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Development of International Standards and Certification schemes for Marine Energy Technologies

Deliverable D.1.5.1

Recommendations for procedures adaptation: IEC TS 62600-2, Part 2: Design requirements for marine energy systems and IEC TS 62600-10, Part 10: Assessment of mooring system for marine energy converters (MECs)

Project No. 2S01-020

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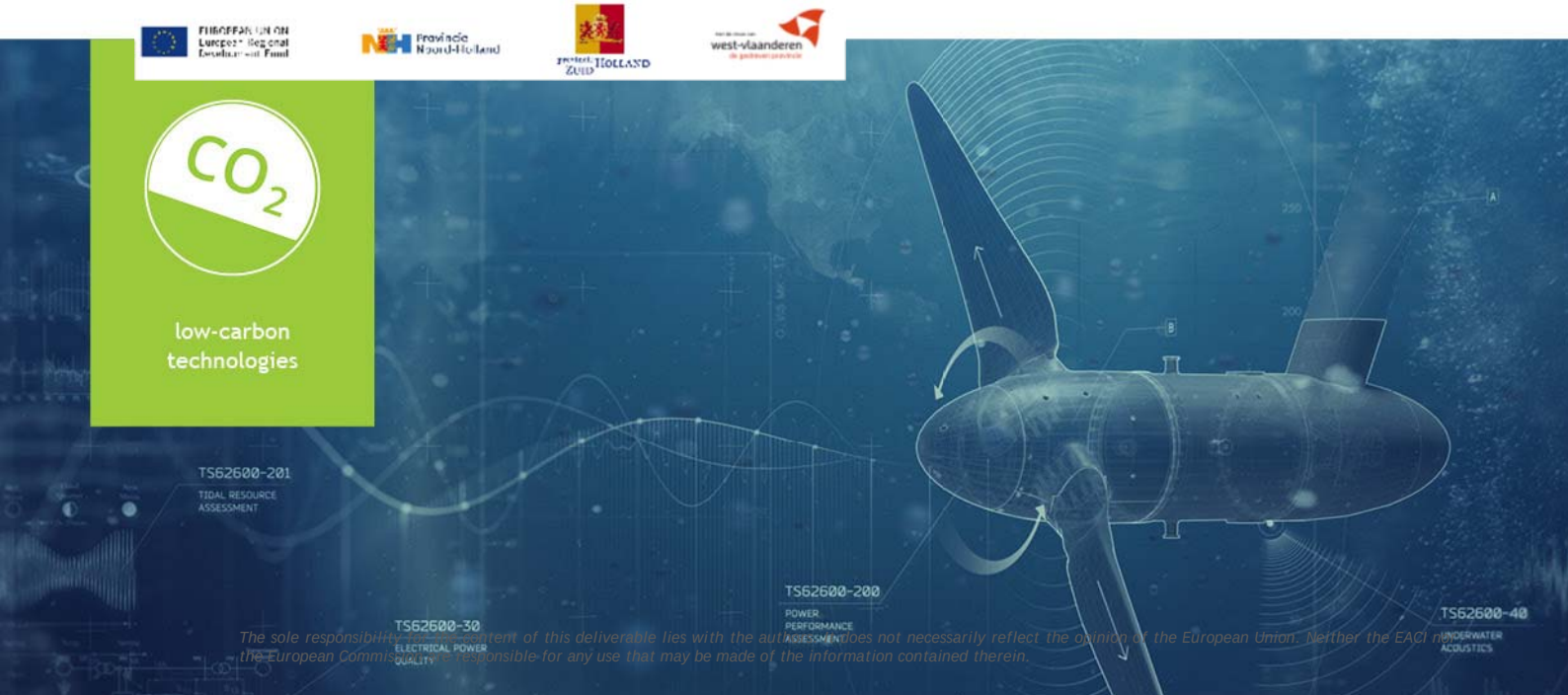

Author

NAME [USE TABLE-TITLE]	ORGANISATION [USE TABLE-TITLE]
Claudio Bittencourt Ferreira	DNV GL
Dan Butterworth (Approval) Digitally signed by Daniel Butterworth Date: 2018.06.27 08:01:50 +01'00'	DNV GL

Revision history

REVISION	DATE	AUTHOR	ORGANISATION	DESCRIPTION
Draft	10/06/2018	CBF	DNV GL	Issue for Tocardo comments
0	26/06/2018	CBF	DNV GL	Final

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Annex A

Figures

No table of figures entries found.

Tables

1. Introduction

Description: Report with recommendations for procedures adaptation to 62600-200 Power performance assessment, 62600-201 Tidal energy resource assessment, 62600-2 Design requirements, 62600-10 Moorings and 62600-30 Electrical power quality.

This report is focused on the 62600-2 Design requirements and 62600-10 Moorings (2015). Since the issue of D.1.6.1, a new CD was released for the 62600-2. The CD Jan 2018 was used in this deliverable.

The report has taken into account the design and verification activities carried out for the deployment of the Tocardo floating tidal turbine platform at Berth 8 of the tidal test berth at EMEC, in the Fall of Warness, Orkney Isles.

As the 62600-2 or -10 were not used during the reference project, the report describes the methodology used by DNV GL to derive recommendations for the IEC TC-114 Technical Specifications (TS) taking into account that industry standards were used.

Some limited third party verification was performed by Lloyd's Register in parts of the floater and a design third party verification was carried out for the moorings. However, there was no overall approach leading to certification. Thus, the certification process has not been considered in this report as there are no new elements to add since the issue of D.1.6.1.

The design of the floating structure was based on:

- **Pontoons: Container Certification Scheme 2007, CSC and ISO 1496-1**
- **Couplings: First principles of structural engineering and stress levels permitted by Lloyd's Rules and updating allowable forces considering FEA from DAMEN**
- **Initial scantlings: DNV-OS-E403 – Offshore Loading Buoys and DNV-OS-C201**
- **Strut connection: Allowable stress for Steel Grade A – 213MPa.**

The mooring system was designed based on DNVGL-OS-E301 (with operational measures implemented to cover difference in the return period of the loading considered).

General recommendations, limited to tidal energy converters, are reported here. It is not the intention to duplicate any recommendations and actions already conveyed to relevant IEC TC-114 Maintenance Teams.

2. References

/1/ DNVGL-SE-0163 Certification of Tidal Turbines and Arrays (Oct 2015)
/2/ DNVGL-ST-0164 Tidal Turbines (Oct 2015)
/3/ IEC TS 62600-1, Part 1: Terminology
/4/ IEC TS 62600-2, Part 2: Design requirements for marine energy systems
/5/ IEC TS 62600-10, Part 10: The assessment of mooring system for marine energy converters
/6/ IEC TS 62600-200, Part 200: Electricity producing tidal energy converters – Power performance assessment
/7/ IEC TS 62600-201, Part 201: Tidal energy resource assessment and characterization

3. Methodology - 62600-2 Design requirements

The methodology applied to derive the recommendations for the IEC TC-114 Technical Specifications was based on:

Comparing the 62600-2 (CD 2018) with previous observations issued in D.1.6.1;

Comparing 62600-10 (2015) with DNVGL-OS-E301 the standard used by Leask Marine; and

High level review of the documentation below:

