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Cathodic protection of offshore wind structures

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Foreword

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This document was prepared by Technical Committee ISO/TC 156, *Corrosion of metals and alloys*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Cathodic protection (CP), possibly together with protective coating, is applied to protect the immersed external surfaces of offshore wind farm structures and appurtenances from corrosion due to seawater or seabed environments.

CP, possibly together with protective coating, can be applied to protect the internal flooded and seabed and sediment exposed surfaces from corrosion.

The general principles of CP in seawater are detailed in ISO 12473, see chapter 2.

CP involves the supply of sufficient direct current to the surfaces of the structure in order to reduce the steel to electrolyte potential to values where corrosion is considered insignificant or acceptably low.

CP is designed to protect the submerged and buried areas of the structure from corrosion. The parts that are not permanently immersed will not be permanently protected by the CP system.

This standard introduces guidance for the use of available metocean data to

- assess the CP demand of immersed and frequently wetted areas
- determine seawater flow velocities to assess the CP design parameters

This is in addition to the primary use of the metocean data in structural design.

Cathodic protection of offshore wind structures

1 Scope

This European Standard will address the external and internal cathodic protection for offshore wind farm structures. It will be applicable for structures and appurtenances in contact with seawater or seabed environments. This Standard address:

- Design and implementation of cathodic protection systems for new steel structures,
- Assessment of residual lifetime of existing cathodic protection systems,
- Design and implementation of retrofit cathodic protection systems for improvement of the protection level or for life extension of the protection,
- Inspection and performance monitoring of cathodic protection systems installed on existing structures,
- Guidance on cathodic protection of reinforced concrete structures

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 206, *Concrete — Specification, performance, production and conformity*

EN 1992-1-1, *Eurocode 2: Design of concrete structures — Part 1-1: General rules and rules for buildings*

ISO 8044, *Corrosion of metals and alloys — Vocabulary*

ISO 8501-1, *Preparation of steel substrates before application of paints and related products — Visual assessment of surface cleanliness — Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings*

ISO 12473, *General principles of cathodic protection in seawater*

ISO 12696, *Cathodic protection of steel in concrete*

ISO 12944-2, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 2: Classification of environments*

ISO 12944-9, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 9: Protective paint systems and laboratory performance test methods for offshore and related structures*

EN 13670, *Execution of concrete structures*

EN 17243, *Cathodic protection of internal surfaces of steel tanks, equipment, structures and piping containing seawater*

EN 60529, *Degrees of protection provided by enclosures (IP Code)*

ISO 20313, *Ships and marine technology — Cathodic protection of ships*

IEC 61000-1-2, *Electromagnetic compatibility (EMC) — Part 1-2: General — Methodology for the achievement of functional safety of electrical and electronic systems including equipment with regard to electromagnetic phenomena*

IEC 61400-24, *Wind energy generation systems — Part 24: Lightning protection*

EN 60529, *Degrees of protection provided by enclosures (IP Code)*

3 Symbols and abbreviations

3.1 Symbols

A	Area, m^2
C	Anode cross section periphery, m
ΔU	Driving potential, V
fc	Coating breakdown factor
I	Current, A
$I_{anode(initial)}$	Initial current output of an individual galvanic anode material, A
$I_{anode(final)}$	Final current output of an individual galvanic anode material, A
I_{max}	Maximum protection current demand for a CP zone, A
$I_{total(initial)}$	Total current required for polarization of the structure, A
$I_{total(final)}$	Total current required for re-polarization of the structure, A
J	Current density, A/m^2
L	anode body length, m
$L_{initial}$	Anode initial length, m
L_{final}	Anode final (or end of life) length, m
N	Number of anodes
Q	Practical electrochemical capacity for the anode alloy in the environment considered, Ah/kg
ρ	Resistivity of an electrolyte, Ωm
Ra	Anode resistance to remote seawater, Ω
r	Anode radius, m
R	Circuit resistance, Ω
S	Arithmetic mean of anode length and width, m
T	Temperature, °C
T_{anode}	Effective lifetime of the anode, years
T_{design}	Required design life, years

u	utillisation factor for CP design calculations
$V_{initial}$	Initial net volume of anode alloy (excluding the steel insert), m^3
V_{insert}	Volume of that portion of the insert only within the anode body, m^3
V_{final}	Final (or end of life) net volume of anode alloy, m^3
V_{gross}	Overall volume of the anode body including that portion of the insert only within the anode body, m^3
W_{anode}	Net weight of an individual galvanic anode material, kg
W_{total}	Minimum total net weight of galvanic anode material, kg

