
- NFPA 11 *Standard for Low-, Medium-, and High-Expansion Foam'* Ch. 7
- NFPA 13 *Standard for the Installation of Sprinkler Systems*
- NFPA 15 *Standard for Water Spray Fixed Systems for Fire Protection*
- NFPA 16 *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems*.

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6.5.4 Automatic sprinkler systems

6.5.4.1 Minimum requirements

The sprinklers shall be resistant to corrosion by marine atmosphere. In accommodation and service spaces the sprinklers shall come into operation within the temperature range from 68 degrees C to 79 degrees C, except that in locations such as drying rooms, where high ambient temperatures might be expected, the operating temperature may be increased by not more than 30 degrees C above the maximum deckhead temperature.

(see FSS Code Ch. 8 Sec. 2.3.1.1)

Sprinklers shall be grouped into separate sections each of which shall contain not more than 200 sprinklers. Each section of sprinklers shall be capable of being isolated by one stop valve only. The stop valve in each section shall be readily accessible in a location outside of the associated section or in cabinets within stairway enclosures. The valve' s location shall be clearly and permanently indicated. Means shall be provided to prevent the operation of the stop valves by any unauthorized person.

(see FSS Code Ch. 8 Sec. 2.4.2.1 and 2.4.2.2)

A test valve shall be provided for testing the automatic alarm for each section of sprinklers by a discharge of water equivalent to the operation of one sprinkler. The test valve for each section shall be situated near the stop valve for that section.

(see FSS Code Ch. 8 Sec. 2.4.2.3)

A gauge indicating the pressure in the system shall be provided at each section stop valve and at a central station.

(see FSS Code Ch. 8 Sec. 2.4.2.5)

The sprinkler pump and tank shall be situated in a position reasonably remote from any machinery space of category A and shall not be situated in any space required to be protected by the sprinkler system.

(see FSS Code Ch. 8 Sec. 2.4.3)

Any required automatic sprinkler, fire detection and fire alarm system shall be capable of immediate operation at all times and no action by the crew shall be necessary to set it in operation.

(see FSS Code Ch. 8 Sec. 2.5.1.1)

Each section of sprinklers shall include means for giving a visual and audible alarm signal automatically at one or more indicating units whenever any sprinkler comes into operation. Such alarm systems shall be such as to indicate if any fault occurs in the system.

Such units shall indicate in which section served by the system a fire has occurred and shall be centralised in the substation control room and, in addition, visible and audible alarms from the unit shall also be placed in a position other than on the aforementioned spaces to ensure that the indication of fire is immediately received by the crew.

(see FSS Code Ch. 8 Sec. 2.5.2.1)

Means shall be provided for testing the automatic operation of the pump on reduction of pressure in the system.

(see FSS Code Ch. 8 Sec. 2.5.3)

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.

Further guidance references:

— FSS Code Ch. 8 *Automatic sprinkler, fire detection and fire alarm systems*

— NFPA 13 *Standard for the Installation of Sprinkler Systems*

— NFPA 16 *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems*.

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6.5.5 Fixed pressure water-spraying and water mist extinguishing systems

6.5.5.1 Minimum requirements

The system and its components shall be designed to withstand ambient temperatures, vibration, humidity, shock, impact, clogging and corrosion normally encountered.

(see MSC/Circ.1165 Sec. 13, MSC.1/Circ.1430 Sec. 3.10)

The electrical components of the pressure source for the system shall have a minimum rating of IP 54.

(see MSC/Circ.1165 Sec. 16, MSC.1/Circ.1430 Sec. 3.4)

The piping system shall be sized in accordance with an hydraulic calculation technique.

(see MSC/Circ.1165 Sec. 18, MSC.1/Circ.1430 Sec. 3.3)

The capacity and design of the system shall be based on the complete protection of the space demanding the greatest volume of water.

(see MSC/Circ.1165 Sec. 20)

The system operation controls shall be available at easily accessible positions outside the spaces to be protected.

(see MSC/Circ.1165 Sec. 21, MSC.1/Circ.1430 Sec. 3.2)

Pressure source components of the system shall be located outside the protected spaces.

(see MSC/Circ.1165 Sec. 22)

A means for testing the operation of the system for assuring the required pressure and flow shall be provided.

(see MSC/Circ.1165 Sec. 23)

Activation of the system shall give a visual and audible alarm in the protected space and at substation control room. An alarm in the substation control room shall indicate the specific valve / section of the system activated.

(see MSC/Circ.1165 Sec. 24, MSC.1/Circ.1430 Sec. 3.5)

Guidance note:

Further guidance references:

— FSS Code Ch. 7 *Fixed pressure water spraying and water-mist fire-extinguishing systems*

— MSC/Circ.1165 *Revised guidelines for the approval of equivalent water-based fire-extinguishing systems for machinery spaces and cargo pump-rooms*

— MSC.1/Circ.1430 *Revised guidelines for the design and approval of fixed water-based fire-fighting systems for ro-ro spaces and special category spaces*

— NFPA 15 *Standard for Water Spray Fixed Systems for Fire Protection*

— NFPA 16 *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems*

— NFPA 750 *Standard on Water Mist Fire Protection Systems*

— VdS 2109 VdS *Guidelines for Water Spray Systems - Planning and Installation*.

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6.5.6 Fixed gas fire extinguishing systems

6.5.6.1 Minimum requirements

Where the quantity of the fire-extinguishing medium is required to protect more than one space, the quantity of medium available is not required to be more than the largest quantity required for any one space so protected. The system shall be fitted with normally closed control valves arranged to direct the agent into the appropriate space. Adjacent spaces with independent ventilation systems not separated by at least A-0 class divisions shall be considered as the same space.

(see FSS Code Ch. 5 Sec. 2.1.1.1)

Means shall be provided to safely check the quantity of the fire-extinguishing medium in the containers. It shall not be necessary to move the containers completely from their fixing position for this purpose.

(see FSS Code Ch. 5 Sec. 2.1.1.3)

Containers for the storage of fire-extinguishing medium, piping and associated pressure components shall be designed to pressure codes of practice to the satisfaction of the administration having regard to their locations and maximum ambient temperatures expected in service.

(see FSS Code Ch. 5 Sec. 2.1.1.4)

Except as otherwise accepted by the administration pressure containers required for the storage of fire-extinguishing medium shall be located outside the protected spaces.

(see FSS Code Ch. 5 Sec. 2.1.2.2)

A fitting shall be installed in the discharge piping to permit the air testing.

(see FSS Code Ch. 5 Sec. 2.1.2.6)

The necessary pipes for conveying fire-extinguishing medium into the protected spaces shall be provided with control valves so marked as to indicate clearly the spaces to which the pipes are led. Suitable provisions shall be made to prevent inadvertent release of the medium into the space. The pipes may pass through accommodations providing that they are of substantial thickness and that their tightness is verified with a pressure test, after their installation, at a pressure head not less than 5 N/mm². In addition, pipes passing through accommodation areas shall be joined only by welding and shall not be fitted with drains or other openings within such spaces. The pipes shall not pass through refrigerated spaces.

(see FSS Code Ch. 5 Sec. 2.1.3.1)

Means shall be provided for automatically giving audible and visual warning of the release of fire-extinguishing medium into any spaces in which personnel normally work or to which they have access. The audible alarms shall be located so as to be audible throughout the protected space with all machinery operating, and the alarms shall be distinguished from other audible alarms by adjustment of sound pressure or sound patterns. The pre-discharge alarm shall be automatically activated. The alarm shall operate for the length of time needed to evacuate the space, but in no case less than 20 s before the medium is released.

(see FSS Code Ch. 5 Sec. 2.1.3.2)

Audible and visual alarms shall be provided in the protected space and additional visual alarms at each access to the space.

When the system has been installed, pressure-tested and inspected, the following shall be carried out:

— a test of the free air flow in all pipes and nozzles
— a functional test of the alarm equipment.

(see FSS Code Ch. 5 Sec. 2.2.3)

Where a fixed gas fire-extinguishing system is used, openings which may admit air to, or allow gas to escape from, a protected space shall be capable of being closed from outside the protected space.

(see SOLAS Ch. II-2 Reg. 10.4.2)

Guidance note:

Further guidance references:

- FSS Code Ch. 5 *Fixed gas fire extinguishing*
- ISO 14520-1 *Gaseous fire-extinguishing systems — Physical properties and system design — Part 1: General requirements*
- NFPA 2001 *Standard for Clean Agent Fire Extinguishing Systems*
- VdS 2380 *Fire Extinguishing Systems using Non-Liquefied Inert Gases. Planning and Installation*
- VdS 2381 *Fire Extinguishing Systems using Halocarbon Gases. Planning and Installation*.

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6.5.7 Fixed low-expansion foam fire-extinguishing systems

6.5.7.1 Minimum requirements

The foam concentrates of low-expansion foam fire-extinguishing systems shall be approved by the administration based on the guidelines adopted by the Organization (refer to the Revised Guidelines for the performance and testing criteria and surveys of low expansion foam concentrates for fixed fire-extinguishing systems, MSC.1/Circ.1312). Different foam concentrate types shall not be mixed in a low-expansion foam system. Foam concentrates of the same type from different manufacturers shall not be mixed unless they are approved for compatibility.

(see FSS Code Ch. 6 Sec. 4.1.1)

Means shall be provided for effective distribution of the foam through a permanent system of piping and control valves or cocks to suitable discharge outlets, and for the foam to be effectively directed by fixed sprayers onto other main fire hazards in the protected space. The means for effective distribution of the foam shall be proven acceptable to the administration through calculation or by testing.

(see FSS Code Ch. 6 Sec. 4.2.1)

The means of control of any such systems shall be readily accessible and simple to operate and shall be grouped together in as few locations as possible at positions not likely to be cut off by a fire in the protected space.

(see FSS Code Ch. 6 Sec. 4.2.2)

Guidance note:

Further guidance sources:

- FSS Code Ch. 6 *Fixed foam fire extinguishing*
- NFPA 11 *Standard for Low, Medium, and High-Expansion Foam*.

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6.5.8 Fixed high-expansion foam fire-extinguishing systems

6.5.8.1 Minimum requirements

The foam concentrates shall be approved by the administration. Different foam concentrate types shall not be mixed in a high-expansion foam system.

(see FSS Code Ch. 6 Sec. 3.1.3)

System piping, foam concentrate storage tanks, components and pipe fittings in contact with the foam concentrate shall be compatible with the foam concentrate and be constructed of corrosion resistant materials such as stainless steel, or equivalent. Other system piping and foam generators shall be full galvanized steel or equivalent. Distribution pipework shall have self-draining capability.

(see FSS Code Ch. 6 Sec. 3.1.5)

Means for testing the operation of the system and assuring the required pressure and flow shall be provided by pressure gauges at both inlets (water and foam concentrate supply) and at the outlet of the foam proportioner. A test valve shall be installed on the distribution piping downstream of the foam proportioner, along with orifices which reflect the calculated pressure drop of the system. All sections of piping shall be provided with connections for flushing, draining and purging with air. All nozzles shall be able to be removed for inspection in order to prove clear of debris.

(see FSS Code Ch. 6 Sec. 3.1.6)

The system source of power supply, foam concentrate supply and means of controlling the system shall be readily accessible and simple to operate, and shall be arranged at positions outside the protected space not likely to be cut off by a fire in the protected space. All electrical components directly connected to the foam generators shall have at least an IP 54 rating.

(see FSS Code Ch. 6 Sec. 3.1.12)

The piping system shall be sized in accordance with a hydraulic calculation technique to ensure availability of flows and pressures required for correct performance of the system.

(see FSS Code Ch. 6 Sec. 3.1.13)

The arrangement of the protected spaces shall be such that they may be ventilated as the space is being filled with foam. Procedures shall be provided to ensure that upper level dampers, doors and other suitable openings are kept open in case of a fire. For inside air foam systems, spaces below 500 m^3 does not to not comply with this requirement.

(see FSS Code Ch. 6 Sec. 3.1.14)

Protected spaces shall be provided with audible and visual alarms within the protected space warning of the release of the system. The alarms shall operate for the length of time needed to evacuate the space, but in no case less than 20 s.

(see FSS Code Ch. 6 Sec. 3.1.20)

After installation, the pipes, valves, fittings and assembled systems shall be tested to the satisfaction of the administration, including functional testing of the power and control systems, water pumps, foam pumps, valves, remote and local release stations and alarms. Flow at the required pressure shall be verified for the system using orifices fitted to the test line. In addition, all distribution piping shall be flushed with freshwater and blown through with air to ensure that the piping is free of obstructions.

(see FSS Code Ch. 6 Sec. 3.4.1)

Functional tests of all foam proportioners or other foam mixing devices shall be carried out to confirm that the mixing ratio tolerance is within +30% to -0% of the nominal mixing ratio defined by the system approval.

(see FSS Code Ch. 6 Sec. 3.4.2)

Guidance note:

Further guidance sources:

— FSS Code Ch. 6 *Fixed foam fire extinguishing*

— NFPA 11 *Standard for Low-, Medium-, and High-Expansion Foam*.

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6.5.9 Portable extinguishers

The accommodation, service and working spaces and control stations shall be provided with portable fire extinguishers of approved types and design.

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.

(see FSS Code Ch. 4 Sec. 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.

(see FSS Code Ch. 4 Sec. 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 are not reqiured to be installed in rooms where persons cannot enter during operation e.g. in converter rooms on HVDC offshore substations. 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 offshore substation 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 of sufficient vent area shall be mounted in walls or in the roof of the blast structure, to prevent overpressure build-up.

6.6.4 Equipment selection

6.6.4.1 Hazardous zones

Hazardous areas shall be categorised into hazardous zones and arranged in accordance with IEC 60079-10-1 (potentially relevant for battery rooms, lockers or boxes, paint stores or welding gas bottle stores, as well as ventilation ducts serving such spaces). Selection/installation of protected equipment in hazardous areas shall be in accordance with IEC 60079-14.

Electrical equipment and cables installed in hazardous areas shall be limited to that necessary for operational purposes.

(see MODU Code 6.6.1)

6.6.4.2 Explosion groups and temperature classes

The following explosion groups and temperature classes are applicable:

— for battery rooms for NiCd and lead acid batteries: minimum gas group II C and temperature class T1
— for paint stores: minimum gas group II B and temperature class T3
— for storerooms containing welding gas bottles: minimum gas group II C and temperature class T2.

6.7 Fire and gas detection and alarm systems

6.7.1 General

The fire and gas detection and alarm systems shall be designed to allow testing without interrupting other systems onboard and be regarded as a safety system, see [3.7].

If shutdown actions are performed by the fire and gas detection systems, the requirements for the shutdown system, see [9.4], apply.

6.7.2 Fire detection

6.7.2.1 System design requirements

Any required fixed fire detection and fire alarm system with manually operated call points shall be capable of immediate operation at all times. Notwithstanding this, particular spaces may be disconnected, for example, workshops during hot work. The means for disconnecting the detectors shall be designed to automatically restore the system to normal surveillance after a predetermined time that is appropriate for the operation in question. The space shall be manned or provided with a fire patrol when detectors required by regulation are disconnected. Detectors in all other spaces shall remain operational.

(see FSS Code Ch. 9 Sec. 2.1.1)

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 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:

- paging systems, fire alarm or public address systems
- fan stops
- fire doors
- fire dampers
- sprinkler systems
- smoke extraction systems
- low-location lighting systems
- fixed local application fire-extinguishing systems
- closed circuit television (CCTV) systems
- other fire safety systems.

(see FSS Code Ch. 9 Sec. 2.1.2)

The fire detection system may be connected to a decision management system provided that:

- the decision management system is proven to be compatible with the fire detection system
- the decision management system can be disconnected without losing any of the functions required by this chapter for the fire detection system
- any malfunction of the interfaced and connected equipment shall not propagate under any circumstance to the fire detection system.

(see FSS Code Ch.9 Sec. 2.1.3)

Detectors and manual call points shall be connected to dedicated sections of the fire detection system. Other fire safety functions, such as alarm signals from the sprinkler valves, may be permitted if in separate sections.

(see FSS Code Ch. 9 Sec. 2.1.4)

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.

(see FSS Code Ch. 9 Sec. 2.1.5)

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) 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.

(see FSS Code Ch. 9 Sec. 2.1.6)

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 changeover switch shall be arranged such that a fault will not result in the loss of both power supplies. 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.

