RULES

PUBLICATION 130/P

OFFSHORE WIND FARMS

August
2021

Publications P (Additional Rule Requirements) issued by Polski Rejestr Statków
complete or extend the Rules and are mandatory where applicable.

GDAŃSK

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PRS/RP, 10/2023

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PART I

General information and requirements

1 GENERAL

PRS has identified the offshore wind energy as a dynamically developing industry branch in many aspects. Further development of this publication in cooperation with various stakeholders should ensure continuous improvement in the implementation and admission of the latest technologies at the required level, maintaining risk at acceptable level and in increasing safety during the whole life cycle of the offshore wind farms projects.

PRS participates in the process of technical requirements development on international markets, among the others through participation in the work of IACS working groups and cooperation with IMO sections, and through the realization of innovative research and development projects. PRS shares its knowledge and experience by organizing seminars and trainings addressed to various sectors of industry, administration and academia.

The Polish Register of Shipping is a classification society performing an independent supervision activity to the principles defined in the *Charter of Polski Rejestr Statków S.A.*, the *Supervision Activity Regulations* and in the *Rules*.

The PRS activity is based on the system of surveys and on the assumption that other parties participating in that activity (manufacturers of components and materials, work executors, etc.) correctly perform their duties.

PRS survey activities and issuing documents shall not exempt the design engineers, work executors, owners, manufacturers, suppliers, operators or other parties from their duties and responsibilities for correct execution of taken obligations.

A document, certificate, report, recommendation or other information issued by PRS means only a statement on fulfilling appropriate requirements provided in the Rules or other documents adopted by PRS and the Customer as the basis for PRS activity and it does not replace certificates and guarantees issued by manufacturers.

1.1 Publication objective

1.1.1 Focus on reliability and safety

The PRS objective is to ensure reliability and safety of novel technologies and innovative solutions used by the industry and introduced on the market. The objective is realized through updating technical requirements. PRS develops own Rules, revises the existing ones and introduces new requirements aimed at effective and safe performing particular stages of the process of the Offshore Wind Farm realization.

The calculation guidelines and procedures may be replaced by other methods if they have been proved effective and safe. Management of business continuity within the life cycle is essential. This issue has been presented in the PN-EN ISO 22301 Social security – Business continuity management systems – Requirements, where holistic approach has been applied to identify potential hazards in the Organization and to form its resilience, in order to improve business performance.

1.1.2 Focus on risk management in the process of forming effectiveness and safety

Risk, as a permanent element in the realization of projects, should be properly managed for their safe execution. The risk management is a continuous or phased process, present at each project stage, using appropriate methods of risk identification and reduction to an acceptable level, e.g. within the ALARP analysis. The guidelines on risk management are presented in PN ISO 31000 – Risk management – Guidelines. Application of the Guidelines may be adapted to each organization and its context. This Standard presents a common approach to management of each kind of risk which is not restricted to specific branch or sector. The approach applies throughout the whole life cycle of the Organization and its activity, including making decision at all hierarchy levels, taking into account internal and external conditions.

1.1.3 Focus on quality

Quality assurance shall be an integral part of procedures for designing, controlling, manufacturing, installing, operating and repairing of the Offshore Wind Farm (OWF) infrastructure. PRS continuously raises qualifications of own Surveyors, extending the range of their competences.

Full identification and traceability of (material, equipment and human) resources engaged and used at particular stages through their appropriate documentation, allows for managing quality processes and their continuous improvement.

1.1.4 Focus on project management

Project management through documented systematized processes, identification of resources and information necessary for task execution, selection of working teams taking into account their competence and assignment to them appropriate roles and responsibilities, allows to supply products effectively and to manage interrelations among various areas, what is a significant element of quality activities system.

1.1.5 Focus on changes

Dynamical development of technologies and associated new technical and system challenges motivate the development of Organization and its products. Permanent analysis of processes enables their continuous improvement through increase of quality and reduction of probability for specified risks which evoke negative consequences. **PRS allows the possibility of applying alternative, innovative technical and procedural solutions, upon their individual consideration.**

1.2 Hierarchy of reference documents

This Publication refers directly to the following rules and publications:
1. National regulations,
2. PRS Rules (as a priority, rules for the offshore units apply),
3. IMO conventions,
4. International ISO standards and European standards (EN),
5. IEC standards,
6. NORSOK standards,
7. American standards (including those for offshore),
8. Client specifications,
9. Other documents.

PRS may recognize processes, products and services supplied with the use of other rules as conforming to safety and quality requirements, upon individual consideration.

PRS allows to use PRS offshore units publications for analogical technical scope.

1.2.1 Reference rules and standards

- **Supervision Activity Regulations**,
- **Publication 105/P** – Marine Units. Fixed Offshore Platforms and Equipment. Rules for the Construction and Survey,
- **Publication 11/P** – Environmental Tests on Marine Equipment,
- **Publication 2/P** – Alternative Survey Arrangements for Machinery,

- **Publication 9/P** – Requirements for Computer Based Systems,
- **Publication 23/P** – Pipelines Prefabrication ,
- **Publication 30/P** – Principles for Certification of Welders,
- **Publication 34/P** – Inspection of Underwater Welded Joints,
- **Publication 40/P** – Non-metallic Materials,
- **Publication 49/P** – Requirements Concerning Mobile Offshore Drilling Units,
- **Publication 51/P** – Procedural Requirements for Service Suppliers,
- **Publication 52/P** – Underwater Inspection of Mobile Offshore Drilling Units in Lieu of Drydocking,
- **Publication 54/P** – Alternative Hull Survey Arrangements,
- **Publication 55/P** – Survey of Corrosion Protection and Anti-fouling Systems,
- **Publication 56/P** – Procedural Requirements for Laboratories,
- **Publication 74/P** – Principles for Welding Procedure Qualification Tests,
- **Publication 80/P** – Non-destructive Testing,
- **Publication 108/P** – Qualification and Certification of Plastics' Welders,
- **Publication 17/I** – Industrial Surveys based on Approved Planned Maintenance System for Machinery,
- **Publication 18/I** – Guidelines on the Performance of Non-destructive Tests of Bottom Part of the Mobile Offshore Drilling Units,
- Rules for the Classification and Construction of Mobile Offshore Drilling Units,
- **PN-EN ISO 22301** Social security – Business continuity management systems – Requirements,
- **PN-EN ISO 9001** Quality management systems,
- **PN-EN ISO 14001** Environmental management systems,
- **PN-EN IEC 60721** Classification of environment conditions,
- **PN-EN ISO 14040** Environmental management – — Life cycle assessment — Principles and framework
- **PN ISO 31000** Risk management – Guidelines,
- **PN-EN ISO/IEC 27000** *Information technology – Security techniques – Information security management systems – Overview and vocabulary,*
- **PN-EN ISO/IEC 27001** *Information technology – Security techniques – Information security management systems – Requirements,*
- **PN-ISO/IEC 27005** Information technology – Security techniques – Information security risk management,
- **PN-EN IEC 62443** Security for industrial automation and control systems,
- **PN-EN 61508** Functional safety of electrical, electronic and programmable electronic safety-related systems – Part 1: General requirements
- **PN-EN 61511** Functional safety - Safety instrumented systems for the process industry sector
- **PN-EN 62061** Safety of machinery, functional safety of safety-related electrical, electronic and programmable electronic control systems,
- **PN-EN ISO 13849** Safety of machinery — Safety-related parts of control systems
- **PN-EN ISO/IEC 17020** Conformity assessment – Requirements for the operation of various types of bodies performing inspection,
- **PN-EN ISO 22475-1** Geotechnical investigation and testing – Sampling methods and groundwater measurements – Part 1: Technical principles for execution,
- **PN-EN ISO 19900-03** – Petroleum and natural gas industries. Specific requirements for offshore structures,
- **PN-EN ISO 19901-1** – Petroleum and natural gas industries – Specific requirements for offshore structures. Part 1: Metocean *design* and *operating* considerations,
- **PN-EN ISO 19901-2** Petroleum and natural gas industries – Specific requirements for offshore structures – Part 2: Seismic design procedures and criteria,

- **PN-EN ISO 19901-4** – Petroleum and natural gas industries – Specific requirements for offshore structures – Part 4: Geotechnical and foundation design considerations,
- **PN-EN ISO 19901-5** – Petroleum and natural gas industries – Specific requirements for offshore structures – Part 5: Weight control during engineering and construction,
- **PN-EN ISO 19902** Petroleum and natural gas industries – Fixed steel offshore structures,
- **PN-EN ISO 19906** Petroleum and natural gas industries – Arctic offshore structures,
- **NACE SP0176** Corrosion Control of Submerged Areas of Permanently Installed Steel Offshore Structures Associated with Petroleum Production,
- **NACE TPC 3** Microbiologically Influenced Corrosion and Biofouling in Oilfield Equipment,
- **API RP 2N** Planning, Designing, and Constructing Structures and Pipelines for Arctic Conditions,
- **API RP 2A-LRFD** Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms – Load and Resistance Factor Design,
- **PN-EN IEC 61400-1** Wind Turbines – Part 1: Design Requirements,
- **PN-EN IEC 61400-3** Wind turbines – Part 3: Design requirements for offshore wind turbine,
- **PN-EN IEC 61400-22** Wind turbines – Part 22: Conformity testing and certification,
- **PN-EN 50308** Wind turbines. Protective measures. Requirements for design, operation and maintenance,
- **PN-EN 1990** Eurocode - Basic design rules of structures,
- **PN-EN 1997-1** Eurocode 7: Geotechnical design – Part 1 General rules,
- **PN-EN 1997-2** Eurocode 7. Geotechnical design. Part 2: Ground investigation and testing,
- **PN-EN 1090-1+A1** Execution of steel structures and aluminium structures. Part 1: Requirements for conformity assessment of structural components,
- **PN-EN 1090-2** Execution of steel structures and aluminium structures – Part 2: Technical requirements for steel structures,
- **PN-EN ISO 3834-2** Quality requirements for fusion welding of metallic materials – Part 2: Comprehensive quality requirements,
- **PN-EN ISO 14732** Welding personnel – Qualification testing of welding operators and weld setters for mechanized and automatic welding of metallic materials,
- **PN-EN 1991-1-4** Eurocode 1. Actions on structures. General actions. Wind actions,
- **PN-EN 1992-1-1** Eurocode 2. Design of concrete structures. Part 1-1: General rules and rules for buildings,
- **PN-EN 1993-1-1** Eurocode 3. Design of steel structures. Part 1-1: General rules and rules for buildings,
- **PN-EN 1993-1-6** Eurocode 3. Design of steel structures. Part 1-6: Strength and stability of shell structures,
- **PN-EN 10204** Metallic products – Types of inspection documents,
- **PN-EN 10225** Weldable structural steels for fixed offshore structures. Technical delivery conditions,
- **PN-EN 10025-1**– Hot rolled products of structural steels – Part 1: General technical delivery conditions,
- **PN-EN 10025-2** Hot rolled products of structural steels – Part 2: Technical delivery conditions for non-alloy structural steels,
- **PN-EN 10025-3** Hot rolled products of structural steels – Part 3: Technical delivery conditions for normalized/normalized rolled weldable fine grain structural steels,
- **PN-EN 10025-4** Hot rolled products of structural steels – Part 4: Technical delivery conditions for thermomechanical rolled weldable fine grain structural steels,
- **PN-EN 10025-6+A1** Hot rolled products of structural steels. – Part 6: Technical delivery conditions for flat products of high yield strength structural steels in quenched and tempered conditions,

- **PN-EN 12495** Cathodic protection for fixed steel offshore structures,
- **PN-EN ISO 12944** Paints and varnishes – Corrosion protection of steel structures by protective paint systems,
- **ISO 20340** Paints and varnishes – Performance requirements for protective paint systems for offshore and related structures,
- **PN-EN ISO 1461** Hot dip galvanized coatings on fabricated iron and steel articles – Specifications and test methods,
- **PN-EN 62305** Protection against lightning – Part 1: General principles,
- **PN-EN 196-1** Methods of testing cement – Part 1: Determination of strength,
- **PN-EN 206** *Concrete* – Part 1: Specification, performance, production and conformity,
- **ISO 6934** Steel for the prestressing of concrete,
- **PN-ISO 6935** Steel for the reinforcement of concrete,
- **PN-EN 13670** Execution of concrete structures,
- **PN-EN 12350** Testing fresh *concrete*,
- **PN-EN 1015** Methods of test for mortar for masonry
- **PN-EN 445** Grout for prestressing tendons — Test methods
- **ASTM A775 / A775M** Standard Specification for Epoxy-Coated Steel Reinforcing Bars,
- **ASTM A934 / A934M** Standard Specification for Epoxy-Coated Prefabricated Steel Reinforcing Bars,
- **ASTM D3963 / D3963M** Standard Specification for Fabrication and Jobsite Handling of Epoxy-Coated Steel Reinforcing Bars,
- **ASTM C1437** Standard Test Method for Flow of Hydraulic Cement Mortar,
- **ASTM C940** Standard Test Method for Expansion and Bleeding of Freshly Mixed Grouts for Preplaced-Aggregate Concrete in the Laboratory,
- **ASTM C953** Standard Test Method for Time of Setting of Grouts for Preplaced-Aggregate Concrete in the Laboratory,
- **ASTM C1741** Standard Test Method for Bleed Stability of Cementitious Post-Tensioning Tendon Grout,
- **IEC 60502** Power cables with extruded insulation and their accessories for rated voltages from 1 kV up to 30 kV,
- **IEC 60840** Power cables with extruded insulation and their accessories for rated voltages above 30 kV up to 150 kV,
- **IEC 62067** Power cables with extruded insulation and their accessories for rated voltages above 150 kV up to 500 kV,
- **E-Cigre B1.43** Recommendations for mechanical testing of submarine cables,
- **E-Cigre B1.27** Recommendations for testing of long ac submarine cables with extruded insulation for system voltage above 30 to 500 kV,
- **E-Cigre B1.32** Recommendations for testing HVDC extruded cable systems for power tranmission at a rated voltage up to 500 kV,
- **ITU G.Sup41** Design guidelines for optical fibre submarine cable systems,
- Legal acts relevant for geotechnical, mining and geological activities,
- Legal acts relevant for construction activities,
- Legal acts relevant for marine areas and maritime administration,
- Legal acts relevant for the material recycling,
- **DNVGL-ST-N001** Marine operations and marine warranty.

1.3 Abbreviations, terms and definitions

1.3.1 Abbreviations

ALARP – As Low as Reasonably Practicable – the level of risk acceptance.

CLV – Cable Laying Vessel.

CTV – Crew Transfer Vessel.

FAT – Factory Acceptance Test.

FEED – Front End Engineering and Design.

FMEA – Failure Mode and Effect Analysis.

FMECA – Failure Mode, Effect and Criticality Analysis

HAT – Harbour Acceptance Test.

HLV – Heavy Lift Vessel.

HV – high voltage

HVAC – High Voltage Alternating Current.

HVDC – High Voltage Direct Current.

IACS – International Association of Classification Societies.

IMO – International Maritime Organization.

ITP – Inspection Test Plan.

LEMP – Lightning Electromagnetic Pulse.

LPZ – Lightning Protection Zones.

NDT – Nondestructive Testing.

OWF – Offshore Wind Farm – a set of WTGs with associated transmission infrastructure, localized offshore within one consent.

WTG – Wind Turbine Generator – localized in the offshore area assembly of structures and equipment within one system, which converts wind energy into electrical energy.

PMS – Planned Maintenance System.

PRS – Polski Rejestr Statków S.A.

RNA – Rotor Nacelle Assembly

SAT – Site Acceptance Test

SCADA – Supervisory Control And Data Acquisition.

SOV – Service Operation Vessel.

QMS – Quality Management System.

UXO – Unexploded Ordnance –military debris on the seabed, as well as chemical weapons or munition.

WPQR – Welding Procedure Qualification Record.

WPS – Welding Procedure Specification.

1.3.2 Terms and definitions

Maritime administration – for the purpose of this Publication – appropriate public administration executing jurisdiction in the offshore areas.

Service reel – cylindrical drum, made typically of steel, with flanges, used for the installation of pipeline from pipes supplied in a roll (may be used also for the storage and transportation). The service reel is usually equipped with own hydraulic drive, used for control of reel turning and braking.

Transport reel– cylindrical drum or winch which enables transportation of rolled pipes.

Certification –procedure under which a third party grants a written confirmation that a product, process or service conforms to specified requirements. The document confirming positive certification may be issued in the form of e.g. Approval Certificate, Product Type Approval Certificate, Certificate, Acceptance Certificate, etc.

Certificate of Compliance – a document issued in accordance with the certification system principles to confirm that the duly identified product, process or service conforms to specified standard or other normative documents.

Certification cycle – cyclically repeating period counted from the date of completion of initial survey of the object or from the date of certificate renewal survey, equal to the period of certificate validity and including all necessary periodical surveys.

Supplier – organization supplying products, e.g. manufacturer, seller or distributor.

Ecological waste management – waste and dangerous materials management processing possible activities in a way that protects human health and environment from any adverse effect.

Installation of object – technical issues and processes associated with placement of an object in assigned place.

Jack-up – floating self-elevating unit.

Certification body – PRS accepted organization carrying out certification.

Supply chain – a network of entities involved in the process of production, from acquiring raw materials to creating final product.

Dangerous material – material or substance, which could constitute hazard to human health or environment. In accordance with the Regulation REACH: substance on its own, as a component of mixture or product, which is subject to restriction, may not be manufactured, placed on the market or used, unless the restriction conditions are met.

Protective coatings – coatings ensuring corrosion protection.

Object conversion – works aimed at changing object dimensions and/or purpose.

Survey – a set of supervision/control activities executed by PRS in defined time, through checking conformity with technical documentation and carrying out appropriate visual examinations, measurements and tests.

Initial survey – a set of surveys of the object, upon completion of which PRS, issues the Certificate.

Recycling – the activity of full or partial dismantling, carried out in appropriate recycling facility with the purpose to recover components and materials for re-processing, preparation for re-use or their re-use. It should ensure management of dangerous and non-dangerous materials and associated activities, such as storage and processing on site, although without their further processing or disposal in other processes.

Splash zone – the zone in which the structure is cyclically flooded, splashed with water and exposed to air, due to waves action and changes of sea level.

Certification system – the system having own procedures and management principles related to the performance of assessment, leading to the issue of certification document and further maintenance of its validity.

Artificial Island – marine structure – an object permanently installed on the seabed – marine hydrotechnical structure.

Technical Device – a machine installed on the foundation, e.g. transformer platform or tower with RNA.

Approved manufacturer – the manufacturer having quality management system conforming to the requirements of PN-EN ISO 9001, what has been confirmed by a certificate issued by certification body.

Manufacturer – organization having its headquarter or place of residence in the European Union member state, the Swiss Confederation or in the member state of the European Free Trade Association (EFTA) – a party to the European Economic Area (EEA) agreement, which manufactures electrical energy or heat from renewable energy sources or biogas in the renewable energy source systems located on the territory of the Republic of Poland or in the exclusive economic zone (it is subject to the act on renewable energy sources).

2 HIERARCHY OF CERTIFICATION AND SUPERVISION REQUIREMENTS

Hierarchical approach to certification enables efficient verification of compliance with requirements for products and resources in various areas and on various stages of the OWF project development. Moreover, PRS certification of the project stage and project itself is possible on the basis of realization of assumed objectives and achievement of appropriate final effects.

2.1 Issued documents

After completion, with positive result, of appropriate surveys and carrying out relevant tests, PRS issues appropriate certificates and documents.

PRS may issue Certificate of Compliance confirming process completion or performance according to applied rules.

PRS accepts certificates issued by other certification bodies upon separate consideration.
- Certificate of compliance for OWF – a document confirming conformity of manufactured object with technical documentation, requirements of relevant standards and 130/P rules, requirements related to connection to power grid and valid law regulations,
- Safety certificate for OWF – a document confirming ability of the manufactured object to operate safely with assumed operational parameters, considering adopted standards, selection of materials, quality of performed installation works and carried out examinations and tests. The safety certificate for OWF may be issued after PRS issued certificates of compliance for individual WTGs.

2.1.1 Certification of the offshore wind farm

1. Approval of technical documentation for compliance with requirements of respective parts of this Publication,
2. Supervision of production,
3. Supervision during transportation and installation on site,
4. Supervision of commissioning,
5. Acceptance tests.

Certificates shall be issued for those installations for which all the above activities have been confirmed through the issue of appropriate report confirming fulfilment of PRS requirements.

2.1.2 Hierarchy of certification

The hierarchy in various areas of certification has been shown below. The certification confirms compliance of executed tasks or products with guidelines presented in appropriate regulations, such as standards, directives, etc.

2.1.2.1 Certification of the Offshore Wind Energy Sector products

The product certification process for the Offshore Wind Energy sector covers the following groups of products:

a) wind turbines, their components and systems,
b) marine structures and installations, and
c) devices for the operation, installation and maintenance of offshore wind farms.

The way of proceeding to be followed in the process of certification of the above-mentioned products is specified in relevant procedures, instructions and certification programs in force at PRS.

2.1.2.2 Competence certificate

During assessment of organization, PRS checks technical and organizational preparation of the enterprise. The organization should prove its experience in executing particular types of operations and should:

– use process-related technological specifications,
– use principles of work surveillance and control,
– use valid standards and requirements related to performance and control,
– have machinery for process performance,
– have personnel with valid authorized qualifications appropriate for carried out works,
– have personnel supervising processes and controlling them.

The supervising personnel shall have adequate theoretical and practical knowledge. This shall be documented and submitted for verification.

The executive personnel shall have appropriate training adequate for executed works, confirmed by valid certificate.

Organization Certificate of Competence,

Personnel qualification certificate.

2.1.2.3 Process certificate

Process certification is based on checking procedures established in the organization, specifying division into roles, tasks and responsibilities present at different stages and in particular cases, in order to efficiently achieve assumed effects from convertion of basic resources. In the case of technological process, it covers, among the others, quality control of raw materials, process procedures and quality control of final products.

2.1.2.4 Management system certificate

Management systems certification may relate to different functional areas, such as quality, safety, environment, risk, changes, development, etc. Management system may be based on process approach, which increases effectiveness of organization activity. The management system certification proves focus on realization of objectives and implementation of documented methods of their realization supervision. If the organization implemented management systems for various functional areas, it is recommended to combine them within one Integrated Management System, leading to harmonization of various processes affecting the same resources.

2.1.3 Technical documentation of the offshore wind farm

Depending on the scope of approval, the technical documentation of the OWF shall include:
- Applicant's name and headquarter location,
- planned location,
- general description,
- list of main components to be used,
- description of control and safety concept,
- description of safety and protection system,
- installation description,
- assumptions, input data and calculations - if required by PRS,
- principal drawings and schemes,
- main components data sheets,
- description of condition monitoring system,
- drawings and specifications of operation and maintenance systems,
- plan and description of transportation and installation processes - if applicable,
- ECO/REC Declaration for product type.

2.2 Supervision and certification according to this Publication

The subject of supervision in this Publication are the offshore wind farms (OWF), a set of wind power to electricity converters, adopted for installation in the offshore area.

The Publication requirements apply to all phases of planning and realization of the OWF in intermediate and final states, including decommissioning and disposal phase.

The Publication defines the principles of technical supervision fulfilled by Polish Register of Shipping.

The purpose of the supervision performed by PRS is to ensure safe operation of the OWF by means of checking and confirmation of infrastructure and technical condition compliance with the requirements of this Publication and legal regulations applicable in the Project location.

The Publication specifies the requirements, upon fulfilment of which PRS may issue appropriate certificates of compliance to OWF and its components.

The PRS supervision covers processes at different stages of the OWF project development. Additionally, it may cover structural part and branch parts (e.g. a mechanical part) according to Product Type Certification principles.

All OWF components which are necessary for its proper and safe operation, supplied to installation site shall have certificates of compliance issued by PRS or certification bodies (certificates of manufacturing compliance with the requirements of these institutions) or certificates of manufacturing compliance (manufacturer's declarations) with prototype covered with type certificate issued by PRS or certification body.

PRS shall approve the manufacturer of essential OWF components on the basis of valid certificate issued for the quality management system by certification bodies.

If the manufacturer does not have such a certificate, PRS shall evaluate its quality management system. It requires compliance with the requirements of PRS Certification Bureau included in the *Procedure for quality management system certification*. After obtaining positive result in certification process, PRS issues to the manufacturer the *Quality Management System Certificate* valid for 3 years. The validity is conditioned by positive results of annual audits carried out by PRS.