- Tidal Turbine Project – Structural Analysis and Design - Damen Research
- Memo YN 523041 – Bluetec - Strength analysis of the strut connection – 12-11-2015 – Damen Shipyards Gorinchem
- TFS Mooring Analysis – LSK-TOC-REP-001 Rev. 03 26-01-2017 – Leask Marine
- Third Party Verification Report - Floating Tidal System - OP 156.001 Rev. 2.0 – Orcades Marine
- Third Party Verification Report - Post Approval Mooring Inspection - Follow Up Report – OE156 Rev. 1.0 – Orcades Marine
- Marine Design Appraisal Document ROT/06.H.1059/FV issue number 1 dated 11Dec2006 – Damen Coupling Device - Lloyd's Register
- DMB Certification Couplings Rev.4 dated 14Mar2012 – Damen Shipyards Gorinchem
- Design Appraisal Document – Pontoons to be transported as 40' DMB Container; DMB 40'x8'x8' RET0233720/001/CONT/AJB issue 00 dated 11Mar2010 - Lloyd's Register

The gaps and recommendations were derived in relation to the IEC TC-114 TSs TS-62600-2 (Ref. /4/), -10 (Ref. /5/) and partially the -201 (Ref./7/). The Table 1 below shows the overall level of compatibility between the documents showing initial gaps and where content can be found regarding technical requirements.

Certification module	DNVGL-ST-0164	IEC TC-114 TSs
Technology Qualification	(Sec. 1.10)	
Design Basis Evaluation		
Design Evaluation	(Sec. 4 to 17)	62600-2, -10, -201 (part)
Manufacturing Survey	(Sec. 8, 9, 10, 11, 12, 13, 14, 18)	
Testing Plan	(Sec. 18)	62600-200, -30, -40
Transport and Installation Survey	(Sec. 3, 16)	
Commissioning Survey	(Sec. 3, 10, 12, 13, 14, 18)	
Final Evaluation	(Sec. 3)	
In-service Evaluation	(Sec. 3, 17, 18)	

TABLE 1 - CONTENTS COMPARISON BETWEEN TSS AND ST-0164

3.1. Review scope

3.1.1. Floater

The design of the floater was segmented into couplings, container, strut connection and overall assembly. There was not one common approach for all parts as a mixed set of standards and rules were applied providing no overall acceptance criteria.

Technology assessment and the investigation of the impact of uncertainties as well as the impact of use of proved technology in a different condition that it has been proved were not carried out.

There is no clear reference to the scope and extent of fabrication survey.

The design also seems to be influenced by the limited deployment time. In general, there was not a proper verification for FLS may be due to the limited time of deployment (six months) of the floater and the operational measures that were defined to mitigate the reduced return period seastate considered in the design. The approach used does not naturally align with the 62600-2 (CD Jan 2018) or the technical requirements specified in DNVGL-ST-0164 (Ref. /2/).

Considering the above and that it is not the objective to identify the gaps in the design regarding the standards but the other way around, a review of the 62600-2 (CD Jan2018) considering the previous recommendations described in D.1.6.1 was carried.

3.1.2. Moorings

The moorings were designed and third party verified using the DNVGL-OS-E301. However, the overall level of acceptance (probability of failure) for the moorings were not satisfied considering the return period considered in the design that it is lower than the 100-year return period required by DNVGL-OS-E301. This resulted in operational measures been proposed to mitigate the issue.

Risk assessment and the assessment of the impact of uncertainties as well as of the use of proved technology in a different condition which has been proved were not carried out.

There is no reference to any fabrication survey, although there is reference to a pre-deployment survey carried out by TPV of the mooring lines, clump weights and chains. No reference to standards were made.

Considering the above and that it is not the objective to identify the gaps in the design regarding the standards but the other way around, a review of the 62600-10 (2015) against requirements from DNVGL-ST-0164 was performed.

4. Certification Procedures

The certification aspects are not covered here. See deliverable D.1.6.1.

5. Technical requirements

5.1. List of contents

A short comparison of the contents of the 62600-2 (CD Jan2018) and the ST-0164 is presented below and will be used to outline the recommendations to TC-114 regarding the 62600-2 later in this document. ##

62600-2	ST-0164	Comments
1. Scope / 2. Normative references / 3. Terms and definitions / 4. Symbols and abbreviated terms	1. Introduction (including References, Definitions and Risk Based Approach)	
5 Principal elements (including safety levels, design principle for structures and foundations, risk and technology assessment)	2. Design Principles (including safety philosophy, safety levels, structural and system design)	Safety levels and safety philosophy are similar between 62600-2 and ST-0164
	3 Manual for Onshore and Offshore works	No equivalent in 62600-2
6. Environmental conditions	4. Site conditions and Characterisation	They both cover the main aspects regarding site conditions
7. Design Load Cases	5. Loads and Load Effects	ST-0164 ST-0164 describes the characteristic loads for temporary design conditions and operational design conditions while 62600-2 only informs for operating conditions. Additional cases are prescribed for floating tidal turbines and reference to multiple rotors is given. Reference is also made to RP-C205. Extensive description of design load cases (combining current, water level, wave and wind) and simulation requirements is provided. For transient

62600-2	ST-0164	Comments
		load cases the requirements are higher than specified in 62600-2 Design Load Cases for Floating Tidal are provided in ST-0164 but not on 62600-2
7. Design Load Cases	6. Load and Resistance Factors (including uncertainties associated with site characterisation data)	ST-0164 load factors are different from 62600-2 (gravity and temp conditions) and different load factors were calibrated and proposed for different safety classes.
8. Materials	7. Materials for Structures and Blades	62600-2 restricts information to a high level regarding steel concrete and composites. Limited information on composite material.
9. Partial Safety Factors for materials	8. Design and Construction of Steel Structures (ULS, FLS, ALS and SLS) 11. Design and Construction of Blades	ST-0164 ST-0164 introduces the different aspects to be checked in steel structure, provides guidance for the different limit states and define specific standards to cover all failure modes and associated analytical procedures. 62600-2 62600-2 are not addressing all aspects of limit states and it is restricting to define partial safety material factors. For steel, concrete and composite materials identify a standard to be used for design of different materials. In general, it is not discussed how the partial safety factors for materials and the specified partial load factors in table 7.4 (7.3.5 Partial safety factors) are compatible with the partial safety factors of the codes identified for design check
10. Electrical, mechanical, instrumentations and control systems	12. Machinery Systems and components (pitch, yaw, drivetrain, auxiliary systems and hydraulic system)	62600-2 provides a brief guidance on consideration of failures in systems regarding the integrity of MEC structure, lightning protection. ST-0164 provides requirements for design of machinery systems and components.
10. Electrical, mechanical, instrumentations and control systems	13. Protection and Safeguarding (including control, safety)	62600-2 provides general advice on considerations for controls regarding failures leading to abnormal operating conditions. ST-0164 provides the technical requirements for design of control, safety, protection, instrumentation of control and safety systems, actuating systems, auxiliary energy storage, remote control, overall safeguarding and the documentation required to demonstrate compliance with the technical requirements. Reference is made to ST-0124 for electrical protection systems.