(see FSS Code Ch. 9 Sec. 2.2.1)

There shall be sufficient power to permit the continued operation of the system with all detectors activated, but not more than 100 if the total exceeds this figure.

(see FSS Code Ch. 9 Sec. 2.2.3)

The emergency source of power specified above shall be sufficient to maintain the operation of the fire detection and fire alarm system for the periods required by Table 5-2.

(see FSS Code Ch. 9 Sec. 2.2.4 and MSC.1/Circ. 1554)

6.7.2.2 Component requirements

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.

(see FSS Code Ch. 9 Sec. 2.3.1.1)

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 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.

(see FSS Code Ch. 9 Sec. 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 60092-504. 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.

(see FSS Code Ch. 9 Sec. 2.3.1.3)

The operation temperature of heat detectors in drying rooms and similar spaces of a normal high ambient temperature may be up to 130ºC, and up to 140ºC in saunas.

(see FSS Code Ch. 9 Sec. 2.3.1.4)

Guidance note:

The table below provides a guideline for the selection of fire detectors for typical areas on an offshore substation. The actual selection of fire detectors depends on the installed equipment in the considered space, combustial materials, geometry of the space, ventilation principles, and as per outcome of further risk considerations and risk assessment. Detectors may offer more than one detection principle in the same device.

Table 6-4 Selection of fire detectors

Area	*Detection principle*
Mechanically ventilated utility spaces, 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	Smoke
Main transformer/reactor rooms, auxiliary transformer rooms (units filled with mineral oil, synthetic ester or dry insulated)	Smoke, heat, flame
Diesel generator or generator rooms	Flame or smoke
Rooms containing gas bottles (typically inert gas for fire suppression system)	Smoke
Firewater pump rooms	Smoke and/or flame
Storage area, workshops	Smoke or heat
Paint store	Heat or flame
Fuel oil storage, diesel engine room	Flame
Accommodation: cabins, corridors, staircases, public rooms, radio room, laundry	Smoke
Accommodation: galley, galley hood or duct	Heat or smoke
Open decks and areas subject to high air speeds	Flame

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

Flame detectors shall be tested according to standards EN 54-10 and IEC 60092-504. Alternative testing standards may be used as determined by the administration.

(see FSS Code Ch. 9 Sec. 2.3.1.5)

Detectors fitted in hazardous areas shall be tested and approved for such service.

(see FSS Code Ch. 9 Sec. 2.3.1.8)

All detectors shall be of a type such that they can be tested for correct operation and restored to normal surveillance without the renewal of any component.

(see FSS Code Ch. 9 Sec. 2.3.1.6)

The control panel for the fire detection system shall be tested according to standards EN 54-2, EN 54-4 and IEC 60092-504.

(see FSS Code Ch. 9 Sec. 2.3.2)

6.7.2.3 Sectioning

Detectors and manually operated call points shall be grouped into sections.

(see FSS Code Ch. 9 Sec. 2.4.1.1)

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.

(see FSS Code Ch. 9 Sec. 2.4.1.2)

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.

(see FSS Code Ch. 9 Sec. 2.4.1.3)

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.

(see FSS Code Ch. 9 Sec. 2.4.2.1)

The maximum spacing of detectors shall be in accordance with Table 6-5 below:

Table 6-5 Maximum spacing of detectors

Type of detector	*Maximum floor area per detector [m^2]*	*Maximum distance between detectors [m]*	*Maximum distance away from walls [m]*
Heat	37	9	4.5
Smoke	74	11	5.5

Other spacing may be permitted based upon test data which demonstrate the characteristics of the detectors.

(see FSS Code Ch. 9 Sec. 2.4.2.2)

Detectors in stairways shall be located at least at the top level of the stair and at every second level beneath.

(see FSS Code Ch. 9 Sec. 2.4.2.3)

Where a fixed fire detection and fire alarm system is required by SOLAS reg. II-2/7.5 of SOLAS, spaces having little or no fire risk are not required to be fitted with detectors. Such spaces include void spaces with no storage of combustibles, private bathrooms, public toilets, fire-extinguishing medium storage rooms, cleaning gear lockers (in which flammable liquids are not stowed), open deck spaces and enclosed promenades having little or no fire risk and that are naturally ventilated by permanent openings.

(see FSS Code Ch. 9 Sec. 2.4.2.5)

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.

(see FSS Code Ch. 9 Sec. 2.4.3.1)

A section with individually identifiable capability shall be arranged so that it cannot be damaged at more than one point by a fire.

(see FSS Code Ch. 9 Sec. 2.4.3.2)

Manually operated call points complying with FSS Code 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.

(see SOLAS Ch. II-2 Reg. 7.7 and IACS UI SC241)

6.7.2.4 System control requirements

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 is not required to be an integral part of the detection system.

(see FSS Code Ch. 9 Sec. 2.5.1.1)

The control panel shall be located continuously manned central control room or fire control station.

(see FSS Code Ch. 9 Sec. 2.5.1.2)

On offshore substations of types B and C an indicating unit that is capable of individually identifying each detector that has been activated or manually operated call point that has operated shall be located in a location permanently attended by authorized personnel (substation control room). Indicating units shall, as a minimum, denote the section in which a detector has activated or manually operated call point has operated.

(see FSS Code Ch. 9 Sec. 2.5.1.3)

Clear information shall be displayed on or adjacent to each indicating unit about the spaces covered and the location of the sections.

(see FSS Code Ch. 9 Sec. 2.5.1.4)

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.

(see FSS Code Ch. 9 Sec. 2.5.1.5)

Means to manually acknowledge all alarm and fault signals shall be provided at the control panel. The audible alarm sounders on the control panel and indicating units may be manually silenced. The control panel shall clearly distinguish between normal, alarm, acknowledged alarm, fault and silenced conditions.

(see FSS Code Ch. 9 Sec. 2.5.1.6)

The system shall be arranged to automatically reset to the normal operating condition after alarm and fault conditions are cleared.

(see FSS Code Ch. 9 Sec. 2.5.1.7)

When the system is required to sound a local audible alarm within the cabins where the detectors are located, a means to silence the local audible alarms from the control panel shall not be permitted.

(see FSS Code Ch. 9 Sec. 2.5.1.8)

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.

(see FSS Code Ch. 9 Sec. 2.5.2)

6.7.3 Gas detection

A fixed automatic gas detection and alarm system shall be provided and arranged as to monitor continuously enclosed areas in which an accumulation of flammable or toxic gas is expected to occur.

(see MODU Code Sec. 9.11.1)

This requirement includes the following areas:

— hazardous areas, except in zone 0 according to IEC 60079-10 and areas mechanically ventilated
— ventilation outlets from hazardous areas having mechanical ventilation
— ventilation intakes of enclosed machinery spaces contiguous to hazardous areas and containing internal combustion engines and boilers

— ventilation intakes and near other openings of accommodation spaces.
(see IACS UR D11.7.1)

Guidance note:

In spaces 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.

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

The gas detection system shall indicate both by audible and visible alarm in the substation control room for unconfirmed and confirmed gas detection.

Guidance note:

For hazardous areas the alarm level should be 25% and 60% of lower explosion limit whereas for ventilation inlets it is common to have 10% and 30% of lower explosion limit (or less). Unconfirmed level is normally a single low level detection. Confirmed can either be one high level detection or two detectors at any level in a voting configuration.

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

Dedicated gas detection system monitoring potential SF6 gas release may be omitted in the GIS room, if pressure monitoring is integrated into the GIS equipment.

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.

A fire control plan complying with SOLAS regulation II-2/15.2.4 shall be permanently exhibited.

(see MODU Code 9.19)

In all offshore substation 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 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.

Plans 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 Introduction

This section provides functional requirements for the safe and reliable operation of machinery and utility systems on offshore substations. Sections of this standard containing important information related to design of machinery and utility systems:

— [5.5] *Auxiliary power system*
— [3.3] and [6.4.2.2], segregation of the equipment
— [9.4] *Automatic actions and shutdown*.

The requirements of this section refer to standard DNV-OS-D101. Where discrepancy occurs, the present standard shall prevail.

National/local requirements to machinery and utility systems and their components approval shall be observed.

7.2 Safety concept and design principles

7.2.1 General

Machinery and utility systems shall be designed so that:

— the maintaining of operational conditions as per [5.3.1] is ensured
— damage and escalation of fire is limited
— the integrity of the systems reaches the expected life time and high reliability is achieved
— the safety of personnel is ensured and risks of injury to human life is reduced to a minimum.

7.2.2 Design basis

Unless otherwise specified in the detailed requirements for the component or system, the machinery and utility systems shall be designed to operate under the following environmental conditions:

— ambient air temperature in the machinery space between 0°C and +45°C, on open deck areas between –25°C to +45 °C
— relative humidity of air in the machinery space up to 96%
— sea water temperature up to +32°C.

7.2.3 Design process

7.2.3.1 General

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.

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.

Consideration shall be given to the consequence of each system or equipment failure for the safety of the personal, environment and asset.

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 shall be dimensioned in accordance with the requirements set out in the design basis and relevant codes and standards as agreed for the specific project.

Parts of systems designed for different forces, pressure and temperatures (stresses), shall be limited to safe loading of the parts with lower design capability, or alternatively safety devices shall be fitted which prevent the over-stressing of the system or plant item designed for the lower design parameters with an acceptable reliability.

Electrical equipment may not be endangered by any potential leakages or condensate affecting its safe operation.

Machinery and utility systems as well as their components shall be subject to constructional, material tests, pressure, leakage and functional tests.

7.2.3.2 Protection and safeguarding

For the case 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, measures shall be undertaken 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 increased
— no unintentional start-up sequences are initiated
— alarms are generated with local as well as remote indication.

Machinery and utility systems shall be installed and safeguarded in such a way that the risk of accidents is reduced to an acceptable level:

— Moving or rotating parts, chain and belt drives, linkages and other components which could constitute an accident hazard for the operating personnel shall be fitted with guards to prevent contact.
— Drainage facilities shall be designed in such a way that the discharged medium is safely drained off.
— 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.
— Service gangways, operating platforms, stairways and other areas open to access during operation shall be safeguarded by guard rails. The outside edges of platforms and floor areas shall be fitted with coamings unless 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.
— Safety valves and manual valves and shut offs shall be easily accessible. Safety valves shall be installed to prevent the occurrence of excessive operating pressures.

7.2.3.3 Emergency stops

Emergency stops of at least the following pumps and fans shall be arranged from easily accessible positions outside the space being served:

— fuel oil transfer pumps
— fuel oil feed and booster pumps
— power ventilation.

On offshore substations of type B and C the means provided for stopping the power ventilation serving machinery spaces or hazardous areas shall be entirely separate from the means provided for stopping ventilation of other spaces.

(see MODU Code 9.3.21)

Emergency stop is not required for the following:

— fans not capable of supplying outside air to the space such as fans in HVAC temperature control units, fans for heating coils, ventilation fans for cabinets and switchboards etc.
— pumps for systems containing less than 500 l of flammable liquid.

7.2.3.4 Corrosion protection

Parts which are exposed to corrosion shall be 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, see [4.8.8].

7.2.3.5 Noise and vibration

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.

National/local requirements to the noise and vibration limitation shall be observed.

7.2.3.6 Hot surface and fire protection

Surfaces, having temperature exceeding 60°C, with which the personnel are likely to come into contact during operation shall be suitably protected or insulated.

Surfaces of machinery with temperatures above 220°C, e.g. exhaust gas lines, silencers, turbochargers, shall be effectively insulated with non-combustible material or equivalently protected to prevent the ignition of combustible materials which can come into contact with these surfaces. Where the insulation used for this purpose is oil absorbent or may permit the penetration of oil, the insulation shall be encased in steel sheathing or equivalent material.

7.3 Piping design

7.3.1 General

Piping systems shall consist of permanently installed pipes and fittings supported in such a way that their weight is not taken by connected machinery or that heavy valves and fittings do not cause large additional stresses in adjacent pipes.

Axial forces due to internal pressure, change in direction or cross-sectional area shall be taken into consideration when mounting the piping system.

The support of the piping system shall be such that detrimental vibrations shall not arise in the system.

Installation of pipes for water or oil behind or above electrical equipment shall be avoided as far as possible. If this is impracticable, all detachable pipe joints and valves shall be at a safe distance from the electrical equipment or well shielded from it.

Routing of water pipes and air and sounding pipes through freezing chambers shall be avoided.

7.3.2 Classes of piping systems

The designated piping class is used to indicate the materials, manufacturing, testing and inspection requirements which shall be applied to ensure the operational integrity of piping. Piping classification is applied on the basis of intended medium, pressure and temperature conditions. Piping shall be subdivided into three classes as given in Table 7-1.

Table 7-1 Classes of piping systems

Piping system for	*Class I* [1)]		*Class II* [1)]		*Class III* [1)]	
	p [bar]	*t [°C]*	*p [bar]*	*t [°C]*	*p [bar]*	*t [°C]*
Steam	> 16	or > 300	≤ 16	and ≤ 300	≤ 7	and ≤ 170

Piping system for	*Class I 1)*		*Class II 1)*		*Class III 1)*	
	p [bar]	*t [°C]*	*p [bar]*	*t [°C]*	*p [bar]*	*t [°C]*
Thermal oil	> 16	or > 300	≤ 16	and ≤ 300	≤ 7	and ≤ 150
Flammable fluids 2)	> 16	or > 150	≤ 16	and ≤1 50	≤ 7	and ≤ 60
Other media 3)	> 40	or > 300	≤ 40	and ≤ 300	≤ 16	and ≤ 200
p = design pressure, i.e. the maximum working pressure (shall not be less than the highest set pressure of the safety valve or relief device). t = design temperature, i.e. the maximum temperature of the medium inside the pipe. 1) For class II and III piping both specified conditions shall be met, for class I piping one condition only is sufficient. 2) Flammable fluids include: lubricating oil, flammable hydraulic oil, fuel oil. 3) Open ended pipes (drains, overflows, vents, etc.) independently of the pressure and temperature, are pertaining to class III.						

7.3.3 Materials

Materials used in piping systems shall be suitable for the medium and service for which the system is intended. Requirements of DNV-OS-D101 Ch.2 Sec.2 [2] *Materials* shall be observed.

7.3.4 Design conditions

All components in a piping system shall be satisfactorily matched with regard to function, capacity and strength.

Requirements to piping design and components in DNV-OS-D101 Ch.2 Sec.2 *General piping design* shall be observed.

7.3.5 Connections

Metallic pipes shall be connected by welding or brazing DNV-OS-D101 Ch.2 Sec.6 *Pipe fabrication, workmanship, and testing* or by detachable connections in accordance with DNV-OS-D101 Ch.2 Sec.2 [7] *Detachable pipe connections*.

Plastic pipes shall be connected by welding, gluing, cementing, lamination or similar methods in accordance with DNV-OS-D101 Ch.2 Sec.6 [5] *Joining of plastic pipes*.

7.3.6 Fabrication and testing

Fabrication of the piping systems shall be performed in accordance with DNV-OS-D101 Ch.2 Sec.6 *Pipe fabrication, workmanship, and testing*.

Both sides of all welded piping joints shall, wherever possible, be visually examined. Non-destructive testing (NDT) is required depending on the class of pipes and type of joints. These shall be applied in accordance with DNV-OS-D101 Ch.2 Sec.6 [2.5] *Non-destructive testing*.

Pressure testing of metallic pipes shall be performed in accordance with DNV-OS-D101 Ch.2 Sec.6 [6] *Hydrostatic tests of piping*.

Pressure testing of plastic pipes shall be performed in accordance with DNV-OS-D101 Ch.2 Sec.6 [5.6] *Pressure testing of plastic pipes*.

All piping systems shall be properly flushed, checked for leakage and functionally tested under working conditions.

7.4 Generator sets

7.4.1 General

The requirements contained in this section are valid for combustion engines (prime movers) driving auxiliary, emergency generators or GDG.

The rated power shall meet the requirements of [5.5.2.3], [5.5.3.4] and [5.5.4].

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.

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7.4.2 Starting equipment

7.4.2.1 General

Engine starting equipment shall enable start-up of the engine using only the means available on the offshore substation.

Means shall be provided to ensure that availability of the auxiliary power system can be recovered from the 'black substation' condition as per [5.3.1.5].

7.4.2.2 Electrical starting equipment

Where engines are provided with electric starting equipment, requirements of [5.5.2.1] and [5.5.3.1] shall be fulfilled.