2.2.1 Scope of supervision and certification

In accordance with the *Supervision Activity Regulations*: „The aim of PRS' technical supervision is to ensure compliance of the supervised object with the relevant Rules requirements and other applicable sets of requirements, as well as with the approved and/or noted or agreed technical documentation and/or the requirements specified in the contract". In accordance with the principles of this Publication, the supervision of PRS covers, among the others:

- materials and welding in construction, conversion and repair of structures being a part of OWF,
- structural strength,
- stability of structures transported to installation site in the intact condition, as well as damage stability in damage condition,
- watertightness and protection against weather conditions,
- offshore installation processes,
- devices and technological systems located in subsea, submerged and atmospheric zone,
- Power transmission devices and systems,
- safety and risk analyzes,
- surveys related to marine warranty.

In each part of the Publication, in paragraphs related to supervision and certification, examples of activities and products which are subject to PRS supervision and certification, are presented.

3 OFFSHORE WIND FARM

3.1 Development process of the offshore wind farm project

The OWF project is a set of activities aimed at safe transmission of electrical energy produced by OWF into the national grid. Project begins with making decision on starting analysis of boundary conditions and potential profitability of the OWF investor and ends with bringing the site of OWF to an acceptable condition as of before OWF development. PRS may take part in each administrative or technical phase, within agreed scope. To execute OWF project safely, a list of the OWF project development stages with description of different activities, has been presented below.

Each OWF project shall be treated individually, therefore, upon earlier agreement, PRS may accept proposed development method.

3.1.1 Location and environmental study

This phase submits information on the parameters of analyzed area for designed OWF, in particular within the scope of the project feasibility, economical reasonability, its effect on the environment and boundary conditions of its realization.

Each considered location shall be treated individually and so shall be planned related measurement campaigns like atmospheric (e.g. meteorological) and oceanographic (e.g. geophysical, geological, biological and hydrological) conditions.

Data acquired during this stage shall be reliable and precise, as they will be basis for decisions on proceeding to next project stages and they will be the input data for other processes.

3.1.2 Engineering

Specified parameters of the analyzed area are the basis for variant conceptual works which define options of OWF project realization, such as concepts of structure selection, OWF location or O&M strategy.

Part of the design stage is OWF infrastructure layout concept (with its parameters), what enables to choose the optimum realization variant. The decision results in commencing process of technical design of the OWF elements, such as support structures or technical devices. According to chosen method of technical design process, a set of documentation is prepared, which allows for execution of next stages.

3.1.3 Construction

The documentation created during engineering stage is the basis for proceeding to manufacturing phase of the OWF project development. Construction phase applies to products, which may be components or systems of various complexity and completeness. This stage ends with acceptance (according to specified quality parameters) of fabricated products, which are ready for transportation and final installation in the OWF area.

3.1.4 Transportation and installation

The stage of transportation and installation mixes up with an earlier stage – construction, as it includes transportation of components between different processes, until completion of system. At this stage, planning and supervision of performed processes shall reduce the risk of losses and maximize the processes safety to reach their levels acceptable by all stakeholders.

3.1.5 Commissioning, operation and maintenance

The completed set of trials, tests and analyzes, confirming technical and organizational readiness for safe OWF operation, allows to obtain certificates enabling proceeding to the operational phase of OWF development project.

During operation, care must be taken to secure the continuity of infrastructure operation in a manner of service personnel and machinery safety.

After expiry of the designed infrastructure operation life, PRS allows extension of the validity of certificates confirming further operability of the OWF after analysis of submittals.

3.1.6 Decommissioning and disposal

After the operational phase, the OWF owner is obliged to bring the OWF area to previously agreed pre-development state, by dismantling of the infrastructure and its disposal in the least harmful to the environment way.

3.2 Offshore wind farm infrastructure – point and line elements

The infrastructure of the offshore wind farm consists of point and line elements. The following division is aimed at systematizing the names and presenting typical engineering solutions used in OWF projects.

3.2.1 Wind turbine generator

Wind turbine generator is a basic element of an offshore wind farm. It consists of the rotor-nacelle assembly (RNA) and support structure.

3.2.1.1 Rotor-nacelle assembly

3.2.1.1.1 Gearbox-operated

Traditional type of WTG, in which the rotor is mounted on the shaft, which drives the generator through the gear system.

3.2.1.1.2 Direct drive

WTG type, where the rotor is mounted on the generator shaft.

3.2.1.2 Support structure

The support structure is the structure between working elements, such as RNA, and the seabed. In case of WTG, part in atmospheric zone (tower), transition piece (if applicable) and submerged part (foundation) may be specified. In transformer platforms, only the foundation is the support structure.

3.2.1.2.1 Tower

A structure, usually made of steel, in the form of truncated cone, transferring loads from RNA to the foundation.

3.2.1.2.2 Foundation

A structure (a set of structures) which transfers loads from the tower to the seabed and is subject to hydrodynamic loads. The foundation is an underwater structure, located in or directly above the seabed, with associated elements located above water level up to the place where the foundation takes loads characteristic for the splash zone and up to the assumed highest wave crestlevel. The following main foundation types also apply to transformer platforms.

– Gravity base – the structure in the form of a platonic solid or solid of revolution, used in the smallest depths, not permanently connected with the seabed.
– Monopile – the structure in the form of a cylinder with the cylindrical cone together with the transition piece creates the foundation. The function of the transition piece is to connect the foundation with the tower as well as mooring.
– Jacket – the structure similar to lattice support structures of high voltage lines, requires less material than monopile and is can be used in deeper areas. Elements connecting jacket to the seabed may be in the form of e.g. piles or caissons.
– Floating – the structures able to float on water surface, are not connected directly to the seabed, although they are connected with it by anchoring systems.

3.2.1.2.3 Additional equipment

A set of structures and systems which enable wind farm installation and safe and monitored operation. This set includes systems measuring meteorological conditions, operation parameter measuring systems, fender and mooring structures, connection structures, lifting appliances and similar.

3.2.2 Balance of Plant

The balance of plant of the OWF includes elements of line infrastructure (i.e. cabling) and point infrastructure (offshore transformer platforms and WTG).

The BoP project shall ensure maximum safety of people and minimum risk of damage to the OWF infrastructure and to an external electrical system during O&M in all standard and extreme external conditions.

3.2.2.1 Offshore transformer platform

An offshore transformer platform consists of the foundation and platform. It is a point element of balance of plant system changing electric parameters.

3.2.2.1.1 DC platform

Application of this type of platform depends on planned connection technology to national power grid. The distance between offshore substation (OSS) to onshore substation is a key parameter in the consideration of possible technology choice. DC OSS is more technology advanced and cost-intensive structure than AC OSS – it has energy converting (export) function.

3.2.2.1.2 AC platform

3.2.2.1.2.1 Collector type platforms

The collector type platforms are an intermediate element in the OWF BoP system – they gather energy from part of all WTGs.

3.2.2.1.2.2 Converter type platform

Converter type platforms have energy export function, i.e. they are a point element of the BoP system connecting the OWF to national power grid.

3.2.2.2 Onshore substation

Conventional transformer substation used as connecting point between the OWF and the national power grid.

3.2.2.3 Cabling

Line elements of the OWF BoP system, used for current and data transmission.

3.2.2.3.1 Inter array cables

The linear part of BoP system used for connecting WTGs with OSS.

3.2.2.3.2 Export cable

The linear part of BoP system used for connecting OWF (exporting platform) with the connecting point (e.g. onshore substation).

3.2.2.4 Measurement stations

The measurement stations deliver information on conditions in the OWF area.

3.2.2.4.1 Metocean stations

The metocean stations are installed at the initial phase of the OWF project development, aimed at providing data on the conditions of defined marine area, i.e. wind and sea state parameters. Mostly, the stations are floating lidar buoys or bottom-fixed meteorological masts.

3.2.2.4.2 Control and measurement station

The station task is to provide real time monitoring of the OWF operation parameters, such as position of rotor blades of WTG, electrical parameters in the OSS, condition of safety systems etc., using various systems such as e.g. SCADA.

3.3 Vessels

Vessels are not the OWF elements, although they are necessary at each stage of the project.

3.3.1 Survey vessels

Vessels used for collecting data and information on environmental conditions of the area of planned wind farm e.g. biology (e.g. presence of marine mammals and fish) or geophysical and geological conditions of the seabed.

3.3.2 Installation vessels

The main classification parameter of installation units is related to their purpose, i.e. installation of line infrastructure (CLV) and point infrastructure (WTG, OSS). Depending on type and size of point infrastructure elements, vessels can be floating cranes, jack-ups, semi-submersibles or heavy lift vessels (HLV). If properly outfitted, same vessel may be used for installation of various components, e.g. monopile foundations and RNA.

3.3.3 Operation and maintenance vessel

O&M vessels are used during OWF commissioning and O&M phase. Depending on the scope of O&M works, various vessels are used (selected due to their size). CTVs and SOVs are mainly used types of vessels.

PART II

Environmental and location assessment

1 GENERAL

This part of Publication describes the scope of environmental assessment of OWF area and zone nearby. The examinations concern acquiring meteorological, biological, geological and other data required for the project development.

Collected data will be used at least for two purposes i.e. obtaining administrative permits and for further stages of the OWF project. The survey campaign shall be planned to maximize the use of human and technical resources and resulting reduction of impact on environment (e.g. use of fuel impact).

1.1 Rules and reference standards

– **PN-EN ISO 14040** Environmental management – Life cycle assessment – Principles and framework,
– **PN-EN ISO 22475-1** Geotechnical investigation and testing – Sampling methods and groundwater measurements – Part 1: Technical principles for execution,
– **PN-EN 1997-2**: Eurocode 7. Geotechnical design. Ground investigation and testing,
– **PN-EN IEC 60721** Classification of environmental conditions,
– **PN-EN IEC 61400-3** Wind turbines – Part 3: Design requirements for offshore wind turbine,
– Legal acts relevant for geotechnical, mining and geological activities.

1.2 Supervision and certification

The supervision and certification may cover aspects listed below:
– quality and reliability of data,
– methods of sampling and sample analysis,
– methods of data analysis,
– survey reports.

2 METHODS OF ASSESSMENT STAGE

2.1 Onshore surveys

Chosen methods shall determine mode of environmental survey and consider relevant rules and requirements for input data of next stages of the OWF project development (especially the design stage).

2.2 Offshore surveys

2.2.1 Meteorological surveys

The result of carried out surveys shall be an effect of planned measurement campaing lasting at least one year, what allows to observe characteristic extreme values noted occuring in specific periods of time. The purpose of the meteo surveys is to acquire data on the specifics of climate conditions of the considered area. The most important data are wind parameters that determine annual energy production (AEP) potential). The microclimate features will also provide information on boundary conditions for OWF infrastructure design requirements e.g. observed mean temperature restricts the selection of construction materials; humidity may have effect on the selection of anti-corrosion systems; the solar radiation may influence the development of living organisms and in consequence define the rate of structure biofouling;

2.2.2 Oceanographic survey

2.2.2.1 Bathymetry

Bathymetry surveys use the phenomenon of wave propagation in water. They allow precise defining depths and creating 3D map of the sea bottom, which is necessary for the engineering phase.

2.2.2.2 Geology and geotechnics

Geological and geotechnical surveys shall provide necessary data sets on the thickness and arrangement of seabed layers and their strength parameters, which allows to start support structures design and to plan properly the installation process. Planned measurement campaign shall consider sufficient number of measuring points, which, after analysis, will provide the map with appropriate resolution, enabling planning OWF infrastructure layout with accuracy assumed at this stage.

2.2.2.3 Geophysics

Geophysical surveys cover a wide range of measurements using physical phenomena for mapping the layout of subsoil layers. They can include: sonar, magnetometric, seismoacoustic and seismic surveys.

During the geophysical survey, also hydrological and hydrochemical conditions (e.g. water quality, sea currents and waves, turbidity and salinity, electrical conductivity etc.) are assessed. Ice and seismic conditions are also important parameters. The measurement campaign for hydrological and hydrochemical tests shall last for at least 1 year, allowing observation of seasonal trends and extremes of examined parameters.

2.2.2.4 Biology

Measurement campaign shall be properly planned and performed, in order to achieve required data of biosphere i.e marine mammals, bats, birds, fish and benthos organisms. To count marine mammals number, the acoustic method may be applied.

2.2.3 Anthropogenic surveys

Current and potential anthropogenic pressure should be analyzed, as well as other types of factors resulting from human activities. The scope of survey should include fishery, cultural heritage, ship traffic and UXO.

3 CHARACTERISTICS OF SELECTED PROCESSES OF THE ENVIRONMENTAL AND LOCALIZATION ASSESSMENT STAGE

3.1 Geological surveys

The results of geological and engineering surveys should provide sufficient information allowing to solve to following issues: subsidence, cyclic displacements, ultimate bearing capacity, structure dynamics, stress distribution below the foundation, scour and erosion, soil liquefaction, piling, hard layer penetration.

Detailed seabed surveys should be preceded by documentation for geological works, complying with national law regulations.

Preliminary geological surveys include bathymety, sonar surveys and seismoacoustic profiling, the aim of which is to prepare precise bathymetric maps of the seabed and basic geological profiles, as well as to localize obstacles such as boulders or shipwrecks.

Detailed geological engineering surveys of the seabed for infrastructure installation should be performed using boreholes and penetration testing. The tests shall deliver answers to questions listed below:

– what is the arrangement of layers in the location of designed object?
– what are the subsoil characteristics?
– what are the characteristics of individual subsoil layers in the area of designed object?
– what could be the impact of the object installation and how can it be counteracted if it is negative?

Methods of performing geological works can be divided into stages depending on the degree of detail of the input data. An example of the operation scheme is shown below:

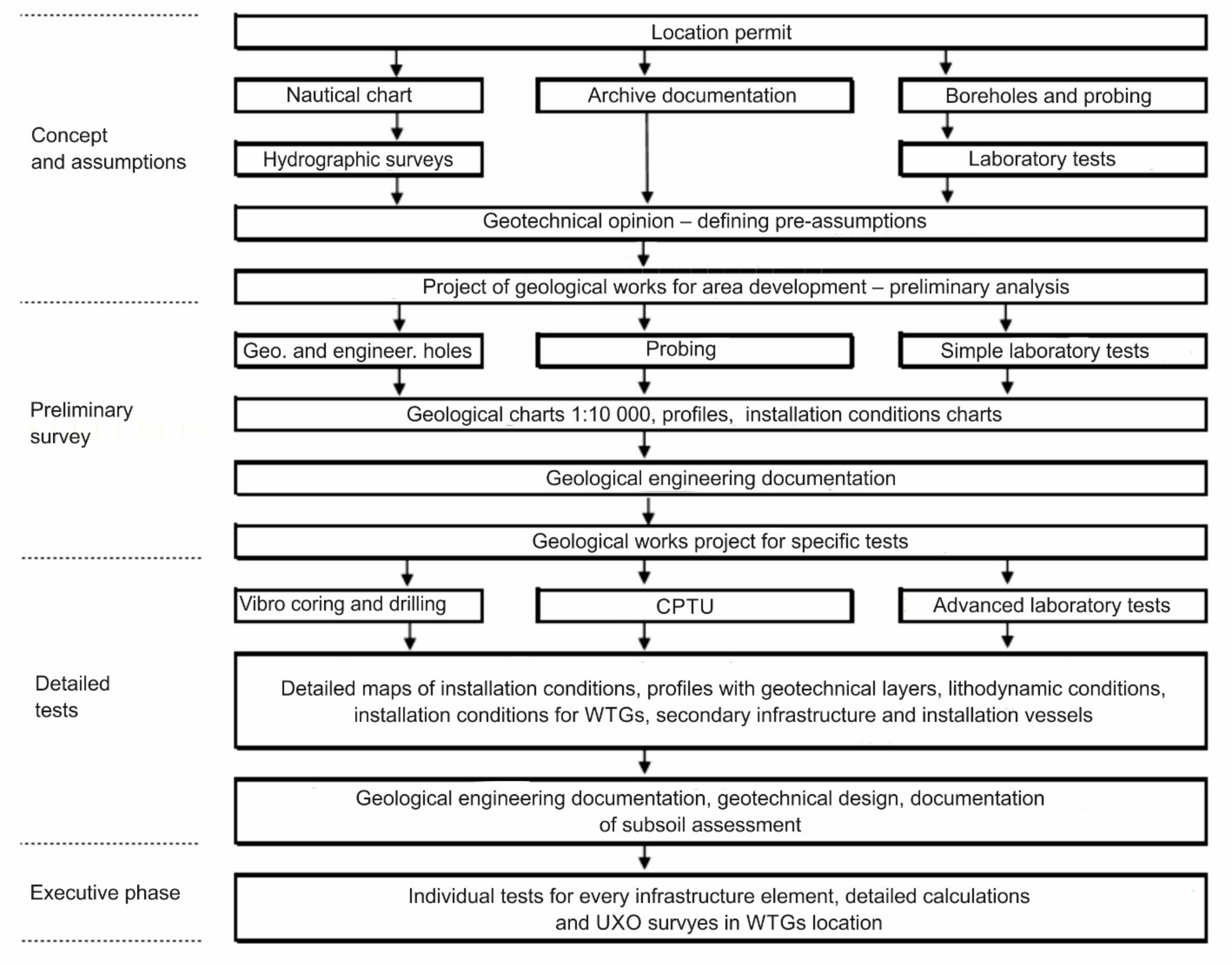

Fig. 1 - Scheme of geological works execution

3.1.1 Geological works

All geological works executed to recognize geotechnical conditions for the needs of the OWF shall be performed after fulfilling all requirements of national law and obtaining necessary permits. It applies in particular to design documentation approval and competences of persons performing geological works. Geological works should be preceded by detailed analysis of archival documentation and available literature. Preliminary assumptions of the constructions installation and its procedures should be used as basis for planning the number and type of in-situ surveys and laboratory tests and conditions of their execution.

Before carrying out field tests, sampling and laboratory testing, a complex concept (campaign strategy) of the subsoil surveys should be developed. Realization of it should ensure achieving proper level of subsoil conditions recognition.

PRS allows to perform, within geological works for particular structures, different number of borehole testing using one technology or several complementary ones. This information shall be included in the geological works documentation with justification of any deviations from legal regulations and superior standards.

3.1.2 Geological documentation

The results and interpretation of geological works, degree of intended purpose achievement and its reasoning description should be in the geological documentation. To determine the geological and engineering conditions for installation of the OWF structures, the geological and engineering documentation complying with national law requirements shall be prepared.

4 CHARACTERISTICS OF SELECTED ASSESSMENT TYPES

4.1 Wind

Wind conditions shall be defined on the basis of long-term field measurements. Depending on the circumstances, local conditions shall be correlated with long-term data from local meteo stations.

The monitoring period shall be of sufficient length to provide reliable data for at least 12 months. If changes of seasons significantly influence wind conditions, the monitoring period shall cover these effects.

4.1.1 Wind statistics

For the WTG support structure design process, the wind loads shall be assumed on the basis of statistical data on wind parameters in installation location of WTG.

These statistical data shall be based on measurements of wind speed and direction. The information on measurement campaign duration, sensors location above sea level and resolution of time intervals in which wind speed has been averaged should be provided.

The distribution of wind speed at the installation location is essential for engineering process, as it presents the frequency of occurrence of load conditions. For design loads calculations, it shall be assumed that the wind speed averaged in 10 minute interval is in Rayleigh distribution.

Statistical data related to environmental conditions (especially wind) shall be compiled in accordance with the requirements of IEC 61400-3 Standard, Chapter 12.

4.1.2 Wind parameters

Long-time prediction of average and extreme (gust) wind speed shall be made using reliable methods. Results shall be comprehensively presented in the documentation submitted to PRS.

It is recommended that statistical data used for long-term prediction of wind speed should be based on the same averaging time interval which applies to design loads.

Wind conditions used to determine design loads of WTGs support structures are specified by the value of average speed and turbulence of wind.

It is recommended to pay special attention to assessment of turbulence intensity and other parameters, when low frequency trends are occuring in the wind speed data.

When the shape of seabed or other local conditions (e.g. presence of objects of anthropogenic origin) may affect the turbulence intensity, these effects shall be reflected in the data.

The assessment of turbulence intensity may be affected by anemometer characteristics, sampling speed and the time of averaging. These effects shall be considered when predicting turbulence intensity on the basis of measured data. Moreover, the effect of aerodynamical trace of WTGs located nearby shall be considered.

The wind conditions used in this Publication are divided into:
- standard wind conditions, occuring more than once a year,
- extreme conditions, having values for realtively long recurrence periods.

Extreme wind conditions are used to determine peak wind loads. These conditions include peak wind speeds during storms and rapid changes of wind speed and direction. These conditions take into account potential effects of wind turbulence and therefore only the deterministic effects shall be considered in design calculations.

4.2 Waves

4.2.1 General

This subchapter contains general rules used to determine waving parameters. Based on these parameters, the so called computational waves are determined, which, together with other environmental loads, are used in defining design load cases for structure strength analysis.

The below indicated chapters/paragraphs of IEC 61400-3 shall apply. Detailed methods of analysis and calculations shall base on recognized standards. They shall be described and submitted to PRS.

Description of sea waving is needed for further analysis, which are to confirm construction sufficient safety level:
- extreme stress value in individual structure elements,
- structure vibration analysis,
- fatigue strength analysis,
- impact loads of local parts of the structure,
- shear force and bending (tilting) moment in connection place between support structure and foundation,
- gap between the water surface and construction part which is significantly wider than main part of the immersed in water support structure (air gap) - if applicable.

The waving description shall reflect the environmental conditions at construction location and it shall be appropriate for analyzed type of support structure.

Available statistical data on the probability of waving with specific parameters (such as significant wave height (H_s), mean wave period (T_0) or a period corresponding to an extreme value of so called waving spectral density function (T_p) and waves motion direction) shall be used.

4.2.2 Breaking waves

Waves in deep water may be subject to breaking phenomenon, when the wave gradient (relation of wave height to its length) exceeds 1/7 ratio.

In shallow water, the breaking waves phenomenon occurs when their height exceeds ca. 78% of water depth and this is highly influenced by the slope of seabed. The breaking waves phenomenon shall be considered at determining sea waving loads, especially for shallow water.

A detailed description of the breaking waves phenomenon, containing useful mathematical formulas is included in Annex C to IEC 61400-3.

4.3 Sea currents

4.3.1 General

This paragraph provides general rules to be used in determination of sea current speed distribution, applied during defining of design load cases.

These loads are applied in the construction strength analysis and comply with requirements of Chapter 6 of IEC 61400-3.

4.3.2 Current speed components and methods of their design values determination

Sea current may significantly influence the values of loads acting on the subsea part of structure and may change seabed shape, changing seabed effects on the foundation.

Sea current direction also affects arrangement of ship/boat mooring platforms and fenders.

The distribution of current speed and direction shall be determined for the installation location, considering current division into components due to moon tides, storm tides and surface currents associated with sea waving and wind speed.

Based on available statistical data for the installation site, extreme values of close-to-water-surface current speed shall be estimated (with 1 year recurrence period). It is not required to determine current speed distribution as a function of distance to water surface, when measured results (statistical data) for this parameter are not available. Use of relation of current speed to water depth is sufficient.

4.3.3 Current speed assumptions

When determining design loads of construction considering sea current effect, the fluctuations of current speed in time and space are omitted.

It is assumed that current has specified constant speed and direction, but its value depends on vertical coordinate (a distance to calm water surface).

The following components of current speed are considered:
– surface speed due to moon tides and storm tides, atmospheric pressure variations etc.
– current speed close to water surface as an effect of the wind,
– current speed close to coastline as an effect of sea waves, parallel to shore.

Total current speed is a sum of three components listed above.

When determining design loads, it is assumed that the current and waving water speed are added geometrically (in vector). Impact of current speed on waves length and periods, which is very low, is omitted.

The impact of current speed on the construction fatigue load can be omitted, when the current speed is significantly lower than extreme speed of waving water and no vortex shading or no ice flo occurs.

The designer, in agreement with PRS, decides on neglecting the impact of sea current speed on the structure fatigue strength, after analyzing statistical environmental data for the installation location.

4.4 Tides and water level changes

The tide can be divided into:
- astronomical (moon) tides,
- storm tides (caused by wind and atmospheric pressure changes).

Momentary water level in the OWF are is subject to changes (it rises or descends) due to above mentioned tides and waves being in motion. Characteristic water levels in the WTG location are defined by the parameters complying with IEC 61400-3, listed below:
- highest still water level,
- highest astronomical tide,
- mean water level,
- lowest astronomical tide,
- lowest water level,
- positive storm surge,
- a range of astronomical tides,
- negative storm surge,
- highest level of wave crests,
- lowest level of wave crests.

The water level required to check the criterion of air gap under the bottom (deck) of widened part of support structure (above water) is the highest still water level (HSWL). The range of water level variability shall be considered at designing location of communication platforms, fenders for mooring vessels and corrosion protection system (in splash zone). Characteristic water levels adopted in the construction strength analysis shall be clearly shown in the documentation submitted to PRS for approval.

PART III

Engineering

1 GENERAL

In this Part, two principal elements may be identified:
- design of processes,
- technical design.

Design of processes refers to possible activities performed for the optimum variant of the OWF project realization.