62600-2	ST-0164	Comments
10. Electrical, mechanical, instrumentations and control systems	14. Electrical Systems	62600-2 provides general advice on considerations for controls regarding failures leading to abnormal operating conditions and electrical isolation. ST-0164 provides technical requirements for design and testing of electrical machines, power transformer, frequency converters, switchgear, back-up power system, cables, lightning protection and array cabling. Reference is made to several IEC standards covering components.
11. Mooring and foundation considerations	9. Foundation and Mooring Systems Design	ST-0164 refers to specific standards to address mooring design and the proposed standards are compatible with the risk based approach. 62600-2 now refers to 62600-10 for the mooring. The -10 uses return period of 100 years for ULS and ALS, while -2 uses 50 years. There is no discussion on compatibility of risks and safety levels between -2 and -10.
12 Life Cycle Considerations (12.3 Stability and Watertight Integrity) and 7.3.7.11	10. Floating Stability	62600-2 gives general advice in 5.8.1 9refering to Clause 12) and 7.3.7.11 refers to DNV-OS-C301 (now replaced by DNVGL-OS-C301) and add few considerations to the temporary conditions (ISO 19901-6 Marine Operations). Not acceptance criteria are given. In Clause 12, refers back to DNV-OS-C301 and add some informative text regarding stability and watertight stability. ST-0164, for manned units, OS-C301 is recommended. For unmanned general requirements related to risk assessment. Requirements for intact and damaged stability is given as well as watertight integrity.
	11. Design and Construction of Blades	62600-2 does not provide requirements for blades. There is only reference to EUROCOMP for design of composites in general. Partial safety factors for composite materials are given in section 9.
	16. Marine Operations	62600-2 does not address marine operations. There is only a list aspects to be considered for transportation in 12.5 and general discussion on metocean limits during transport and commissioning
12. Life Cycle Considerations	17. Maintenance	62600-2 General notes and guidance is presented regarding inspection requirements and considerations during design stage, planning inspections and

62600-2	ST-0164	Comments
		maintenance, maintenance execution and condition assessment.
	18 Tests and Measurements (including power performance and load measurements)	This section in ST-0164 consolidates all the requirements for tests and measurement for blades, main gearbox, generator, transformer, converter, medium-voltage switchgear, load measurements, power performance and safety & function tests
12. Life cycle considerations		62600-2 provides general considerations regarding aspects to be considered during the design life of the energy converter that should be observed by the designer.
Annex A	15. Corrosion Protection	ST-0164 defines, for fixed and floating units, the corrosion zones and applicable methods for corrosion protection, corrosion allowance and cathodic protection coatings 62600-2 provides general guidance regarding corrosion protection philosophy in chapter 5 and more discussion points, guidance and note as well as some references (ISO 11306 for corrosion rates, 12944 for coatings, 12473 for general considerations of cathodic protection, EN 12495 for design for cathodic protection design for fixed steel structure with EN 13173 for floating and ISO 19903 for characterisation of corrosion environment for concrete structures) in Annex (normative) A

TABLE 2 - CONTENT COMPARISON BETWEEN 62600-2 AND ST-0164

A short comparison of the contents of the 62600-10 (2015) and the ST-0164 is presented below and will be used to outline the recommendations to TC-114 regarding the 62600-10 later in this document.

ST-0164

The ST-0164 addresses moorings for floating tidal in Sec. 9.3 Foundation and mooring system design. Requirements for simulation, design load cases, safety level and risk are provided in other parts of the ST-0164.

Regarding anchor foundations reference is made to OS-J103 Sec.9 for guidance on the geotechnical design of the anchoring systems that transfer loads between (1) the mooring lines of the mooring system and (2) the seabed soils. It also gives guidance on the design of grouted rock anchors for transfer of loads from the mooring system to a seabed consisting of rock rather than soil.

For mooring system, safety class is connected to the risks and to the target safety levels in section 2.1.2. The acceptability of risk is given in the Risk Matrix defined in 1.10.5 (and in /1/ section 3.2.4.2) and consideration of redundancy is discussed in the context of floating tidal turbines.

Design tension

For mooring lines, the ultimate loads are given as the sum of two factored characteristics tension components associated to mean tension and dynamic tension:

$$T_d = \gamma_{mean} \cdot T_{c,mean} + \gamma_{dyn} \cdot T_{c,dyn}$$

A description of how to derive the mean and dynamic tension based on 50-year contour in Hs, Tp, and U10 space is given. Reference is made DNVGL-OS-E301 on how to establish the characteristic mean and dynamic tension from time series of tensile response of mooring lines. The mean and dynamic load factors are given to Normal and High Risk covering ULS and ALS as shown in the table below.

Table 9-1 Load factor requirements for design of mooring lines

Limit state	*Load factor*	*Risk*	
		Normal	*High*
ULS	γ_{mean}	1.30	1.50
ULS	γ_{dyn}	1.75	2.20
ALS	γ_{mean}	1.00	1.00
ALS	γ_{dyn}	1.10	1.25

Resistance

The characteristic capacity is based on requirements from DNVGL-OS-E301, DNVGL-OS-E303 and DNVGL-OS-E304 as the basis for manufacturing of the different mooring line components. The characteristic capacity of mooring line is given as below:

$$S_c = \mu_s \cdot \left(1 - COV_S \cdot (3 - 6 \cdot COV_S)\right);\ COV_S < 0.10$$

In which

μ_S, is the mean value of the breaking strength of the component and
COVs, is the coefficient of variation of the breaking strength of the component.

When statistics of the breaking strength of a component are not available, the characteristic capacity of the body of the mooring line can be derived from the minimum breaking strength of new components, or from test results. Reference is made to DNV-OS-J103 Sec. 8-2.3 for further guidance.

Design criterion

The design criterion is specified for ULS and ALS as

$$S_c > T_d$$

and for FLS as

$$D_D = DFF \cdot D_C \quad \text{and} \quad D_D \leq 1.0$$

In which D_C is the characteristic cumulative fatigue damage caused by the stress history in the mooring line over the design life, and in which DFF denotes the Design Fatigue Factor. Requirements for DFF depend on the safety class and are given in 8.3.4.

The characteristic cumulative fatigue damage D_C can be calculated by Miner's sum and for characteristic S-N curves for chain and steel wire ropes, reference is given to DNVGL-OS-E301.

For simplicity, the characteristic cumulative fatigue damage may be calculated by means of the simple conservative "combined spectrum approach" outlined in DNVGL-OS-E301.

62600-10

Most of the content of 62600-10 can be considered as guidance with text of a descriptive nature but not many requirements are given. There are only few parts that effectively make reference to other standards and even in this case, the standard fails to provide some interface and connection between the international standards (listed in its normative references) and the 62600-10 design philosophy. Also, it fails to provide connection with

the 62600-2 safety levels (it is not even in the normative reference list).

Clause 9 - Analysis procedure is generic and informative on the issues to be considered but there are no parameters and requirements informing what is and what is not acceptable. The TS allows for frequency domain, and quasi-static analysis and there is only a generic discussion on the limitations of such approach, but not parameters to characterise when the approaches are not acceptable. In 9.6 it defines the design return period for ULS and ALS as 100-year although the 62600-2 is applying the 50-year return period for the same limit states. The consequence class design factor presented in Table 4 and the consequence classes are defined in section 8.5 Table 3 – Consequence class. However, there is no connection with risk levels and acceptance of risk through a risk matrix (that it is also not given).

Table 3 – Consequence class

Life safety category	Consequence class		
	High consequence	Medium consequence	Low consequence
Manned non-evacuated	3	3	3
Manned evacuated	3	2	2
Unmanned	3	2	1

Table 4 – Consequence class associated design factors

Consequence class	Design factor (DF)
3	1,5
2	1,3
1	1,0

The Consequence class design factor multiplies the Safety factors given in Table 5. The design criterion is:

MBL / Design tension > ASF = SF and DF

in which

MBL is the Minimum Breaking Load associated with the expected corroded line size,
Design tension is the Most Probable Maximum (MPM) dynamic tension,
SF is the safety factor and
DF is the Design factor.