7.4.2.3 Compressed air starting equipment

Starting air systems shall 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 shall be such that the starting air receivers 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 shall 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 shall be sufficient to provide not less than three engine starts.

If starting air systems are used for supplying pneumatically operated controls, instrument air or tyfon alarm sound emitters, due attention shall be paid to the air consumption of this equipment during calculation of the capacity of the main starting air receivers. Consumers with high air consumption shall be provided with a separate air supply.

If starting air systems of different engines are fed by one receiver, it shall be ensured that the receiver air pressure cannot fall below the highest of the different systems minimum starting air pressure.

The starting line to each engine shall be fitted with a non-return valve and a drain.

7.4.3 Control equipment

For auxiliary engines and emergency application engines the controls according to Table 7-2 shall be provided.

Table 7-2 Alarms and indicators

Describtion	*Auxiliary engines*	*Emergency engines*
Engine overspeed	A, S	A, S
Lubricating oil pressure at engine inlet	I, L, S	I, L
Lubricating oil temperature at engine inlet	I, H	I, H
Fuel oil pressure at engine inlet	I	
Fuel oil leakage from high pressure pipes	A	A
Cylinder cooling water pressure or flow at engine inlet	I, L	I, L
Cylinder cooling water temperature at engine outlet	I, H	I, H
Starting air pressure (if applicable)	I, L	I, L
Oil mist concentration in crankcase or alternative monitoring system	I, H	I, H
I: indicator A: alarm H: alarm for upper limit L: alarm for lower limit S: shutdown with alarm for shutdown.		

The presentation of alarms and indicators shall be clear, distinctive, unambiguous and consistent.

(see IMO Code on alerts and indicators, 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.

7.4.4 Exhaust gas ducts

7.4.4.1 Duct layout

Exhaust ducts from multiple engine installations shall not be connected, but shall have separate outlets, unless arranged with bypass or other precautions are taken to prevent the loss of main function in the event of failure and to prevent the return of exhaust gases to a stopped engine.

Account shall be taken of thermal expansion in arrangement and support of the ducts.

Exhaust ducts shall not be led in the vicinity of fuel oil tanks and storage tanks.

Exhaust outlets for internal combustion engines shall discharge outside hazardous areas. Hazardous area classification shall be documented by drawings including location, of air inlets and exhausts, see [7.11.2.4].

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

(see IACS UR D8.3.1)

Possible adverse effects of the exhaust gas outlets on helicopter operations and to personnel on the substation shall be considered and mitigated.

7.4.4.2 Silencers

Engine exhaust lines should be fitted with effective silencers or other suitable means should be provided. Silencers should be provided with an inspection opening.

Exhaust lines and silencers should be provided with suitable drains of adequate size.

7.4.4.3 Precautions against sparks from exhaust gases

Exhaust gases shall be discharged to the atmosphere at a sufficient height and distance.

7.5 Fuel system

7.5.1 Fuels

Spaces, where the fuel with a flashpoint below 60°C (closed cup) is stored, shall be regarded as hazardous areas, zone 2. See DNV-OS-D101 Ch.2 Sec.3 [6] *Storage and transfer systems for liquids with flashpoint below 60°C (e.g. helicopter fuel)*.

A space, where fuel with a flash point between 43°C and 60°C is stored, can only be categorized as non-hazardous area, if it is ensured that the difference between the flash point of the fuel and the ambient temperature in the space will never be less than 10°C.

7.5.2 Fuel tanks

7.5.2.1 Fuel tanks location and distribution

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 not be entirely lost (at least one storage tank and one daily service/settling tank are presumed).

Capacity of the fuel tanks shall meet requirements of [5.5.2.3], [5.5.3.4] and [5.5.4].

Fuel tanks shall be separated from tanks containing lubricating, hydraulic oil, drinking water. This does not apply to waste oil collected for disposal.

Location of fuel tanks shall be compatible with the offshore substation steel structure, fastening, earthing, as well as under due consideration of potential fire and explosion risks.

7.5.2.2 Fuel tanks arrangement

Air, overflow and sounding pipes shall be in accordance with DNV-OS-D101 Ch.2 Sec.3 [5] *Air, overflow and sounding pipes*.

Where fuel oil tanks are situated near to hot surfaces, the tanks shall be duly insulated. In order to keep the fuel oil temperature well below the flash point, care shall be taken that the free air circulation is not impeded.

The plate thickness in free standing fuel oil tanks shall not be less than 5 mm. For very small tanks the plate thickness may be reduced to 3 mm. Sides and bottom of the tanks shall be well stiffened. Large tanks shall be fitted with wash bulkheads.

If the fuel tank may be subject to ambient temperatures that may affect the properties of the fuel, arrangements shall be considered to maintain adequate fuel condition.

Fuel tanks or fuel pipe flanges located in vicinity of prime movers / combustion engines or other equipment with a high surface temperature shall be provided with adequate spill trays or shielding. Spray stops shall be applied on pipe connections. Such tanks and pipes shall also be protected against heat radiation.

Only appliances, mountings and fittings forming part of the fuel tank equipment shall be fitted to tank surfaces.

All valves and cocks on oil tanks shall be mounted and protected in such a way that they cannot be damaged as the result of an accident.

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.

If fuel is stored in separate containers, fixed piping for filling, suction, overflow, air and sounding pipes, tank gauges, as well as drains with self-closing appliances shall be foreseen.

7.5.2.3 Remotely controlled shut-off arrangement for fuel tanks

Fuel pipes, which, if damaged, would allow oil to escape from a storage, settling or daily service tank having a capacity of 0.5 m^3 and above and situated above the floor, shall be fitted with a cock or valve directly on the tank capable of being closed from a safe position outside the space concerned.

Fuel oil valves on tanks shall be 'quick-acting shut-off valves', arranged for remote operation. The operation shall be carried out from a central position outside the space itself and at a safe distance from openings to engine rooms. This is not applicable for valves closed during normal service, valves on tanks situated below the floor or valves on tanks less than 0.5 m^3.

The controls for remote shut-off for emergency generator and emergency fire pump shall be located separately from the controls of the other valves in order to avoid erroneous operation.

Every oil fuel pipe, which is led into the engine room from a tank situated above the floor outside this space, shall also be fitted with a quick-acting shut-off valve in the engine room close to the bulkhead. This is not applicable where the valve on the tank is arranged for remote shut-off.

The arrangement shall be such that paint, corrosion etc. will not impair the efficiency of the remote operation of the valves.

Hydraulic or pneumatic systems shall not be used as means for keeping quick-acting shut-off valves in open position.

The means used to operate the quick acting shut-off valves shall be independent of any power sources located in the same space as the valves.

Materials readily rendered ineffective by heat shall not be used in the construction of the valves or the closure mechanism.

7.5.3 Fuel system lines

7.5.3.1 Piping layout

Piping conveying flammable liquids under pressure in the engine room shall be laid in well-lit places, in order that the piping can be kept under observation.

All detachable pipe connections and valves in oil fuel pressure piping shall be at a safe distance from exhaust pipes or other heated surfaces and electrical appliances.

The number of detachable pipe connections shall be limited to those which are necessary for mounting and dismantling.

Fuel oil pipes shall not be routed through fresh water, lubricating oil or thermal oil.

The arrangement of piping and valves shall be such that oil cannot enter tanks not intended for this purpose.

The design pressure for piping in fuel systems with a working pressure above 7 bar and a working temperature above 60°C shall be minimum 14 bar. Other fuel systems shall have a minimum design pressure of 3 bar or maximum working pressure, whichever is greater.

(see IACS UR P1.2.7)

7.5.3.2 Arrangement of valves and fittings

The positioning of valves shall be such that any possible leakage will not lead to oil spray on hot surfaces of the machinery or on electric motors and appliances.

In multi-engine installations, which are supplied from the same fuel source, means of isolating the fuel supply and spill piping to individual engines shall be provided. The means of isolation shall not affect the operation of the other engines, and shall be operable from a position not rendered inaccessible by a fire on any of the engines.

All valves in the fuel oil system shall be controllable from positions above the floor plates.

Filters shall be fitted in the supply lines to the auxiliary and emergency diesel generators. They shall be arranged in such a way that they can be cleaned without simultaneous interruption of auxiliary and emergency generators fuel supply.

7.6 Drain system

7.6.1 General

Drain system shall be provided to direct rainwater, firewater, spills and leakages from deck areas, utility spaces, drip trays, bounded areas for safe handling.

Drain system serves to protect against spread of leakage, pool fire and escalation of fires and shall be regarded as a safety system. The pipes for discharge fluids shall have an adequate capacity to ensure that discharged medium is safely drained off. Means shall be provided ensure that the release of oily water to sea is prevented. National requirements shall be observed.

All areas with potential risk of oily leakage shall be fitted with bunding, coamings. Drip trays shall be installed under equipment where leakages may occur. Oil filled electrical equipment (including transformers, shunt reactors) shall be fitted with drip trays or bunding. The drip trays design shall prevent spread of discharged medium, see [3.5.6].

Measures to prevent burning oil from reaching the drain tank should be provided (grates, flame traps, fire retardant gratings).

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 shall be observed for the installation site.

Guidance note:

Further guidance references:

— DNV-OS-E201 *Oil and gas processing systems*

— NORSOK P-002 *Process system* .

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7.6.2 Arrangement of drain system

7.6.2.1 Areas with the risk of oil leakage

Drain system for areas that can potentially be polluted by oily water shall terminate at the oily drain holding tank(s) or caisson. Oily drain holding tanks/caissons shall be dimensioned for the largest amount of firewater and oil coming from an oil-filled equipment upon the greatest incident. Additional 15% spare capacity is recommended.

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/local requirements to the system and its components approval shall be observed.

Guidance note:

Further guidance references:

— International Convention for the Prevention of Pollution from Ships (MARPOL 73/78), Annex I Reg. 39 *Special requirements for fixed or floating platforms*

— IMO MEPC.107(49) *Revised guidelines and specifications for pollution prevention equipment for machinery space bilges of ships.*

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The collection system (including collection piping and drain tank with vent) for areas with oily leakage shall be separate from the collection system for non-polluted areas.

7.6.2.2 Non-polluted areas
Drains from non-polluted areas may be routed directly to sea.

Weather decks (i.e. open decks or parts of decks which may be exposed to sea and weather loads) shall be fitted with drains sufficient in number and size to provide effective drainage of the peak rainfall.

7.6.2.3 Helicopter decks
The deck shall be constructed so that water/fluids will not accumulate on the helicopter deck.

Drainage facilities in way of helicopter decks should be:

— constructed of steel or other arrangements providing equivalent fire safety
— lead directly overboard independent of any other system
— designed so that drainage does not fall onto any part of the unit.

(see MODU Code Sec. 9.17.5)

7.7 Sewage system

7.7.1 General

Sewage system shall serve to handle:

— drainage and other wastes from all toilets and urinals
— drainage from medical premises (dispensary, sick bay) via wash basins, wash tubs and scuppers located in such rooms
— other waste waters when mixed with any of the drainage systems defined above.

National/local requirements to material selection, sewage water treatment and performance testing shall be observed.

Guidance note:

Further guidance references:

— International Convention for the Prevention of Pollution from Ships (MARPOL 73/78), Annex IV *Prevention of pollution by sewage from ships*
— IMO MEPC.227(64) *Guidelines on implementation of effluent standards and performance tests for sewage treatment plants.*

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7.7.2 Sewage system arrangement

Offshore substations shall be provided with a sewage treatment plant or a sufficiently dimensioned holding tank for transportation ashore.

A piping for the discharge of sewage to a bunker station shall be arranged. The piping shall be provided with a standard discharge connection and a screw-down non-return valve.

Sewage discharge pipes located in operational areas shall be specially protected. Individual sanitary discharge pipes shall be connected to common discharge pipes.

Vent pipes shall be led to an open deck, consideration shall be given to prevent smell disturbance.

Sewage tanks shall be fitted with a filling connection, a flushing connection and a level alarm.

7.8 Potable water system

7.8.1 General

National/local requirements to material selection, water treatment and testing shall be observed.

Where the distillate produced by the substations own evaporator is used for the drinking water supply, the treatment of the distillate shall comply with national/local requirements.

Guidance note:

Further guidance references:

- VDI 6023 *Hygiene in drinking water installations*
- DIN 50930-6 *Corrosion of metals - Corrosion of metallic materials under corrosion load by water inside of pipes, tanks and apparatus - Part 6: Evaluation process and requirements regarding the hygienic suitability in contact with drinking water*
- NORSOK P-002 *Process systems*.

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7.8.2 Potable water system layout

Potable water tanks shall have no common walls with tanks containing substances other than feed water or distillate.

Pipes not carrying potable water shall not be led through drinking water tanks.

In no case sanitary arrangement or corresponding piping shall be fitted directly above the potable water tanks.

Potable water tanks located at the installations shell or outside shall be provided with means for tank heating to prevent freezing.

Potable water piping shall not be connected to pipes carrying other media or laid through tanks which do not contain drinking water.

Potable 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.

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.

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.

7.9 Cooling system

7.9.1 General

Shut-off valves shall be provided at the inlet and outlet of all heat exchangers.

Every heat exchanger and cooler shall be provided with a vent and a drain.

7.9.2 Cooling pumps

Main and stand-by cooling water pumps shall be provided for each fresh water cooling system.

Stand-by cooling water pumps shall 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 shall be secured against unintended operation.

7.9.3 Cooling of emergency generator

Internal combustion engines driving emergency generators shall be fitted with independent cooling systems.

Such cooling systems shall be protected from freezing, where necessary.

7.10 Bunker stations

7.10.1 General

Electrical equipment within bunkering area shall be selected and equipped in accordance with [6.6.4.1], where relevant, see [7.5.1].

Access to the bunker station during bunkering operations shall be restricted to trained and authorized personnel. Reliable communication/coordination shall be foreseen between bunker station and tank location and/or control room.

7.10.2 Arrangement of bunker station

Bunkering lines, if present, for fuel, oily sludge, water, sanitary sludge and other fluids shall lead to a bunker station.

The bunker station shall be located on the open deck.

The bunkering of fuels shall be performed by means of permanently installed lines either from the open deck or from bunker stations located below deck which shall be isolated from other spaces. Bunkering lines for fuel shall not to be led through accommodation spaces, service spaces or control stations.

The bunker station and fuel transfer pipes shall be provided with shut-off valves located directly at the transfer point and directly before the distribution manifold to the fuel tanks. The shut-off valves shall be designed in a way that they can be closed manually and by remote control. The position of the shut-off valve shall be indicated locally and in the substation control room, see [3.6.2].

Bunker stations shall 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 shall be fitted below the bunkering connections and where leakage may occur.

Discharge pipelines for oily and sewage water shall be fitted with standard discharge connections.

7.11 Heating, ventilation and air conditioning system

7.11.1 General

The ventilation system shall be designed to maintain acceptable working and living environment for the personnel and non-detrimental conditions for equipment and machinery. National/local requirements shall be observed.

Guidance note:

Further guidance references:

- DNV-OS-A301 *Human comfort*
- DNV-RU-SHIP Pt.4 Ch.6 Sec.6 *Refrigeration systems*
- IEC 60079-10-1 *Explosive atmospheres. Classification of areas. Explosive gas atmospheres*
- 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 9943 *Shipbuilding – Ventilation and air treatment of galleys and pantries with cooking appliances*
- ISO 15138 *Petroleum and natural gas industries - Offshore production installations. Heating, ventilation and air-conditioning*
- EN 12097 *Ventilation for Buildings - Ductwork - Requirements for ductwork components to facilitate maintenance of ductwork systems*
- EN 12599 *Ventilation for buildings - Test procedures and measurement methods to hand over air conditioning and ventilation systems*
- NORSOK C-001 *Living quarter areas*
- NORSOK H-003 *Heating, ventilation and air conditioning (HVAC) and Sanitary Systems*
- NORSOK S-002 *Working environment*.

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The air inlets and air outlets on open deck shall be positioned such as to avoid the ingress of exhaust air through the inlet openings into machinery space (short circuiting of air).

Requirements of [6.4.7] to ventilation ducts, duct penetrations and dampers shall be observed.

Spaces where flammable or toxic gases or vapours may accumulate, or where a low oxygen atmosphere may occur, shall be provided with adequate ventilation.