At this stage of project development, by design of processes a conceptual designing is meant, what allows to achieve characteristic parameters of analyzed activities, enabling selection of the solution, which will be realized at later stages and which detailed programming is described in further parts of the Publication. Examples of processes for which concepts may be created are shown below:
- logistics concepts – transportation and installation (T&I),
- operation and maintenance (O&M) concepts.

Specific realization of the above processes is connected with results of technical design (engineering), therefore when assessing e.g. support structure type, the processes shall be taken into account, in line with whole product life cycle analysis.

The following stages of engineering process are applicable to any type of design work to an appropriate extent.

The part related to engineering, specifies load cases, which shall be considered in the analysis of strength and fatigue strength of support structure.

These loads apply to all states of structure, i.e. include:
- loading to the ship (barge, pontoon etc.),
- sea transport to installation site,
- installation process,
- commissioning (tests),
- operation,
- inspections, maintenance, repairs.

The loads are divided into several types (components).

The load components acting simultaneously shall be selected in a way that causes the most adverse local and global stress distribution in the support structure. It applies to loads acting simultaneously with the environmental loads. Load cases shall be defined by a combination of specific situations arising from assembly, installation, maintenance and operation or designed operational and external conditions. All the probable load cases indicated on that basis shall be considered, taking into account control and protection systems.

Requirements apply to support structures and platforms being OWF components, made of steel or reinforced concrete. They apply to their construction and assessment of their strength and durability criteria.

The purpose of design calculations is to manage the probability of reaching a limit state value below limit assigned to considered type of structure.

This Publication allows, also for engineering stage, the division of WTG and OSS construction into submerged zone and atmospheric zone parts in order to apply relevant rules. For underwater part, i.e. foundation, appropriate legal regulations and rules relevant for building activities may be applicable. The atmospheric zone part, i.e. tower with RNA and OSS topside, may be treated as a single technical device, with the application of appropriate rules for devices operating in offshore conditions.

The requirements concerning strength and fatigue strength of support structure are of general nature.

1.1 Rules and reference standards

- **Publication 105/P** – Marine Units. Fixed Offshore Platforms and Equipment. Rules for the Construction and Survey,
- **Publication 40/P** – Non-metallic Materials,
- **Publication 49/P** – Requirements concerning Mobile Offshore Drilling Units,
- **PN-EN ISO 19900-03** – Petroleum and natural gas industries. General requirements for offshore structures,
- **PN-EN ISO 19901-1** – Petroleum and natural gas industries. Specific requirements for offshore
- structures – Part 1: Metocean design and operating conditions,
- **PN-EN ISO 19901-2** Petroleum and natural gas industries – Specific requirements for offshore structures – Part 2: Seismic design procedures and criteria,
- **PN-EN ISO 19901-4** – Petroleum and natural gas industries – Specific requirements for offshore structures – Part 4: Geotechnical and foundation design considerations,
- **PN-EN ISO 19902** Petroleum and natural gas industries – Fixed steel offshore structures,
- **PN-EN ISO 19906** Petroleum and natural gas industries – Arctic offshore structures,
- **NACE SP0176** Corrosion Control of Submerged Areas of Permanently Installed Steel Offshore Structures Associated with Petroleum Production,
- **API RP 2N** Planning, Designing, and Constructing Structures and Pipelines for Arctic Conditions,
- **API RP 2A-WSD** Planning, Designing, and Constructing Fixed Offshore Platforms – Working Stress Design,
- **API RP 2A-LRFD** Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms – Load and Resistance Factor Design,
- **PN-EN IEC 61400-1** Wind Turbines – Part 1: Design Requirements,
- **PN-EN IEC 61400-3** Wind turbines – Part 3: Design requirements for offshore wind turbine,
- **PN-EN 1990** Eurocode - Basic design rules of structures,
- **PN-EN 1991-1-4** Eurocode 1. Actions on structures. General actions. Wind actions,
- **PN-EN 1992-1-1** Eurocode 2. Design of concrete structures – Part 1-1: General rules and rules for buildings,
- **PN-EN 1993-1-1** Eurocode 3. Design of steel structures - Part 1-1: General rules and rules for buildings,
- **PN-EN 1993-1-6** Eurocode 3. Design of steel structures – Part 1-6: Strength and Stability of Shell Structures,
- **PN-EN 12495** Cathodic protection for fixed steel offshore structures,
- **PN-EN ISO 12944** Paints and varnishes – Corrosion protection of steel structures by protective paint systems,
- **PN-EN ISO 1461** Hot dip galvanized coatings on fabricated iron and steel articles – Specifications and test methods,
- **ISO 20340** Paints and varnishes – Performance requirements for protective paint systems for offshore and related structures,
- **PN-EN 196-1** Methods of testing cement – Part 1: Determiniation of strength,
- **PN-EN 206** *Concrete* – Part 1: Specification, performance, production and conformity,
- **ISO 6934** Steel for the prestressing of concrete,
- **PN-ISO 6935** Steel for the reinforcement of concrete,
- **PN-EN 12350** Testing fresh *concrete*,
- **PN-EN 1015** Methods of test for mortar for masonry
- **PN-EN 445** Grout for prestressing tendons — Test methods
- **ASTM C1741** Standard Test Method for Bleed Stability of Cementitious Post-Tensioning Tendon Grout,

– **ASTM C940** Standard Test Method for Expansion and Bleeding of Freshly Mixed Grouts for Preplaced-Aggregate Concrete in the Laboratory,
– **ASTM A775 / A775M** Standard Specification for Epoxy-Coated Steel Reinforcing Bars,
– **ASTM A934/A934M** Standard Specification for Epoxy-Coated Prefabricated Steel Reinforcing Bars,
– **ASTM C1437** Standard Test Method for Flow of Hydraulic Cement Mortar,
– **ASTM C953** Standard Test Method for Time of Setting of Grouts for Preplaced-Aggregate Concrete in the Laboratory,
– Legal acts relevant for geotechnical, mining and geological activities,
– Legal acts relevant for building activities,

1.2 Supervision and certification

– certification of OWF elements and components design,
– tower design verification,
– foundation design verification,
– dynamical condition calculations verification,
– safety system verification,
– control, monitoring an d access systems verification,
– electrical system verification,
– safety systems, such as lightning protection system, verification.

2 METHODS OF ENGINEERING STAGE

These rules require that the dynamical loads shall be determined based on the structure dynamical model. The model shall be used to determine loads within the entire wind speed range, considering turbulence, other extreme conditions and operation conditions. All appropriate combinations of external and operation conditions shall be analyzed. It shall be assumed that extreme environmental conditions may occur simultaneously with normal conditions i.e. wind, waving and sea current conditions. A minimum set of such combinations is defined in these rules as load conditions.

To increase certainty to the assumed design values, to verify structure dynamics model and designed operation states, the prototype testing may be used.

Verification of the project relevance shall be made by calculations and/or by experiments. If, during verification, experimental results are used, then in order to reflect indicated characteristics and design values of operation conditions, external conditions during tests shall be specified. The selection of test conditions, including load tests, appropriate safety factors shall be considered.

Wind and operation conditions during transportation, installation, maintenance shall be specified. The design shall consider maximum allowed wind conditions, able to cause significant loads.

2.1 Limit state method. Analyzed limit states

Stresses are usually determined by computational models. The construction and its components behaviour, as well as types of loads affecting them, are simplified and approximated. The model and type of selected approximation shall be appropriate to examined limit states. The model dimensioning is possible after obtaining test results. It may be necessary to supplement the general calculation model with the examination of local strength (e.g. in concentrated load zones).

The following limit states are considered:
– ultimate limit state (ULS) – ultimate bearing capacity; applies to material resistance yield strength and buckling (steel structures) or ability to transfer bending moments and axial forces (concrete structures); exceeding ULS may result in:

- loss of structure balance or its part considered as rigid body (e.g. collapse),
- breaking critical sections of the structure after exceeding the strength limit (in some cases the strength limit is reduced due to multiple loads or ultimate material deformation),
- the structure transformation into dynamic mechanical system (e.g. collapse), loss of stability (buckling etc).
- serviceability limit state (SLS) – for steel structures refers to the structure deformation level, for concrete structures, refers to permissible size of cracks in concrete; exceeding the limit may result in:
- deformations that preclude effective use or disrupt aesthetics of structural and non-structural elements,
- excessive vibration, harmful to the environment or disruptive for non-structural elements and equipment (especially resonance effect),
- local damage (including cracks) reducing structure durability or negatively influencing performance or aesthetics of structural and non-structural elements.
- fatigue limit state (FLS).

For the above limit states, the assessment criteria for structure strength or stiffness apply using partial safety factors (LRFD method – Load and Resistance Factor Design).

The partial safety factors depend on uncertainty (accuracy) and heterogeneity of loads and materials, the accuracy of analysis methods and importance of structure elements due to failure effects.

Partial safety factors for loads shall take into account:
- the possibility of load adverse deviations from assumed value,
- inaccuracy due to adopted load model.
  Partial safety factors for material shall take into account:
- the possibility of material strength adverse deviations from assumed value,
- the possibility of inaccurate assessment of structural elements strength or load capacity,
- uncertainty of geometric parameters,
- uncertainty of relation between material properties within the structure and material properties specified on the basis of test samples control, i.e. uncertainty of conversion.

At the assessment of structural conformity, relevant international and national standards for materials may be applied. Combination of partial safety factors based on national or international standards with factors taken from these Rules shall be treated with extra attention. It shall be ensured that final safety level is not lower than the safety level provided by these rules.

2.1.1 Dynamic properties of structure

For the construction safety assessment, the value of natural vibration frequency of the support structure shall be compared with dynamically induced frequencies by rotating rotor, natural vibration frequencies of rotor blades and other elements of turbine or platform and with sea waving induced frequencies.

The impact on natural vibrations frequency of aerodynamic and hydrodynamic damping, material damping and seabed and foundation induced damping shall be estimated.

Vortex-induced vibrations present in the air (wind) and in water (waves and currents) shall also be considered.

The effect of any displacements of seabed, etc. on natural vibration frequencies of structure shall be assessed.

2.1.2 Service life of the structure

These PRS guidelines for design of support structures for WTGs are based on the assumption that turbine is operated for a minimum of 20 years.

PRS will assess the possibility of construction operation for a period longer than 20 years on the basis of project evaluation considering applied safety factors.

2.2 Processes of engineering stage

2.2.1 Concept design

The concept design may include feasibility study as a basis for decision on proceeding to engineering phase. The conceptual design is an initial representation (e.g. as models and sketches) of functions and capabilities (e.g. possible technological processes) based on assumptions of strategic objective for infrastructure element. Collected information on the location shall be considered, including environmental conditions and safety factors resulting from geological and geotechnical conditions.

2.2.2 Basic design

The front end engineering and design (FEED) focus is on establishing technical requirements within functional specification. The scope of this phase shall include selection of technological processes, objects arrangement and configuration plan. Initial optimization of arrangements presented in the form of schemes and diagrams shall also be made. The FEED activities base on identified and quantified loads, which are the basis for the selection of calculation methods allowing to determine required strengths and pre-dimensioning of the OWF element.

2.2.3 Detailed design

Contents and detail level of this phase of engineering shall enable obtaining law required permissions and performing by PRS safety assessment of designed solutions. Depending on the type and scope of designed element, presentation of fabrication technology, used materials and characteristics of systems process elements may be required.

3 CHARACTERISTICS OF SELECTED ENGINEERING PROCESSES

3.1 Basic design

3.1.1 Load types

The strength analysis of support structure shall consider the below types of loads:
– static loads,
– working loads,
– loads due to various deformations (temperature, soil deformations around foundation, etc.),
– loads due to environmental conditions (values acquired during activities described in Part II),
– loads in structure movement conditions (vibration).

3.1.1.1 Static loads

Basic components of static loads:
– RNA dead weight (including all components inside the nacelle such as power generator, transmission, control system, cables etc.),
– the dead weight of complete support structure below the RNA, with secondary elements such as communication deck, fenders, ladders, corrosion protection system, cables etc.,
– the weight of foundation,
– hydrostatic pressure with values appropriate for location of support structure elements in relation to water free surface,
– static effect of soil on foundation.

3.1.1.2 Working loads

The working loads occur during normal operation conditions of construction. They have no constant values. They result from various operations necessary for functioning of technical equipment.

Typical working loads are given below:
- the dead weight of personnel and stores needed for operation of technical devices,
- forces from mooring of supply vessel to support structure,
- forces induced by lifting appliances in the processes of assembly and service of technical equipment,
- loads induced by landing helicopter (applicable to constructions with a helideck),
- loads transferred to support structure by operating technical devices.

RNA impact on support structure depends on the parameters of electrical network, the element of which is power generator. Normal values of grid parameters or acceptable range of their variability are defined in IEC 61400-3. Impact of these network parameters on the load transferred by RNA to support structure shall be taken according to IEC 61400-1.

In the process of support structure design, dynamic nature of working loads shall be considered, where applicable.

The loads from working loads category, present during the construction loading to the ship, shipment and installation, shall also be considered.

3.1.1.3 Loads due to various deformations

Temperature differences in different parts of the support structure may cause stresses of significant values.

Necessity of such loads consideration during the structural strength assessment, shall be analyzed by designers and agreed with PRS.

The impact of theoretically possible soil displacements and deformations in the area of foundation, in particular influence on stress level in the support structure, shall also be analyzed.

3.1.1.4 Environmetal loads

The OWF structures shall be designed considering environmental impact (wind, waves, seabed, etc.) with parameters resulting from installation location.

The environmental impact shall be considered when planning processes of the construction transportation, assembly, operation and disassembly. The design (characteristic) values of environmental impact are considered in this analysis.

Available statistical data on parameters of environmental impact and reliable mathematical models to estimate extreme values of these parameters shall be used. Statistical data and mathematical models shall be described and submitted to PRS for information.

The wind conditions used in analysis of loads and safety are divided into normal wind conditions occurring frequently during normal operation and extreme conditions, which are specified for annual or 50-year recurrence period.

When designing the structure, the listed below types of loads and environmental parameters shall be considered:
- wind,
- sea waves,

- sea current,
- sea tiding and seasonal, as well as storm, changes of sea level,
- air and water temperature,
- salinity,
- air density,
- ice and snow accumulation on the structure,
- marine growth on structure surface,
- ice floats,
- seismic and geological conditions.

3.1.2 Characteristics of selected types of loads

3.1.2.1 Calculation of environmental loads

To determine environmental loads, PRS will accept use of documented calculation methods with sufficient accuracy proven in practice, appropriate for the proposed type of structure and environmental conditions of the installation location.

Methods of determining the impact of environmental conditions on structures may be based on appropriate model tests or measurements in real conditions of structures similar to the designed one.

3.1.2.1.1 Earthquake

For structures installed in seismic areas, the impact of time-varying displacements of ground, in which the structure is installed, on the stress level occurring in the structure shall be considered.

Seabed induced loads on structure, in the form of specified vertical and horizontal displacements over time, resulting from an earthquake, shall be adopted on the basis of available recorded cases of this type. Alternatively, normal spectral density functions of ground displacement during an earthquake, recommended in API RP 2A-WSD, may be applied.

For earthquake conditions, the structure strength analysis shall consider effects accompanying this phenomenon as liquefaction of the soil in the foundation area, possible exceeding of soil shear strength, water masses associated with vibrating structure, (tsunami) waves etc.

3.1.2.1.2 Construction biofouling

Structure biofouling (shellfish, seaweed, etc. on wet structure elements) causes increase of the structure weight and dimensions causing increase of hydrodynamic loads from waves and current and increase of surface roughness resulting in the increase of coefficient C_d.

This influences hydrodynamic loads, dynamic characteristics (e.g. change in natural frequency), availability of structure for inspections and corrosion intensity.

In general, the structure biofouling process starts intensively after installation of the support structure on the seabed, although with time the biofouling intensity (increase in thickness of marine growth layer) decreases.

The intensity of biofouling of structure elements and type of lichen accumulation depends mainly on the position of the structure element in relation to sea surface level, its location in relation to wind and wave directions and also on salinity, temperature and oxygen content in water.

The marine growth affects corrosion intensity, especially in variable immersion zone (due to astronomical tides and waves) and in zones relatively close to the mean level of still water surface.

The marine growth may destroy corrosion protection system (e.g. paint coatings, cathodic protection).

The designer shall estimate the thickness of marine growth on the structure surface, depending on the structure lifetime and vertical coordinate (distance to mean sea level), on the basis of available data from measurements for other structures located near the planned site of wind turbine.

It may be assumed in the support structure design, that the marine growth is removed after its specified thickness is exceeded.

In such case, appropriate scope and schedule of inspections and maintenance works (biofouling removal) shall be planned to prevent environmental loads of values higher than assumed in the design.

3.1.2.1.3 Ice loads

Loads of impact nature (symmetrical or asymmetrical) shall be considered, if caused by movement of ice floe or bigger ice masses (multi-year ice, icebergs) due to sea current, sea waving and wind.

Statistical data on ice on water surface shall be used to estimate significant ice parameters and ice-related issues such as:
– thickness of ice sheet of 50 years recurrence period (H),
– ice crushing strength (σ_c),
– risk of ice floe movement due to sea current or sea waving,
– ice load on structure due to changes of water level,
– ice concentration (accumulation) near the structure.

Guidelines for calculation ice related loads are given in IEC 61400-3, Annex E.

The ice loads depend on local climate conditions, sea level, possible movements and structure size and shape.

The below listed ice loads shall be considered:
– horizontal load from a permanent ice cover in the area of support structure, caused by temperature changes,
– horizontal load from a permanent ice cover, caused by sea level fluctuations and arch effect,
– horizontal load from moving ice sheets,
– vertical load from permanent ice cover, caused by changes of sea level,
– pressure from ice accumulated above and under water (eg. hummocked ice, ice ridges).

The report describing used method of determination of ice loads and their use in the calculation model for the structural strength analysis, shall be submitted to PRS for information.

It shall be assumed that the ice loads may affect the structure within normal water level range (NWLR).

It is assumed that the sea waving effect on ice load can be neglected. In many cases, performing dynamic analysis of structure response to ice load is required, considering the possibility of load pulsations causing resonance. Performing model tests to estimate ice loads may be advisable.

3.2 Detailed design

3.2.1 Systems

Equipment is defined as a set of installations and systems of technical devices cooperating for specific functional purpose.

PRS considers safety and production systems as the most important in the OWF case, electrical systems are production system (including power systems).

Documentation submitted for consideration shall include:
– description of control and protection systems,
– specific list of warnings, alarms and interlocks for control and safety systems, with operation range and settings of control and protection system elements.

For all outdoor equipment, the environmental conditions of installation site shall be defined in accordance with Publication 11/P. Details of test procedures, including acceptance criteria and service definitions shall be presented to PRS.

It shall be proved that all the outdoor equipment installed is able to withstand defined conditions. It shall be done by application of environmental testing procedures.

3.2.1.1 Safety systems

PRS considers fire-, anti-explosion-, electric shock- and environment protection systems as the most important safety systems - in appropriate scope of Publication 105/P, Parts V and VIII.

The purpose of the safety systems is to ensure that (even in case of malfunction) the OWF infrastructure remains in a safe position (conditions). In case of any malfunction, the safety system shall ensure system operation according to assumed safety concept.

The safety system is superior to control system. It starts to operate in case of exceeding safety values and when the control system is not able to maintain OWF elements within the normal operation range. The safety system is intended for maintaining the installation in a safe condition in predicted abnormal or faulty conditions caused by internal and/or external reasons.

Cases when a fault shall directly activate the safety system and/or relevant responses of control systems are described below.

The following example drawing illustrates interaction of control and safety systems.

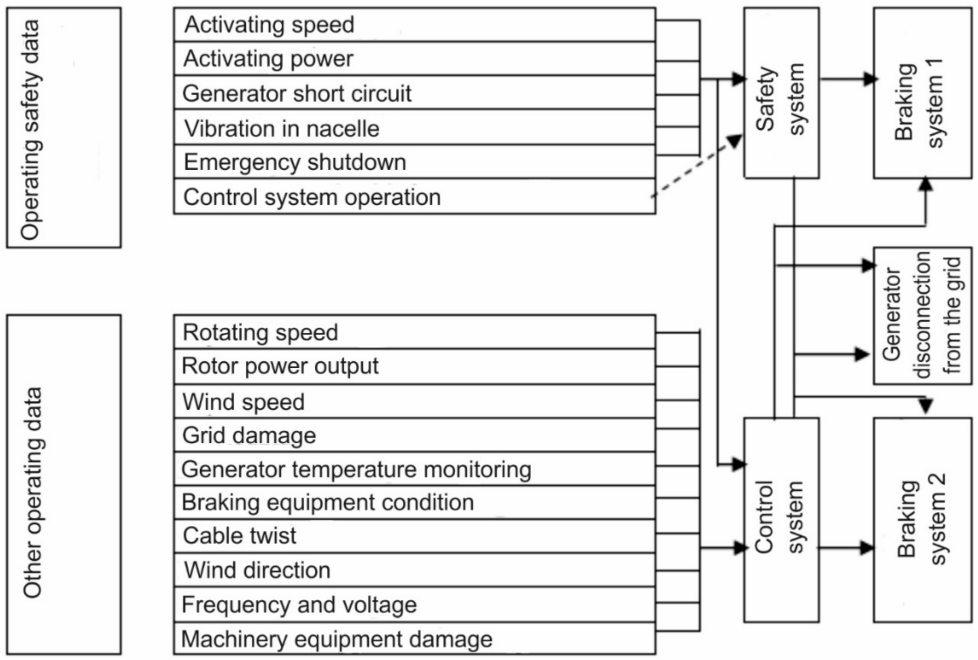

Fig. 1 Example of interaction of control and safety systems

Damage to a single element, which is essential for the safety system functioning, e.g. sensor or a braking system, may not result in dysfunction of the whole safety system (the principle of single failure detected in the safety-related system). Simultaneous failure of two independent elements is classified as an unlikely incident and therefore it may be, for some cases, neglected in rough analysis. Where the elements are interdependent, their joint failure may be sometimes considered as one failure. Individual elements of the safety system shall be of highest quality in terms of operational reliability and repeatability.

The safety system shall be fully functionally independent of the control system. The safety system shall have access to two fully independent control systems operating at the same time. The term "independent" means that potential failures of common origin, in particular systematic errors, shall be strictly avoided during design phase. In consequence, damage to a single element must not cause functional failure of the control and safety systems.

Limiting values initiating operation of safety system shall be defined in such a way, that design basic values cannot be exceeded and the OWF is not exposed to danger, but also to avoid unjustifiable safety system intervention in the control system.

The safety system shall have privileged access (in relation to control system) to a minimum of two control systems and equipment used for disconnecting OWF from the grid. After being activated (in the case of deviation from standard operational range), the safety system shall operate immediately to maintain OWF in safe condition and, where possible, to initiate return to normal operation mode with the use of all available control systems e.g. by the reduction of rotor speed.

Activating safety system does not have to result in immediate OWF disconnecting. After activation of the safety system, manual cancelling of the interlock shall be possible in each case. Cancelling safety system action shall be independent of the control system operation and may not be activated automatically. If the safety system has been activated before the power loss, the interlock cancelling may not be activated automatically after power is back. The interlock cancelling method shall be selected so that the operator can check the condition of safety system activating system before deleting.

PRS may approve the arrangement, where input elements are common for control and safety systems, if the system is made in convention "2 of 3", what means that:
– each safety essential parameter is controlled by three independent systems. Broadly defined failure of the circuit of one of the systems gives only an error signal (failure alarm) without stopping the system. Failure of two system circuits results in starting safety system and disconnection of the OWF element.
– all the elements of control and safety systems shall be made to a higher standard. The requirements for output circuits remain unchanged.

Any manual or automatic intervention may not disrupt the operation of safety system. Each element allowing manual intervention shall be distinctly marked and described.

3.2.1.2 Electrical systems

The electrical systems shall comply with the requirements of Publication 105/P, Part VI and Publication 49/P, as well as appropriate IEC Standards mentioned in reference regulations section, within the scope applicable in the given design.

All electrical components shall be designed to meet the operational conditions expected in the installation site. The electrical system design shall consider variable nature of power generation in WTG and effect of electromagnetic interference.

External environmental conditions shall be adopted in accordance with definitions of environmental conditions. The assumptions on indoor temperature, where electrical installation have been placed, shall be submitted to PRS for evaluation.

The offshore wind farms will be connected to onshore high voltage grids with direct or alternate current technology. Appropriate rules for operators of transmission systems shall be considered.

Implementation of the rules may lead to conditions having effect on loads during the WTG operation. It shall be considered, how these conditions affect operation of generator, converter and control and safety systems. This shall be considered, especially in the case of the below listed failures of internal grid:
- voltage drop,
- frequency changes,
- required minimum short-circuit current.