The safety factors are taken from ISO 19901-7 a standard with requirements for floating production and mobile offshore units. The 62600-10 alerts about possible limitation when applied to MECs. The safety factors, in this case, are only associated with the design condition and method of analysis. The consequence of failure is not taken into account. By introducing the consequence class design factor, the 62600-10 has the intention to introduce the impact of consequence on the safety factors, but there is no traceability on how the selected values align with the ISO intended safety level and the risk levels discussed in other parts of the TS or how they reduce the probability of failures in a compatible way with the consequences.

At the moment, the consequence class 1 (a mooring failure may include minimal human injury, minimal environmental impact, minimal navigable waterway impact and minimal financial or property impact) has a design factor of 1.0, i.e. the target safety level used by ISO 19901-7 is applied. Although the definition of minimal is not given, it seems to imply a close to zero impact, i.e. something that can be ignored.

In this case, it is possible to state that the 62600-10 has a target safety level higher than the ISO 19901-7.

5.2. References

5.2.1. General

In general, the reference to other standards is used to provide important additional and specific technical requirements covering subjects that requires careful consideration and that due to the complex nature and extent of content is not included in the main standard. The content of the referenced standard must be

compatible with the principles of the main standards for the technologies addressed within the context of their application range.

The IEC define normative references as documents that some or all of their content constitutes requirements of the referencing document (main standard). Normative references are restricted to IEC or ISO references. The IEC also provides bibliography, documents that were considered during the development of standard or that provides more information on the different subjects addressed in the standard. Compliance with their content is not a requirement.

DNV GL provides a list of relevant DNV GL standards and recommended practices that are applicable to fulfil the technical requirements of the main standard. However, DNV GL also refers to other industry standards (non-DNV GL codes) in which the technical content is also considered acceptable to DNV GL. In case of any conflict between the requirements of this standard and a non-DNV GL reference document the requirements of the DNV GL standard shall prevail. Non-DNV GL codes or standards may be applied as an alternative provided that it can be demonstrated that the resulting safety level is the same or higher than specified in DNVGL-ST-0164. Where a reference in the main standard is made to codes other than DNV GL documents, the valid revision of these codes shall be taken as the revision which was current at the date of issue of this standard, unless otherwise noted. When code checks are performed according to other codes than DNV GL codes, the resistance and material factors as given in the respective codes shall be checked for compatibility with the main standard. Where applicable, national and governmental regulations may override the requirements of this standard.

5.2.2. IEC and DNV GL reference list

The TS 62600-2 (CD Jan2018) defines the following normative references:

Reference	Title
IEC 60812	Analysis techniques for system reliability – Procedure for failure mode and effects analysis (FMEA)
IEC 60092-352	Choice and installation of electrical cables
IEC 61882	Hazard and operability studies (HAZOP studies) - Application guide
IEC 62305-3	Protection against lightning – Part 3: Physical damage to structures and life hazard
IEC TS 62600-1	Marine energy – Wave, tidal and other water current converters – Part 1: Terminology
IEC 62600-101	Marine energy - Wave, tidal and other water current converters - Part 101: Wave energy resource assessment and characterization
IEC 62600-201	Marine energy - Wave, tidal and other water current converters - Part 201: Tidal energy resource assessment and characterization
IEC TS 62600-10	Marine energy – Wave, tidal and other water current converters – Part 10: Assessment of mooring system for marine energy converters (MECs)
ISO 2394	General principles on reliability for structures
ISO 12473	General principles of cathodic protection in sea water
ISO 17776	Major accident hazard management during the design of new installations
ISO 19900	Petroleum and natural gas industries – General requirements for offshore structures
ISO 19901-1	Petroleum and natural gas industries – Specific requirements for offshore structures – Part 1: Metocean design and operating considerations
ISO 19901-4	Petroleum and natural gas industries – Specific requirements for offshore structures – Part 4: Geotechnical and foundation design considerations
ISO 19901-6	Petroleum and natural gas industries – Specific requirements for offshore structures – Part 6: Marine operations
ISO 19902	Petroleum and natural gas industries – Fixed steel offshore structures
ISO 19903	Petroleum and natural gas industries – Fixed concrete offshore structures
ISO 31010	Risk management -- Risk assessment techniques
EUROCOMP	Structural design of polymer composites
DNV-OS-C301	Stability and watertight integrity
DNV-OS-C501	Composite components
DNV-OS-D101	Marine and machinery systems and equipment
DNV-OS-D201	Electrical installations
DNV-RP-C205	Environmental conditions and environmental loads

TABLE 3 - NORMATIVE REFERENCES - 62600-2

The TS 62600-10 (2015) defines the following normative references:

Reference	Title
IEC TS 62600-1	Marine energy – Wave, tidal and other water current converters – Part 1: Terminology
ISO 17776:2000	Petroleum and natural gas industries – Offshore production installations – Guidelines on tools and techniques for hazard identification and risk assessment
ISO 19901-1:2005	Petroleum and natural gas industries – Specific requirements for offshore structures – Part 1: Metocean design and operating considerations
ISO 19901-7:2013	Petroleum and natural gas industries – Specific requirements for offshore structures – Part 7: Stationkeeping systems for floating offshore structures and mobile offshore units
API RP 2SK	Design and Analysis of Station keeping Systems for Floating Structures, 3rd Edition, October 2005
API RP 2I	In-Service Inspection of Mooring Hardware for Floating Structures, 3rd Edition, 2008

TABLE 4 - NORMATIVE REFERENCES - 62600-10

The references given in ST-0164 are extensive as they address several systems and components, complementing and further detailing the technical requirements from ST-0164. The normative references are sourced from Service Specifications, Standards, Offshore Standards and Recommended Practices, Rules for Classification, Rules for Certification and Classification Notes as published by DNV GL, legacy DNV and legacy GL. In addition, a long list of other references, provided in Annex A, is given in ST-0164 mainly covering electrical and mechanical components. They are referred within the text of ST-0164 as required, but in general other references are used to indicate acceptable standards that can be used to provide additional / supplementary technical requirements.

Reference	Title
DNVGL-OS-B101	Metallic Materials
DNVGL-OS-C301	Stability and Watertight Integrity
DNVGL-OS-C401	Fabrication and Testing of Offshore Structures
DNVGL-OS-E301	Position mooring
DNVGL-OS-E302	Offshore Mooring Chain
DNVGL-OS-E303	Offshore Fibre Ropes
DNVGL-OS-E304	Offshore Mooring Steel Wire Ropes
DNVGL-SE-0124	Certification of Grid Code Compliance
DNVGL-SE-0163	Certification of tidal turbines and arrays
DNVGL-ST-0125	Grid Code Compliance
DNVGL-RP-0005	RP-C203: Fatigue design of offshore steel structures
DNV-OSS-312	Certification of Tidal and Wave Energy Converters
DNV-OS-C501	Composite Components
DNV-OS-C502	Offshore Concrete Structures
DNV-OS-H101	Marine Operations, General
DNV-OS-J101	Design of Offshore Wind Turbine Structures
DNV-OS-J103	Design of Floating Wind Turbine Structures
DNV Rules for Classification of Ships Pt. 2 Ch. 2 Metallic Materials	
Rules for Ships Part 4 Chapter 6 Piping Systems	
DNV-RP-A203	Technology Qualification
DNV-RP-B401	Cathodic Protection Design
DNV-RP-C104	Column-Stabilised Units
DNV-RP-C201	Buckling Strength of Plated Structures
DNV-RP-C202	Buckling Strength of Shells
DNV-RP-C204	Design against Accidental Loads