Guidance note:

By adequate ventilation is meant natural or mechanical ventilation sufficient to prevent an accumulation of gases above a concentration of 25% of their lower explosion limit (LEL).

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All spaces where oil-burning installations, settling tanks or daily service fuel oil tanks are located shall be easily accessible and well ventilated.

Where a fixed gas fire-extinguishing system is used, openings which may admit air to, or allow gas to escape from, a protected space shall be capable of being closed from outside the protected space.

(see SOLAS Ch. II-2 Reg. 10.4.2)

7.11.2 Requirements for specific spaces

7.11.2.1 Accommodation spaces

The HVAC system with air intakes shall be so located and constructed that fire hazardous, noxious gases, exhaust, dust, etc. are prevented from entering into accommodation spaces.

7.11.2.2 Control stations

Practicable measures shall be taken for continuously manned control stations on substations of type B and C in order to ensure that ventilation, visibility and freedom from smoke are maintained. 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. Local closing arrangement shall be arranged for all air inlets to control stations. At the discretion of the administration, such requirements do not need to apply to control stations situated on, and opening on to, an open deck or where local closing arrangements would be equally effective.

(see SOLAS Ch. II-2 Reg. 8.2 and DNV-SI-0364 Sec.3 [8]).

7.11.2.3 Battery compartements

Ventilation arrangement for battery rooms shall be in accordance with [5.5.6.4].

7.11.2.4 Hazardous areas

Hazardous areas shall be arranged according to [6.6.4].

Ventilation ducts serving or passing through the hazardous areas shall be in accordance with [6.4.7].

Ventilation systems for hazardous areas should be separate from ventilation systems for non-hazardous areas, see [7.11.2.4].

(see IACS UR D8.3.1)

Hazardous enclosed spaces shall be ventilated with under-pressure in relation to adjacent less hazardous locations. Fans shall be interlocked to ensure outlet fan is engaged prior to inlet fan, and ventilation failure shall initiate alarm at a manned location.

Guidance note:

See EN 14986 *Design of fans working in potentially explosive atmospheres*.

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(see IACS UR D8.3.2)

Air inlet ducts designed for constant relative under-pressure shall be rigidly constructed to avoid air leaks.

(see IACS UR D8.3.2)

The ventilation system shall be suitable to maintain at least 50 Pa differential pressure between hazardous area and non-hazardous area when all penetrations are closed.

Guidance note:

The design of doors should take account of differential pressures between spaces, such that personnel can easily open doors without hazard.

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Inlet and outlet ventilation openings shall be arranged to provide efficient ventilation in relation to the location of equipment and sources in the area.

(see IACS UR D8.3.2)

Adequate ventilation of hazardous areas is required to ensure that releases are rapidly dispersed. The adequacy of ventilation conditions shall be justified and documented.

(see MODU Code 6.4.1)

Guidance note:

Adequacy of ventilation of hazardous areas should prevent stagnant areas and achieve a minimum of 12 volumetric air changes per hour.

Open areas without significant obstructions are considered to have adequate ventilation if air velocities are rarely below 0.5 m/s and frequently above 2 m/s.

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The outlet air from hazardous spaces shall be routed through separate ducts to outdoor area which, in the absence of the considered exhaust, is of the same or lesser hazard than the ventilated space. The internal spaces of such ducts belong to the same zone as the inlet space.

(see IACS UR D8.3.2)

Areas on open deck within 1 m of inlet and exhaust ventilation openings or within 3 m of exhaust outlets with mechanical ventilation are classified as zone 2.

7.11.2.5 Machinery space ventilation

The capacity and arrangement of machinery spaces ventilation shall cover demands for operating the machinery at full power in all weather conditions.

The capacity of the ventilation plant shall be such as to provide acceptable working condition in the engine rooms, to supply the necessary combustion air to the diesel engines and to prevent heat sensitive apparatus from overheating.

In order to meet these requirements, the air shall be distributed to all parts of the engine room, so that pockets of stagnant hot air are avoided. Special considerations should be given to areas with large heat emission and to all normal working areas, where reasonably fresh and clean outdoor air should be provided through adjustable inlet devices.

The required air flow for combustion and evacuation of heat emission shall be calculated according to ISO 8861 or another recognised maritime standard.

The positions of air inlets and air outlets shall be such as to prevent short-circuiting of air.

Supply and extract volumes shall be balanced to create a slight positive overpressure in the machinery space/engine room.

Guidance note:

The positive pressure should normally not exceed 50 Pa.

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7.11.2.6 Emergency generator rooms

The ventilation system serving the emergency generator room shall ensure a sufficient supply of combustion and cooling air for the equipment installed.

Ventilation louvers for emergency generator rooms and closing appliances where fitted to ventilators serving emergency generator rooms shall comply with the following:

— Ventilation louvers and closing appliances shall be operable under a fire condition.
— Power-operated ventilation louvers and closing appliances shall be of a fail-to-open type. Closed ventilation louvers and closing appliances are acceptable during normal operational condition, see [5.3.1.1].
— Power-operated ventilation louvers and closing appliances shall open automatically whenever the emergency generator is starting/in operation.
— On substations of type B and C it shall be possible to close ventilation openings by a manual operation from a clearly marked safe position outside the space where the closing operation can be easily confirmed. The louver status (open/closed) shall be indicated at this position. Such closing shall not be possible from any other remote position.

7.11.2.7 Galleys

A separate supply air system shall be provided for the galley. This supply air system shall take in outdoor air only, see ISO 9943. Exhaust duct from galley ranges shall be provided in accordance with [6.4.7].

7.12 Marking

In order to avoid operating and switching errors, all parts of the machinery and utility systems whose function is not immediately apparent, shall be adequately marked and labeled.

Piping systems shall be adequately identified according to their purpose. Valves shall be permanently and clearly marked.

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 *In-service inspection and maintenance*.

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 concept 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 offshore substation
— 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 substation 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 substation 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].

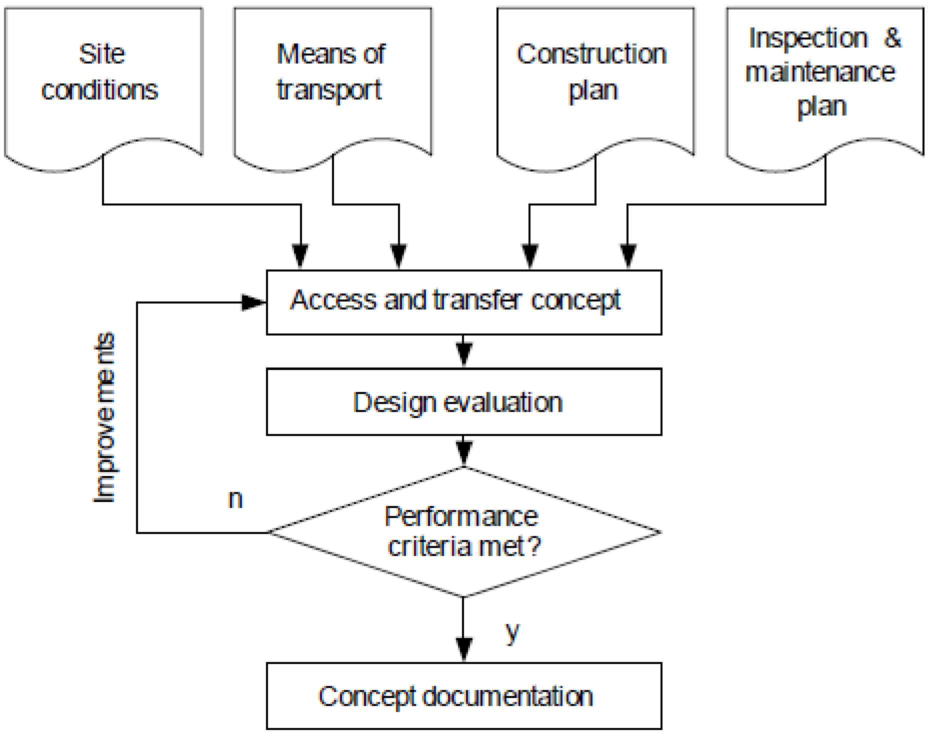

Figure 8-1 Performance-based access and transfer concept design

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:

— offshore substation 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 DNV-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

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.

Section [8.4] outlines minimum requirements applicable to helicopter transfer.

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 outlined in the below subsections 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 [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) The fendering system shall be designed for the loads given in [4.4.4].
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.

8.3.2 Gangway docking systems

8.3.2.1 General

Gangway docking type operations consist of a vessel mounted gangway which is connected directly or indirectly to the installation. Where gangway docking operations shall be used, the criteria in [8.3.2.2] shall be applied.

8.3.2.2 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, see [4.4.4].
b) 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.
c) The vessel shall have a dynamic positioning system where deemed necessary following a formal safety assessment.
d) Maximum safe working load and maximum number of people allowed on the gangway at any one time shall be clearly marked.
e) 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 DNV-ST-0358 *Offshore gangways*.

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8.3.3 Personnel carriers

8.3.3.1 General

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 shall be used, the criteria belowshall be applied.

8.3.3.2 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 manriding'. A certificate or report shall be provided to demonstrate that the man-riding equipment is functional.
c) 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
- UK: HSE Technical Guidance on the Safe Use of Lifting Equipment Offshore (HSG221).

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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

Helicopter decks and heli-hoist decks used for transfer of personnel and cargo by helicopter shall fulfill national requirements. If national requirements do not cover in sufficient detail, CAP 437 should be applied.

Guidance note 1:

Local authorities 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)).

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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 can be a large source of disturbance and present a significant safety risk to flight operations. Turbulence generators and, where applicable, diesel generator exhausts should be taken into consideration and helicopter landing areas should be located upwind of major obstructions. Airflow studies may include wind tunnel testing and CFD analyses.

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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.

8.4.2 Helicopter decks

8.4.2.1 Fuelling facility

Where a fueling facility is planned, the following shall be considered:

a) A designated area shall be provided for the storage of fuel tanks which shall 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.

   (see MODU Code Sec. 9.17.6.1)

   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 shall be provided with arrangements whereby fuel spillage may be collected and drained to a safe location.

   (see MODU Code Sec. 9.17.6.2)

c) Tanks and associated equipment should be protected against physical damage and from a fire in an adjacent space or area.

   (see MODU Code Sec. 9.17.6.3)

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.

   (see MODU Code Sec. 9.17.6.4)

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.

   (see MODU Code Sec. 9.17.6.5)

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.

   (see MODU Code Sec. 9.17.6.6)

g) Electrical fuel pumping units and associated control equipment should be of a type suitable for the location and potential hazard.

   (see MODU Code Sec. 9.17.6.7)

h) Fuel pumping units should incorporate a device which will prevent over-pressurisation of the delivery or filling hose.

(see MODU Code Sec. 9.17.6.8)

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.
(see MODU Code Sec. 14.2.2)

j) All equipment used in refuelling operations shall be properly electrically bonded and earthed.

(see MODU Code Sec. 9.17.6.9)

8.4.2.2 Fire protection

a) The construction of the helidecks shall be of steel or other equivalent materials. If the helideck forms the deckhead of a topside structure, it shall be insulated to A-60 class standard. If aluminium or other low melting point metal construction that is not made equivalent to steel is used (see DNV-RU-SHIP Pt.6 Ch.5 Sec.5 [1.8.11]) and the helideck is located above a deckhouse or similar structure, the following provisions shall be satisfied:

    1) if the helideck is cantilevered over the side of the offshore substation, after each fire that may have an effect on the structural integrity of the helideck or its supporting structures, the helideck shall undergo a structural evaluation to determine its suitability for further use;
    2) if the helideck is located above the topside or similar structure, the following conditions shall be satisfied:

        — the uppermost topside deck and bulkheads under the helideck shall have no openings
        — windows under the helideck shall be provided with steel shutters
        — after each fire on the helideck or supporting structure the helideck shall undergo a structural analysis to determine its suitability for further use.

    (see MODU Code Sec. 9.17.2)

b) A helideck shall be provided with both a main and an emergency means of escape and access for firefighting and rescue personnel. These shall be located as far apart from each other as is practicable and preferably on opposite sides of the helideck.

(see MODU Code Sec. 9.17.3)

c) In close proximity to the helideck, the following fire-fighting appliances shall 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 minimum application rate of 6 l/m^2 within a circle having a diameter equal to the D-value
— a minimum of 5 min discharge capability shall be provided
— foam delivery at the minimum application rate shall 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 organization

Guidance note:

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'.

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5) at least two nozzles of an approved dual-purpose type (jet/spray) and hoses sufficient to reach any part of the helideck.

(see MODU Code Sec. 9.17.4)

Guidance note:

A deck integrated firefighting system (DIFFS) for spray distribution of foam is an alternative to fixed monitor systems and particularly useful for offshore substations of type A.

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d) Drainage facilities in way of helidecks shall be:

1) constructed of steel or other arrangements providing equivalent fire safety
2) lead directly overboard independent of any other system
3) designed so that drainage does not fall onto any part of the unit.

(see MODU Code Sec. 9.17.5)

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 the relevant parts of ISO 14122-series where applicable.
c) Barriers shall be fitted at openings direct to sea.

8.5.2.2 Stairs

Stairs should be preferred over ladders. Where stairs are used, they shall be designed according to ISO 14122-3 where applicable 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 where applicable.
— 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 where applicable 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.

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— 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 EN 353-2: 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.

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— 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 'gate 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*.

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c) Handrails for access to helicopter decks may be required to 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.

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Helicopter decks and heli-hoist decks shall be marked in accordance with national requirements. If national requirements do not cover in sufficient detail, CAP 437 should be applied.

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. 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.

Requirements for emergency response strategy, rescue and evacuation means and safety equipment shall be applied in accordance with the relevant national or local requirements.

Guidance note:

Local requirements:

— Denmark: The Danish Energy Agency's Offshore Safety Act 2006
— UK: *Offshore Installations (Prevention of Fire and Explosion, and Emergency Response) Regulations (PFEER), Construction (Design and Management) Regulations (CDM)*
— USA: The US Minerals Management Service (MMS) Code of Federal Regulations (CFR) on Mineral Resources including API RP 75 for the Development of Safety and Environmental Management Program for Outer Continental Shelf Operations and Facilities.

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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 offshore substation against hazardous events (see App.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.

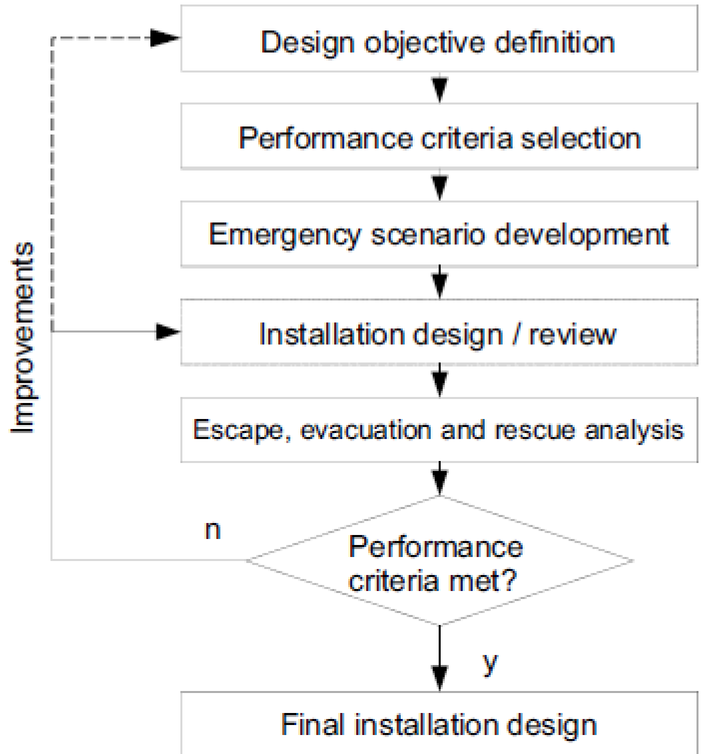

Figure 9-1 Escape, evacuation and rescue assessment (principle)

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
— substation location and availability of emergency services
— layout of the substation and arrangement of equipment
— location of sources of hazardous events
— manning concept, distribution of persons and human factors

— regular means of access to and egress from the substation.

9.2.4 Design process

At the beginning of the design process applicable local and national regulations shall be clarified.

Activities that could lead to accidental events shall be described, building on the safety assessment process described in [2.3], including:

— normal work activities
— installation or repair
— transportation, transfer and storage of explosive, flammable or toxic materials
— other hazardous activities.