Connection of the offshore wind farms, in parallel, to onshore grid requires additional selection and approval from the relevant grid operator. Relevant Grid Code Compliance Certification (GCC) can be required.

Acceptable values limit shall be agreed with the onshore grid operator. Total harmonic distortion (THD) should not exceed 10 %.

In general, electrical power (effective) is used as a measurement parameter. If the design concept includes possibility of exceeding the power value, it shall be measured as a control parameter. The power measurement shall be considered as operation parameter and treated accordingly. It may be associated with other physical parameters, although with clear reference to power. In this case, relation between the substitute operation parameter and power shall be defined within test phase and written in appropriately available form (e.g. as a functional diagram).

3.2.1.3 Lightning protection and surge protection devices

The below requirements apply to basic parts of the lightning protection device:
- lightning rods,
- down-conductors,
- earthing connections,
- bonding systems,

and apply also to additional equipotential connections and isolation gaps to other systems in the object and to surge protection elements and systems.

Protected space shall be divided into lightning protection zones (LPZ) to determine spaces of different current intensity and lightning discharge field as the source of interference (LEMP). The zones purpose is to change electromagnetic conditions on their borders. After defining the degree of protection, the lightning protection zones with their requirements shall be established.

Protected space shall be divided into LPZs to designate space of different intensity of LEMP and to establish connection points at the zone borders. Equipotentialisation should be performed at the boundaries using:
- equalizing conductors (if galvanic continuity is not ensured by metallic structure),
- surge arresters (where the equalizing conductors are not allowed).

Equipotentialisation will cause significant change of electromagnetic conditions at the zone boundaries. Requirements for individual zones shall be adapted for requirements for protected system environment. The requirements for connections between zones depend on elimination of disturbance in higher zone.

LPZ 0_A – electrical and electronic systems and devices located in this zone are exposed to direct lightning current and the lightning electromagnetic pulse.

The below listed parts are exposed to direct lightning strike:
- rotor blades and external hub,
- parts of nacelle cover,
- wind measuring sensors,
- interiors of nacelle when it is made of non-metallic material,
- non-metallic or concrete towers without reinforcement connections made in accordance with appropriate requirements.

LPZ 0_B – Systems and devices operating in this zone are exposed to surges induced by lightning current or this current induced electromagnetic field. Devices operating in this zone are not exposed to direct effect of lightning current.

LPZ 1 – The zone whose interior is not exposed to direct lightning impact and currents are reduced as compared with the current in zone **LPZ 0_B**.

Devices and systems operating in this zone are protected against current and voltage surges by surge arresters and a single shield, protecting them from direct effect of lightning electromagnetic pulse.

The systems and elements of surge protection system installed in this zone are defined as basic protection.

In WTG, the zone **LPZ 1** includes:
- internals of the rotor blades, including rotor hub (sensors, actuators etc.), if effective lightning-protection (e.g. shielding, conductors) is applied,
- devices, located inside of the nacelle, completely clad with metal sheets, if they are correctly connected to an equipotential bonding system,
- cables which are laid in metallic pipes or channels or shielded (pipes, channels, shields shall be connected to the equipotential bonding on both sides),
- wind measuring sensors, if located in the protection zone of vertical lightning rod connected to down-conductors and bonding conductors,
- the interior of steel or reinforced concrete towers, if designed according to applicable standards and connected to the lightning and foundation earthing.

LPZ 2 and 3 – Subsequent zones established by installation of surge arresters and additional shielding at the zone borders.

The **LPZ 2** includes those internal devices within **LPZ 1**, which require additional shielding system and surge protection device for a further reduction of the electromagnetic field effects.

At each zone border, a local equipotential bonding shall be installed to connect all conductors, cables, metal installations, housings, shields, reinforcement etc.

All conductors and cables passing through the borders of **LPZ 0** and **LPZ 1** shall be included in the lightning protection system (equipped with e.g. surge protectors, connectors and protecting conductors), so that expected lightning current does not cause any damage.

All metal parts of electrical equipment which do not conduct current shall be connected by local equipotential connections. The protecting elements and devices for the above connections shall be selected considering their immunity to interferences and hazards in the given zone.

At the border of **LPZ 0** with **LPZ 1**, the local equipotential connections shall be interconnected and connected with lightning protection system.

The surge protection devices shall be selected in accordance with the degree of protection, considering the system conformity and characteristics. The protection shall be designed in a way, that the surge transferred to electrical equipment do not exceed limits relevant for insulation degree.

For the power, control and communication cables and conductors penetrating from **LPZ 0** into **LPZ 1**, appropriate down-conductors shall be provided. At the border of **LPZ 1** to **LPZ 2**, required surge protection shall be applied.

At the next zone borders, relevant levels of surge protection shall be applied.

3.2.1.4 Other systems

All other systems shall be designed in accordance with the requirements of relevant Parts of Publication 105/P and Publication 49/P.

4 ENGINEERING SPECIFICS OF SELECTED CONSTRUCTIONS

The structure design shall be based on verification of structural integrity of load transferring elements. Single load strength and fatigue strength of structural elements shall be verified through tests or calculations proving structural integrity. Acceptable safety level shall be confirmed and verified by calculations or tests proving the design load does not exceed appropriate design strength. The calculations shall be performed using properly selected methods. Calculation descriptions shall be included in the design documentation. The level of loads during each test shall consider safety factors adopted in relevant calculations.

The occurrence of errors, which can be source of hazard during fabrication of certain parts, shall be prevented by appropriate design of those parts, otherwise relevant information shall be placed on them and/or on their casings. In order to avoid risk, such information shall be placed on moving parts and/or their casings, when movement direction is known. Any additional information, which can be necessary, shall be given in the operation instructions and maintenance manuals.

In the case a incorrect connection may be source of hazard, such connections shall be avoided by structure design, otherwise placing information on pipes, flexible conductors and/or joints should be done.

4.1 General

4.1.1 Access to structure

The support structure shall be designed so, that every element is accessible for inspection in the process of manufacturing. During WTG operation, access for inspection shall be ensured in reasonable extent, to effectively assess technical condition of areas, which significantly affect the structure safety.

Weakening of the structure by communication openings shall be appropriately compensated.

4.1.2 Access and passages to devices

Access and passages to devices may be corridors, platforms, galleries, stairs, ladders and brackets made of non-combustible materials.

General requirements concerning access shall also be applied in case of walkways to rooms, where periodical service, inspections and maintenance of machinery and devices are performed.

The design shall provide safe access to all structural elements for surveys and maintenance operations.

The above mentioned walkways shall have clear height of at least 1.9 m and may be located above the workplace at a height of at least 2.5 m, counting from the workplace floor level.

In the walkways, the floor surface may not be slippery.

Openwork floors must not have holes with an area of more than 1700 mm^2 and their dimensions may not allow passing through a ball of diameter exceeding 36 mm.

Horizontal access from the open space shall be secured by a 1.1 m high balustrade with a bar located halfway up its height and a curb of at least 0.15 m high.

Ladders or brackets fixed permanently to the structure may serve as passage between various structure levels.

The width of the mentioned ladders or brackets shall be at least 0.5 m and spacing between rungs must not exceed 0.3 m. Above the 3 m level from the floor, the ladders or brackets shall have fall arresters. This condition may be met with protecting hoops spaced no more than 0.8 m apart, with vertical bars spaced no more than 0.3 m apart.

The ladder or bracket distance from the wall or other structure it is fixed on may not be less than 0.15 m and the biggest distance of protecting hoop to the ladder may not be less than 0.7 m and more than 0.8 m.

The landings with guardrail shall be placed every 8-10 m along the ladder height or the brackets row. Upper ends of ladder uprights (side stringers) shall extend at least 0.75 m above the entrance (platform) level, unless other fall protection system has been applied.

If the height between successive platforms (to which upper ends of ladder uprights extend) exceeds 10 m, a certified fall protection system of an approved type shall be applied.

4.1.3 Safe entry equipment

If the design assumes entrance with ladder of a height exceeding 10 m not divided by platforms, a system shall be provided to enable safe entry on the top for a minimum of 2 persons, stepping one after another, equipped with personal protective equipment of an approved and authorized type.

4.1.4 Persons and cargo transportation equipment

When lifting devices are used as a part of the construction, national requirements shall be met.

The distance between locked landing doors of a lift and an opposite wall or other partition shall be at least;
- 1.6 m – for passenger lifts,
- 1.8 m – for small cargo lifts.

Designing communication walkways directly under lift casings and locating spaces intended for people is not allowed. It does not apply to small cargo lifts of lifting capacity up to 250 kg if the structural ceiling below the lift casing withstands the load of at least 5000 N/m^2.

Only devices and cables associated with the lift O&M may be placed in lift casings.

4.2 Selection of foundation type

The design of foundations should consider impact of changes in the seabed configuration and possible scouring effects in the area of foundation on the rigidity of the structure affecting dynamic characteristics of the structure (e.g. frequency and form of free vibrations).

Foundation installation shall ensure required level of the object safety and shall be processed so, that it does not cause harmful deformations, which can arise as a result of changes occurring in the ground works or due to exceeding soil load capacity.

Characteristics of the soil, which parameters shall be defined sufficiently before starting construction process, is decisive for the selection of foundation type.

The analysis of phenomena of seabed configuration changes and scouring, as well as the selection of structural arrangements reducing the phenomena, shall be carried out in accordance with the requirements of ISO 19901-4.

Products manufactured in accordance with individual documentation prepared by the object designer or agreed with him, for which the supplier issued a declaration on the product conformity with the documentation, national rules and obligatory standards, are also accepted for a single use in the building object.

4.3 Offshore substation

The offshore substation shall maintain voltage stability within the whole OWF grid. Voltage stability and other conditions of electric grid shall be defined by the operator of cooperating onshore station and shall comply with appropriate parts of IEC 61400. The voltage stability may be ensured by e.g. the use of network transformers equipped with the on-load tap changer.

Inter array cables from the WTGs shall be able to be disconnected and efficiently earthed at both ends. In order to increase the supply reliability, parallel supply by a special loop may be applied. Normal operation shall be performed with open loop.

4.3.1 Air gap under the lower part of structure

An air gap not less than 1.5 m is required between wave crest level of 50 years recurrence period (at the highest sea water level) and higher located parts of the support structure, which have bigger width in relation to the parts washed by water.

5 STEEL STRUCTURES

The requirements of this subchapter apply to constructions and strength and fatigue strength of steel support structures for WTGs and OSS.

The strength assessment of steel support structure made of tubular elements may be performed according to e.g. requirements of API RP 2A-WSD.

5.1 Materials

The requirements apply to steel support structure having properties/parameters defined in Publication 105/P, Part II, Chapter 2. The possibility of using other steel types and other materials (except concrete) will be separately considered by PRS.

Selection of steel grades for individual structure elements depends on strength class of the element (special, primary or secondary class). Classes of particular elements intended for fabrication of OWF structures are presented below.

Special class of structures refers to the most loaded parts located in the intersections of main structural elements and other highly stressed connections, where a crack formation may result in a serious failure of structure, for example:
– elements of leg structure directly connected with footings and foundation,
– the most loaded elements of the support structure.

Primary class of structure refers to main load-bearing elements of structures, where a crack formation may result in a serious failure of structure, for example:
– main structural elements (not belonging to special class),
– parts supporting elements of very heavy devices,
– structural elements for ships mooring and ladders.

Secondary class of structure refers to less critical parts due to combination of lower load and favourable shape or where crack formation is not likely to result in a serious failure of structure, for example:
– structural divisions,
– structural stiffening elements,
– structure cover elements.

5.2 Corrosion protection

Applied corrosion protection system for the support structure shall comply with the requirements analogical to specified in Publication 105/P, Part II, Chapter 2.

The structural design shall enable corrosion reduction and consider application of efficient corrosion protection system. The design of coating protected surfaces shall provide proper preparation of surface, coating, inspection and maintenance.

Considering the corrosion exposure, smooth surfaces shall be designed. Where possible, all stiffeners, fittings, wires etc. shall be located in areas of low corrosion exposure. Holes in non-accessible elements shall be welded. In places, where water or other corrosive agents may accumulate, appropriate solutions shall be applied, such as slopes, penetrations, drains and ventilation.

Where paint coating or other protection coating may not be applied, materials sufficiently robust in service in highly corrosive environment shall be used.

The use of the corrosion protection system is allowed, if it complies with the requirements specified in the international standards for ocean engineering structures (ISO Standards, EN Standard etc.), such as ISO 19902.

The principles applied to support structures are summarized below:
– external and internal elements of support structure located above the level D shall have protective coating. In the case of hardly accessible internal surfaces, protective coating may not be applied, although corrosion additions shall be used in this case.
– in the splash zone, i.e. in the area between levels D and E, the use of cathodic protection system (or an equivalent system) is not effective. In this case, protective coating and corrosion additions shall be used.
– In the structure area which is permanently immersed (below the level E), cathodic protection system, protective coatings (such as in the first enumeration) and corrosion additions shall be applied.

5.2.1 Required values of corrosion additions

In the area of structure above the splash zone, where internal spaces are not protectively coated, corrosion addition, calculated for the assumed service life of the structure (at least 20 years) and with assumed corrosion intensity 0.1 mm per year, shall be applied. If the internal surfaces are protectively coated, then, for the calculation of the required addition by the above specified method, instead of assumed service life, its value may be taken after being reduced by the time of protective coating effectiveness (a maximum of 10 years, unless the documented data from manufacturers prove longer time of the protective layer effectiveness).

In area of variable immersion, the required corrosion addition (i.e. considering the protective layer effectiveness period) shall be calculated taking into account the below listed corrosion intensity:

– 0.30 mm/year – for external surfaces,
– 0.15 mm/year – for internal surfaces.

For permanently immersed structure elements, with obligatory cathodic protection system, corrosion additions shall be applied, which are similarly calculated, although for calculations purposes the whole planned service life of structure and corrosion intensity of 0.10 mm/year is used.

5.3 Connections

5.3.1 Welded joints of the support structure elements

Sections of the support structure transferring high stresses from environmental loads and RNA-induced loads, shall be welded to the full penetration. The requirements referring to structures, according to ISO 19902, shall be applied.

Where the structure elements are connected with fillet welds (e.g. connections of stiffeners and primary supporting members with the plating, connections of flanges and webs in primary supporting members, etc.) in general, two-side continuous welds, of thickness equal to 0.7 of the added element, shall be used. For such welds, performing strength calculations is not required.

The strength of any fillet welds may be checked regarding calculated normal and shear stresses in the weld, acc. to requirements of PN-EN 1993-1-1 and PN-EN 1993-1-8, where application of material coefficient γ_m = 1.25 is required.

5.3.2 Bolted connections

Where flange or friction bolted connections have been applied in the WTG support structure, their structure and strength shall comply with the requirements of PN-EN 1993-1-1.

5.3.3 Grouted connections

Grouted connections are the connections of tubular elements, where the space between the external and internal pipes are filled with special injection.

Such connections may be used for joining tubular elements and tubular piles of the support structure driven into seabed.

The strength and fatigue strength of grouted connections shall be calculated by methods required in ISO 19902 or API RP 2A-LRFD.

5.4 Structure strength in transportation and installation conditions

The requirements for OWF elements loading onto vessels, their shipment and unloading and on installation site are specified in ISO 19902 – to the extent applicable to such construction type.

6 CONCRETE STRUCTURES

This Chapter applies to design of concrete support structure of the WTG, in the context of structure safety in accordance with mandatory principles and practices. The atmospheric zone support structure (tower) of the WTG is defined as a part of structure of the whole turbine, which shall ensure load capacity from the structure foundation to RNA by transferring natural loads and the loads from RNA to the foundation below. Concrete structures described in this section apply only to the part of support structure made exclusively from the reinforced concrete or prestressed concrete. If a part of the support structure is manufactured from another material (e.g. at certain height upwards the support structure material is changed to steel), this part shall be designed according to separate guidelines. This section does not apply also to foundation, combined steel-concrete support structure, concrete structures for non-gravitational (floating) foundations, nor to other components of the offshore wind turbine (e.g. RNA), regardless of their material.

The requirements of this sub-chapter shall be used for structures made from reinforced concrete and those from pre-stressed concrete.

6.1 Materials

Materials conforming to PN-EN 1992-1-1 and PN-EN 1990 shall be used.

The requirements for cement, aggregates, additives to concrete mix as well as techniques and practices for producing concrete mix shall be in accordance with procedures and practices of PN-EN 206-1. The use of concrete C45 or higher grade is recommended, considering contact of concrete with sea water.

The reinforcement shall be in accordance with PN-EN 1992-1-1 and ISO 6935 or with other appropriate international standards. Prestressed steel shall also comply with the requirements of ISO 6934.

The reinforcement shall have appropriate properties e.g. strength, ductility, hardness, weldability, joint properties (ribbed joints), corrosion resistance and chemical composition. The hot rolled, ribbed bars of good welding quality and high plasticity shall be applied. Documents confirming the properties shall be submitted by the manufacturer to PRS.

The reinforced steel shall be delivered together with certificate. The certification requirement may be withdrawn, if the reinforcement is manufactured and tested within national or international certification system and all required test data are documented on the basis of statistical data from the manufacturer. All of the delivered steel shall be clearly identifiable.

Galvanized reinforcement may be used, when it does not react with cement grout, what is harmful for joints with galvanized reinforcement. Stainless steel may be applied, if the requirements for mechanical properties of normal reinforced steel are complied with. Epoxy reinforcement may be applied, if the requirements for mechanical properties of normal reinforcement bars are complied with. When the epoxy reinforcement is used, the requirements of: ASTM A 775/A 775M-97 and ASTM A 934/A 934M-97 shall be fulfilled.

To maintain the required durability of concrete in the marine environment, structural concrete shall be properly protected against physical and chemical effects. In order to ensure required corrosion protection of reinforcement, relatively small concrete permeability shall be maintained. It is achieved by the use of:
– thick aggregates,
– proper classification of fine and coarse aggregates,
– rich concrete mixes of minimum cement content 300 kg/m^3,
– low water to cement rate in the concrete mix, not exceeding 0.45,
– good concrete laying technique, proper handling, transportation, placing and consolidation of concrete and absence of concrete mix segregation.

Additionally, hazards to concrete durability in operation phase, due to concrete freezing and defreezing, abrasion and fire exposure, shall be considered.

Young concrete curing is the factor, which has significant impact on concrete durability. Concrete curing shall be in compliance with PN-EN 206-1 and it shall be aimed at:
– protection of young concrete against adverse effect of wind, sunlight and precipitation,

- maintenance of appropriate temperature and humidity of curing concrete mix,
- minimizing shrinkage of young concrete due to its drying,
- ensuring the lowest possible difference of temperatures inside and outside the concrete,
- preventing from freezing the batched water and ensuring proper development of concrete strength at low temperatures.

Test concrete mixes shall be prepared and subjected to tests within the phase of designing concrete structure, to ensure, that the required values of strength, creep, resistance to environmental conditions etc. have been achieved. The term test mix means samples of concrete (shaped as cylinders of diameter 150 mm and height 300 mm or cubes 100 x 100 mm) having parameters of concrete mix adopted in the design (concrete class, water to cement proportion, impurities, cement content in the mix etc.).

6.2 Cement based connections in the concrete support structure

This sub-chapter applies to cement-based connections of the concrete support structure elements (concrete-concrete connections) or concrete elements with steel structural elements (concrete–steel connections). Material and its connection requirements have been described, as well as recommendations for joints design and execution.

Considering the impact of marine environment (including concrete shrinkage and reduction of fatigue strength), avoiding design of cement connections for the sea water affected zone is recommended.

Initially mixed mortar is tested and supplied in accordance with the recommendations of ASTM, ISO or EN Standards. Recommended tests for fresh and hardened joints are given below:
- cement mortar flow test, acc. to ASTM C1437,
- structural binder density, acc. to EN 12350-6 or EN 1015-6,
- segregation, acc. to ASTM C940,
- the air content in structural binder, acc. to EN 12350-7 or EN 1015-7,
- the hardening time of structural binder, acc. to ASTM C 953 or EN 196-3.

The results of testing initially mixed cement mortar for structural binder are submitted, together with certificate, to PRS.

For the improvement of properties, steel fibres may be added to cement mix. Such mortar is defined as steel fiber strengthened/reinforced mortar. The length of fibres shall ensure bond between cement mortar and fibres.

6.3 Construction details

Grouting procedure shall be prepared and submitted to PRS. It is recommended, that the procedure should include at least the below listed information:
- requirements for properties of fresh joint (e.g. its density, flow, segregation etc.),
- requirements for hardened joint (e.g. compression strength, tensile strength, elasticity modulus, joint volume etc.),
- requirements for mixture composition and mixing method,
- the method of transporting fresh cement mix,
- requirements for pumps and other machinery,
- grouting pressure,
- restrictions for grouting speed.

The grouting procedures and initial cement mix shall be documented prior to their use in the structure. For this purpose, the onshore tests of the initial cement mix shall be performed.

Before starting the operation, it shall be ensured that the joint connecting the concrete support structure with another concrete element or a steel post is not damaged and that air and excessive mortar may be removed more quickly than the filling rate.

Performance of the joint is recommended at the temperature of adjacent structure between +5°C and +30°C and when it can be maintained for at least 72 h after completion of grouting. Grouting may be effected at temperatures lower than +5°C or higher than +30°C, if cement mix has been subject to appropriate tests. The tests results shall be submitted to PRS and shall prove that, the joint properties will not deteriorate. Tests shall be performed for fresh cement mix and for hardened joint. When joint between concrete support structure and other concrete or steel element is planned to be done at a temperature lower than +5°C, it shall be ensured that, the grouted surface is free from frost and ice.

The ASTM C1741, ASTM C940 and EN445 present testing methods for fresh cement mix.

Grouting shall be performed by continuous and constant way, starting from the lowest inlet. The grouted surface shall be cleaned from any oil and grease and dried before grouting.

During the grouting process, documentation shall be supplemented by essential information, such as mix identification, component materials, the mass of cement mix, the mixing time, the date and hour of mixing, the joint volume, mix sampling for checking, etc.

PART IV

Fabrication

1 GENERAL

1.1 Reference rules and standards

- **Publication 105/P** – Marine Units. Fixed Offshore Platforms and Equipment. Rules for the Construction and Survey,
- **Publication 11/P** – Environmental Tests on Marine Equipment,
- **Publication 23/P** – Pipelines Prefabrication,
- **Publication 30/P** – Principles for Certification of Welders,
- **Publication 40/P** – Non-metallic Materials,
- **Publication 49/P** – Requirements concerning Mobile Offshore Drilling Units,
- **Publication 74/P** – Principles for Welding Procedure Qualification Tests,
- **Publication 80/P** – Non-destructive Testing,
- **Publication 108/P** – Qualification and Certification of Plastics' Welders
- Rules for the Classification and Construction of Mobile Offshore Drilling Units,
- **PN-EN ISO 9001** Quality management systems,
- **PN-EN ISO 14001** Environmental management systems,
- **PN-EN ISO 19900-03** – Petroleum and natural gas industries. General requirements for offshore structures,
- **PN-EN ISO 19902** Petroleum and natural gas industries – Fixed steel offshore structures,
- **PN-EN ISO 19906** Petroleum and natural gas industries – Arctic offshore structures,
- **API RP 2N** Planning, Designing, and Constructing Structures and Pipelines for Arctic Conditions,
- **PN-EN 1090-1+A1** Execution of steel structures and aluminium structures - Part 1: Requirements for conformity assessment of structural components,
- **PN-EN 1090-2** Execution of steel structures and aluminium structures – Part 2: Technical requirements for steel structures,
- **PN-EN ISO 3834-2** Quality requirements for fusion welding of metallic materials – Part 2: Comprehensive quality requirements,
- **PN-EN ISO 14732** Welding personnel – Qualification testing of welding operators and weld setters for mechanized and automatic welding of metallic materials ,
- **PN-EN 10204** Metallic products – Types of inspection documents,
- **PN-EN 10225** Weldable structural steels for fixed offshore structures. Technical delivery conditions,
- **PN-EN 10025-1** Hot rolled products of structural steels – Part 1: General technical delivery conditions,
- **PN-EN 10025-2** Hot rolled products of structural steels – Part 2: Technical delivery conditions for non-alloy structural steels,
- **PN-EN 10025-3** Hot rolled products of structural steels – Part 3: Technical delivery conditions for normalized/normalized rolled weldable fine grain structural steels,
- **PN-EN 10025-4** Hot rolled products of structural steels – Part 4: Technical delivery conditions for thermomechanical rolled weldable fine grain structural steels,
- **PN-EN 10025-6+A1** Hot rolled products of structural steels. – Part 6: Technical delivery conditions for flat products of high yield strength structural steels in quenched and tempered conditions,
- **PN-EN 12495** Cathodic protection for fixed steel offshore structures,
- **PN-EN ISO 12944** Paints and varnishes – Corrosion protection of steel structures by protective paint systems,
- **ISO 20340** Paints and varnishes – Performance requirements for protective paint systems for offshore and related structures,

- **PN-EN ISO 1461** Hot dip galvanized coatings on fabricated iron and steel articles – Specifications and test methods,
- **PN-EN 62305** Protection against lightning – Part 1: General principles,
- **PN-EN 13670** Execution of concrete structures,
- **IEC 60502** Power cables with extruded insulation and their accessories for rated voltages from 1 kV up to 30 kV,
- **IEC 60840** Power cables with extruded insulation and their accessories for rated voltages above 30 kV up to 150 kV,
- **IEC 62067** Power cables with extruded insulation and their accessories for rated voltages above 150 kV up to 500 kV,
- **E-Cigre B1.43** Recommendations for mechanical testing of submarine cables,
- **E-Cigre B1.27** Recommendations for testing of long ac submarine cables with extruded insulation for system voltage above 30 to 500 kV,
- **E-Cigre B1.32** Recommendations for testing HVDC extruded cable systems for power transmission at a rated voltage up to 500 kV,
- **ITU G.Sup41** Design guidelines for optical fibre submarine cable systems.