Reference	Title
DNV-RP-C205	Environmental Conditions and Environmental Loads
DNV-RP-C208	Determination of Structural Capacity by Non-linear FE analysis Methods
DNV-RP-G101	Risk Based Inspection of Offshore Topsides Static Mechanical Equipment
DNV-RP-H101	Risk Management in Marine and Subsea Operations
CN No. 30.4	Foundations
CN No. 30.7	Fatigue Assessment of Ship Structures
GL Rules for Classification and Construction - I Ship technology - Part 5 "Underwater Technology", Chapter 3 "Unmanned Submersibles (ROV, AUV) and Underwater Working Machines"	
GL Rules for Classification and Construction - III Naval Ship Technology - Part 1 "Surface Ships", Chapter 2 "Propulsion Plants"	
GL Rules for Classification and Construction IV – Industrial Services, Part 2 – GL Guideline for the Certification of Condition Monitoring Systems for Wind Turbines Edition 2013	
GL Rules for Classification and Construction IV – Industrial Services, Part 7 – Offshore Substations, Edition 2013	
GL Rules for Classification and Construction IV – Industrial Services, Part 2 – GL Guidelines for the certification of Offshore Wind Turbines, Edition 2012	
GL Technical Publication “Recommendations for Rudder Design Preventive Measures to Decrease or Avoid Rudder Cavitation”	

TABLE 5 - NORMATIVE REFERENCES – ST-0164

Both ST-0164 and 62600-2 refer to the following documents:

Reference	Title
IEC 62305-3	Protection against lightning - Part 3: Physical damage to structures and life hazard
ISO 19902	Petroleum and natural gas industries - Fixed steel offshore structures
DNVGL-OS-C301	Stability and Watertight Integrity
DNV-OS-C501	Composite Components
DNV-RP-C205	Environmental Conditions and Environmental Loads

TABLE 6 – COMMON DOCUMENTS 62600-2 AND ST-0164

It is important to highlight that the IEC 62600-2 (DRAFT) Marine energy - Wave, tidal and other water current converters - Part 2: Design requirements for marine energy systems is referred to in ST-0164 to reflect the overall compatibility regarding safety philosophy and safety classes definitions between the two documents.

6. Main observations and recommendations

6.1. Certification process

Not covered in this report. See deliverable D.1.5.1.

6.2. Technical requirements

62600-2 (CD Jan 2018)

Reference is made to deliverable D.1.6.1 Sec. 6.2. The previous recommendations were re-visited and new recommendations given when applicable.

Considering the comments in Table 6 - Content comparison between 62600-2 and ST-0164, and the required technical content to achieve prototype / type certification, the main comments and recommendations are presented below. Please note that comments provided to TC-114 and passed on to the TC-114 MT 62600-2 are not addressed here although some of the recommendations may be similar.

1. The 62600-2 should be either renamed to reflect the scope focused on structural design requirements or significant content to cover all systems that are part of a marine energy converter must be added. In case of confirmation of the scope restricted to structures, other TSs will be needed to cover the overall technical requirements for design, construction, testing, deployment and in-service life of all turbine systems and support structure. For an estimate of work required in the case of extension of scope of 62600-2, please see ST-0164.

    - A new introduction was written. However, it is still not explicitly referring to the focus on structural scope as it mentions "minimum design requirements for marine energy converters".

2. There is a general inconsistency and lack of detail in the resistance / capacity model of the TS (Section 9). This has been the centre of many comments and may require enormous amount of work to provide the necessary detailed requirements. However, considering that once the forces, stresses and displacements are identified for the ULS, FLS and ALS, the requirements for the resistance / capacity model can be obtained from existing standards for the detailed design of steel, concrete and composite structures with the necessary level of detail to control all failure modes. In this case, the 62600-2 should provide the necessary interface between the design philosophy applicable to TECs and of those selected standards to cover the resistance model as well as which sections of the nominated standards are applicable.

    - TS (Section 9) has been updated. The resistance / capacity model for design is now linked to design standards (ISO 19902 for steel structures, ISO 19903 for concrete structures and EUROCOMP to composite structures) where all failure modes are addressed. Partial material safety factors are given for steel, concrete and composite, but it is not clear why reference is not made to the nominated standards. Explicit reference to the applicable / specific parts of the nominated standards should be made.

    - Please note that EUROCOMP is not an international standard. EUROCOMP Design Code is the product of the work of the EUROCOMP Project Steering Committee, which represents the views of a wide body of designers, academic and manufacturing organisations as to what is considered to be current good practice and it applies to the structural design of buildings and civil engineering works in glass fibre reinforced polymeric composites. Compatibility with marine application needs to be addressed as well as the partial safety factors.

3. The existing text in Section 9 should be replaced by clear recommendations on the applicability (and where needed, adaptation) of the standards. It is expected that the number of recommendations would be limited as adopting resistance / capacity model of the nominated standards for steel, concrete and composite, will also requires that the partial safety factors in 62600-2 are derived / calibrated / adjusted with due consideration of the resistance / capacity models for the different nominated standards.

    - The partial safety factors in 62600-2 should be calibrated and checked / adjusted with due consideration of the resistance / capacity models for the different nominated standards.

    - In 7.3.5 the statement "In order to cope with the fact that the technology of many designs is new and yet unverified, 807 the partial load safety factors in Table 5 may be increased" is providing allowance for uncertainties and novelties. However, there is no requirement on how this is to be carried out.

4. Section 8 refers to carbon steel, stainless steel, aluminium, composites and concrete as structural materials. In this case, nominated standards covering aluminium and stainless steel as structural materials will need to be selected. It is probably not the intention of the 62600-2 to have the use of aluminium and stainless steel for large parts of the structures, but more likely application in local details or secondary structures in case of aluminium. Section 8 should be re-worded to consider the acceptable materials from the nominated standards for resistance models. In this case, the nominated standards would define specific criteria for structural categorisation and material selections as well as inspection requirements during fabrication.

    - Standards have been nominated to provide the criteria for material selection. However, reference to aluminium is still present without any reference to a design code to help on the material selection, but also with the design requirements for the use of aluminium.

5. Partial safety factors defined in the 62600-2 require calibration in line with the minimum simulation requirements for the different limit states and the resistance criteria from nominated standards for definition of resistance model. The 62600-2 provides some consideration regarding simulation for tidal energy converters, but the resistance model is scattered and limited. For tidal energy converters, the partial safety factors presented in DNVGL-ST-0164 have been calibrated considering the most critical failure mode, the simulations requirements for the different limit states and the material factors considered in the different standards for steel, composite and concrete capacity model. For blades, the factors and resistance / capacity model were specified for application in tidal energy converters and included in the standard.

- The partial load safety factors presented in 62600-2 should have their suitability against the target safety levels of nominated standards verified.
- The nominated composite design code does not provide specific requirements for blades. It is recommended that specific requirements for blades are developed or a nomination of a standard addressing blade material, design and construction should be made.