All foreseeable accidental events relevant for the offshore substation, the whole wind power plant and conditions that might follow shall be considered for development of representative emergency scenarios, including:

— fire or explosion on the offshore substation, 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, see [5.5]
— alarms and communications, see [9.3]
— automatic actions and shutdown, see [9.4]
— means of escape (including bridge links to other offshore installations if relevant), see [9.5]
— mustering facilities and temporary safe areas, see [9.6]
— means of evacuation, see [9.7]
— means of rescue and recovery including emergency response and rescue vessel (ERRV), SAR helicopters and marine craft in the vicinity of the substation, see [9.8].

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 detection
— gas detection

— fire extinguishing medium release (extinguishing gas flooding systems)
— power-operated watertight door closing (e.g. on floating installations)
— major equipment fault detection or shutdown.

An alarm system comprises of the following as relevant:

— manual alarm input devices
— input lines from detectors 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:

— LSA Code Sec. 7.2 *General alarm and public address system*
— SOLAS Ch. 3 Sec. I Regulation 6 *Communications*
— DNV-SI-0364 *SOLAS interpretations*, DNV-SI-0364 Sec.4 [3.3.2] and DNV-SI-0364 Sec.4 [3.3.3]
— IMO MSC/Circ.808 *Recommendation on performance standards for public address systems on passenger ships, including cabling*.

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9.3.2 Requirements

An alarm concept shall be established ensuring that the alarms are simple and unambiguous. The concept shall define which alarms are broadcast to the entire substation 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 substation control room. see [3.6.2].

A general emergency alarm system shall be provided to alert the personnel or to call them to the assembly points. The general emergency alarm system shall be arranged with closed loop(s) or with fuses/breakers at each deck, such that failure in any one loop does not affect other loops or the central unit.

The alarms shall be clearly audible at all locations on the substation (including lowest access platform and ladder), and shall be easily distinguishable. If noise in an area prevents the audible alarm being heard, a visible means of alarm shall be provided.

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 control stations.

The minimum sound pressure levels for the emergency alarm tone in interior and exterior spaces shall be 80 dB (A) and at least 10 dB (A) above ambient noise levels existing during normal equipment operation in moderate weather. The sound pressure levels at the sleeping position in cabins and in cabin bathrooms shall be at least 75dB (A) and at least 10 dB (A) above ambient noise levels.

(see LSA Code, Sec. 7.2.1)

In addition to the general emergency alarm system, a public address system is required to make announcements. Public address system shall be clearly audible in all spaces which are normally accessible to personnel during routine operations.

If the public address system is used to transmit the general emergency alarm, the following requirements shall be fulfilled:

— the requirements for the general emergency alarm shall be fulfilled

— the system shall be so arranged to minimize the effect of a single failure, by the use of at least two amplifiers, segregated supply with fuse protection, segregated cable routes and segregated arrangement
— at least two loudspeaker circuits, supplied from separate amplifiers, shall be installed in each fire zone, respectively in its subdivisions
— the loudspeaker circuits shall be so arranged that an announcement at a reduced acoustic irradiation is maintained in the event of a failure of an amplifier or loudspeaker circuit
— where loudspeakers with built-in volume controls are used, the volume controls shall be disabled by the release of the alarm signal
— it shall be possible to transmit the undistorted and clearly audible alarm signal at all times, other simultaneous transmissions shall be automatically interrupted
— it shall be possible to operate all loudspeakers at the same time.

Guidance note:

It is acceptable to integrate the public address and general alarms functions within the same system, or with the fire alarm system subject to the following:

— Compliance with Paragraph 5.8 of IMO Res. 1021(26) *Code on Alerts and Indicators*.
— The integrated system is approved according to provisions defined by national or local requirements.
— The integrated system is arranged to minimise single failure, which implies provision of:

1) System central with redundant design i.e. duplication of signal generator, amplifiers, central control unit and any other essential part of the system. For the offshore substations of type B and C, the required provision of two separate racks/centrals is considered to satisfy the above duplication requirement. For the offshore substations of type A a single rack arrangement is acceptable.
2) At least two separated and segregated cable routes, one from each amplifier. The segregation of the cable loops shall be such that in case of failure of one loop in one area, the general/fire alarm and public address announcements shall continue to be audible in that area.

— At least two separated and segregated cable routes, one from each amplifier. The segregation of the cable loops is such that in case of failure of one loop in one area, the general/fire alarm and public address announcements continue to be audible in that area.

See DNV-SI-0364 Sec.4 [3.3.3].

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The minimum sound pressure levels for broadcasting emergency announcements shall be:

— in interior spaces 75 dB (A) and at least 20 dB (A) above the speech interference level
— in exterior spaces 80 dB (A) and at least 15 dB (A) above the speech interference level.
(see LSA Code, Sec. 7.2.2)

Emergency announcements are allowed to mute the alarm. Where audible alarms are interrupted by announcements the visual alarm shall not be affected.

The alarm and communication system shall be powered in accordance with [5.5].

9.3.3 External emergency communication

Appropriate arrangements and systems shall be provided for communication in all foreseeable emergency scenarios between:

— the substation and persons not on the substation, but engaged in activities in connection with the substation
— the substation and persons beyond the substation.

These arrangements and systems shall remain effective in an emergency. Requirements of [5.5] shall be observed.

9.4 Automatic actions and shutdown

9.4.1 General

In the event of abnormal conditions (e.g. high hydrogen concentration, smoke or flame detection) automatic actions of the safety systems shall minimize the escalation of events, minimize the extent and duration of such events.

Automatic actions may be performed by the fire and gas detection systems, regarded in this case as a shutdown system.

The shutdown system comprises:

— manual input devices (push buttons)
— field devices (e.g. level, pressure sensors)
— interfaces towards other safety systems, see [3.5.7]
— a central control unit receiving and evaluating signals from the manual input devices and the interfaced systems, and creating output signals to devices that shall be shut down or activated
— output actuators as e.g. relays, valves and dampers, including status indicators
— signal transfer lines between the shutdown system central control unit and all input devices, interfaced systems and output actuators
— power supply.

Automatic actions/shutdown shall not result in adverse cascade effects. 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 substation. It shall be continuously available and fulfil the requirements of [5.5].

9.4.2 Shutdown concept

The shutdown concept shall comprise functional requirements for the safety systems upon detection of an abnormal condition.

The shutdown concept 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 substation (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 or ship collision.

Total substation shutdown

— can require disconnection of the offshore substation from the grid
— shall not stop or impede the operation of emergency consumers (among others active fire protection, emergency lighting, navigation aids).

System shutdown may 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
— shall not stop or impede the operation of emergency consumers (among others active fire protection, emergency lighting, navigation aids).

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.

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.

The shutdown system shall be designed to ensure that any ongoing operations can be terminated safely when a shutdown is activated.

Personnel lifts, work platforms and other man-riding equipment shall be designed to enable safe escape after the shutdown, e.g. by controlled descent to an access point on a lower level.

Arrangements that are protected by automatic safety systems shall have pre-alarms to alert when operating parameters are exceeding normal levels.

Depending on the shutdown level attributed to a particular accidental event, following actions or their combinations can be required to achieve the targets set in the shutdown concept:

— shutdown of HV equipment
— disconnection of the offshore substation from the external grid
— start-up of emergency power supply, take-over of power supply of emergency services by transitional/ emergency source of power
— shutdown of fuel system pumps, activation of fuel system shut-off arrangements
— shutdown of power ventilation
— closure of smoke and fire dampers
— closure of openings (doors, louvers, etc.)
— stop of the batteries charging
— initiation of audible siren signalling, visual warning, automatic announcements
— automatic activation of CCTV cameras/recording.

9.4.4 Minimum requirements

Shutdown system shall be so designed that the risk of its malfunction and inadvertent operation are minimized.

If automatic actions are required to minimize the escalation, extent and duration of abnormal events, see App.A, the function shall be implemented in a safety system that is mutually independent of the control and alarm systems related to the same equipment under control.

Guidance note:

The shutdown system should have continuous availability and be regarded as a safety system. This implies the following:

— The system is not vulnerable to a single failure and is fail-safe on instrumentation failure.

— The independency between safety systems and other systems is intended to provide a robust single fault tolerance.

— The independency requirement does not intend to prevent the different control-, alarm- and safety system units from communicating status information over e.g. a network, but each unit shall be able to perform its main functions autonomously.

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Actions shall be initiated by shutdown system automatically. Manual initiation of actions shall be provided where automatic action can be detrimental to safety.

Manual shutdown buttons/control elements shall be protected against unintended activation and be provided with clear label describing the extent of the system being shut-down.

Manual activation shall be simple and quick to operate. The operator shall have sufficient time to acknowledge and execute shutdown before an accidental event escalates.

Shutdown shall initiate an alarm at the substation control room. The initiating device and operating status of devices affected by the shutdown action shall be indicated at the substation control room.

Automatic reset shall be prohibited. Local or remote reset is required.

The system shall contain provisions for the testing of its functionality as well as input and output devices.

The tests and visual examinations shall verify that all requirements of this standard are met. The test procedures shall specify in detail how the various functions shall be tested and what shall be observed during the tests. Failures shall be simulated as realistically as possible, preferably by letting the monitored parameters exceed the alarm and safety limits. Alarm and safety limits shall be checked.

9.5 Means of escape

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, workshops, substation control rooms, further workshops as per [3.6], cranes and muster areas are generally considered to be regularly attended. 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 as not regularly attended.

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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 substation.

Single exists may be used for small rooms where personnel rarely spend time, but dead ends shall not exceed 7 m.

Guidance note 2:

Dedicated escape routes need not necessarily apply to very infrequently attended 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.

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Two means of escape shall be provided from every machinery space of category A and space containing major electrical equipment.

Guidance note 3:

The number of means of escape may be reduced based on a consideration of the nature and use of the space.

(see MODU Code Sec. 9.4.1)

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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 shall be given to routing of medium and high voltage cables in escape routes.

The surfaces of decks, walkways, platforms, stairs and ladder rungs etc. shall be non-slip, and designed for drainage and easy cleaning of contaminants like mud and oil, where relevant.

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.

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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.

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, see [5.7.2] and [5.7.3].

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.

Guidance note:

See IMO Resolution A.752(18) *Guidelines for evaluation, testing of low-location lighting on passenger ships.*

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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 m^2 per person and 0.7 m^2 or more being preferred.

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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.

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9.6.2 Primary muster area

A primary muster area (sometimes called the temporary safe refuge or shelter area) shall be 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 shall 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 result of:

— 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 Means of evacuation

9.7.1 General

Arrangements shall be made to ensure safe evacuation of all persons from the offshore substation. 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.

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. Initial treatment of casualties must be provided for immersion (e.g. cold shock, hypothermia, near drowning). The conditions should be suitable to ensure a good prospect of recovery and survival of casualties.

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Means of evacuation shall be of approved type.

9.7.2 Primary means of evacuation

A primary means of evacuation having own motive power to enable persons to move quickly away from the substation shall be provided. Such means may include:

— transfer or rescue vessel equipped with appropriate arrangements for personnel transfer operations
— helicopter
— davit-launched lifeboat or free fall lifeboat.

For substations of type A either transfer helicopter, transfer vessel or rescue vessel equipped with appropriate arrangements for personnel transfer operations shall be provided. Their location or distance to the offshore substation shall be such to ensure safe evacuation of all persons from the offshore substation in due time without involvement of secondary means of evacuation.

For substations of type B and C at least one davit-launched lifeboat or free fall lifeboat with the capacity of maximum manning shall be available. Should manning ever exceed the lifeboat capacity, additional provisions shall be made.

Guidance note:

See:

— SOLAS Ch. III Reg. 21 *Survival craft and rescue boats*
— LSA Code Ch. IV *Survival craft*
— LSA Code Ch. VI *Launching and embarkation appliances*.

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Primary evacuation means should be available and remain unimpaired by excessive toxic fumes, smoke, unacceptable heat loads, hot liquids and falling objects for up to 30 minutes after all reasonably foreseeable accidental events begin.

Guidance note:

Evacuation means are 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.

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9.7.3 Secondary means of evacuation

In addition, a secondary means of evacuation shall be provided for the safe evacuation of all persons from offshore substations without entering the sea (even temporary) for the case if the primary evacuation means fails to operate. Such means may include davit-launched liferaft(s) or liferaft(s) served by marine evacuation systems. Their operational limitations shall be considered for the definition of weather conditions acceptable for offshore maintenance works.

Guidance note:

See:

— SOLAS Ch. III Reg. 21 *Survival craft and rescue boats*
— LSA Code Ch. IV *Survival craft*
— LSA Code Ch. VI *Launching and embarkation appliances*.

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Secondary evacuation means should be available and remain unimpaired by excessive toxic fumes, smoke, unacceptable heat loads, hot liquids and falling objects for up to 30 minutes after all reasonably foreseeable accidental events begin.

9.7.4 Means of entering the sea

Further, appropriate location(s) on the substation shall enable persons wearing personal protective equipment [3.5.8] a safe entering to the sea as the very last option for evacuation. Means of descent to the sea, such as personal controlled descent devices, scramble nets, or embarkation ladders, shall be provided.

9.8 Means of rescue and recovery

9.8.1 General

Arrangements shall be made to enable persons to be rescued and recovered from the sea or near the substation to a place of safety. Arrangements are regarded as being appropriate for personnel rescue and recovery operations 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. During the development of the rescue and recovery strategy the following shall be considered:

— the number of persons that may potentially need to be rescued and recovered at once
— the capacity, distance and response times of the rescue and recovery services
— potential limitations on availability, daytime, weather conditions and sea states
— the nature of work activities being carried out (e.g. over side/under deck work would require a dedicated rescue craft).

Incidents to be considered shall include a person falling overboard or a helicopter ditching on landing or take-off.

Means of rescue and recovery include:

— facilities on the offshore substation
— facilities and services external to the substation, such as vessels, public sector and commercially provided search and rescue facilities.

Facilities and services external to the substation and on the offshore substation shall meet national/local requirements.

Guidance note:

In relation of the facilities on the offshore substation the following informative guidance, see:

— SOLAS Ch. III Reg. 21 *Survival craft and rescue boats*
— MODU Code Sec. 10.8 *Rescue boats*.

Facilities and services external to the substation can include helicopters, emergency response and rescue vessels (ERRV).

Engagement of the local coastguard, armed forces or other authorities may be arranged.

Where rescue and recovery from the water by a helicopter is foreseen, search/rescue expertise and equipment (SAR) is applied.

Helicopters ordinarily used for personnel transfer are not used for these purposes.

ERRV equipped with a 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. When ERRV 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.

Fast rescue craft of ERRV is a high speed, maneuverable craft equipped with adequate means of communicating with the ERRV by radio, carrying an adequate portable searchlight, deployed from an ERRV for the purposes of rescue and recovery of survivors and marshalling or towing life rafts. It may have an enclosed cabin for crew and survivors.

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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:

See 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 concept 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.

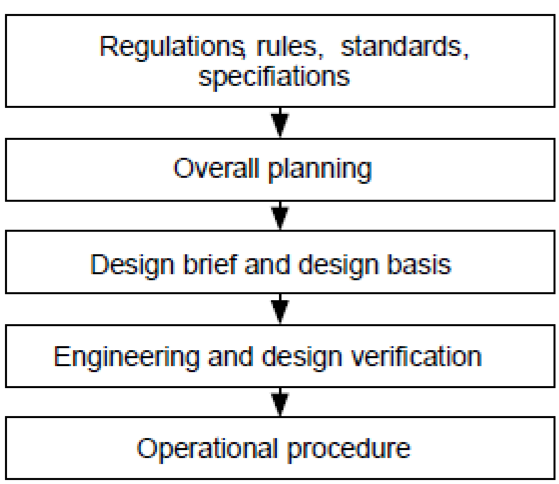

Figure 10-1 Planning and design procedure

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 and commissioning

10.3.1 Steel structure

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 DNV-OS-C401 *Fabrication and testing of offshore structures*.

Guidance note:

The application of European and International standards may be agreed as along 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 DNV-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.

For secondary structures being welded directely to primary or special, or for secondary structures being important for the safety of personnel it is advised to increase the required material certificate level to that of primary structures.