1.2 Supervision and certification

For elements supplied by an approved manufacturer, verification of certificates issued by certification bodies is obligatory.

To perform the supervision of fabrication, the manufacturers shall achieve the status of an approved manufacturer.

The scope of supervision of organization's quality management in fabrication depends on the scope of manufacturer's activity covered by QMS certificate conforming to the requirements of PN-EN ISO 9001 and it shall be agreed with PRS. PRS performs the below activities:
- verification and tests of materials and components, whose certificates have not been accepted,
- analysis of quality records such as: test documentation, records on manufacturing processes, reports,
- analysis of manufacturing processes, including storage conditions and ways of proceedings with products,
- checking corrosion protection of products,
- participation in acceptance tests combined with their supervision,
- supervision during transportation and installation,
- identification of components,
- checking and verification of work procedures,
- checking quality of prefabricated elements of sections and components intended for assembly and installation,
- supervision of key fabrication nodes,
- checking the riveted joints,
- supervision of NDT,
- checking internal electric system (e.g. wiring layout, equipments' earthing, earthing system),
- checking external systems (e.g. electrical, lightning protection, safety, control, access control).

2 FABRICATION STAGE METHODS

2.1 Quality control

Focus on quality is one of PRS objectives, therefore quality control exists in each process of fabrication stage. The quality requirements shall be precisely described and measurable in order to assess their execution.

In order to enable verification of quality requirements defined for each manufacturing process, aimed at ensuring operation safety, a records shall be kept to allow traceability of fabrication processes and resources used. The fabrication operations shall be described and resources together with their characteristics shall be traceable. The resources include also human resources, tools and materials.

2.2 Processes of fabrication stage

The workshop drawings (for assembly and individual parts) of the OWF elements prepared in standardized format, shall enable clear identification (parts, purpose, drawing No., index of changes). The drawings shall include data on surface finishing, heat treatment, corrosion protection and other operations necessary for proper fabrication of the element.

2.2.1 Material

Control of raw materials for their suitability in the manufacturing process and control of final products confirming their characteristic parameters, mechanical properties and compliance with requirements, shall be performed.

Processes related to material flow cover its delivery, storage, processing and control. Marking of materials shall enable matching issued material certificates with the products.

2.2.2 Fabrication

Depending on the type of fabrication, the following sub-processes may be distinguished: prefabrication, basic fabrication and assembly. The prefabrication is related to operations resulting in flat components (two-dimensional - one dimension is considered so small as compared to two others). In the process of basic fabrication, flat components are joined in three-dimensional elements, which are joined into complete product/structure during assembly process.

2.2.3 Corrosion protection

All processes leading to corrosion protection.

2.2.4 Outfitting

Outfitting processes cover all operations ensuring, that installed machinery, devices and systems will operate properly within systems they are assigned to and will achieve assumed parameters.

2.2.5 Acceptance tests

Positively passed acceptance tests qualify the product for next stage of its and the OWF project development. Three kinds of tests can be distinguished considering their chronology: FAT, HAT and SAT. For the performance of next test stages, acceptance of previous tests results is needed.

3 CHARACTERISTICS OF SELECTED PROCESSES OF FABRICATION STAGE

3.1 Material

Selection of materials during engineering shall consider the load type (static and dynamic loads) and service conditions.

Materials used for manufacturing machinery parts such as gears, bearings, brakes, couplings, etc. shall comply with quality requirements and test conditions provided in appropriate standards, unless agreed otherwise.

Materials shall comply with the requirements of Publication 49/P, Publication 105/P, Part II and Publication 40/P. Materials used after adaptation or conversion process shall be considered separately by PRS.

Materials used for individual elements in the fabrication of steel structures shall be in accordance with safety categories. The categories depend on the importance of elements applied in the structure for its safety. Marking of materials shall enable matching the issued material certificates with products.

Materials which, due to their chemical composition, mechanical properties and application conditions, do not conform with provisions of the above referenced publications are, in each case, subject to separate consideration by PRS.

This Chapter covers specifications of materials used for fabrication of steel structures. All used materials shall comply with the criteria of standards their fabrication was based on. The applied materials are required to have appropriate tensile strength properties and good weldability. The documentation justifying the use of proposed steel shall be submitted to PRS.

In technically justified cases, PRS may require performing control tests of the certified materials.

All the materials used for fabrication of fiber reinforced plastics shall be approved by PRS. PRS may accept certificates issued by other certification bodies, after separate consideration.

Before start of the elements fabrication, the *Product Type Approval Certificates* for materials shall be presented to PRS. Exceptionally, PRS may accept a non-approved material on the basis of positive results of its properties testing.

Destructive tests of materials may be carried out only by laboratories having appropriate PRS approval.

3.2 Fabrication

As an example of fabrication process, a welding process used in the fabrication of the OWF elements, which is one of main fabrication processes, has been described. The specification covers inspections, testing and fabrication preparation. The welding process has been described in Publication 105/P, Part II, Publication 23/P, Publication 30/P and Publication 74/P.

Before welding, the fabricator shall obtain PRS approval for fabrication of welded structures. PRS may accept approval granted by other certification bodies, on the basis of other standards than referenced in the above publications (e.g. PN-EN ISO 3834-2 or PN-EN 1090-2), after separate consideration.

3.2.1 Plans and specifications

Submitted drawings or specifications shall clearly indicate welding scope for the main parts of the structure. The welding process, welding consumables and joints shall be indicated on the drawings or in separate specifications (welding book) submitted for approval. Inspector shall be informed about planned sequences and procedures to be used at the erection and welding of main structural elements. In each case, welding procedures and consumables, relevant for executing weld joint of strength and hardness comparable with base material, shall be used. The welding consumables shall also be approved by PRS. Acceptance of the welding consumables approved by another certification body is subject to separate consideration.

The division of structure into executive units and division of welded joints into those made during prefabrication and those made during assembly of structure shall be so designed, that possibly small number of weld joints would be performed during assembly and in out-of-position places.

The sequence of elements assembly and division of structure assembly operations to executive units called *Assembly Plan* and as its result - *Welding Plan* - describing welding sequence, shall be developed. Proper welding sequence enables minimization of remaining stresses and permanent deformations. Cumulation of welds and too low spacing between welds shall be avoided.

3.2.2 Supervision

It shall be proved that all welders and welding operators, who would be engaged in the structure assembly, are properly qualified (in accordance with Publication 30/P) and are experienced in the assigned kind of work and in proper execution of welding processes (in accordance with Publication 74/P). All changes made during execution of the project are subject to PRS inspector acceptance, shall be documented and attached to as-built documentation. Qualifications of welding personnel confirmed by other certification body may be recognized upon separate consideration.

3.2.3 Welding procedures

Welding procedures (WPS and WPQR) for all welds, including types of welding consumables, beveling angle, welding method and welding position shall be agreed with, and accepted by, PRS prior to the structure assembly.

Special preacutions must be taken during preparation of welding, initial heating, welding sequence, delivering heat and checking interpass temperature in case of welding thick sections.

Welding residues such as slag, weld spatter or drops and burrs shall be removed and sharp edges shall be chamfered or rounded.

3.2.4 Preparation for welding

In the case of welding structure elements made of steel of either normal or higher strength or from aluminium, the requirements shall be fulfilled related to:
– base materials,
– welding consumables (e.g. PN-EN ISO 14171),
– welding procedure,
– qualifications of welders,
– weld quality control,
– joint preparation (PN-EN ISO 9692-1:2014).

Absence of contamination is an essential factor in joint preparation for welding. The welded surface and its adjacent area shall be free from oil, scale, rust, paint, etc.

Welding procedures for structure elements made of high strength steel will be separately considered by PRS.

Structure straightening after welding may be performed to a limited scope after agreeing the straightening procedure with PRS.

3.3 Quality control

NDT processes, used in the fabrication of OWF elements, are a component of the quality control processes. The NDT processes are described below and also in Publication 80/P and Publication 23/P.

Drawings and specifications shall indicate the scope of NDT for the weld. Prepared Inspection Test Plan (ITP), which presents all control stages in the manufacturing process of a steel structure, shall be agreed with PRS before fabrication.

The NDTs shall be performed in accordance with the ITP. The Plan shall contain all inspection stages during the structure fabrication. The Plan shall be prepared by the manufacturer and approved by the Client and PRS. The NDT procedures shall be approved by PRS.

The NDT methods shall be chosen on the basis of the testing scope and method abilities dependent on selected materials and types of joints.

Where the heat treatment is required, the NDT shall be performed after finished process of post welding heat treatment (PWHT).

The test reports should comply with previously approved NDT procedures. All tests shall be documented in such a way, that test conditions could be recreated. The reports shall be identifiable and specify type of nonconformities and their location, as well as acceptance criteria. All repaired welds shall be documented and marked.

3.3.1 The scope of non-destructive testing

The scope of non-destructive testing is defined by a designed importance of element due to strength class. Welds connecting elements of higher strength class with those of lower strength class shall be tested for conformity with higher class requirements. The strength class of element shall be shown on the drawing- based on this class, the category of inspection and NDT scope are defined. Detailed description of NDT scope is given in Publications 23/P, 49/P and 80/P.

All welds shall be tested in 100% with visual test method (VT).

Table 1
Minimum scope of NDT for welded elements

Element class	Inspection category	Type of joint	Test method			
			Visual	Magnetic[1]	Radiography[2]	Ultrasonic[3]
Special class	I	butt joints angle joints girth joints cruciform joints	100%	100%	100% – – –	– – – 100%
Primary class	II	butt joints angle joints girth joints cruciform joints	100%	20%	10% – – –	– – – 20%
Secondary class	III	butt joints angle joints girth joints cruciform joints	100%	Spot[4]	Spot[4] – – –)	– – – Spot[4]

1) Penetrant tests may be applied only to non-ferro-magnetic materials.
2) Tests may be partly or completely replaced by ultrasonic testing upon agreement.
3) The ultrasonic testing may be applied to materials of thickness ≥ 10 mm. The UT for materials of thickness from 8 to 10 mm shall be previously agreed with PRS.
4) Approximately ca. 2% to 5%.

The required acceptance levels for joints together with reference to relevant standards according to the element class and test method, are given in the below table. In the case of joining elements of various classes, the higher class acceptance level shall be applied.

Table 2
Acceptance levels related to structure class

Element class	Inspection category	Type of joint	Test method				
			Visual EN ISO 5817	Penetrant EN ISO 23277	Magnetic[1] EN ISO 23278	Radiography[2] PN ISO 10675-1 and -2	Ultrasonic[3] EN ISO 11666, 15626, 22825, 23279
Special class	I	butt joints angle joints girth joints cruciform joints	B	2x	2x	1	2
Primary class	II	butt joints angle joints girth joints cruciform joints	B	2x	2x	1	2
Secondary class	III	butt joints angle joints girth joints cruciform joints	C	2x	2x	2	3

1) Penetrant tests may be applied only to non-ferro-magnetic materials.
2) Tests may be partly or completely replaced by ultrasonic testing upon agreement.
3) The ultrasonic testing may be applied to materials of thickness ≥ 10 mm. The UT for materials of thickness from 8 to 10 mm shall be previously agreed with PRS.

3.3.2 Repair of welds

Defects disclosed through NDT or other tests, shall be repaired. The part of weld, where welding defect occurred, shall be removed and new weld shall be done in accordance with qualified welding procedure. The repair procedure shall be agreed with PRS. The place of repair shall be properly prepared and re-examined after repair. All repairs shall be documented in the welding book.

3.4 Equipment

Where auxiliary systems are powered by hydraulic or pneumatic energy, the systems shall be fabricated so as to avoid potential hazards associated with these types of energy. Means for isolating or discharging the accumulated energy shall be provided.

All lines and/or hoses transfering hydraulic oil or compressed air and their connections shall be fabricated in such a way that they could withstand expected internal stresses and be protected against anticipated external effects.

Precautions shall be undertaken to reduce the risk of body injury due to breaking off the systems.

3.4.1 Electrical systems

The resistance to the marine environment conditions may be improved by application of materials coating. In the case of electrical systems, below listed factors shall be considered:
– control of atmospheric conditions,

– coating systems or other anti-corrosion protection, depending on the used materials (metals, plastics, glass fibres and others).

The electronic power converters shall be so designed that the level of harmonic interference of generated alternating current does not negatively influence operation of onshore grid electrical equipment, resulting in the equipment damage and faulty operation.

3.4.1.1 Power cables and their accessories

The design and type tests of subsea power cables and their accessories shall, respectively to their rated voltage, comply with requirements of IEC 60502, IEC 60840 and IEC 62067.

The cables selection criteria and manufacturer's declarations shall be given in the documentation submitted to approval.

Wires and cables, parameters of which comply with appropriate standards and their suitability has been proved in practice, may also be used for the assembly.

3.4.1.2 Alternating current power systems

The power cables subsea systems shall be subject to type tests:
– checking mechanical properties using appropriate procedures included in Publication *E-Cigre B1.43 Recommendations for mechanical testing of submarine cables*. The scope of tests shall cover at least the coiling test and tensile strength test with bending,
– water penetration test based on recommendations included in Publication *E-Cigre B1.27 Recommendations for testing of long ac submarine cables with extruded insulation for system voltage above 30 to 500 kV*,
– high voltage test,
– insulation resistance test,
– partial discharge measurement.

3.4.1.3 Direct current power systems

– cables used for connection of wind farms with shore using high voltage direct current HVDC line shall comply with requirements for cable tests defined in the recommendations *E-Cigre B1.32 Recommen-dations for testing HVDC extruded cable systems for power transmission at a rated voltage up to 500 kV*,
– mechanical tests of direct current subsea cables.

3.4.2 Lightning and surge protection

These requirements apply to installation and commissioning of lightning protection system for OWF objects.

Mostly the underground metal parts not insulated from the ground shall be used as earthing of lightning protection system.

Properly fabricated non-insulated foundations made of reinforced concrete can be used as an earthing. Coating concrete with damp-proof layer may not be considered as an insulation layer. Concrete foundation may be used as an earthing, provided that during its fabrication, the reinforcement has been galvanically connected in possibly highest number of places with special clamps, binding wires or by welding. For the base of diameter more than 3 m, connection from the foundation earthing to steel structure shall be made in at least four points.

If the achieved earthing resistance is not less than 10 Ω, an artificial earthing shall be executed. The earthing type: ring, radial or driven in the ground (deep vertical) depends on the location and ground resistance.

The resistance of an earthing measured at each control bond (earthing ends) shall be less than 10 Ω. The ends of ring earthing or foundation earthing shall be introduced into the structure interior and connected to equipotential bonding.

The WTG support structures are fabricated from steel pipes, lattice structures or reinforced concrete. Therefore, there is no need to make artificial earthing if the requirements specified in further part of this section are complied with.

In order to achieve protection zone LPZ 1 for the interior of WTG support structure made of reinforced concrete or closed steel structures, it is necessary to ensure the earthing continuity from the foundation to the RNA yaw system shall be ensured.

The reinforced concrete structure can meet required parameters if, during fabrication, reinforcement has been galvanically connected in as many points as possible (e.g. using clamps). The connection from the concrete into the tower interior shall be done in two or more places as a reference point. Moreover, metal flanges at the foundation and at the tower top shall be connected with reinforcement.

At defining protection zones for lattice structures, it shall be assumed, that inside they comply only with the requirements of the protection zone LPZ 0_B.

The lightning protection system for wind measurement sensors shall be made with shielding spikes with proper down conductors, able to safely discharge the lightning.

3.4.3 Fire protection

Fire instructions shall be placed in visible places and the locations of hand-held fire-extinguishing and fire-breaker switch shall be marked.

Fire switch shall be provided, located near the main entrance to the object or main grid connection and shall be properly marked. Properly marked main switch located in the switchboard room or an emergency stop button enabling disconnection of the OWF infrastructure (its shutdown) is considered to be a fire breaker.

Escape routes shall be marked and their proper lighting ensured, even when the main power switch is turned off.

An emergency escape route shall be ensured in the case the main communication way is cut off by fire.

The OWF infrastructure elements shall be equipped with hand-held fire-extinguishing equipment intended for extinguishing fires of electrical equipment with extinguishing medium mass of a minimum 2 kg (or capacity 2 dm^3).

The equipment shall be placed in easily accessible locations (at least 1 m wide), visible and not exposed to mechanical damage or heat sources (heaters).

The equipment shall be subjected to technical tests and maintenance, in accordance with the principles defined in separate rules and equipment service manuals.

Maintenance activities shall be performed at least once a year, within the scope conforming to manufacturer's service manual.

Detailed requirements for fire protection systems are specified in Publication 105/P, Part V.

3.4.4 Other systems

The design and the reflectometric tests of optical fibres shall be performed according to the provisions of International Telecommunication Union G.Sup41.

4 FABRICATION SPECIFICS OF SELECTED ELEMENTS OF THE OFFSHORE WIND FARM

4.1 Cubature structures

Drawings, which show main dimensions and the specification of masses, the inertia moments and the centres of gravity, shall be submitted to PRS for approval.

4.1.1 Platform structures

The manufacturing procedure is similar to the process of fabrication of vessel superstructure. After the flat sections used for decks and walls are fabricated, they are assembled into sections and modules, which are then corrosion preserved and outfitted. The platform structures fabrication is described in Publication 105/P.

4.1.2 Jacket structures

In jacket structures, tubes and nodes are primary elements, which are assembled into cubature sections in the form of e.g. legs and then modules (e.g. lower and upper). Depending on the technical capabilities, modules are corrosion preserved and outfitted before assembly.

4.1.3 Gravity base foundations

In the case of gravity base foundation made of concrete, the structure fabrication stages include also:
– execution of the formwork and associated scaffolding,
– reinforcement execution,
– concreting, compacting and curing,
– removal of the formwork and associated scaffolding.

4.2 Tubular structures

4.2.1 Monopiles/towers

The flat elements are rolled up in the form of rolls/cargs, which are then welded together. After that structure is protected against corrosion and outfitted.

4.2.2 Transition pieces for monopiles

Process similar to fabrication process of a monopile with additional phases such as assembly of separately fabricated platforms.

4.3 Rotor-nacelle assembly

4.3.1 Lightning protection

The earthing continuity from the generator bedplate to the foundation earthing shall be ensured using the below arrangements:
– bearings capable of conducting the lightning current down,
– slip rings with brushes capable of conducting the lightning current (this device may be placed inside the yaw system),
– spark gaps.

Above mentioned connections shall be of high conductivity and low inductance.

The wire connections bypassing turntables are not recommended, taking into account significant length of the bypassing wiring, due to range of the nacelle rotation up to 720°. High frequency of the shunts earthing current may result in high difference of potentials. If the bedplate (generator and gear) is connected to the yaw system of RNA with flexible damping elements (shock absorbers), shunting these elements with flexible flat copper tapes of sufficient cross-section is necessary. However, when the bedplate is connected to the yaw system (and thus to earthing system) by bolts, there is no need to make additional connections.

The rotor blades shall be equipped, along their whole length, with a wire able to conduct down the lightning. The connection shall be made so that the lightning charge is safely (without thermal and mechanical damage) brought through the rotor hub structure to nacelle and then further to the foundation earthing.

The system conducting the lightning current from the rotor hub down to the foundation shall be designed to ensure safe (without thermal and mechanical damage) conduction for the required protection level.

The recommended elements which meet those requirements may include:
– bearings adapted to conduct the discharge current,
– appropriate slip rings with metal slide adapted to conduct the lightning current (these elements may be located inside the yaw system of RNA),
– surge arresters.

The clutch between the gearbox and generator shall be isolated. The isolation shall prevent conduction of the lightning current through generator and its bearings.

When the gearbox and generator are connected to their own foundation with flexible damping elements, it is necessary to bridge them with flat elastic bands of required cross-section.

When the gearbox and generator are connected by bolting with their foundation (foundation and machinery) and this can be considered sufficient, additional connections are not necessary.

Where electrical elements (apparatus, switches, control devices, etc) are integral with the equipment, they shall be connected metallically to each other and to main foundation.

If the above connections have not been executed during the equipment assembly, they shall be executed by a copper wire (cross-section at least 10 mm^2) with equipotential bonding connected to the foundation. The connecting wires shall be protected against mechanical damage and as short as possible.

Metal nacelle cover shall be connected to the equipotential bonding system. The nacelle shall be connected with the foundation in several points, over entire surface, with a steel band of adequate cross-section. All existing hinges shall be shunted using flexible copper bands of possibly highest cross-section.

If a non-metallic nacelle cover is used, vertical spikes shall be fitted, together with appropriate down conductors, connected to the foundation. The height and number of vertical spikes with down conductors shall be determined by the nacelle size. When defining spike height, it shall be considered that the 45° protecting cone shall cover the whole nacelle. Each case of the given size of nacelle shall be considered separately.

It is recommended, that the switchboards of the switchgear should be manufactured with complete metal casing and galvanically connected to equipotential bonding. The above casings may not be needed if the interzone connection is not required or when switchgear apparatus is manufactured in accordance with the requirements for the given protection zone.

PART V

Transportation and installation

1 GENERAL

1.1 Reference rules and standards

- **PN-EN ISO 19900-03** – Petroleum and natural gas industries. General requirements for offshore structures,
- **PN-EN ISO 19901-1** – Petroleum and natural gas industries – Specific requirements for offshore structures. Part 1: Metocean *design* and *operating* considerations,
- **PN-EN ISO 19901-2** Petroleum and natural gas industries – Specific requirements for offshore structures – Part 2: Seismic design procedures and criteria,
- **PN-EN ISO 19901-4** Petroleum and natural gas industries – Specific requirements for offshore structures – Part 4: Geotechnical and foundation design considerations,
- **PN-EN ISO 19901-5** Petroleum and natural gas industries – Specific requirements for offshore structures – Part 5: Weight control during engineering and construction,
- **PN-EN ISO 19902** Petroleum and natural gas industries – Fixed steel offshore structures,
- **PN-EN ISO 19906** Petroleum and natural gas industries – Arctic offshore structures,
- **PN-EN 1997-1** Eurocode 7. Geotechnical design. General rules,
- **PN-EN 1997-2** Eurocode 7. Geotechnical design. Part 2: Ground investigation and testing,
- Legal acts relevant for geotechnical, mining and geological activities,
- Legal acts relevant for building activities,
- Legal acts relevant for marine areas and maritime administration,
- **DNVGL-ST-N001** Marine operations and marine warranty.

1.2 Supervision and certification

- verification of installation plan and procedure,
- approval of materials to be built-in on the seabed at the installation site,
- review of documents demarkating the structure installation site on the seabed,
- review of required tests and reports,
- supervision during transportation and assembly,
- checking transportation damages,
- supervision of structure installation works,
- checking the quality of performed works and their compliance with the design, permits, rules and technical knowledge,
- participation in final acceptance activities and commissioning,
- review of as-built documentation.

2 METHODS OF THE TRANSPORTATION AND INSTALLATION STAGE

The strength of vessels and of the OWF structure elements seated on them during transportation shall comply with the requirements defined in the *NOBLE DENTON* for marine transport operations or equivalent.

Transportation and installation (e.g. seating, anchoring, towing or moving OWF elements) shall be supervised by persons with required marine qualifications.

Procedure for installation works shall comply with the PRS approved executive plan, developed on the basis of the OWF infrastructure manufacturer's instructions. The documentation for transportation, installation and assembly procedures shall specify permissible atmospheric and marine conditions (e.g. average wind speed). The approval by other certification body shall be agreed with PRS.

The executive plan shall be prepared considering the requirements included in these Rules or on the basis of Publication 105/P, Part III provisions, by analogy.

PRS distinguishes two main types of transportation and installation, considering their specifics – methods for structures and cabling.

2.1 Technical documentation

2.1.1 Executive plan

Documentation shall also include the executive plan, which covers among the others procedure for execution of particular installation works and technical specifications for performance and acceptance of the works, taking into account reliability and possibility of preservation of designed solutions as a result of conclusions and recommendations from risk analysis.