6. Although the ST-0164 is a specific document for tidal turbines, what is proposed above is largely applied to the ST-0164, as there was no benefit to re-write capacity models into the standard when they are already available in other standards. For example, in ST-0164, the description of the design by partial safety factors method is discussed briefly and reference is made to DNV-OS-J101 Sec.2. For structural probability-based design, reference is made to the requirements in DNV-OS-J101 Sec.2. For guidance on analysis of ship impact, reference is made to DNV-OS-J101 Sec.4. The same is done for guidance on wave breaking and slamming loads. For selection, structural categorisation and material certificate requirements of structural steel for design and construction of support structures, reference is made to the materials section of DNV-OS-J101 Sec.6. The requirements for structural design given in DNV-OS-J101 are referred to with the exceptions, deviations and additional requirements specified in ST-0164. Other standards are referred to for some specific steel constructions such as shell, tubular members and joints, non-tubular beams, etc. DNV-OS-J101 Sec.7 Design of Steel Structures, provides the overall framework for the requirements for the different limit states.
   - See comment 3 above.
7. Specific provisions for control of uncertainty on the site characterisation should be provided in 62600-2 (uncertainty factor or use of sensitive studies to identification of magnitude of uncertainties). It is recognised that there is a large spatial variation on characterisation of site. Also, site measurements are normally of short duration and the robustness of statistics, especially for waves, are not sufficient for a reasonably accurate definition of design condition for extreme seastates. The existing TSs are focused on performance rather than extreme conditions.
   - It is still valid.
8. Specific provision in 62600-2 should be given to address the uncertainty regarding the analytical models.
   - It is still valid.
9. For a risk-based document, there is a need to provide partial safety factors considering the different safety levels.
   - This is still valid. In addition, it needs to be consistent with the nominated design standards.
10. There is a need to define if Allowable Stress Design (ASD) is to be accepted and guidance given on how to apply the requirements for the 62600-2 to ASD.
    - ASD is no longer referred to.
11. There is a need to address multiple turbines. Load combinations in 62600-2 should include provision for multiple turbines for ULS, ALS and FLS.
    - It is still valid.
12. Geotechnical aspects are to be included. Again, reference to existing standard should be used and the 62600-2 should discuss the specific problems related to limited geotechnical site data and the compatibility between selected standards and 62600-2 safety philosophy.
    - Reference is made in general to ISO 19901-4 Geotechnical and foundation design considerations for geotechnical aspects. However, the specific problems related to limited geotechnical site data and the compatibility between selected standards and 62600-2 safety philosophy.
13. There is a need to emphasise, in 62600-2, the application of risk assessment and to define the conditions where abnormal and accidental cases are to be considered. Also, it is recommended to connect the safety levels with a risk matrix used in the risk assessment / technology qualification. This correlation between safety levels and risk is to be further defined in 62600-2 with due consideration of contents of IECRE OD on technology qualification.
    - It is still valid.

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1. To refer to international standards and to focus on the specifics for MECs is described as the objective of the TS. However, the use of international standards needs to be guided and interfaced properly to integrate the adaptable parts of the standard to the needs of MECs. With the text in most of the TS clauses being

informative, references to the parts of the international standard(s) providing requirements for the different parts of the mooring system should be added to the text (this includes, for example, specification of analysis requirements, corrosion allowance, marine growth, etc.). Any specific deviation from the standards (dispensation or additional requirements) should be provided.

2. Clause 5.4 – Safety and risk consideration and 8 – Safety and risk considerations does not offer a risk matrix to identify the risk levels (low, medium and high). These would provide a consistent and clear methodology to assess the range of risks (as described in 62600-2). This would also allow to connect risks with target safety levels that would lead to the proper safety factors. Furthermore, reference is made to ALARP principle in 8.2.5 but no parameters were offered to allow an ALARP assessment. Also, it is not clear how this is implemented in the TS requirements.

3. In 8.3.4. reference is made to the probability of the initial mooring failure occurring is the inverse of the return period of environmental condition that results in failure, i.e. 1/100 (i.e. 10-2). This is not correct. That is only the probability that the environmental conditions used for design could be exceed. The probability of failure of the mooring line has to consider the resistance side of the equation (the mooring line capacity) and the load and material factors applied.

4. In Table 3 – Consequence class, the life safety category column (manned non-evacuated, manned evacuated and unmanned structures) are implicitly a category of consequence. Thus, the table 3 are crossing consequence (loss of life) with consequence (safety versus safety, damage, financial, environmental). It is recommended to applied the risk approach allowing to assess all types of consequences against their likelihood with clear definition of levels of risk (low, medium, high), in a risk matrix, with clear connection with target safety levels. The connection between risk and target safety level makes the clear connection between design factor and risk allowing to define what should be the overall required target safety level. If the present approach of ASF = DF*SF is to be kept to make a clear connection with the safety factors from ISO 19901-7, the design factors should be calibrated to achieve the overall safety level. Otherwise, different safety factors could be derived for different risk levels.

5. Annual probability of failure: As the ISO 19901-7 is considered for safety factors and definition of line tension, it is recommended to explicitly inform what is the target annual probability of failure considered in the 62600-10 considering that different target safety levels are to be applied depending on the risk of MEC. See below. ISO 19901-7 does not explicitly inform the targets that it is used in the standard.

6. It is recommended that the three categories low, medium and high consequence should be re-defined and reassessed. At the moment, even for low consequence the minimum safety factor to be considered is the value from ISO 19901-7 that is applied to Floating Offshore Units, without consideration of different consequences (as it is a standard specific for an object, the consequence is probably implicit for this type of unit). The minimum ASF for low consequence is the same as the ISO 19901-7 and it is increased by 1.3 and 1.5 for consequence classes 2 and 3 respectively. Mooring systems should not be targeting the low safety level as the consequences and associated likelihoods are normally combined in a medium to high risk, especially for arrays construction. Thus, the consequence classes could be reduced from three to two and the overall target annual probability of failure considered should be 10^{-4} to normal and 10^{-5} to high risk.

7. No requirements are given for FLS safety margins. Consideration should be given, in this case, to the different safety margins required considering the risk levels.

8. The 62600-10 should be compatible and refer to the safety philosophy as in 62600-2 Clause 5 Principal elements. Also 62600-2 should be included in the list of normative references in 62600-10.

9. Reference is made to “temporary mooring” in section 9. However, there is no definition of temporary mooring and in what conditions this would be applied to MECs. If this is a way to reduce requirements for short deployments for prototypes, this needs to be clearly defined. From the definition in 3.10, it is thought that the temporary mooring is considered to be “mobile mooring” (though this is also misleading as temporary mooring normally refers to marine grade equipment used on ships for in-shore or quayside *temporary* applications). It is recommended that such classifications “temporary” and “mobile” are removed from the TS. Even with short deployments mooring systems for MECs should not be classed as “mobile mooring” as this is a specific definition for the O&G sector and has implicit assumptions for mooring in-service management under the Class regime.

10. Definitions of axial and lateral loading should be given with regards to the anchor holding capacity safety factors (Table 7 and Table 8).

11. In Clause 6, reference is made to Dynamic Positioning. Even as a descriptive text, this reference seems out of scope for MEC and should be removed.

12. Mooring system proof loading (10.2): There is a requirement for all moorings to be load tested after initial installation. Although this is a sensible requirement for moorings with drag anchors and other foundations that there is a large uncertainty regarding the final installation integrity, consideration should be given to other ways to demonstrate suitable construction in case load testing is not possible due to the magnitude of loading or the foundation is of a different type (for example, pile anchors).