Table 10-1 Material certificates

Certification process	*Material certificate (EN10204)*	*Structural category*
Test certificate as work certificate, inspection and tests witnessed and signed by an independent third party body	3.2	special
Work certificate test results of all specified tests from samples taken from the products supplied. Inspection and tests witnessed and signed by QA department	3.1	primary
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	2.2	secondary

For definition of structural categories DNV-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 DNV-OS-C101 Ch.2 Sec.3. The extend and acceptance criteria stipulated in DNV-OS-C401 Ch.2 Sec.7 Table 2 shall be complied with.

10.3.2 Systems and equipment

10.3.2.1 General

General requirements on manufacturing and the qualification of manufacturers are defined in this section and in DNV-SE-0073 and DNV-SE-0190.

Testing and commissioning of the substation electrical system is usually performed in three stages:

— factory acceptance tests
— harbour acceptance tests
— site acceptance tests.

Guidance note:

Further guidance can be found in:

— DNV-RP-0423 *Manufacturing and commissioning of offshore substations*
— CIGRE Technical Brochure 483 *Guidelines for the Design and Construction of AC Offshore Substations for Wind Power Plants*.

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10.3.2.2 Factory Acceptance Tests

The target of the factory acceptance tests (FAT) is to check conformity with the specifications and functional requirements as well as quality aspects. Typically, machinery and electrical equipment as well as lifting devices are subject to a FAT:

— large main and auxiliary power electrical equipment (main transformers, HV switchgears, generator sets, UPS)
— LV switchgear and control gear
— cranes and davits.

All the substation main power equipment shall be tested at a test facility which shall be accredited according to definition in 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 power 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 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.

10.3.2.3 Harbour Acceptance Tests

The target of the harbour acceptance tests (HAT) is to test systems or modules after the assembling and installation completion at the construction yard.

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.

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.

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Auxiliary power system 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, including (but not limited to) the following checks:

— Generators sets: operation (running), start fail, over-speed, low oil pressure, high cooling water temperature, high generator temperature, emergency stop function.

— Battery systems: check of electrical control of protection unit, check of operation at final setting of the protection unit.
— Ventilation system: leakage-free operability, ventilation operability check, air flow capacity check, area pressurization ability, checks on the interface to the shutdown systems, functionality of fire dampers.
— Fire and gas detection systems: check of functionality, check of the interface with shutdown systems.
— Firefighting systems: extinguishing release check, check of the interface with shutdown systems, fire doors closure.
— Main and emergency lighting: check of operability, lighting level.
— Public address/general alarm: sound level and sound purity testing, amplifier redundancy functionality, activation of visual and audible alarm, automatic announcement.

All the performed construction yard acceptance tests and construction yard commissioning activities shall be documented.

10.3.2.4 Site Acceptance Tests

The principle purpose of the site acceptance tests (SAT) is to ensure that upon installation of the topside on the substructure, the system in question is fully integrated i.e. installed properly and interfaced correctly with all other systems.

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 CIGRE Technical Brochre 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 may not be required where disassembly of the equipment is necessary.

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The main power energization activities shall be performed according to a commissioning switching program (CSP), shall be submitted for information to the grid operator.

All the performed site acceptance tests and site commissioning activities shall be documented.

10.4 Transport and installation

10.4.1 Planning of operations

Acceptance standard, basic assumptions, dynamics considered, etc. and shall comply with the principles and requirements of DNV-ST-0054.

The planning of transport and installation shall cover planning principles, risk evaluation and documentation. Operational prerequisites such as design criteria, weather forecast, organisation, method statements/ operation manuals as well as preparation and testing shall be covered.

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 transport and installation 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 concept and intentions of DNV standards.

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.

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.

Load transfer operations cover load-out, float-out, lift-off, pile upending, on-bottom stability, piledriving and mating operations.

Environmental loads and load cases as well as on-bottom stability requirements and requirements to structural strength shall be defined.

Operational aspects for ballasting, pile installation and grouting shall be considered.

Guidance and recommendations for lifting operations, onshore, inshore and offshore are given in DNV-ST-N001.

Design of slings, grommets and shackles as well as design of the lifting lugs/lifting eyes and the lifted object itself shall be covered.

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 pull-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.

10.4.2 Transport and installation documentation

Operational aspects shall be documented in the form of calculations, operation manuals and procedures.

The documentation shall demonstrate that concepts, principles and requirements of DNV-ST-0054 are complied with.

Documentation for transport and installation 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 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.

Guidance note:

As-built drawings should contain the same level of detail as the approved design drawings and it is considered good practice to issue as-built drawings based on approved design drawings.

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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 *Arrangement principles*
— Sec.9 *Emergency response*.

11.2 Safety concept 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.

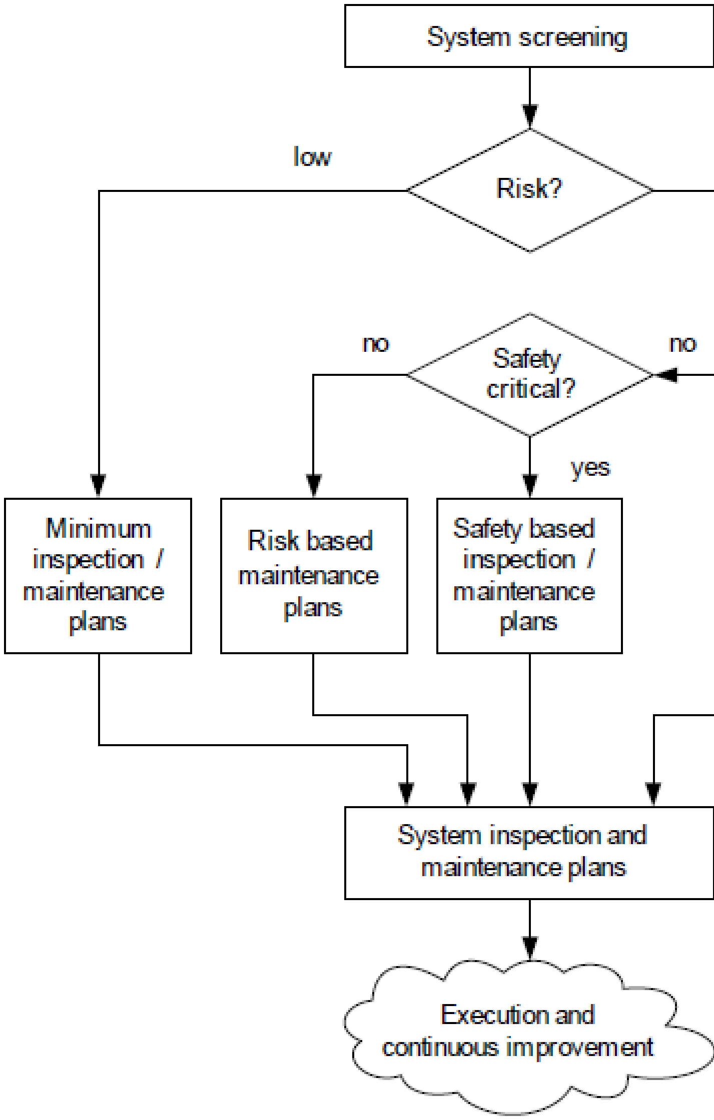

Figure 11-1 Risk based maintenance concept

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 power plants 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 observed.

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

A substation inspection and maintenance plan shall be established. The maintenance plan shall state which actions shall be taken for preventive and corrective maintenance.

Preventive maintenance shall include both scheduled maintenance activities and conditions monitoring based maintenance activities.

Inspection and maintenance activities shall 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
— substation decks, walls and appurtenances
— walkways, stairs, ladders
— J-tubes, fenders, pipework
— lifting appliances
— helicopter deck
— lifeboats.

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 regular inspections:

— main and auxiliary transformers
— high and medium voltage switchgear
— auxiliary power system
— emergency power generation equipment (generator sets, battery systems)
— measurement, monitoring, control (parameters and settings), protection and shutdown systems
— earthing and lightning protection.

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.

For large oil-filled electrical equipment (i.e. shunt reactors, main, earthing and auxiliary transformers), oil samples shall be taken on regular basis. The frequencies of the analysis and the frequencies of the interventions to improve the oil may be based on trends and comparisons of analysis results.

If the main transformer is equipped with an online monitoring system, 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.

11.4.4 Safety systems

The following items shall be covered by regular inspections:

— fire protection systems
— emergency lighting
— communication systems
— life-saving appliances, personal safety and protection equipment
— fall arrest systems

— ventilation system
— drain system
— fuel system
— markings, warnings, and identification panels.

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.

11.5 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 A-1 Safety consequence scale

Category	*CoF (PLL)*	*Description*
HH	> 1	multiple fatalities
H	1	single fatality
M	10^{-1}	major injury, permanent disability

Category	*CoF (PLL)*	*Description*
L	10^{-2}	minor injury
LL	10^{-3}	slight injury

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 concept.

Table A-2 Environmental consequence scale

Category	*CoF (litres of oil)*	*Description*
HH	> 16 000	massive effect
H	10 000 - 16 000	major effect
M	1000 - 10 000	local effect
L	100 - 1000	minor effect
LL	< 100	slight effect, negligible

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 A-3 Economic consequence scale

Category	*CoF [€]*	*Description*
HH	> 5 M	massive effect
H	500 k - 5 M	major effect

Category	*CoF [€]*	*Description*
M	50 k - 500 k	local effect
L	5 k - 50 k	minor effect
LL	< 5 k	slight effect, negligible

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 A-4 Probability of failure scale

Category	*PoF / year*	*Description*
HH	$> 10^{-2}$	failure expected
H	10^{-3} to 10^{-2}	high probability of failure
M	10^{-4} to 10^{-3}	Medium probability of failure
L	10^{-5} to 10^{-4}	Low probability of failure
LL	$< 10^{-5}$	failure not expected

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 (ALARP). 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.

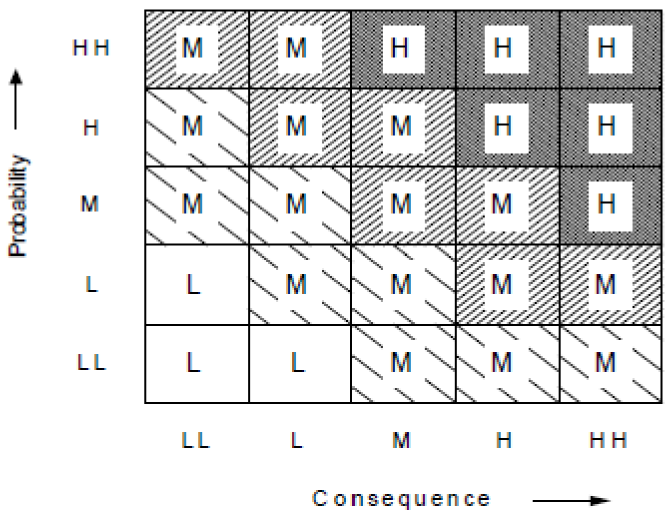

Figure A-1 Example of a risk matrix

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 concepts and design measures to prevent, control and mitigate the risks.

The following Figure B-1 illustrates the 5 step process to risk based design:

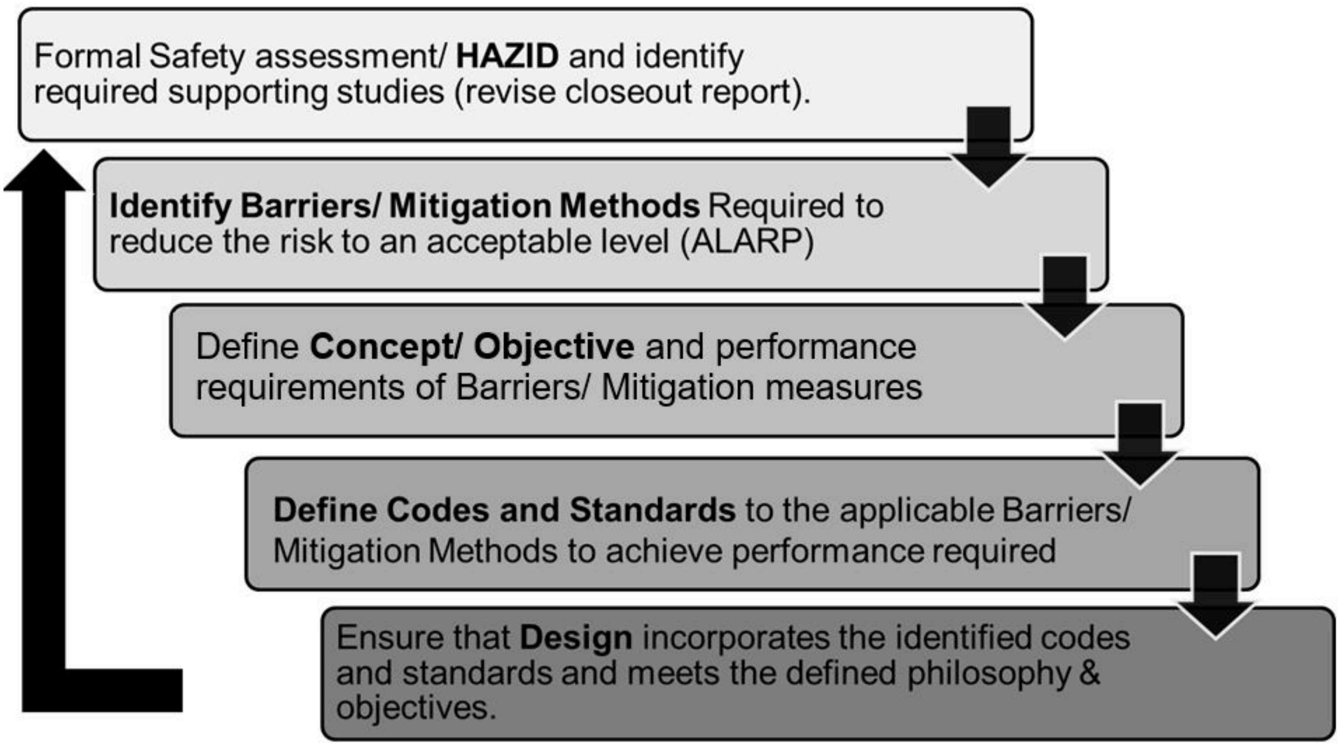

Figure B-1 Five step process to risk based design

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

No.	*Hazardous event*	*Possible causes*	*Possible consequences*
1. Structural incident			

1.1	Structural damage	Ship impact Transformer explosion Fire in sump tank Extreme weather Subsidence Scouring Earthquake Subsea/splash zone corrosion	Fatality (P) Substation collapse (A)
1.2	Collision of vessel with substation	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 Electrical incident			
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)
3 Fire and explosion incident			
3.1	Main transformer fire or explosion	Internal fault Short circuit Lack of cooling medium Oil degradation External fire Overload Poor layout or design Inadequate drainage	Injury, fatality (P) Release of burning oil (E) Downtime (A)
3.2	Utility transformer fire	Internal fault Short circuit Lack of cooling medium External fire Overload	Injury (P) Downtime (A)

3.3	HV switchgear fire or explosion	Lack of insulation gas (SF6) Earthing fault Short circuit Overload Malfunction of equipment Poor maintenance Lack of training Incorrect work procedures	Injury (P) Downtime (A)
3.4	LV equipment fire	Short circuit Overload Malfunction of equipment	Injury (P) Downtime (A)
3.5	Emergency generator fire	Internal fault Generator allowed to run out of fuel Fuel system leak Poor maintenance	Injury (P) Environmental pollution (E) Loss of emergency power (A)
3.6	Toxic smoke	Fire on transformer or electrical equipment Explosion Loss of containment	Injury (P) Damage (A)
3.7	Fire in accommodation	Kitchen or cabin use Smoking Poor housekeeping Unattended electrical equipment	Injury, fatality (P)
3.8	Fire or explosion at helicopter deck	Ignited leak or static discharge	Injury (P)
3.9	Fire or explosion in battery room	Ignited hydrogen leak	Injury (P) Damage (A)
3.10	Fire or explosion in paint store/ chemical store	Ignited hazardous material	Injury (P) Damage (A)
3.11	Fire or explosion in hypochlorite package	Ignited hydrogen leak	Injury (P) Damage (A)
4 Access and transfer incident			
4.1	Marine transfer incident	Slips, falls caused by marine growth, ice Ladder failure caused by marine environment Lack of instruction and training	Injury (P)

4.2	Helicopter crash, ditching	Mechanical failure Pilot error Poor weather/visibility Loss of fuel Faulty Navigational Aids	Injury, fatality (P) Helicopter/installation damage (A)
4.3	Helicopter rotor impact	Lack of training or control Poor housekeeping Lack of helideck protection (nets, lights, etc.) Adverse weather	Injury, fatality (P) Helicopter damage (A)
4.4	Helicopter winching incident	Poorly controlled winching Mechanical failure of winching system Poor weather	Injury, fall, fatality (P) Helicopter damage (A)
4.5	Unauthorised access to high risk area	Lack of locks, signage	Injury (P) Tampering with equipment (A) Release (E)
5 Emergency response incident			
5.1	Man over board	Boat transfer Maintenance work Personnel working over water	Injury, fatality (P)
5.2	Loss of escape route or transfer back to shore	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	Being stranded, injury (P)
5.3	Loss of communication to vessels or shore	Cable or equipment fault Onshore problem Loss of power Fire, explosion Maintenance activities	Delays (P)

5.4	Failure of flood lights, navigation aids	Loss of power	Unsafe operations (P, A)
5.5	Shortages in food and water supply	Poor planning Inclement weather	Discomfort, injury (P)
5.6	Uncoordinated search and rescue	Poor procedures Lack of equipment Lack of training Language	Delays, injury, fatality (P)
6 Other incidents			
6.1	Release from cooling oil system	Loss of containment	Injury (P) Contamination (E) Downtime (A)
6.2	Failure of HVAC system	Wrong design Malfunctioning of fire dampers Failure of detector	Smoke ingress into cabins (P) Feeding fire with oxygen (A)
6.3	Occupational hazards	Vessel movement Adverse weather and sea states	Injury (P)
6.4	Epidemic illness	Food poisoning Bio hazard Escherichia coli Legionnaires' disease	Injury (P)

B.2 Safety critical systems

B.2.1 General

After 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 substations.