2.1.2 As-built documentation

The as-built documentation consists of: construction documentation, drawings and descriptions of the object realization (if needed), geodetic surveys and measurements book and, for the object realization by assembly, also the assembly log with changes made in the course of performed works and as-built geodetic surveys.

2.2 Processes of the transportation and installation stage

2.2.1 Transportation planning and preparation

All operations shall be planned with safety as the priority. In this process, any required legal permits shall be obtained.

2.2.2 Loading

The process of cargo placement on the means of transport shall be appropriately supervised and secured, considering its specifics.

2.2.3 Transportation

The cargo transportation process may be completed in an intermediate (temporary) location. A temporary location is a place such as higher-complexity components factory, an installation port, etc. The last transportation process is delivery of the product to OWF installation site.

2.2.4 Installation

PRS distinguishes four main types of installation due to their specifics. The first criterion is related to the sea level – is it above water or the underwater infrastructure. The above water installation differs significantly from the underwater one due to size of technical equipment, i.e. WTG and transformer platforms. The installation of underwater infrastructure has been divided considering its type, i.e. point infrastructure (foundation and its scour protection) and line infrastructure (cabling and its scour protection).

2.2.5 Commissioning

Commissioning activities include verification of correctness of performed installation and assembly processes and confirmation of readiness for commissioning and operation stage.

3 CHARACTERISTICS OF SELECTED PROCESSES OF THE TRANSPORTATION AND INSTALLATION STAGE

The operations of transportation and installation processes shall be performed by suitably trained personnel or persons instructed in the scope of related activities.

Depending on the work conditions, the executive personnel shall apply attested eye, feet, hearing and head protection equipment. Personnel performing rope-access activities (e.g. climbing the tower or working above the earth or water surface) shall be trained in this kind of activity and shall use approved safety belts, climbing safety equipment or other safety equipment.

All operations shall be executed with the use of the equipment approved for that purpose and in accordance with proceedings recommended by the manufacturer of the equipment. The whole equipment shall be kept in a good condition and be suitable for the intended purpose. Cranes, lifts and lifting equipment, including all slings, hooks and other devices, shall be suitable for safe lifting and shall have valid use certificates.

When planning, the environment parameters defined by the manufacturer of the equipment, shall be observed. The elements to be considered include:
- wind speed,
- snow and icing,
- ambient temperature,
- impact of the sand carried by wind,
- lightning strikes,
- visibility,
- rain.

Loading, transportation and installation shall be planned so that work proceeds safely and in accordance with general and national rules. As need arises, during the planning the below shall be considered:
- detailed drawings, the list of activities and commissioning plan,
- principles of proper handling elements being installed,
- principles of materials delivery and storage,
- installation procedures,
- quality assurance procedures.

The organizer of those activities shall identify and minimize existing and potential hazards in accordance with ALARP principle.

The manufacturer of the OWF elements is obliged to deliver:
- the operation and maintenance manual (installation instruction) including drawings, specifications and assembly and installation instructions, with clear description of the requirements,
- details on all loads, weights, lifting points, special tools and proceedings necessary for handling and installation.

3.1 Loading

The place of loading OWF elements shall be prepared, maintained, operated and managed so that works can be performed in a safe and efficient manner. Depending on the circumstances, unauthorized persons access shall be prevented. The means of transport shall be suitable to the type of carried cargo and adapted, i.e. equipped with technical devices ensuring cargo stability and minimizing the risk of damage and loss of transported elements.

3.2 Transportation

Access to the place of unloading shall be safe. For road transport, the below listed factors shall be considered:
- obstacles and access roads,
- traffic,

- road surface,
- road width,
- the distance between vehicles,
- permitted loading of road surface,
- movement of elements in the site of storage.

Depending on the manufacturer's recommendations, for safe performance of each type of transportation operations, special tools, mounting beds, grips and other devices shall be used.

3.2.1 Alternative methods of transportation

PRS, in line with the principle of focus on changes, development and continuous improvement, allows using alternative methods of transportation and installation, however, their acceptance requires separate consideration and analysis.

3.2.2 Towing of structure

Within the scope of this paragraph provisions, the requirements of administrative authorities of the country of structure registration or the country whose waters the structure will be towed on, may also be applicable.

Meeting the requirements of administrative authorities may be considered by PRS as equivalent to compliance with the requirements of this chapter.

The OWF infrastructure elements, which will be towed to the installation site as buoyant, shall comply with the requirements contained in Publication 105/P, Part I, Chapter 10.

3.3 Installation

For the OWF infrastructure elements transported and installed in the installation site with the use of specialized vessels, no stability calculations are required. A specialized vessel is vessel performing operations for the specified branch of industry, e.g. an offshore or a performing limited scope of whole installation phase, e.g. cable laying vessel, not intended for standard cargo shipping.

The structure installation shall comply with the requirements of *NOBLE DENTON* or equivalent.

The cabling installation shall comply, by analogy to an appropriate scope, with the requirements of Publication 105/P, Annex on installation of the subsea pipeline systems with application of relevant standards and rules.

The installation shall be performed by employees trained and instructed about methods of proper and safe execution of the operations.

During installation, no OWF element or its part may be electrically-live, unless it is required by installation process itself. In the latter case, power connection shall be done in accordance with written manufacturer's instructions.

All elements whose motion (rotation or movement) may cause potential hazard shall be secured against undesirable motion.

Threaded fasteners and other fastening devices shall be installed applying tightening torques recommended by the manufacturer and following its other instructions. Connectors, considered critical, shall be checked and procedures for that shall be established and applied for the control of proper installation tightening torque and for compliance with other requirements. Used torque wrenches shall have valid use certificate.

In particular, inspections shall be performed to check:
- correct assembly and connection of lashings, ropes, turnbuckles, struts and other equipment and devices,
- correct attachment of lifting devices necessary for safe installation.

Cranes, hoists and lifting accessories, including all lifting slings, hooks and other devices required for safe installation, shall be suitable for safe lifting and final load placement. It is recommended that manufacturer's instructions and documentation related to installation and handling, should contain information on expected loads and safe lifting points for elements and units. The whole hoisting equipment, slings and hooks shall be checked and certified for the required safe working load.

4 INSTALLATION SPECIFICS OF SELECTED ELEMENTS OF THE OFFSHORE WIND FARM

4.1 Foundation

The installation processes of the OWF foundations shall be executed in safe manner that minimizes negative impact on the environment, e.g. vibrations and noise. Depending on the type of foundation elements, there will be differences in the installation process due to used technical means, e.g. anchoring in the ground with caissons requires other equipment than for pile driving.

Selection of installation vessel and process procedure are determined by the dimensions and weight of installed structure. The installation precision shall also be taken into account, when considering the results of subsoil examination.

Where necessary, the ground being in contact with the structure installed on the seabed shall be appropriately protected against erosion and washing out.

4.2 Cables

The subsea cables installation process shall be based on the guidelines of Publication 105/P, Annex A, to the possible scope.

The installation method determines the type and equipment of the CLV, as well as hydro- and meteorological conditions in which the process can be executed. The adopted method shall prevent damages and ensure safety of people, environment and existing infrastructure.

Before the operation, plan for communication among individual positions related to cable laying, shall be prepared. The plan shall be agreed with PRS.

Regardless of CLV type and the method of its positioning, the positioning shall ensure, at defined weather conditions, works are performed within tolerances provided in the project:
- correct route of the laid cable,
- correct position and heading of CLV during cable releasing from its deck, as well as when stationary, for the purpose of performing operations that require it,
- proper tensile stress in the released cable,
- safe distances between vessel with the laid cable and existing infrastructure.

The dynamically positioned ship, having DP notation in Class certificate, shall meet the above listed requirements in automatically control manner.

Each installation vessel, performing other tasks than CLV, shall be equipped respectively for intended work. The equipment shall ensure compliance with safety, technological and other requirements applicable for the works executed independently or in a team.

Plastic deformations of cables delivered in a coil occuring in the process of installation, result in fatigue degradation after small number of cycles, defined as Low Cycle Fatigue (LCF) or Ultra Low Behaviour Cycle Fatigue (ULBCF). The degradation may also occur when switching the current on and off. It can be assumed that plastic deformations resulting from the installation process, in permissible limits, will significantly influence the cables reserve of fatigue strength only when they will be subjected, after being laid, to variable loads of high number of cycles, resulting in stresses not exceeding the yield strength or to loads resulting in plastic deformations.

On the Baltic Sea, the subsea cables may be in many cases treated as a static object, that is not subject to variable loads. It applies, in particular, to cables, whose immediate strength calculations have been made using working stress design method.

When bidirectional plastic deformations may occur during service, with small number of cycles, as well as in any case, where the cable or parts thereof cannot be treated as a static object (see above), it is recommended that the cable delivered in coil manufacturer should submit the result of computer modelling of fatigue degradation.

The spacing between parallelly installed cables shall be such as to minimize interaction with currents flowing through them and to take into account service and maintenance of cables and theirs fasteners.

PART VI

Commissioning and operation

1 GENERAL

Startup, operation and maintenance procedures shall be planned, considering safety and shall be described in the operation and maintenance manual.

The requirements apply also to temporarily installed electrical measurement devices.

The commissioning shall be performed in accordance with manufacturer's instructions. They shall contain a description of proceedings for the first power connection (to grid).

Prior to commissioning, in the presence of PRS representative, specification (test programme), together with all planned tests description, shall be submitted for approval. Prior to testing, the contractor shall provide evidence that the installation has been performed correctly and tested to necessary degree to ensure safe operation. When such evidences are missing, appropriate tests will be performed at commissioning stage.

The assessment of electrical conditions between the OWF and the grid, which will result from OWF connecting to existing electrical grid and devices, shall be performed to ensure its compatibility. The assessment shall cover at least:
– rated value and permissible range of changes in supply voltage,
– rated value and permissible range of frequency changes,
– phase asymmetry,
– symmetrical and asymmetrical interference,
– the number of voltage losses in the grid,
– cycles of automatic re-connection,
– short-circuit impedance,
– external harmonics.

1.1 Reference rules and standards

– Rules for the Classification and Construction of Mobile Offshore Drilling Units,
– **Publication 2/P** – Alternative Survey Arrangements for Machinery,
– **Publication 34/P** – Inspection of Underwater Welded Joints,
– **Publication 51/P** – Procedural Requirements for Service Suppliers,
– **Publication 52/P** – Underwater Inspection of Mobile Offshore Drilling Units in Lieu of Drydocking,
– **Publication 54/P** – Alternative Hull Survey Arrangements,
– **Publication 55/P** – Survey of Corrosion Protection and Anti-fouling Systems,
– **Publication 17/I** – Industrial Surveys based on Approved Planned Maintenance System for Machinery,
– **Publication 18/I** – Guidelines on the Performance of Non-destructive Tests of Bottom Part of the Mobile Offshore Drilling Units,
– **PN-EN ISO/IEC 17020** Conformity assessment – Requirements for the operation of various types of bodies performing inspection,
– **PN-EN ISO/IEC 27000** *Information technology – Security techniques – Information security management systems – Overview and vocabulary*
– **PN-EN ISO/IEC 27001** *Information technology – Security techniques – Information security management systems – Requirements*
– **PN-ISO/IEC 27005** Information technology – Security techniques – Information security risk management
– **PN-EN IEC 62443** Security for industrial automation and control systems
– **PN-EN 61508** Functional safety of electrical, electronic and programmable electronic safety-related systems – Part 1: General requirements
– **PN-EN 61511** Functional safety - Safety instrumented systems for the process industry sector

– **PN-EN 62061** Safety of machinery, functional safety of safety-related electrical, electronic and programmable electronic control systems
– **PN-EN ISO 13849** Safety of machinery — Safety-related parts of control systems
– **NACE TPC 3** Microbiologically Influenced Corrosion and Biofouling in Oilfield Equipment,
– **PN-EN 50308** Wind turbines. Protective measures. Requirements for design, operation and maintenance,
– Legal acts relevant for marine areas and maritime administration (see Annex I).

1.2 Supervision and certification

– Commissioning certificate,
– Periodic inspection certificate,
– Certificate of service competence,
– Certificate of maintenance plan acceptance,
– Safety certificate.

2 METHODICS OF THE COMMISSIONING AND OPERATION STAGE

The elements of the OWF infrastructure, which may be subject to commissioning and maintenance listed in this Chapter are given as examples. Considering that dynamic technological development may lead to creating new solutions and eliminating the existing ones, each OWF design shall be treated individually and the elements indirectly or directly influencing the safety during the whole period of the design life shall be identified.

The manufacturer shall provide the manual for the operator in the Polish language. During commissioning, the manual shall be supplemented with information on specific local conditions.

The workplace instructions are intended for the operator or its representative, to provide necessary knowledge for performing proper operation supervision of the OWF and its elements.

The operation and maintenance manual shall be prepared in (or translated into) the Polish language. It shall contain information and details which can be understood by a qualified personnel with appropriate technical training. Remarks on the safety and measures to prevent accidents shall be provided in the text before the description of particular system operation. The remarks shall be explicitly marked as related to safety.

The operation and maintenance manual as well as the instructions shall be made of material (paper, plastic foil) respective to their storage conditions.

The manual shall be made available to operation and maintenance personnel. The manual shall be understandable to the operator.

The operation and maintenance manual as well as workplace instructions shall contain listed below information:
– description of the OWF element,
– remarks for the users,
– hints for finding errors and damages.

The description of the OWF element shall include:
– manufacturer's data,
– characteristics of the object physical parameters,
– operating parameters,
– purpose and type of particular elements, serial number or the manufacturer's number and the year of fabrication.

The remarks for users shall include descriptions and explanations on:
- activities aimed at ensuring safety and measures to prevent accidents,
- protection and control systems,
- safe operation range,
- emergency procedures,
- procedures for operational start and stop of the system,
- all messages displayed by the system (lists of accidents and damages),
- all types of damage and their repair methods,
- functions and operation of all operating and indicating elements, such as switches, buttons, lamps, measuring instruments,
- elements and functions subject to periodic verification and adjustment, together with data on particular set values.

Without any own repair, the operator shall be able to recognize the cause of the malfucntion and (if it cannot be removed by a simple action) to notify the repair team about the scope of activities necessary for its removal.

2.1 Processes of commissioning and operation stage

2.1.1 Startup

During the commissioning process, safety and operation parameters of the OWF technical devices are checked – within the site acceptance test (SAT).

The structures shall be installed in accordance with manufacturer's instructions. For the confirmation of appropriate conditions, such as lubricating condition and readiness for commissioning all elements, they shall be subjected to a preliminary inspection. The inspection shall be confirmed using appropriate forms.

2.1.2 Commissioning

Upon acceptance of SAT results, PRS certificates are issued to confirm readiness for safe operation.

2.1.3 Operation

The operation process is the longest process within OWF project development – if no unexpected incidents occur which can terminate the OWF project, this process lasts for a minimum of 20 years.

2.1.3.1 Maintenance

The whole OWF infrastructure, including technical equipment, shall be subjected to periodical surveys confirming its capability of further operation. PRS assumes 5 year survey cycle of the OWF components, according to submitted and accepted schedule of surveys and inspections.

2.1.3.2 Repairs

The repair process is different from routine servicing and maintenance (and minor repairs) due to operations complexity and the amount and variety of engaged resources. If the repair cannot be made by 3 technicians within 5 hours, such operation is treated as non-routine and qualified as a repair. It is associated with appropriate procedures for service work safety and operational continuity of the OWF power system. The repairs require carrying out risks analysis and compliance with operations procedures. Repairs are also understood as operations of technical devices replacement.

2.1.3.3 Lifetime extension

Before the last cycle of periodical surveys of the OWF infrastructure in accordance with designed life cycle, the OWF owner may request PRS to verify the possibilities of extending the service life.

The extension period depends on the infrastructure condition and possibilities of its modernization, as well as on administrative limitations.

3 CHARACTERISTICS OF SELECTED PROCESSES OF THE STAGE

A checklist of planned activities and a list of items to be checked before and during commissioning shall be submitted to PRS for approval.

3.1 Startup

After OWF installation, its testing shall be carried out for confirmation of correct, safe and functional operation of all its devices, control systems and apparatus. The tests shall be performed according to manufacturer's instructions. The test program shall cover at least:
– safe startup,
– safe withdrawal,
– safe emergency withdrawal,
– safe withdrawal from run-up or its representative simulation condition,
– functional tests of the protection system.

3.1.1 Operation documentation

The operation documentation, together with test plan and proof that the OWF has been correctly erected under PRS supervision, shall be submitted to PRS for assessment.

The OWF commissioning is carried out in attendance of PRS surveyor.

3.1.2 Supervision during acceptance tests

The measurements during tests shall include:
– power curve measurement,
– noise measurement.

New OWF elements under PRS supervision will be checked additionally, including measurements during operation, loads, stress and moments in support structure.

The measurements can be used as a basis for stress analysis.

The test results should include:
– assessment of measurements,
– reliability analysis of achieved results,
– comparison with calculations, where applicable.

Measurements shall be performed with efficient tools provided with valid calibration certificates.

The recommendations for the measurement system and assessment shall be agreed with PRS before installation of the measuring system.

3.2 Commissioning

Each OWF object shall be provided with maintenance manual containing at least manufacturer's requirements for maintenance and emergency procedures. It is recommended that the manual should describe also the unplanned operational service procedures.

The purpose of the maintenance manual is to provide service personnel with information necessary to perform scheduled and unscheduled inspections.

It is recommended that the service checklist will be prepared in tabular form with survey and adjustment instructions grouped acc. to due timeperiod.

In the manual parts subject to wear shall be indicated and criteria for their replacement specified.

The maintenance manual shall contain:
– information referencing the manual to the object,
– the remarks on safety and the measures to prevent accidents, to be necessarily applied before starting the survey, e.g. the use of appropriate protective equipment when climbing the tower,
– description of all activities performed during periodic survey; the description can be prepared using appropriate drawings, figures (pictograms). Issues being the subject of individual service activities such as checks of: oil level, oil pressure, bolt tightening torques, adjustment of brakes, etc. shall be clearly described,
– additional information on the quantity and quality of spare parts and auxiliary materials, e.g. lubricating materials, filters, etc.,
– lubrication plan specifying lubricating frequency, types of lubricants or other special fluids and filters,
– maintenance intervals and procedures,
– a detailed list and description of necessary test procedures for control and safety systems (e.g. overspeed test, emergency shutdown function test) together with applicable check timeperiods,
– survey instructions shall be supplemented with survey log, in which survey intervals will be defined and their performance recorded,
– complete wiring diagram and inter-connections,
– Inspection and tightening plan for bolts, considering control of stresses and tightening torques,
– diagnostics procedures and troubleshooting tips,
– set of drawings for assembly in the operation site,
– description of restart procedure,
– list of recommended spare parts,
– list of tools.

3.2.1 ECO-/REC Declaration

When commissioning the OWF infrastructure, the supplier shall issue the ECO-/REC Declaration for the product type, which confirms compliance with the requirements of the above mentioned documents. If the turbine is delivered in modules, declarations for particular elements shall be issued by the module supplier and then, on the basis of partial declarations, the owner is obliged to issue an overall ECO-/REC Declaration.

The ECO-/REC Declarations for the product type are issued based on information on material contained in the technical data sheets and material safety data sheets received from the manufacturer, whose list, together with the names of products or materials (the name and CAS No.), date and name of the manufacturer, shall constitute an annex to the Declaration.

At the issue of ECO-/REC Declaration, the Technical Data Sheets (TDS) shall provide information on technical parameters and physical and chemical properties of products used for the construction of particular modules. Based on TDS information, the principles of safe transportation of the product to the OWF site shall be determined.

The Material Safety Data Sheets (MSDS) are the source of information on chemical substances present in the products used for the construction and operation of wind turbines. The structure and content of MSDS shall be in accordance with the EC Regulation No. 1907/2006 (REACH) and the European Commission Regulation No. 453/2010. The ECO-/REC Declaration shall consider the hazards described in section 6 – related to unintended release to environment (if applies to marine environment) and in section 14 defining hazards due to maritime transport. Based on UN number of the material, the possibility of product/material transportation shall be confirmed against the IMDG Code guidelines (it applies mainly to lubricants, oils, explosives, readily flammable and insulation materials).

The declaration shall confirm the absence, in the structure and in permanent equipment of the offshore wind turbines, of substances referred to in Annex I to Hongkong Convention (tables A and B in the MEPC.269(68) Guidelines – see Annex 2) and several other compounds (dichloromethane and others) not allowed to be used by legislative acts relevant for recycling area and other acts:

1. asbestos – its varieties defined in *Chemical Abstracts Service* as: actinolite asbestos (CAS No. 77536-66-4), amosite asbestos (grunerite) (CAS No. 12172-73-5), anthophyllite asbestos (CAS No. 77536-67-5), chrysotile asbestos (CAS No. 12001-29-5), crocidolite asbestos (CAS No. 12001-28-4), and tremolite asbestos (CAS No. 77536-68-6) – in accordance with:
   - the International Convention for the Safety of Life at Sea – SOLAS Regulation II-1 / 3-5,
   - the International Maritime Organization MSC/Circ.1045 *Guidelines for maintenance and monitoring of on-board materials containing Asbestos*,
   - the EU Regulation No. 1257/2013 on ship recycling,
   - the Regulation (EC) No. 1907/2006 concerning the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH), establishing a European Chemicals Agency,
   - the Directive 2009/148/EC of 30 November 2009 on the protection of workers from the risks related to exposure to asbestos at work*;*
2. ozone layer-depleting substances (ODS) such as: CFCs, halons, CCl_4 and others, in accordance with:
   - the Regulation (EU) No. 1257/2013 on ship recycling,
   - the *Montreal Protocol* on *Substances* that *Deplete* the *Ozone Layer* (Journal of Laws No. 98, item 490 of 23 December 1992) and 1990, 1992, 1997 and 1999 amendments to the Montreal Protocol,
   - the Regulation (EC) No. 1005/2009 on the substances that deplete the ozone layer;
3. polychlorinated biphenyls (PCB) – in accordance with the Regulation (EC) No 850/2004 of the European Parliament and of the Council of 29 April 2004 on persistent organic pollutants and amending Directive 79/117/EEC,
4. perfluorooctane sulfonic acid – in accordance with the Regulation EC No. 850/2004 of the European Parliament and of the Council of 29 April 2004 the use of the perfluorooctane sulfonic acid and its derivatives in new installations is forbidden,
5. anti-fouling compounds and systems – in accordance with the requirements of:
   - the Regulation (EU) No. 1257/2013 on ship recycling,
   - the Regulation (EC) No. 782/2003 of the European Parliament and of the Council of 14 April 2003 on the prohibition of organotin compounds on ships,
   - the Commission Directive 2002/62/EC of 9 July 2002 adapting to technical progress for the ninth time Annex I to Council Directive 76/769/EEC on the approximation of the laws, regulations and administrative provisions of the Member States relating to restrictions on the marketing and use of certain dangerous substances and preparations (organostannic compounds),
   - Annex 1 to International Convention on the Control of Harmful Anti-fouling Systems on Ships, 2001 (AFS Convention),
6. cadmium and its compounds,
7. hexavalent chromium (chromium VI) and its compounds,
8. lead and its compunds,
9. mercury and its compounds,
10. polybrominated biphenyls (PBB),
11. polibrominated diphenyl ethers (PBDE),
12. hexabromocyclododecane (HBCDD), *di-2-ethylhexyl* phthalate, benzyl butyl phthalate and dibutyl phthalate.

The substances referred to in paragraphs 6-13 are forbidden in use in accordance with:

– the Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (Directive RoHS, replaced by Directive 2011/65/EU, restricting the use and storage of Pb, Cd, Hg, Cr VI, PBB, PBDE),
– the Directive 2011/65/UE of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment,
– the Regulation EU No. 1257/2013 on the recycling of ships,
– the Regulation (EC) No. 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC (REACH Regulation);;

13. polychlorinated naphthalenes,
14. radioactive substances,
15. short-chain chlorinated paraffins, in accordance with:
    – the Directive 2002/45/EC of the European Parliament and of the Council of 25 June 2002 amending for the twentieth time Council Directive 76/769/EEC relating to restrictions on the marketing and use of certain dangerous substances and preparations (short-chain chlorinated paraffins)
    – the Regulation EU No. 1257/2013 on ship recycling;
16. dichloromethane (DMC; CAS 75-09-2), based on the Decision of European Parliament and the Council of 14 February 2008 amending the Directive of the Council 76/769/EEC on the restrictions in marketing and use of some dangerous substances and preparates (dichloromethane) (amendment to Council Directive 76/769/EEC).

The ECO-/REC Declarations are issued during commissioning of the OWF infrastructure elements and then updated after each repair or renovation of element. At those stages, the ECO/REC Declaration shall consider materials referred to in Tables A and B of Annex 2 to this Part of Publication and marked with „X" in the column Part I.