13. Clauses 10.4 and 10.5 addresses the inspection during the in-service life. However, no requirements about the frequency of inspection is provided. It is suggested that, this section does not need to provide a set of requirement but explicitly refer to established offshore standards (e.g. DNVGL-OS-E303 Offshore fibre ropes) and guidance documents (e.g. API-RP-2I and also the UK Oil and Gas mooring integrity management guidelines which provide a basis for performing mooring integrity review considering design, manufacturing, installation and in-service phases).

    Further, the last paragraph in 10.5 refers to apply higher tensions in the mooring line than the normally present under operating conditions. If this is to be performed, this becomes a design governing case and should be included in the ULS design conditions.

14. As a general note, there needs to be a better distinction between requirements (shall and should) and guidance. The use of "guidance note" is a recommended as it clearly demarks what is guidance and what is requirement

Annex A

Reference	*Title*
	AISC LRFD Manual of Steel Construction
ASTM A320	Standard Specification for Alloy-Steel and Stainless Steel Bolting for Low-Temperature Service
ASTM C273	Standard Test Method for Shear Properties of Sandwich Core Materials
ASTM C297	Standard Test Method for Flatwise Tensile Strength of Sandwich Constructions
ASTM C393	Standard Test Method for Core Shear Properties of Sandwich Constructions by Beam Flexure
ASTM D5528	Standard Test Method for Mode I Interlaminar Fracture Toughness of Unidirectional Fiber-Reinforced Polymer Matrix Composites
ASTM D5868	Standard Test Method for Lap Shear Adhesion for Fiber Reinforced Plastic (FRP) Bonding
ASTM D6641	Standard Test Method for Compressive Properties of Polymer Matrix Composite Materials Using a Combined Loading Compression (CLC) Test Fixture
ASTM D7078	Standard Test Method for Shear Properties of Composite Materials by V Notched Rail Shear Method
BGI 753	SF6-Anlagen und -Betriebsmittel
BGV A8	Sicherheits- und Gesundheitsschutzkennzeichnung am Arbeitsplatz
BS 7910	Guide to methods for assessing the acceptability of flaws in metallic structures
CIGRE TB490	Recommendations for Testing of Long AC Submarine Cables with Extruded Insulation for System Voltage above 30 (36) to 500 (550) kV
DIN 3990-4	Calculation of load capacity of cylindrical gears; introduction and general influence factors
DIN 53292	Testing of sandwiches; Tensile test perpendicular to the faces
DIN 53294	Testing of sandwiches; Shear test
DIN 53752	Testing of plastics; determination of the coefficient of linear thermal expansion
DIN 6892	Drive type fastenings without taper action - Parallel keys - Calculation and design
DIN 7190	Interference fits - Calculation and design rules
DIN 743	Calculation of load capacity of shafts and axles
DIN EN ISO 6721-5	Plastics -- Determination of dynamic mechanical properties -- Part 5: Flexural vibration -- Non-resonance method
DIN EN ISO IEC 17020	Conformity assessment - General criteria for the operation of various types of bodies performing inspection
DIN EN ISO IEC 17025	General requirements for the competence of testing and calibration laboratories
DIN EN ISO IEC 45011	Replaced by ISO IEC 17065:2012 Conformity assessment - Requirements for bodies certifying products, processes and services
DIN EN 50160	Voltage characteristics of electricity supplied by public distribution networks
Electra No. 189	Recommendations for tests on power transmission DC cables for rated voltage up to 800 kV
Electra No. 206	Testing DC extruded cable systems for Power Transmission up to 250 kV
Electra No. 218	Addendum to "Recommendations for tests of power transmission DC cables up to 800 kV"
Electra TB No. 219	Recommendations for testing DC extruded cable systems for power transmission at a rated voltage up to 250 kV
EN 10204 (ISO 10474)	Metallic products - Types of inspection documents
EN 1993-1-6	Eurocode 3: Design of steel structures - Part 1-6: Strength and stability of shell structures
EN 50160	Voltage characteristics of electricity supplied by public electricity networks
EN 60909	Short-circuit currents in three-phase a.c. systems
EquiMar Project Deliverable 2.3	Application of Numerical Models

Reference	*Title*
EquiMar Project Deliverable 4.2	Data Analysis and Presentation to Quantify Uncertainty
Equimar Project Deliverable 2.2	Wave and Tidal Resource Characterisation
Equimar Project Deliverable 2.3	Numerical models
Equimar Project Deliverable 2.7	Protocols for wave and tidal resource assessment
Eurocode 3 EN 1993-1-1	Eurocode 3: Design of steel structures - Part 1-1: General rules and rules for buildings
Eurocode 7	Geotechnical design
Eurocode 8-5	Design of structures for earthquake resistance - Part 5: Foundations, retaining structures and geotechnical aspects
IEC 60034	Rotating electrical machines
IEC 60034-1	Rotating electrical machines - Part 1: Rating and performance
IEC 60034-14	Rotating electrical machines - Part 14: Mechanical vibration of certain machines with shaft heights 56 mm and higher - Measurement, evaluation and limits of vibration severity
IEC 60034-16-3	Rotating electrical machines -- Part 16-3: Excitation systems for synchronous machines - Dynamic performance
IEC 60068	Environmental testing
IEC 60076	Power transformers
IEC 60076-1	Power transformers - Part 1: General
IEC 60076-11	Power transformers - Part 11: Dry-type transformers
IEC 60076-16	Power transformers - Part 16: Transformers for wind turbine applications
IEC 60099-1	Surge arresters – Part 1: Non-linear resistor type gapped surge arresters for a.c. systems
IEC 60099-4	Surge arresters – Part 4: Metal-oxide surge arresters without gaps for a.c. systems
IEC 60112	Method for the determination of the proof and the comparative tracking indices of solid insulating materials
IEC 60204-1	Safety of machinery - Electrical equipment of machines - Part 1: General requirements
IEC 60204-11	Safety of machinery - Electrical equipment of machines - Part 11: Requirements for HV equipment for voltages above 1 000 V a.c. or 1 500 V d.c. and not exceeding 36 kV
IEC 60227	Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V
IEC 60228	Conductors of insulated cables
IEC 60269	Low-voltage fuses
IEC 60282-1	High-voltage fuses - Part 1: Current-limiting fuses
IEC 60287	Electric cables - Calculation of the current rating
IEC 60364	Low-voltage electrical installations
IEC 60364-5-52	Low-voltage electrical installations - Part 5-52: Selection and erection of electrical equipment - Wiring systems
IEC 60364-6	Low-voltage electrical installations - Part 6: Verification
IEC 60502	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)
IEC 60721	Classification of environmental conditions
IEC 60721-3-3	Classification of environmental conditions - Part 3-3: Classification of groups of environmental parameters and their severities - Stationary use at weatherprotected locations
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 60947	Low-voltage switchgear and controlgear