Table B-2 An example table of typical safety critical systems

Barrier	*Class*	*Critical function*	*System*
Safety	S1	Safety Sec.2 and Sec.3	1) HAZID 2) HAZOP 3) safety concept/basis of design 4) safety concept (HSE) 5) risk assessments[1)] 6) ALARP studies 7) manning concept.

Prevention	P1	Structural and stability integrity Sec.4	1) Jacket 2) piles 3) foundations 4) topsides/surface structures 5) crane structure/pedestal 6) appurtenances and supports 7) jacking mechanism 8) locking mechanism 9) helideck (impact/load) 10) lifting/transit 11) collision protection (j-tubes) 12) accidental loads 13) ship impact.
	P2	Prevention of collisions/ impacts Sec.3 and Sec.9	1) Collision avoidance system 2) radar/ATR/RACON 3) navaids (marine warning lights) 4) warning lights (aviation) 5) automatic identification system (AIS).
	P3	Prevention of dropped/ swinging object damage [4.4.6]	1) Lifting equipment (EU directive) 2) crane (offshore certification) 3) crane safety devices (hook, cable, brake) 4) dropped object/impact protection.
	P4	Prevention of process hazards and mechanical failure Sec.2 and Sec.3	1) Electrical equipment safety and EMF (EU directives) 2) mechanical equipment safety (EU directives) 3) process control system 4) pressure equipment directive (EU directives).
	P5	Prevention of ignition Sec.3	1) Hazardous area classification(flammable/explosive) 2) heating, ventilation and air conditioning (HVAC) 3) ATEX (EU directives)/ certification of equipment 4) earth bonding and continuity 5) electrical isolation 6) lightning protection.
Control	C1	Fire and gas detection [6.7]	1) Fire detection systems 2) smoke detection systems 3) hazardous gas detection systems (battery room, EDG) 4) manual alarm callpoint (MAC's) 5) SF6 leak detection.
	C2	Emergency isolation [9.4]	1) Emergency pushbuttons and shutdown systems 2) emergency depressurisation.
Mitigation*	M1	Explosion mitigation Sec.6	1) Blast protection 2) blast walls/zones (transformer) 3) blast panels/pressure relief panels.

	M2	Fire mitigation/fighting Sec.6	1) Fire mitigation system (concept) 2) fire walls 3) passive fire protection (divisions, dampers, penetrations, etc.) 4) firewater 5) fire pump systems 6) foam systems 7) liquid and gaseous extinguishing systems 8) fire extinguisher (LSA) 9) drains (transformer oil, helideck, etc.).
Evacuation and escape	E1	General alarm and emergency communications [9.3]	1) General alarm systems (fire/ collision) 2) external communication and emergency response 3) VHF radios (marine/aviation).
	E2	Egress, evacuate and escape Sec.9	1) Escape routes 2) escape route lighting 3) skyscape/life rafts/ TEMPSC/ ERRV/ FRC 4) temp. refuge/muster areas (protection and sizing) 5) emergency and escape lighting 6) emergency PPE (life jacket, suit, smoke hood, PLB) 7) first aid room.
	E3	Helideck [8.4]	1) Layout and Markings 2) emergency equipment 3) fire fighting (DIFFS) 4) helicopter crash rescue equipment 5) effects of airflows over Helideck.
	E4	Emergency power supplies [5.5]	1) Emergency generator 2) UPS.
Environment	N1	Environmental [A.2.3]	1) Leakage containment 2) water emiswions 3) air emissions 4) bunded areas 5) acoustic protection 6) epidemic illness.
* The electrical equipment itself should be specified such that fire and explosion risks are reduced following a performance based design approach. [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 concepts 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 concept. 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 concept 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 concepts and the minimum requirements noted. Code and standard minimum requirements should be evaluated during the development of the design concepts 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 is shown in Figure B-2.

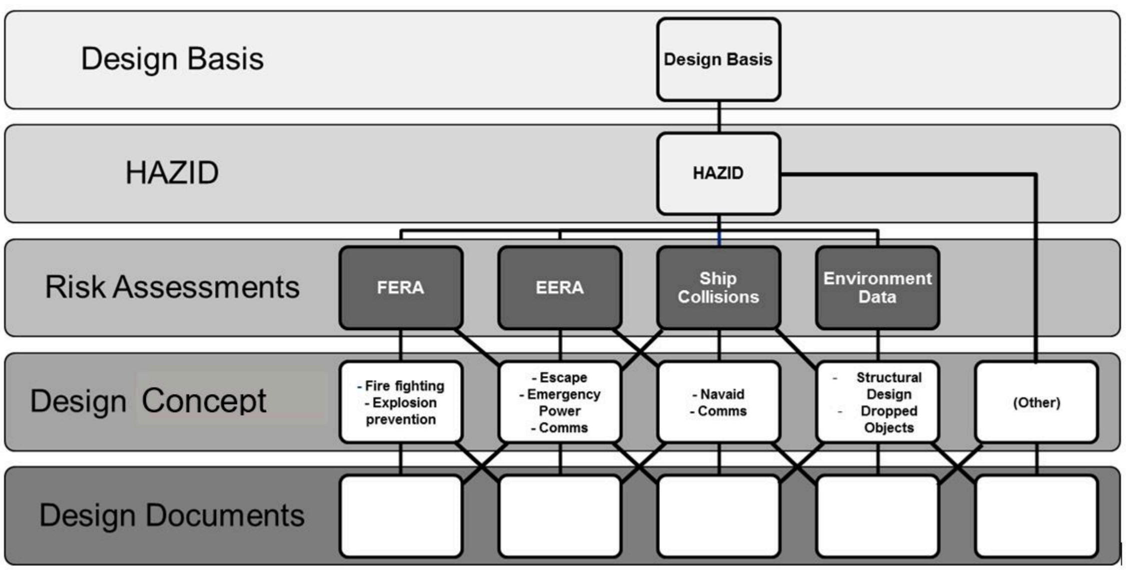

Figure B-2 Diagram of design document hierarchy

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.

Figure B-3 may be used to trace and evaluate if all hazards have protective barriers and where those protective barriers have been realised.

	System	HAZID	Barriers	Concept	Performance Standard	Design
Safety (S)	S1-1 S1-2 ...			-HAZID Doc No. -HAZOP Doc No.		
Prevention (P)	P1-1 P2-5 ...	1.1 1.1 ...	Jacket strength AIS System ...	Structural Des. Concept ...	Doc ref. Doc ref. ...	
Control (C)	C1-1 C2-1 ...	3.7, 3.8 ,3.9, ... 3.2, 3.3, ...	Fire detection Control system ...	Emergency control system Concept	Doc ref. Doc ref. ...	
Mitigation (M)	...	...				
Evacuation & Escape (E)	...	...				
Environment (N)	...					

Figure B-3 Diagram of design document hierarchy

APPENDIX C OPERATIONAL CONDITIONS

C.1 Operational conditions of auxiliary power system comprising main and emergency power supply

This appendix shall be read in conjunction with sections [5.3.1], [5.5.1] and [5.5.3]. The intention of this section is to illustrate the principles outlined in aforementioned sections by means of graphical presentations.

Figure C-1 provides a schematic presentation of the normal operational condition under which the substation, as a whole, is in working order and functioning normally. For details and requirements please see [5.3.1.1].

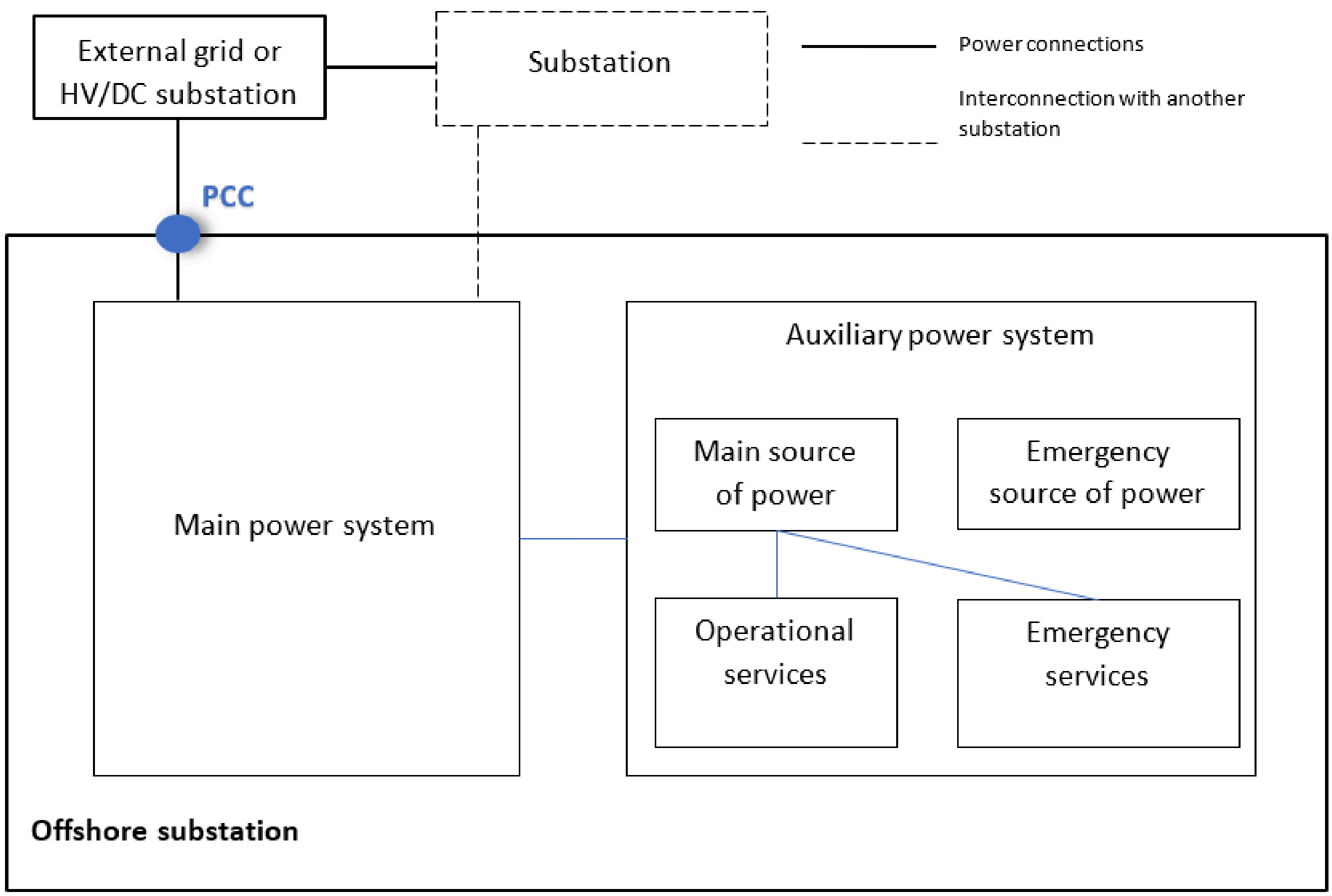

Figure C-1 Normal operational condition

Figure C-2 provides a schematic presentation of the islanded condition under which an electrical connection with the external grid is not available. For details and requirements please see [5.3.1.3].

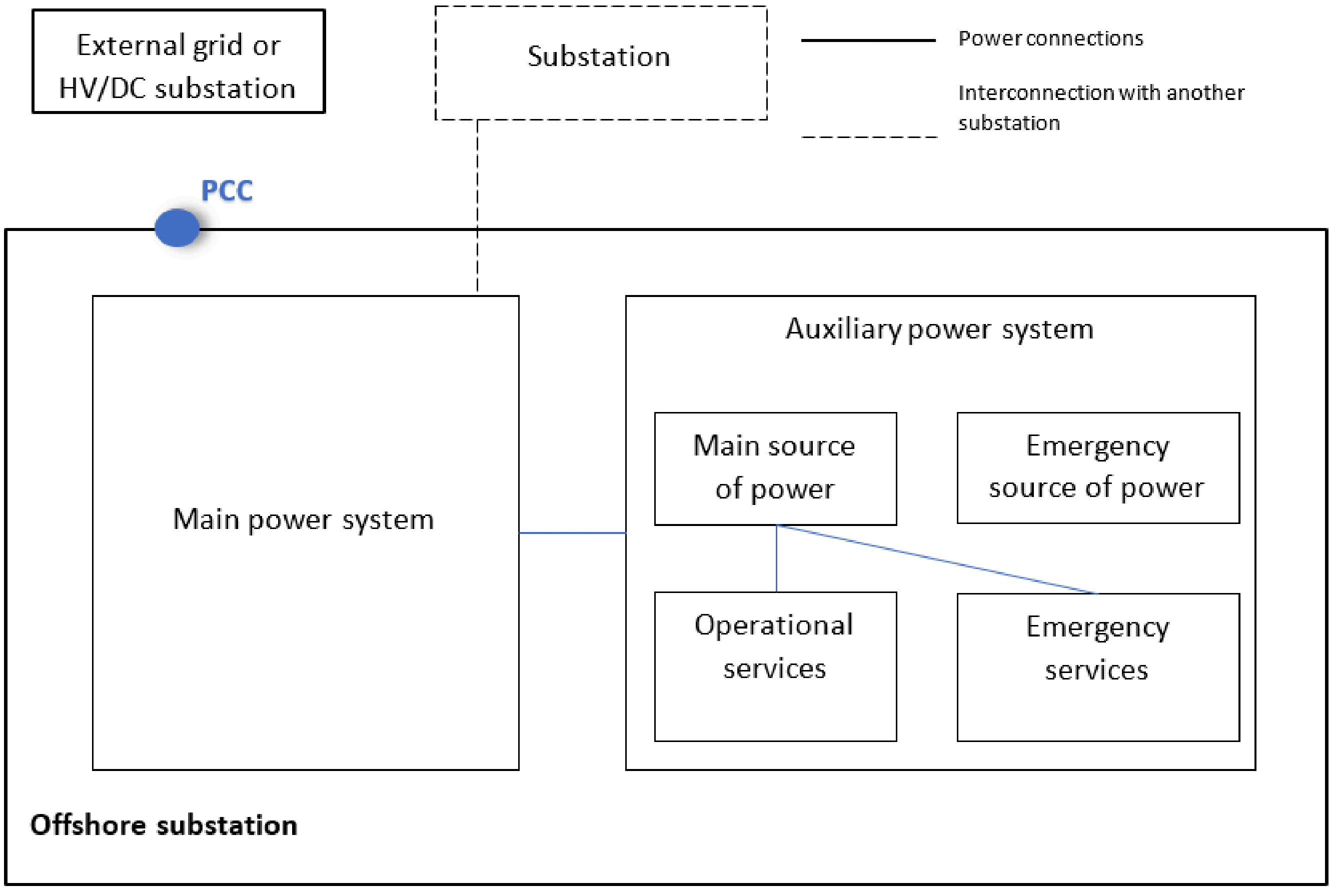

Figure C-2 Islanded condition

Figure C-3 provides a schematic presentation of the emergency condition under which services needed for normal operational and habitable conditions are not in working order. For details and requirements please see [5.3.1.4].