At making decision on recycling, the declaration shall be supplemented by information on possible presence of dangerous materials referred to in Table C of Annex 2 to this Part of the Publication and marked with „X" in the column Part II and III, together with estimation of their amount at the delivery to recycling shop. If no such substances are present, relevant information shall be entered.

The ECO / REC Declaration, with any dangerous materials mentioned therein, shall be sent to scrap yard or to disposal workshop, prior to recycling, for confirmation of the possibility of safe and environment friendly recycling, with special consideration of dangerous materials. The shipyard/recycling shop accepting the ECO/REC Declaration confirms that has properly trained and qualified personnel ready to work at the disposal of indicated dangerous material and that has implemented procedures for safe treatment of the given material, e.g. stores material in a properly safeguarded place, has signed permanent agreements with a company receiving and utilizing the given material, has at its disposal appropriate equipment and personnel authorized for unassisted neutralization or disposal of the material, etc.

Presented in Annex 2 designations and divisions of dangerous materials presented in Annex 2 are in accordance with those adopted in legislative documentation related to ship recycling. The division of materials among Tables A, B and C is in accordance with the systematics introduced by the Marine Environment Protection Committee of the International Maritime Organization in

Resolution MEPC.197(62) and continued in further documents. Table A presents dangerous materials described in Appendix 1 to the Hongkong International Convention for the Safe and Environmentally Sound Recycling of Ships (2009). Table B specifies dangerous materials described in Appendix 2 to the same convention, while Table C collects materials which are potentially dangerous to the environment and to human health.

For the commissioned or operated WTGs, the ECO/REC Declarations covers presence of the same materials taken into account in Part I of the Inventory of dangerous materials prepared for ships and other marine objects (marked with ”X” in Tables A and B; Annex 2), that means the materials present in the structure and in permanent equipment of the turbine. The update of ECO/REC Declaration, executed after making decision on scrapping, extends the scope of materials by those shown in Table C: in Part II (process wastes) and in Part III (stores) of the Inventory of dangerous materials, that would be prepared for other marine operated objects.

3.3 Operation

The operation shall be executed by properly trained and instructed personnel.

The operation supervision process is understood as the procedure focused on effective operation, with minimum number of deficiencies, safely without unnecessary overloads. The operation supervision shall be defined as the procedure for operation in pre-defined conditions. If the operation supervision is performed by the control system, it takes over control and adjustment. Implementation of appropriate PMS systems, which maximize the probability of safe operation, is recommended.

An operation and maintenance record shall be kept, to include at least the data listed below:
– identifier of the infrastructure element,
– work hours,
– hours of withdrawal,
– date and time of recorded failure,
– date and time of operation or repair,
– type of failure or operation,
– activities taken,
– parts replaced.

Unless maintenance manual or instructions recommend other proceedings, after each automatic unplanned withdrawal caused by a failure or improper operation, the operator shall examine the reason before re-starting the system. It is recommended that all unplanned automatic withdrawals should be recorded in the operation and maintenance record.

In the case of external incidents identified as non-critical failures for further safety such as electric load decay and re-emergence, automatic return to normal operation is possible, after completion of withdrawal cycle.

Appropriate steps should be taken to remove basic reason of each indication or warning of abnormal situations or reduced reliability, e.g. on recurring failures (damages) of the same type.

The operation shall be performed according to written procedures. The documentation shall cover procedures for safe operation and include:
– operation manual delivered by the manufacturer,
– principles of electrical systems operation,
– principles of operation and maintenance coordination,
– procedures for maintaining order in the object,
– recommendations for performing works on elevations,

– procedures for handling the equipment,
– proceedings for bad weather,
– principles of communication and contingency plans.

3.3.1 Operation supervision – control and monitoring systems

The control, protection and monitoring systems shall be agreed and established in the design phase in a way to enable the OWF to operate at optimum parameters with appropriate safety margin. The systems shall jointly enable control, monitoring and maintaining within safe limits of parameters such as e.g. turbine speed, braking moment, short circuit currents, vibrations, etc.

With the use of a control system, e.g. DCS (*Distributed Control System*), which includes SCADA functions, the OWF infrastructure is properly controlled, adjusted and monitored. The task of the control system is to keep the devices within defined normal operating limits.

Control system shall be designed to maintain the OWF infrastructure within normal operation limits at defined external conditions. Deficiencies such as power overload, overspeed or overheating shall be detected by the system, which subsequently shall execute appropriate corrections. The control system receives this information by appropriate sensors and it shall be able, at defined internal and external conditions, to initiate operation of safety systems.

The control system functions shall be subordinate to the safety system functions.

Where monitoring of the computer control system is provided (e.g. watch dog type) and it responses more than once a day, appropriate procedure of the safety system shall also be started.

If the safety system has been activated, the control system shall retain the data of the last operation conditions, even if deleting has been used several times (recovery can only take place after damages, which caused activation of the safety system, have been removed).

Operation by the service personnel shall be possible with the use of marked local manual control system, which overrides the automatic/remote control system.

It is recommended to make control and safety system in such a way to enable testing and calibrating as many sensors as possible without their dismantling. On-line testing of as many sensors as possible shall be provided, although, in this case, detecting undetectable dangerous failures is more difficoult. Similar requirement applies to executive systems.

It is recommended to use appropriate functional safety standards in the design of control and safety systems, including general standard PN-EN 61508 related to design of safety-related systems E/E/PE (electrical/ electronic / programmable electronic) and some branch standards, e.g. PN-EN 61511 (process industry), PN-EN 62061 and PN-EN ISO 13849 (machine industry).

Defining a set of safety function involves determining the required safety integrity level (SIL) or the required performance level (PL) on the basis of the risk analysis and assessment, for example taking into account properly defined risk graphs. Safety functions are implemented in safety related control systems of appropriate architecture (structural redundancy in subsystems of: sensors, logical and executive).

Appropriate verification and validation of the designed architecture is then required, as this applies both to hardware and software, to find if it complies with appropriate requirements for SIL or PL. The requirements for verification and validation of software are specified in third part of general standard PN-EN 61508.

In computer industrial automation and control systems (IACS), in which control and safety functions are implemented, data protection and resistance to potential attacks through industrial computer network are essential. It is recommended that these issues should be analyzed using series of standards PN-EN ISO/IEC 27000- in particular the PN-EN ISO/IEC 27001 (requirements) and PN-ISO/IEC 27005 (risk assessment). PN-EN IEC 62443 (14 parts) is standard dedicated to IACS systems cybersecurity. This standard shall be used in the context of resistance analysis of information technology (IT) and operational technology (OT) interrelated systems with reference to the Industry 4.0 concept and to the use of innovative IIoT (*Industrial Internet of Things*) technology.

It shall be considered as a rule that measuring sensors shall be fabricated to the same requirements which apply to operation and reliability of the equipment. In particular, design assumptions for fault tolerance should ensure that the same requirements are met.

The wind speed measurement is not required as a general rule. However, if safe operation depends on the wind speed among other factors or if wind speed is one of input parameters of the control system, then reliable and appropriate means for wind speed measurement shall be provided.

The accuracy of sensors shall be adapted to prevailing conditions. The measurement shall be effectively protected against external interference including intervention of non-authorized persons. It is recommended to set the sensitivity during OWF operation.

3.3.1.1 Short circuit

The OWF shall be equipped with appropriate short circuit current protection devices in main line and in auxiliaries, selected so as to ensure their selective work.

If the protecting devices detect a short circuit in the main line, they shall operate and simultaneously activate the safety system.

At the design stage, appropriate operation of the safety or control system shall be forseen in the case of detecting short circuit in auxiliary devices, depending on their importance.

3.3.1.2 Temperature

The temperature of equipment shall be monitored to ensure that it is maintained within the permissible operating range. To achieve automatic monitoring of measurements, a system providing significant operational reliability shall be chosen, operating without any inspections.

The temperature limit shall be defined and given based on class of used insulation. Where the permissible temperature exceeded its limits, the operation parameters shall be limited to allow cooling down of devices – this is the task of the control system.

Even short-term exceeding of permissible temperature reduces the service life of the equipment; significant exceeding leads to device destruction in a short time. Exceeding power or current can result in overloading both mechanical and electrical parts. Short-term exceeding of the rated operational values shall be reduced by control devices. The safety system shall be activated when the maximum permissible values have been exceeded.

3.3.1.3 Manual safety switches

A minimum of one safety switch for each main part, e.g. in nacelle, near control and adjustment devices, shall be provided as manual intervention means.

The switches design shall enable their use according to their function and shall prevent their use for other purposes.

Activation of emergency shutdown shall prevent exposure of personnel or any OWF element to danger. It means that the safety system immobilizes operation of the OWF elements as quick as possible. The primary goal is not smooth, stepwise action, but rather the quickest braking to standstill, appropriate to the installation strength. If it is reasonable, any delays shall be avoided.

Upon activation of any manual emergency safety switch, response can be similar to the case of safety system activation due to excessive vibration. Activated manual emergency safety switch shall remain in active (armed) position.

3.3.1.4 Vibrations

The safety system shall react if currently measured vibration value exceeds (predefined) set point value. If vibrations are monitored (measured) continuously and the measured value is processed within control system, then (if the vibration reason is known) the vibration level may be monitored (controlled) by the control system.

3.3.2 Maintenance

Certification process shall be performed, in appropriate scope, based on the procedures contained in Publication 17/I and Publication 105/P, Part I, Chapter 5.

PRS can supervise OWF elements, which are covered by an approved planned maintenance system and valid PRS *Approval Certificate*.

In order to maintain validity of the *Safety Certificate*, surveys of installation are performed, in accordance with functioning approved planned maintenance system and respectively to the OWF condition periodically checked by PRS. The surveys may be performed and documented by PRS authorized person. The survey interval is two years and it may be changed respectively to the installation condition.

Each damage shall be reported to PRS. In order to maintain validity of the *Safety Certificate*, each change and main (serious) repair shall be approved by PRS and performed in a specified time, otherwise the Certificate may be voided. The extension of the period during which the works may be performed must be agreed with PRS.

Survey records shall be checked by PRS.

The following components are subject to PRS periodical survey:
– support structure (above water, underwater),
– nacelle,
– all parts of the transmission system,
– rotor blades,
– the hydraulic and/or pneumatic system,
– the safety system, access control and monitoring system (internal and external),
– electrical system (internal and external).

The survey covers:
– operation,
– wear,
– connections (if possible, checking bolt initial stresses),
– crack formation,
– damage,
– leaks,
– corrosion protection,
– noise generation,
– insulation resistance, earthing, equalization of potentials.

The whole system is checked for safety, functionality and operational reliability. The safety, control and access control systems are checked for maintaining limited, designed values.

Following the relevant periodical survey, PRS shall recommend to interested operator/OWF owner necessary repairs and modifications.

The mechanical components of the engine room shall be monitored in accordance with engineering good practices. Such monitoring shall cover physical parameters, which may be measured for indication of proper operation (e.g. level, pressure, temperature of the gearbox oil, temperature of coils, bearings, etc.). Extending the monitoring scope, to which such equipment shall be adapted to, highly depends on the general design concept and the assumed safety standard. Exceeding limit values shall always result in activating the control system shutting down the operation and then allowing the re-start after removal of the deviation reason and confirming it by service personnel. The control system should be designed so that damage prevention shall have priority to operation continuity.

Changes of settings in control and safety systems by unauthorized persons are forbidden. Each change of the set value during operation must be recorded in the report.

4 SPECIFICS OF SELECTED ELEMENTS OF THE OFFSHORE WIND FARM

4.1 Startup

During commissioning, all the functions of the operating system and those of associated external systems shall be checked.

The following shall be submitted to PRS for information:
- data from nameplates of all devices,
- register of completed works and their results,
- records on pre-start and startup tests with control parameters,
- all device associated certificates, catalogue sheets, O&M documentations, etc.

After completion of startup and operation, during the manufacturer's recommended running in period, manufacturer's recommended special activities shall be performed. The special activities may include at least: tightening bolts, change of lubricants, checking correct setting and operation of other elements and proper setting of control parameters.

4.1.1 Wind turbine generator

The below listed activities and tests shall be done:
- visual inspection of the entire installation,
- operation of safety switches in the internal and external systems,
- test of brakes activation due to any reason expected in service,
- check of locking devices (operation, electrical) used during maintenance works,
- checking of the nacelle yaw system,
- system behaviour at the load decay,
- overspeed control system check,
- operation in the automatic mode,
- checking the logic of the system indicating operation of control system,
- checking of control system via external system,
- additionally, the access control system functions shall be checked (if installed).

The access control system is recommended to be installed in cases required by functional considerations. The system shall be protected against surges. It is recommended that the warning of door opening to a limited access space should be recorded in the operation monitoring system.

4.2 Operation supervision

It is recommended to ensure the possibility of collecting and transferring data, such as power output, wind speed and direction, significant incidents, all warnings, alarms and locks.

It is recommended that the basic scope of in-service supervision should also cover the software of data base for collecting data within several year period and their proper processing, to enable receiving the time characteristics of. e.g. power output related to wind speed and direction.

4.2.1 Wind turbine generator

4.2.1.1 Power

For WTG, the power measured in combination with rotational speed is considered as a measurement of average load of the whole WTG. It can also be used as a substitute for the initiation value of safety system activities at the excessive wind speed.

The power measurement devices shall be able to measure average value (ca. 1 to 10 minutes of averaging) and the short duration peak values (measurement accuracy of a minimum 1/sec.).

If power exceeds the overload value, appropriate safety measures shall be automatically activated by the control system. The average long-term current power shall not exceed the rated value, to avoid generator overheating and overloading. Current measures shall be taken in accordance with the design. In each case of exceeding the rated average long-term power value, the WTG shall be stopped. As a rule, the overload shall not exceed 25% and the activating power shall not exceed 50% (output) power rated value of (output) power.

Shutdown of the WTG means suspending power generation.

If the WTG has been shut down due to power overload, automatic re-start may be executed without canceling if it is provided in the design and is not treated as the system error.

Exceeding the overload shutdown value due to extremely high wind speed is treated as external incident. If such situation passes, the WTG can be re-started.

4.2.1.2 Wind

If the wind speed measurement is necessary, as specified above, these requirements can be met by direct measurement of speed or by the measurement of another parameter which is precisely and recognizable connected with the wind speed value. Appropriate measuring points and measuring techniques shall be chosen as a basis for measurement in the given control system. The wind speed (undisturbed to maximum possible extent) at the height of rotor hub, may be used as an appropriate measuring parameter.

Measurement method shall be chosen so that it will not lead to dangerous events in icing condition. Checking of the measured values shall be made (e.g. by comparison with another parameter related to wind speed) and the sensor shall be equipped with a suitable heater, which will operate in case of icing conditions.

If the cut-off value of wind speed is used as a basis of design, the WTG shall be automatically cut-off by the control system in the case cut-off value of wind speed has been exceeded.

If the short-term cut-off value of wind speed is used as a basis of design, the WTG shall be automatically and immediately cut-off by the control system in the case of short-term cut-off value of wind speed has been exceeded.

If the control system detects incorrect measurement of wind speed, the WTG shall be stopped. When using a system of 3 measuring circuits operating acc. to „2 from 3" convention, it is not necessary to stop WTG after failure of one of circuits.

4.2.1.3 Grid

If the WTG looses its load (e.g. grid load), the rotor can run very quickly. This can be harmful for particular components (eg. rotor blades, gear, generator).

The damage to the grid or if WTG operation is independent from the grid, loss of the load, shall be detected by the control and safety system- in this case WTG shall be stopped. The grid damage is considered as an external fault. For this reason, the control system can automatically re-start the WTG, when the grid is able to take the load again. Such action is possible if the braking systems react quickly to prevent increase of the rotor rotating speed over limiting value.

4.2.1.4 Cabling and wiring

If RNA operation can lead to twisting of flexible cables, in particular the cables connecting rotating parts (nacelle) and fixed parts (tower or foundation), technical measures shall be taken to prevent the cabling damage by excessive twisting. It is sufficient to measure the torsion of flexible (movable) cables with a counter depending on the direction of rotation or a similar procedure adopted to determine the total number of nacelle turns. In the design phase, the manufacturer or supplier shall determine:

– acceptable degree of twisting, for moving cables,
– acceptable length of cable suspension and the method of cable fixing and gripping.

The device monitoring the twist shall always react before the maximum permissible twisting degree has been reached.

For RNA with an active system of nacelle guiding, the cable clearing up may be automatic through respective operation of the nacelle guiding drive. If necessary, the WTG shall be stopped. If the twisted cables have been twisted off automatically, the WTG can start without canceling (the alarm signal).

For WTGs without active nacelle guiding system, further nacelle rotation after reaching maximum permissible cable twisting shall be prevented. RNA shall be set in a safe position (condition).

If the WTG control needs the measurement of wind direction, the measuring equipment (e.g. anemometer) shall be continuously monitored (for confirmation of indication correctness) and equipped with appropriate heating. The heating shall be connected in the case of icing conditions.

If the control system detects that wind direction measurement results are incorrect, the WTG shall be stopped.

For RNA equipped with active guiding, it shall be ensured that even in the case of faulty rotation direction, no conditions will occur which bring damage risk to the WTG in result of stresses not anticipated in calculations. The drive of the nacelle with active guiding system shall be of self-locking type. Combination of azimuth spring brakes and non-self-locking drives meets the requirement. Before commissioning, it shall be explicitly determined that the changes of wind direction comply with the design assumptions, i.e. the RNA rotation direction is in accordance with the change of wind direction. It is particularly important when e.g. during long break in operation wind changes direction by ca. 180^0, the WTG remains in standstill state (it does not follow the wind direction changes).

For passive guiding system, before WTG operation it shall be ensured that nacelle guiding accuracy error is less than the design value.

4.2.1.5 Braking systems

At least two braking systems shall be provided used for reduction of rotor speed or rotor will be stopped in each case.

In the event of load loss and damage to one of braking systems at the same time, other systems shall be capable of keeping the rotor speed below the overspeed value, in particular in the case of grid voltage/load decay and damage to respective braking system. The overspeed shall be defined within design process when considering natural frequencies and possibilities of the system destabilization. The rotor speed shall be possible to be reduced to 0 value.

For RNA equipped with rotor blades with adjustable pitch system, when the change of blade position angle is one of the braking systems and if the blade setting mechanism is monitored by a suitable control device stopping WTG, the setting mechanism work is not correct and the rotor blades and their setting mechanism are designed in such a way that in the event of a stop or leakage in the hydraulic system of the setting mechanism, the blades are not able to generate a moment that could accelerate the rotor speed above the maximum value, it can be assumed that damage to this system will only occur in the wind speed range below rated wind speed.

Wind variability (gusts) shall also be considered. It shall be assumed that rotor blades may be set in active (pitch) position in which, due to unfavourable pitch, they may generate the moment exceeding the maximum braking moment of the mechanical braking device. In this case the brake may not cause fire hazard to RNA.

At least one braking system shall operate on the aerodynamic principle and have direct effect on the rotor. If this requirement is not met, at least one braking system shall act on the parts (eg. hub, shaft) rotating with the rotor speed (low-speed side). The measuring device of the overspeed protection switch shall be located in the low-speed part.

The emergency and operational brakes shall be so designed that they can operate properly during loss of external power supply. If the supply from the power battery (e.g. hydraulic or electric one) is necessary for the operation of brakes, it shall be monitored automatically, so that the sufficient amount of energy would be available for at least one emergency braking. If continuous monitoring is not possible, inspections shall be performed in accordance with established and accepted schedule. If the monitoring or inspection result is negative, the WTG shall be immediately stopped. This requirement is met when the aerodynamic brake at the ends of rotor blades is activated by a centrifugal force.

If torque limiting equipment is provided, each of mechanical brakes shall be located between the torque limiting device and the rotor hub.

The WTG braking systems require special consideration in terms of safety requirements. The mechanical braking system is subject to wear. For that reason, the working brake shall (to maximum possible degree) operate to the principle of low wear or no wear. If the WTG design assumes a possibility of increased, uncontrolled wear in relation to response to damage, monitoring of the braking system equipment condition is required.

The brake thickness and/or braking clearance limit in mechanical brakes and, depending on the design, the braking response time or energy consumption can be used as appropriate parameters for monitoring brakes condition.

If monitoring of braking system condition is provided as a substitute to fail-safe solution, it shall comply with the same safety requirements (standards) as the braking system itself (e.g. brake shall operate after damage to monitoring). The response of monitoring equipment shall be so that increasing damages are detected earlier (before the condition when the necessary braking power cannot be achieved) and mitigating actions are taken. If the condition monitoring detects increased wear (abrasion) of the working brake and/or emergency brake(s), the WTG shall be stopped by the control system. The system shall generate an explicit report on the detected damage.

4.2.1.6 Vibrations

Vibrations are forced vibes due to unbalance and operating close to natural vibration frequency. The unbalance may result in damages. Defects are result of e.g. asymmetric position of the rotor blades and other external distortions such as icing of the rotor blades. Damage to rotating elements may also be the source of vibrations.

Vibration measurement shall be continuous and their value compared with the set value. The sensor shall be located in nacelle, eccentrically to the tower axis. Movement of the whole nacelle shall generally be measured as vibration, with the use of appropriate measurement technique. If the nacelle movements forces are not transferred to the tower, appropriate associated movement may be measured as a substitute.

Vibration monitoring allows in general to perform qualification assessment of the WTG condition. If the noted vibration level is too high, it may be assumed that the operation is incorrect.

4.3 Maintenance

In order to ensure safety of the personnel performing inspections and maintenance operations, the following shall be considered and provided:

- safe access and workplace during inspections and operation activities,
- appropriate measures protecting service personnel from accidental contact with rotating elements or moving parts,
- possibility of using ropes, safety belts and other certified protecting equipment during rope access or work at elevations,
- possibility of locking the rotor movement and yaw mechanism or another mechanical movement during servicing and the possibility of unlocking,
- warning marking of the life wires,
- appropriate devices for discharge of accumulated electrical, pneumatic or hydraulic energy,
- appropriate electric shock protection equipment for personnel,
- alternative escape route from any closed working space,

Operational possibility of disconnecting electrical system of WTG elements from all sources of electrical energy, as required for the maintenance activities and tests, shall be ensured. The semiconductor devices may not be used as disconnecting devices.

If lighting or other electrical systems are necessary for ensuring safety during maintenance operations, supply of auxiliary circuits with own disconnecting devices shall be ensured so the circuits remain powered, while any other circuits are disconnected.

If the energy storage system is connected in parallel to powered WTG element (i.e. for improvement of power coefficient), then appropriate automatic switch disconnecting the system is necessary to avoid self-activation in case of power loss in the grid. When the system is properly selected, it is sufficient to prove that it is not able to cause the self-activation.

4.3.1 Wind turbine generator

4.3.1.1 Safety equipment for service activities

The WTG shall be equipped with at least one locking device or its substitute – both for the rotor and nacelle, provided with function of rotation locking. Automatic activation (automatic activation when reaching the standstill state) is not necessary. The braking equipment may not, as a rule, be in the same time treated as a locking device. In exceptional cases, deviation from this principle is possible, when the WTG design ensures that operation of each part of the braking system may be carried out safely. The operation of braking system may be performed safely when all rotating WTG parts that the system should stop, can be in fact secured.

Locking devices shall be designed so that even when the brakes are released, they can safely prevent any rotation of the rotor or nacelle. Locking of the WTG rotor shall have effect on driving system close to the hub and shall fit the whole structure. The nacelle locking is necessary for its protection against horizontal movement.

The design of locking devices is based on the assumption that personnel who enters purposefully and operates in the hazardous area have knowledge about device functioning. Particularly strict requirements shall be made for operational safety, quality and accessibility of the device and its connection with WTG parts subject to locking (e.g. rotor blades, hub, shaft).

The locking devices shall be used in each case when works are carried out on the WTG rotating parts. They shall also be used when the system is stopped by the brake able to bring the rotor to a standstill state or by any provided azimuth brake. The operator is obliged to observe these safety measures. Respective notes shall be placed in the operation documentation.

4.3.1.2 Rotor survey

The rotor survey shall include the below listed checks by a visual inspection and with the use of other available methods:
– surface of rotor blades, considering possible cracks, indents, discolourations,
– elements of blade pitch adjusting mechanism,
– tightening and securing bolts and pins connecting the rotor elements, including the elements of the blade pitch adjusting mechanism,
– axial and radial clearances of the rotor bearing system and clearances of the blade pitch adjusting mechanism,
– condition of lightning protection system.

4.3.1.3 Gearbox survey

When the gearbox is under load, noise volume shall be checked and linear vibration level assessed, as well as tightening bolts securing the gear casing shall be checked. If the gearbox design allows such possibility, visual examinations of gearwheel shall be performed and backlash clearance checked at spot.