Reference	*Title*
IEC 60947-5-5	Low-voltage switchgear and controlgear - Part 5-5: Control circuit devices and switching elements - Electrical emergency stop device with mechanical latching function
IEC 61000-4-30	Electromagnetic compatibility (EMC) - Part 4-30: Testing and measurement techniques - Power quality measurement methods
IEC 61082	Preparation of documents used in electrotechnology
IEC 61400-12-1	Wind turbines - Part 12-1: Power performance measurements of electricity producing wind turbines
IEC 61400-13	Measurement of mechanical loads
IEC 61400-21	Wind turbines - Part 21: Measurement and assessment of power quality characteristics of grid connected wind turbines
IEC 61400-23	Wind turbines - Part 23: Full-scale structural testing of rotor blades
IEC 61400-24	Wind turbine generator systems - Part 24: Lightning protection
IEC 61439-1	Low-voltage switchgear and controlgear assemblies - Part 1: General rules
IEC 61643-12	Low-voltage surge protective devices – Part 12: Surge protective devices connected to low-voltage power distribution systems – Selection and application principles
IEC 61643-22	Low-voltage surge protective devices - Part 21: Surge protective devices connected to telecommunications and signalling networks – Selection and application principles
IEC 61800-1	Adjustable speed electrical power drive systems - Part 1: General requirements - Rating specifications for low voltage adjustables speed d.c. power drive systems
IEC 61800-2	Adjustable speed electrical power drive systems - Part 2: General requirements - Rating specifications for low voltage adjustable frequency a.c. power drive systems
IEC 61800-3	Adjustable speed electrical power drive systems - Part 3: EMC requirements and specific test methods
IEC 61800-4	Adjustable speed electrical power drive systems - Part 4: General requirements - Rating specifications for a.c. power drive systems above 1 000 V a.c. and not exceeding 35 kV
IEC 61800-6	Adjustable speed electrical power drive systems - Part 6:Guide for determination of types of load duty and corresponding current ratings
IEC 61892-2	Mobile and fixed offshore units - Electrical installations - Part 2: System design
IEC 61892-3	Mobile and fixed offshore units - Electrical installations - Part 3: Equipment
IEC 62061	Safety of machinery - Functional safety of safety-related electrical, electronic and programmable electronic control systems
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 62124	Photovoltaic (PV) stand alone systems - Design verification
IEC 62271	High-voltage switchgear and controlgear
IEC 62305	Protection against lightning
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 62477-1	Safety requirements for power electronic converter systems and equipment - Part 1: General
IEC 62600-2	(DRAFT) Marine energy - Wave, tidal and other water current converters - Part 2: Design requirements for marine energy systems
IEC 62600-200	Marine energy - Wave, tidal and other water current converters - Part 200: Electricity producing tidal energy converters - Power performance assessment
IEC 82079	Preparation of instructions for use - Structuring, content and presentation
IEC 82079-1	Preparation of instructions for use - Structuring, content and presentation - Part 1: General principles and detailed requirements

Reference	*Title*
IEC TR 60721-4-3	Classification of environmental conditions - Part 4-3: Guidance for the correlation and transformation of environmental condition classes of IEC 60721-3 to the environmental tests of IEC 60068 - Stationary use at weather protected locations
IMO MEPC.107(49)	Revised guidelines and specifications for pollution prevention equipment for machinery space bilges of ships
ISO 10474	Steel and steel products -- Inspection documents
ISO 1172	Textile-glass-reinforced plastics - Prepregs, moulding compounds and laminates - Determination of the textile-glass and mineral-filler content - Calcination methods
ISO 1219-2	Fluid power systems and components - Graphical symbols and circuit diagrams - Part 2: Circuit diagrams
ISO 1328-1	Cylindrical gears -- ISO system of flank tolerance classification -- Part 1: Definitions and allowable values of deviations relevant to flanks of gear teeth
ISO 13849-1	Safety of machinery - Safety-related parts of control systems - Part 1: General principles for design
ISO 13850	Safety of machinery - Emergency stop - Principles for design
ISO 14126	Fibre-reinforced plastic composites - Determination of compressive properties in the in-plane direction
ISO 14635-1	Gears -- FZG test procedures -- Part 1: FZG test method A/8,3/90 for relative scuffing load-carrying capacity of oils
ISO 17025	General requirements for the competence of testing and calibration laboratories
ISO 175	Plastics - Methods of test for the determination of the effects of immersion in liquid chemicals
ISO 179	Plastics -- Determination of Charpy impact properties
ISO 1940-1	Mechanical vibration -- Balance quality requirements for rotors in a constant (rigid) state -- Part 1: Specification and verification of balance tolerances
ISO 19901-1	Petroleum and natural gas industries -- Specific requirements for offshore structures -- Part 1: Metocean design and operating considerations
ISO 19901-2	Petroleum and natural gas industries - Specific requirements for offshore structures - Part 2: Seismic design procedures and criteria
ISO 19901-8	Petroleum and natural gas industries -- Specific requirements for offshore structures -- Part 8: Marine soil investigations
ISO 19902	Petroleum and natural gas industries - Fixed steel offshore structures
ISO 22475-1	Geotechnical investigation and testing - Sampling methods and groundwater measurements - Part 1: Technical principles for execution
ISO 281	Rolling bearings -- Dynamic load ratings and rating life
ISO 291	Plastics - Standard atmospheres for conditioning and testing
ISO 3521	Plastics -- Unsaturated polyester and epoxy resins -- Determination of overall volume shrinkage
ISO 4413	Hydraulic fluid power - General rules and safety requirements for systems and their components
ISO 4587	Adhesives -- Determination of tensile lap-shear strength of rigid-to-rigid bonded assemblies
ISO 4624	Paints and varnishes - Pull-off test for adhesion
ISO 527	Plastics - Determination of tensile properties
ISO 527-4	Plastics - Determination of tensile properties - Part 4: Test conditions for isotropic and orthotropic fibre-reinforced plastic composites
ISO 527-5	Plastics - Determination of tensile properties - Part 5: Test conditions for unidirectional fibre-reinforced plastic composites
ISO 62	Plastics -- Determination of water absorption
ISO 6270-1	Paints and varnishes -- Determination of resistance to humidity -- Part 1: Continuous condensation
ISO 6336	Calculation of load capacity of spur and helical gears
ISO 6336-1	Calculation of load capacity of spur and helical gears -- Part 1: Basic principles, introduction and general influence factors

Reference	*Title*
ISO 6336-2	Calculation of load capacity of spur and helical gears -- Part 2: Calculation of surface durability (pitting)
ISO 6336-3	Calculation of load capacity of spur and helical gears -- Part 3: Calculation of tooth bending strength
ISO 6336-5	Calculation of load capacity of spur and helical gears -- Part 5: Strength and quality of materials
ISO 6336-6	Calculation of load capacity of spur and helical gears -- Part 6: Calculation of service life under variable load
ISO 7010	Graphical symbols - Safety colours and safety signs - Registered safety signs
ISO 75-2	Plastics -- Determination of temperature of deflection under load -- Part 2: Plastics and ebonite
ISO 76	Rolling bearings -- Static load ratings
ISO 898	Mechanical Properties of Fasteners
ISO 9227	Corrosion tests in artificial atmospheres -- Salt spray tests
ISO 9664	Adhesives - Test methods for fatigue properties of structural adhesives in tensile shear
ISO/TR 13989	Calculation of scuffing load capacity of cylindrical, bevel and hypoid gears
ISO/TS 16281	Rolling bearings -- Methods for calculating the modified reference rating life for universally loaded bearings
NORSOK G-001	Marine soil investigations
NORSOK N-004	Design of steel structures
VDE 0101	Power installations exceeding AC 1 kV
VDI 2230	Systematic calculation of high duty bolted joints

TABLE 7 – OTHER REFERENCES ST-0164