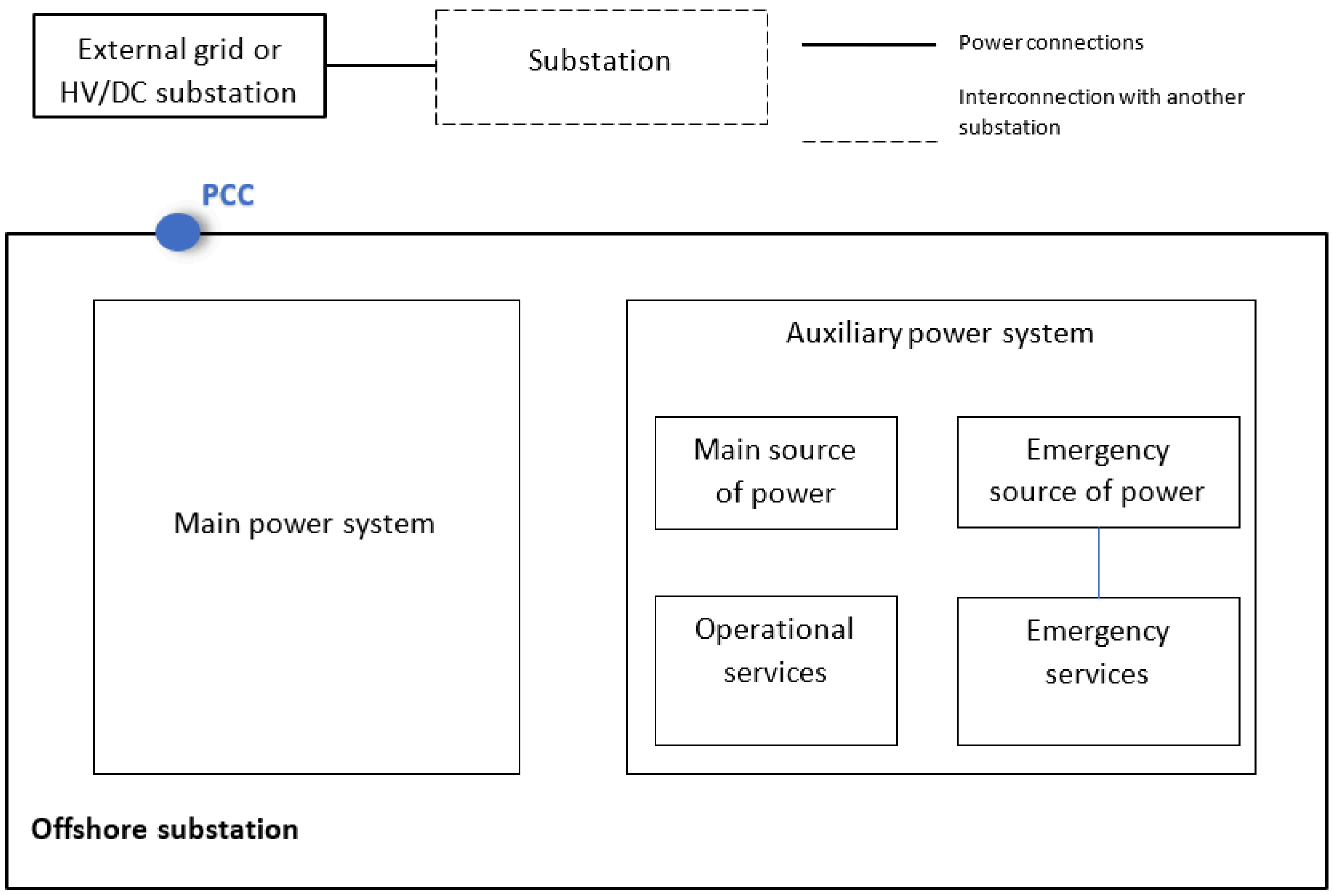

Figure C-3 Emergency condition

C.2 Operational conditions of auxiliary power system comprising meshed power supply

This appendix shall be read in conjunction with section [5.3.1] and [5.5.1]. The intention of this section is to illustrate the general principle of a meshed system and the operational conditions in meshed power supply for auxiliary systems by means of graphical presentations.

Figure C-4 provides a schematic presentation of the normal operational condition under which the substation, as a whole, is in working order and functioning normally. For details and requirements please see [5.3.1.1].

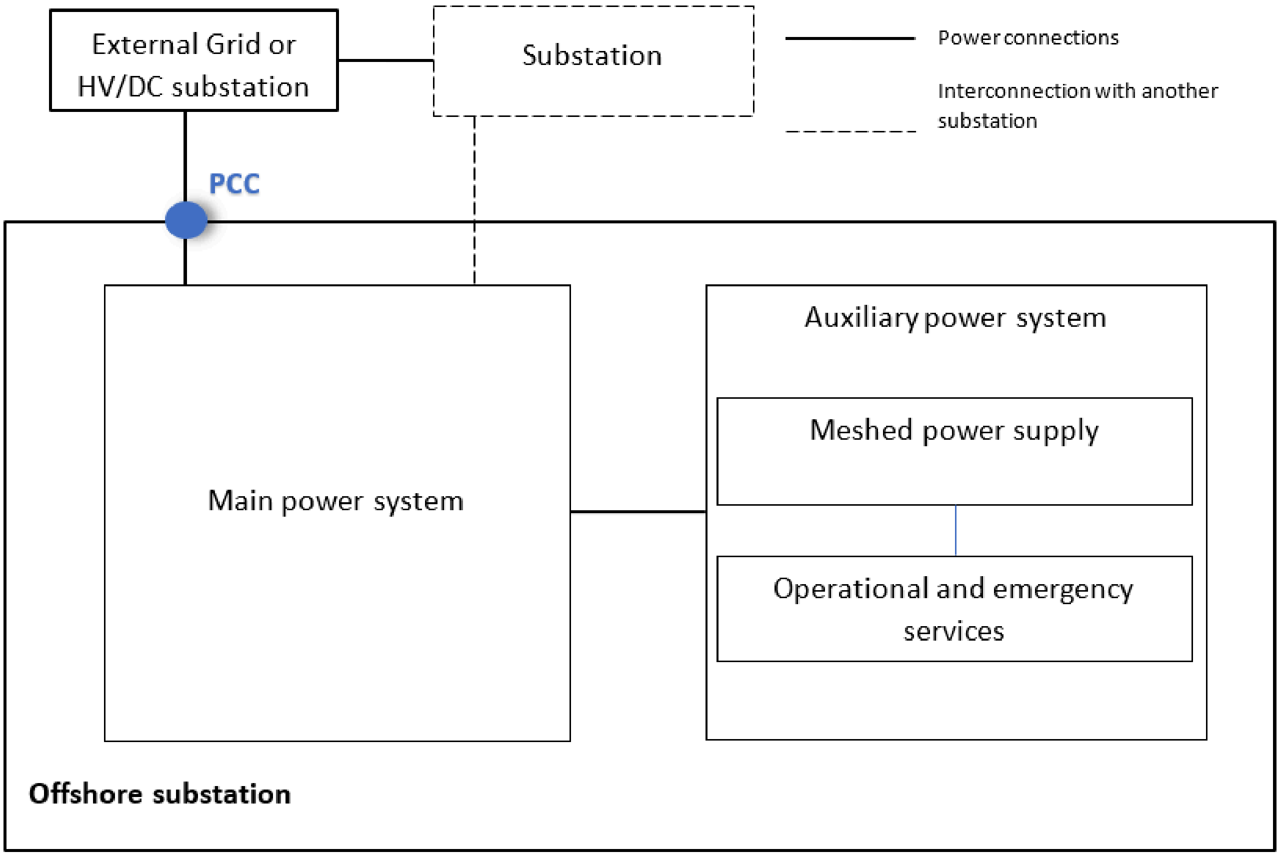

Figure C-4 Normal operational condition

Figure C-5 provides a schematic presentation of the islanded condition under which an electrical connection with the external grid is not available. For details and requirements please see [5.3.1.3].

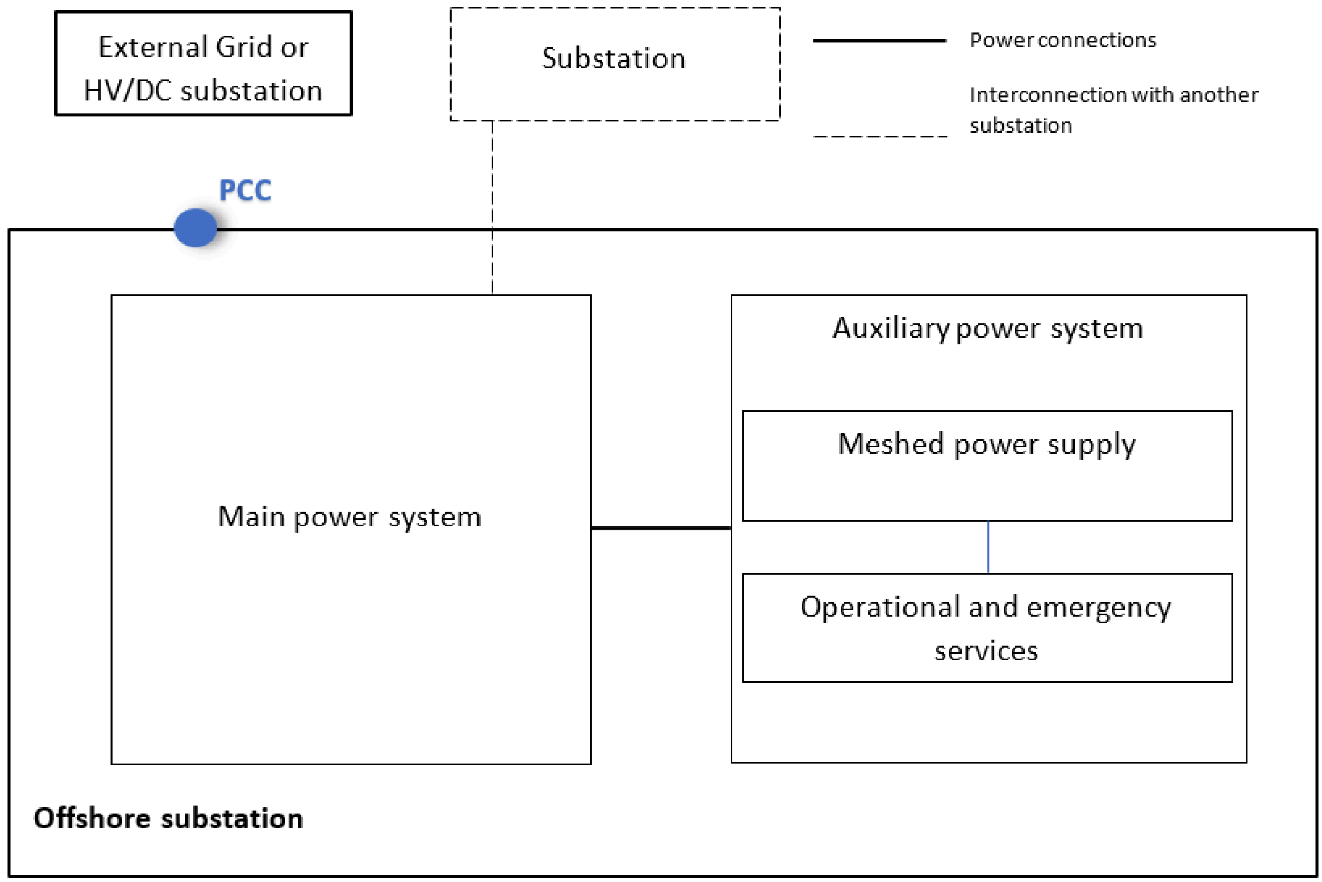

Figure C-5 Islanded condition

Figure C-6 provides a schematic presentation of the emergency condition under which services needed for normal operational and habitable conditions are not in working order. For details and requirements please see [5.3.1.4].

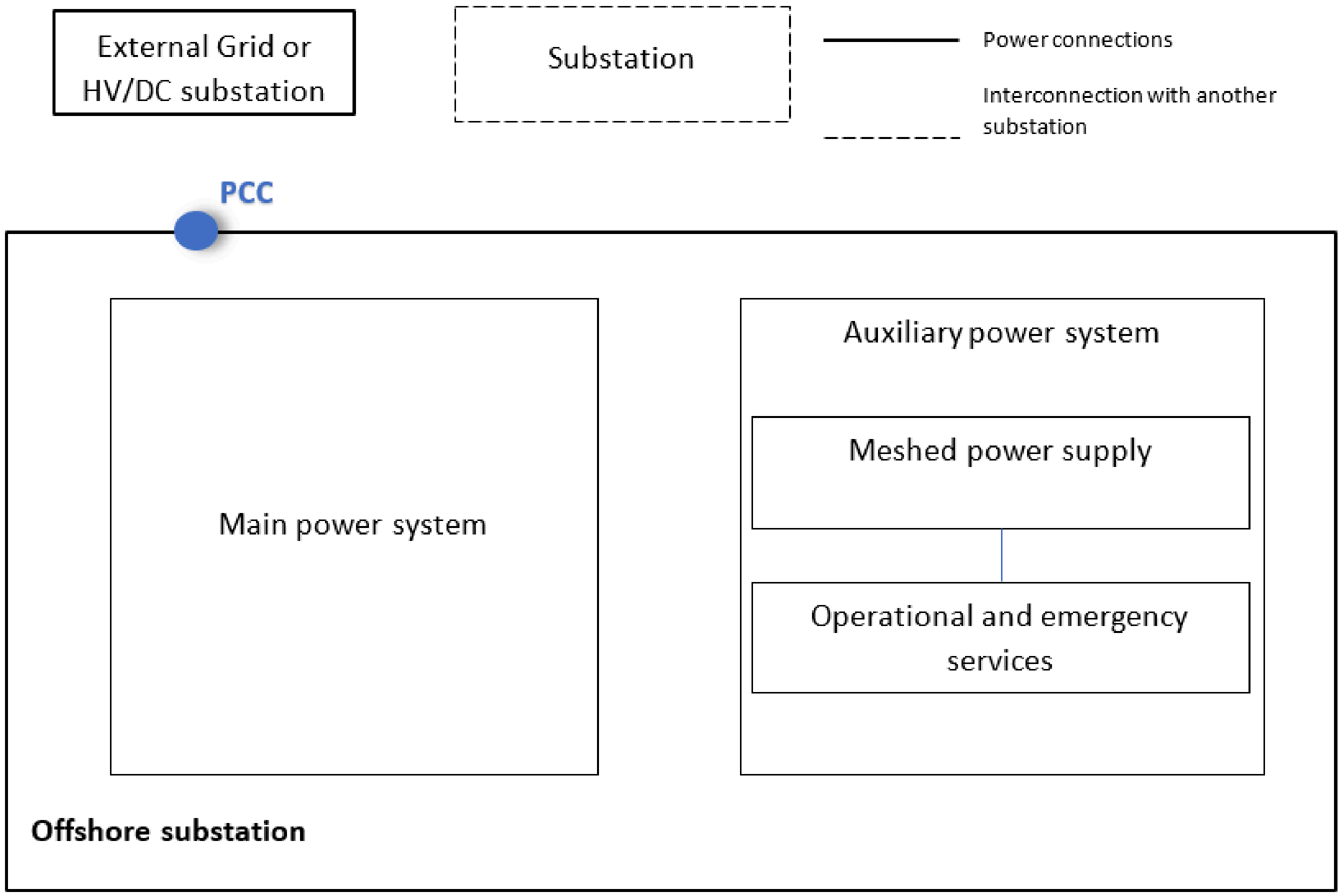

Figure C-6 Emergency condition

CHANGES – HISTORIC

April 2016 edition

General

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

Main changes April 2016

This document has been totally revised.

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