The sample of lubricating oil shall be examined for the presence of water and foreign particles and oil replacement records shall be checked.

4.3.1.4 Survey of shafts and bearings

During the survey of shafts and their bearing system, attention shall be paid to linear vibrations in under load operation, possible corrosion spots and to corrosion protection condition. Clearances and condition of lubricating oil in main slide bearings, where used, shall be checked. Additionally, the flanges of integral couplings shall be inspected for cracks and, in case of any doubt, appropriate defectoscopy method shall be applied.

If excessive linear vibrations or excessive heating of bearings have been detected, proper shaft seating on bearings and proper connection of the shaft sections (alignment), bearings condition and their attachment to permanent structure, shall be checked. In extreme cases, the shaft sections geometry shall be checked.

4.3.1.5 Survey of mechanical brakes and locking devices

Mechanical structure of brakes shall be checked by visual examination for cracks and other dangerous mechanical damages. In particular, for brakes and devices intended for use in emergency, it shall be checked if they are capable of easy and immediate, remote and/or manual, activation.

Brakes shall be checked in operation in conditions corresponding to real conditions, respectively to the brake purpose (application in emergency or in service). Effectiveness of locking devices shall be demonstrated.

4.3.1.6 Survey of disengaging, flexible and other couplings

The operation of disengaging couplings under load shall be checked if it is applicable in service.

Non-metallic elements of flexible couplings shall be subjected to detailed examinations.

The Cardan couplings are subject to visual examinations. If micro-cracks of pins or their attachment are suspected, appropriate defectoscopy method shall be applied.

4.3.1.7 Survey of hydraulic system

Visual examinations of external tanks, tubes, connectors and hydraulics elements shall be performed and the system shall be checked for leakages, cracks and corrosion (in particular an internal corrosion of the hydraulic liquid tanks surfaces).

The sample of hydraulic oil shall be checked for the presence of metallic impurities (for continuously operating systems) and water. Moreover, the oil sample shall be subjected to complete analysis, if it is specified so in the Survey and Maintenance Manual.

Moreover, the operation test shall be carried out. It applies, in particular, to the rotor blades pitch adjusting mechanism and the RNA yaw system. If the PRS accepted Surveys and Maintenance Manual does not provide appropriate operation test for the above systems, the operation test shall be performed in such weather (wind) conditions, that the system checking is possible at considerable scope of the rotor blades pitch change and nacelle directional changes.

4.3.2 Lightning and surge protection equipment

Periodical tests shall be performed at least every 4 years, after each conversion or repair and after identified lightning discharge.

The tests shall include:
– close-up examinations,
– checking connections continuity,
– checking surge arresters,
– checking life threat from step voltage,
– checking life threat from contact voltage.

Each activity associated with lightning protection device shall be recorded and all changes shall be written in the technical documentation.

Timeperiods of tests and visual examinations shall be defined in the service manual for the lightning protection device – however, they cannot be longer than those given above.

4.3.3 Electric shock protection

Checks and periodic tests for electric shock protection shall be performed after each conversion or repair.

The above listed activities shall cover at least:
- visual examinations of protection against direct contact,
- continuity of protection conductors tests,
- tests of protection against indirect contact (measurement of loop impedance, earthing resistance, insulation resistance, protective conductors resistance),
- operation tests of the residual current device,
- measurement of contact and step shock voltages (with earthing equipment above 1 kV).

Each activity related to the electric shock protection shall be recorded and any changes shall be written in the technical documentation.

PART VII

Decommissioning and disposal

1 GENERAL

The requirements presented in the Publication concerning decommissioning and disposal apply to the offshore wind farm infrastructure and its elements installed on the Baltic Sea after 1 January 2019.

1.1 Reference rules and standards

- IMO Conventions,
- Publication 105/P – Marine Units. Fixed Offshore Platforms and Equipment. Rules for the Construction and Survey,
- Legal acts relevant for geotechnical, mining and geological activities,
- Legalacts relevant for construction activities,
- DNVGL-ST-N001 Marine operations and marine warranty.

1.2 Supervision and certification

- Certificate of competences necessary for realization of tasks,
- supervision of decommissioning,
- supervision of dismantling and transportation,
- checking the condition of dismantled elements of the OWF infrastructure,
- verification of dismantling technologies,
- approval of the project of environment condition recovery,
- verification of disposal process,
- checking the quality of performed works and their conformity with the design, permissions, rules and technical knowledge,
- checking of the as-built documentation,
- Certificate of the OWF project termination.

2 METHODS OF THE DECOMMISSIONING AND DISPOSAL STAGE

The rules for the recycling of OWF infrastructure shall be based on the same guidelines as the principles related to the ships operating in the same environment, established in Hongkong Convention, the Regulation of the European Parliament and the Council No. 1257/13 of 2013 and the guidelines developed by the IMO Marine Environment Protection Committee (MEPC 67/INF.8, MEPC 67/3, MEPC 67/3/4, MEPC67/3/3, MEPC 67/3/2, MEPC 67/3/1, MEPC 67/INF.2).

2.1 Process of the decommissioning and disposal stage

Implementing the stage Installation and transportation in chronologically reverse order is a standard solution accepted by PRS.

PRS allows the possibility of partial stopping of work and infrastructure dismantling due to possibility of repowering, i.e. the use of the OWF elements as base elements for installation and operation of other technical equipment such as RNA or the Platform, which will change OWF electrical energy production characteristics. Such activity requires separate arrangements and is conditioned by safety issues and acquired administrative permits.

2.1.1 Operation shutdown

It is a reverse process to the startup process within the commissioning and operation stage. It is aimed at safe shutdown of technical devices operation.

2.1.2 Infrastructure removal

All the OWF elements are subject to removal process, unless it has been otherwise planned and agreed at initial stages of the OWF project development. The removed elements shall be safely transported to storage place and then utilized. PRS allows the possibility of re-use of dismantled elements – depending on their condition and new designation, it is subject to separate analysis and agreement.

2.1.3 Recovery of environment condition

The recovery of environment condition to the state as of before development of the OWF project is the last stage of this project life cycle.

3 CHARACTERISTICS OF SELECTED PROCESSES OF THE STAGE

3.1 Operation shutdown

Before the removal, the operation of all equipment shall be stopped and secured against re-start. Analysis of risks which can affect working personnel (e.g. OWF elements remain electrified) and environment (e.g. oil leakage from stopped generators) shall be performed and the risk minimizing actions undertaken in accordance with ALARP method.

Principles of the OWF elements operation shutdown may base on Publication 105/P, Annex A in Part „De-commissioning".

4 SPECIFICS OF SELECTED ELEMENTS OF THE OFFSHORE WIND FARM

4.1 Infrastructure removal

4.1.1 Foundation removal

Considering the restrictions resulting from the OWF project plan and national regulations, two main options of foundation removal from marine areas exist – a simplified and more complex version (due to amount of operations to be executed).

The simplified version assumes complete removal of foundation and thus executing necessary activities for filling the openings in the seabed.

The complex version assumes partial retaining in-situ parts of foundation.

An example list of technical operations, which shall be executed for the complex version of the foundation removal is given below:
- removal of scour protection, to gain access to the structure,
- executing local trench in seabed, to unveil foundation elements,
- cutting the structure into at least two elements – to be removed one and to remain. The removed element, due to size and technical limitations of vessels, may be cut into smaller elements,
- lifting up the structure – depending on the size and weight, appropriate procedures of lifting and loading onto transporting vessel shall be applied,
- securing the structure elements which remain in the seabed.

It shall be considered that pulling out all installed foundation elements generates noise and vibrations affecting the marine environment.

Examples of technical operations have been listed above, however, it is not a closed list, as it shall be changed in details depending on the type of foundation to be removed. Moreover, during this stage all technical operations must be justified with appropriate analysis and preparations.

ANNEXES

ANNEX 1

REFERENCES RELEVANT FOR NATIONAL LAW

A. THE LAW OF THE REPUBLIC OF POLAND

List of reference documents, public administration bodies and other terms relevant for use in the Republic of Poland is given below.

1 PART I – GENERAL INFORMATION AND REQUIREMENTS

1.1 Legal acts relevant for respective activities

1.1.1 Legal acts relevant for geotechnical, mining and geological activities:

– Geological and mining law – Act of 9 June 2011, Geological and mining law (Journal of Laws 2019 item 868, as amended). [Prawo geologiczne i górnicze – Ustawa z dnia 9 czerwca 2011, Prawo geologiczne i górnicze (Dz.U. 2019 poz. 868 ze zm.)],
– Regulation of the Minister of Environment of 20 December 2011 on detailed requirements for projects of geological works, including works for which concessions are required for their execution (Jounal of laws 2011, No. 288, item 1696) [Rozporządzenie Ministra Środowiska z dnia 20 grudnia 2011 r. w sprawie szczegółowych wymagań dotyczących projektów robót geologicznych, w tym robót, których wykonywanie wymaga uzyskania koncesji (Dz.U. 2011, nr 288, poz. 1696)],
– Regulation of the Minister of Environment of 18 November 2016 on hydrogeological documentation and geological and engineering documentation (Journal of Laws 2016, item 2033) [Rozporządzenie Ministra Środowiska z dnia 18 listopada 2016 r. w sprawie dokumentacji hydrogeologicznej i dokumentacji geologiczno-inżynierskiej (Dz.U. 2016 poz. 2033)],
– Regulation of the Minister of Environment of 6 December 2016 on other geological documentations (Journal of Laws 2016, item 2023) [Rozporządzenie Ministra Środowiska z dnia 6 grudnia 2016 r. w sprawie innych dokumentacji geologicznych (Dz.U. 2016 poz. 2023)],
– Regulation of the Minister of Environment of 20 December 2011 on the use of geological information for remuneration (Journal of Laws 2011, No. 292, item 1724) [Rozporządzenie Ministra Środowiska z dnia 20 grudnia 2011 r. w sprawie korzystania z informacji geologicznej za wynagrodzeniem (Dz.U. 2011, nr 292, poz. 1724)],
– Regulation of the Minister of Environment of 9 June 2015 on transferring information from current documenting geological works (Journal of Laws 2015, item 903) [Rozporządzenie Ministra Środowiska z dnia 9 czerwca 2015 r. w sprawie przekazywania informacji z bieżącego dokumentowania przebiegu prac geologicznych (Dz.U. 2015 poz. 903)],
– Regulation of the Minister of Environment of 30 October 2017 on the collection and sharing of geological information (Journal of Laws 2017, item 2075) [Rozporządzenie Ministra Środowiska z dnia 30 października 2017 r. w sprawie gromadzenia i udostępniania informacji geologicznej (Dz.U. 2017 poz. 2075)],
– Regulation of the Minister of Transport, Construction and Maritime Economy of 25 April 2012 on determination of geotechnical conditions for foundations of building structures (Journal of Laws 2012, item 463) [Rozporządzenie Ministra Transportu, Budownictwa i Gospodarki Morskiej z dnia 25 kwietnia 2012 r. w sprawie ustalania geotechnicznych warunków posadowienia obiektów budowlanych (Dz.U. 2012, poz. 463)],
– Regulation of the Minister of Economy of 25 April 2014 on specific requirements for mining plant operations extracting minerals by drilling holes (Journal of Laws 2014, item 812) [Rozporządzenie Ministra Gospodarki z dnia 25 kwietnia 2014 r. w sprawie szczegółowych wymagań dotyczących prowadzenia ruchu zakładów górniczych wydobywających kopaliny otworami wiertniczymi (Dz.U. 2014, poz.812)],

– Regulation of the Minister of Environment of 8 December 2017 on the mining plant operation plans (Journal of Laws 2017, item 2293) [Rozporządzenie Ministra Środowiska z dnia 8 grudnia 2017 r. w sprawie planów ruchu zakładów górniczych (Dz.U. 2017 poz. 2293)],
– Regulation of the Minister of Environment of 1 July 2015 amending the regulation on detailed requirements concerning geological work projects, including works for which concessions are required for their execution (Journal of Laws 2015, item 964) [Rozporządzenie Ministra Środowiska z dnia 1 lipca 2015 r. zmieniające rozporządzenie w sprawie szczegółowych wymagań dotyczących projektów robót geologicznych, w tym robót, których wykonywanie wymaga uzyskania koncesji (Dz.U. 2015 poz. 964)];

1.1.2 Legal acts relevant for construction activities:
– The act of 7 July 1994, Building law (Journal of laws 2019, item 1186),
– Regulation of the Minister of Transport and Maritime Economy of 1 June 1998 on technical conditions for the maritime engineering structures and their location (Journal of Laws 1998, No. 101, item 645) [Rozporządzenie Ministra Transportu i Gospodarki Morskiej z dnia 1 czerwca 1998 r. w sprawie warunków technicznych, jakim powinny odpowiadać morskie budowle techniczne i ich usytuowanie (Dz.U. 1998, nr 101, poz. 645)],
– Regulation of the Minister of Transport, Construction and Maritime Economy of 25 April 2012 on the detailed scope and form of construction project (Journal of Laws 2012, item 462) [Rozporządzenie Ministra Transportu, Budownictwa i Gospodarki Morskiej z dnia 25 kwietnia 2012 r. w sprawie szczegółowego zakresu i formy projektu budowlanego (Dz.U. 2012, poz. 462)],
– Regulation of the Minister of Infrastructure of 2 September 2004 on detailed scope and form of design documentation, technical specifications of construction and commissioning of building works and the functional-utility program (Journal of Laws 2013, No. 202, item 1129) [Rozporządzenie Ministra Infrastruktury z dnia 2 września 2004 r. w sprawie szczegółowego zakresu i formy dokumentacji projektowej, specyfikacji technicznych wykonania i odbioru robót budowlanych oraz programu funkcjonalno-użytkowego (Dz.U. 2013, nr 202, poz. 1129)].

1.1.3 Legal acts relevant for marine areas and maritime administration:
– The act of 21 March 1991 on the marine areas of the Republic of Poland and maritime administration (Journal of Laws 2018, item 2214) [Ustawa z dnia 21 marca 1991 r. o obszarach morskich Rzeczpospolitej Polskiej i administracji morskiej (Dz.U. 2018 poz. 2214)],
– Regulation of the Minister of Transport and Maritime Economy of 1 June 1998 on technical conditions for the maritime engineering structures and their location (Journal of Laws 1998, No. 101, item 645) [Rozporządzenie Ministra Transportu i Gospodarki Morskiej z dnia 1 czerwca 1998 r. w sprawie warunków technicznych, jakim powinny odpowiadać morskie budowle hydrotechniczne i ich usytuowanie (Dz.U. 1998 nr 101 poz. 645)],
– Regulation of the Minister of Maritime Economy of 23 October 2006 on technical conditions of use and detailed scope of examination of marine hydro-technical structures (Journal of Laws 2006, No. 206, item 1516) [Rozporządzenie Ministra Gospodarki Morskiej z dnia 23 października 2006 r. w sprawie warunków technicznych użytkowania oraz szczegółowego zakresu kontroli morskich budowli hydrotechnicznych (Dz.U. 2006, nr 206, poz.1516)];

1.1.4 Legal acts relevant for recycling activity:
– Regulation of the European Parliament and the Council (EU) No. 1257/2013 of 20 November 2013 on the recycling of ships and amending the EC Regulation No. 1013/2006 and Directive 2009/16/EC [Rozporządzenie Parlamentu Europejskiego i Rady (UE) nr 1257/2013 z dnia 20 listopada 2013 r. w sprawie recyklingu statków oraz zmieniające rozporządzenie (WE) nr 1013/2006 i dyrektywę 2009/16/WE],
– PRS Informative Publication 33/I Recycling of ships. Resolution IMO MEPC.269(68) adopted on 15 May 2015: 2015 Guidelines for the Development of the Inventory of Hazardous Materials, European Maritime Safety Agency,

– The act of 20 February 2015 on the renevable energy sources (Journal of Laws 2015, item 478) [Ustawa z dnia 20 lutego 2015 r. o odnawialnych źródłach energii (Dz.U. 2015 poz. 478)],
– Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment [Dyrektywa Parlamentu Europejskiego i Rady 2011/65/UE z dnia 8 czerwca 2011 r. w sprawie ograniczenia stosowania niektórych niebezpiecznych substancji w sprzęcie elektrycznym i elektronicznym],
– The act of 27 April 2001 Environmental Protection Law (Journal of Laws 2019, item 1396) [Ustawa z dnia 27 kwietnia 2001r. Prawo Ochrony Środowiska (Dz.U. 2019 poz. 1396)],
– Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC (Regulation REACH) [Rozporządzenie (WE) nr 1907/2006 Parlamentu Europejskiego i Rady z dnia 18 grudnia 2006 r. w sprawie rejestracji, oceny, udzielania zezwoleń i stosowanych ograniczeń w zakresie chemikaliów (REACH) i utworzenia Europejskiej Agencji Chemikaliów, zmieniające dyrektywę 1999/45/WE oraz uchylające rozporządzenie Rady (EWG) nr 793/93 i rozporządzenie Komisji (WE) nr 1488/94, jak również dyrektywę Rady 76/769/EWG i dyrektywy Komisji 91/155/EWG, 93/67/EWG, 93/105/WE i 2000/21/WE (Rozporządzenie REACH)],
– Regulation (EC) No 850/2004 of the European Parliament and of the Council of 29 April 2004 on persistent organic pollutants and amending Directive 79/117/EEC [Rozporządzenie (WE) nr 850/2004 Parlamentu Europejskiego i Rady z dnia 29 kwietnia 2004 r. dotyczące trwałych zanieczyszczeń organicznych i zmieniające dyrektywę 79/117/EWG],
– The act of 19 June 1997 on the prohibition of use of asbestos contained materials (Journal of Laws 2017, item 2119) [Ustawa z dn. 19 czerwca 1997 r . o zakazie stosowania wyrobów zawierających azbest (Dz. U. 2017 poz. 2119).

1.2 Abbreviations, terms and definitions

– Maritime Administration – Polish Maritime Offices.

2 PART II – ENVIRONMENTAL AND LOCATION CONDITIONS

2.1 Geological works

The *Geological works project* developed in accordance with legal acts relevant for geotechnical, mining and geological activities shall be considered as design documentation within the scope of geological works.

The administrative body responsible for works executed within maritime areas of the Republic of Poland is the minister responsible for environmental protection matters, acting in agreement with the minister responsible for maritime economy matters (the act of 9 June 2011 – Geological and mining law (Journal of Laws 2019, item 868, as amended)).

2.2 Icing

In the Polish territorial waters of the Baltic Sea, loads due to icing are not considered.

2.3 Sea currents

2.3.1 Ice on water surface

In the Polish zone of the Baltic Sea, the load specified in paragraph „ice on water surface" may be neglected and the load due to marine biofouling needs to be considered only for structures located close to sea shore. The necessity of analyzing load due to ice on water surface will be separately considered by PRS – depending on planned site of structure installation.

2.3.2 Tides

In accordance with the document referred to in Annex 1, Part I 1.1, the legal acts relevant for marine areas and maritime administration, i.e. the Regulation of the Minister of Transport and Maritime Economy of 1 June 1998 on technical conditions for the maritime engineering structures and their location „Polish marine areas are treated as a non-tidal sea".

3 PART III – DESIGNING

3.1 Characteristics of selected kinds of loads

3.1.2 Eartquakes

For structures installed on the Polish territorial waters of the Baltic Sea, loads due to earthquake are not considered in the process of their design.

ANNEX 2

DANGEROUS MATERIALS

The dangerous materials, whose presence or absence are subject of ECO / REC Declaration – systhematics in accordance with Annex I to Hong Kong Convention (*IMO Guidelines*, Table A and B (MEPC.269(68))).

Materials to be included in the *Inventory of dangerous materials*

Table A

<table>
<tr><th rowspan="2">Item</th><th rowspan="2" colspan="2">Material</th><th colspan="3">Inventory</th><th rowspan="2">Threshold value</th></tr>
<tr><th>Part I</th><th>Part II</th><th>Part III</th></tr>
<tr><td>A-1</td><td colspan="2">Asbestos</td><td>X</td><td></td><td></td><td>0.1%</td></tr>
<tr><td>A-2</td><td colspan="2">Polychlorinated biphenyls (PCB)</td><td>X</td><td></td><td></td><td>50 mg/kg</td></tr>
<tr><td rowspan="9">A-3</td><td rowspan="9">Ozone-depleting substances</td><td>CFCs</td><td>X</td><td></td><td></td><td rowspan="9">no threshold value</td></tr>
<tr><td>Halons</td><td>X</td><td></td><td></td></tr>
<tr><td>Other fully halogenated CFC</td><td>X</td><td></td><td></td></tr>
<tr><td>Carbon tetrachloride</td><td>X</td><td></td><td></td></tr>
<tr><td>1,1,1-Trichloroethane (Methyl chloroform)</td><td>X</td><td></td><td></td></tr>
<tr><td>Hydrochlorofluorocarbons</td><td>X</td><td></td><td></td></tr>
<tr><td>Hydrobromofluorocarbons</td><td>X</td><td></td><td></td></tr>
<tr><td>Methyl bromide</td><td>X</td><td></td><td></td></tr>
<tr><td>Bromochloromethane</td><td>X</td><td></td><td></td></tr>
<tr><td>A-4</td><td colspan="2">Anti-fouling systems containing organotin compounds as a biocide</td><td>X</td><td></td><td></td><td>2500 mg total tin/kg</td></tr>
</table>

Table B

Item	Material	Inventory Part I	Inventory Part II	Inventory Part III	Threshold value
B-1	Cadmium and Cadmium compounds	X			100 mg/kg
B-2	Hexavalent Chromium and Hexavalent Chromium Compounds	X			1000 mg/kg
B-3	Lead and Lead Compounds	X			1000 mg/kg
B-4	Mercury and Mercury Compounds	X			1000 mg/kg
B-5	Polybrominated Biphenyl (PBBs)	X			50 mg/kg
B-6	Polybrominated Diphenyl Ethers (PBDEs)	X			1000 mg/kg
B-7	Polychlorinated Naphthalenes (more than 3 chlorine atoms)	X			50mg/kg
B-8	Radioactive Substances	X			no threshold value
B-9	Certain Shortchain Chlorinated Paraffins (Alkanes, C10-C13)	X			1%

Table C

Item	Properties		Materials	Inventory		
				Part I	Part II	Part III
C-1	Liquid	Oiliness	Kerosene			X
C-2			White spirit			X
C-3			Lubricating oil			X
C-4			Hydraulic oil			X
C-5			Anti-seize compounds			X
C-6			Fuel additive			X
C-7			Engine coolant additives			X
C-8			Antifreeze fluids			X
C-9			Boiler and feed water treatment and test re-agents			X
C-10			De-ioniser regenerating chemicals			X
C-11			Evaporator dosing and descaling acids			X
C-12			Paint stabilizers/rust stabilizers			X
C-13			Solvents/thinners			X
C-14			Paints			X
C-15			Chemical refrigerants			X
C-16			Battery electrolyte			X
C-17			Alcohol, methylated spirits			X
C-18	Gas	Explosives/ inflammables	Acetylene			X
C-19			Propane			X
C-20			Butane			X
C-21			Oxygen			X
C-22		Green House Gases	CO_2			X
C-23			Perfluorocarbons (PFCs)			X
C-24			Methane			X
C-25			Hydrofluorocarbon (HFCs)			X
C-27			Nitrous oxide (N_2O)			X
C-28			Sulfur hexafluoride (SF_6)			X
C-29	Liquid	Oiliness	Bunkers: fuel oil			X
C-30			Grease			X
C-31			Waste oil (sludge)		X	
C-32			Bilge and/or waste water generated by the after-treatment systems fitted on machineries		X	
C-33			Oily liquid cargo tank residues		X	
C-34			Ballast water		X	
C-35			Raw sewage		X	
C-36			Treated sewage		X	
C-37			Non-oily liquid cargo residues		X	
C-38	Gas	Explosibility/ inflammability	Fuel gas			X

Item	Properties	Materials	Inventory		
			Part I	Part II	Part III
C-39	Solid	Dry cargo residues		X	
C-40		Medical waste/infectious waste		X	
C-41		Incinerator ash		X	
C-42		Garbage		X	
C-43		Fuel tank residues		X	
C-44		Oily solid cargo tank residues		X	
C-45		Oily or chemical contaminated rags		X	
C-46		Batteries (incl. lead acid batteries)			X
C-47		Pesticides/insecticide sprays			X
C-48		Extinguishers			X
C-49		Chemical cleaner (incl. electrical equipment cleaner, carbon remover)			X
C-50		Detergent/bleacher			X
C-51		Miscellaneous medicines			X
C-52		Fire fighting clothing and Personal protective equipment			X
C-53		Dry tank residues		X	
C-54		Cargo residues		X	
C-55		Spare parts which contain materials listed in Table A or Table B			X

List of amendments effective as of 16 August 2021

Item	*Title/Subject*	*Source*
2.1.2.1	Implementation of new program certification PCW-03-MFW	PRS