3.2 Abbreviations

ABS	Area Below Seabed
AC	Alterning Current
BEM	Boundary Element Method
CA	Corrosion Allowance
CP	Cathodic Protection
CPS	Cable Protection System
CSPE	Chlorosulfonated Polyethylene
DC	Direct Current
EMF	Electromotive Force
EPR	Ethylene Propylene Rubber
ER	Electrical Resistance
FAT	Factory Acceptance Test
FB	Free Board Level
FEM	Finite Element Method
FWZ	Frequently Wetted Zone
GACP	Galvanic Anode Cathodic Protection
HAT	Highest Astronomical Tide
HDPE	High Density Polyethylene
HMWPE	High Molecular Weight Polyethylene
HSC	Hydrogen Induced Stress Cracking
ICCP	Impressed Current Cathodic Protection
IEC	International Electrotechnical Commission

IMCA	International Marine Contractors Association
IP	Ingress Protection Code
ISO	International Organization for Standardization
ITP	Inspection and Test Plan
MMO	Mixed Metal Oxide
MP	Monopile
MSL	Mean Sea Level
MTL	Mean Tide Level
MWL	Mean Water Level
NACE	National Association of Corrosion Engineers
PTFE	PolyTetraFluoroEthylene
PVDF	Polyvinyldene Fluoride
RCD	Residual Current Device
RMS	Root Mean Square
ROV	Remotely Operated Vehicle
SMS	Specified Minimum Yield
TP	Transition Piece
TR	Transformer Rectifier
WTG	Wind Turbine Generator
XLPE	Cross-linked Polyethylene

4 Terms and definitions

For the purposes of this document, the terms and definitions in ISO 8044 and ISO 12473 and the following terms and definitions apply, see chapter 2.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

4.1
atmospheric zone
zone located above the splash zone

4.2
buried zone
zone located under the seabed or expected scour level, whichever is lower

4.3
CP design life
The time for which the CP is designed to protect the structure. Note this may be different to the structural service life

4.4
doubler plate
plate welded onto a member to locally reinforce it or to isolate it from further welding work

4.5
frequently wetted zone (FWZ)
defined as water level, WL(t) plus significant wave height, Hmo, see Annex B for details

4.6
free board level (FBL)
defined as water level for floating structures.

Note 1 to entry: Note to entry: For calculation of frequently wetted zone it will replace WL(t)

4.7
HAT
level of the highest astronomical tide

4.8
hybrid cathodic protection system
a system comprising both impressed current and galvanic anodes

4.9
inspection
an examination of equipment to determine its continued performance characteristics, whether undertaken on a regular program basis or carried out as a simple operation

4.10
jacket structure
multi-legged lattice braced structure

4.11
J-tube
curved tubular conduit designed and installed on a structure to support and guide cables

4.12
LAT
level of the lowest astronomical tide

4.13
marine sediments
top layer of the seabed composed of water saturated solid materials of various densities

4.14
metocean data
any source of meteorological and oceanographic data

4.15
monitoring
an activity continuously on-going or sporadically undertaken at fixed locations to determine the performance of a CP system or parameters related to the performance

Note 1 to entry: Typically, monitoring utilizes fixed sensors, the data from which can be data logged

4.16
monopile
a foundation element driven or drilled into the seabed to support a transition piece and/or tower

4.17
MSL
mean sea level (also known as mean water level, MWL, or mean tide level, MTL)

4.18
primary steel
Primary load carrying elements (monopile pipe, girder structure in jacket

4.19
over-polarization
Over-polarization occurrence in which the structure to electrolyte potentials are more negative than those required for satisfactory cathodic protection.

Note 1 to entry: Over-polarization provides no useful function and might even cause damage to the structure.

4.20
re-polarization
re-polarization covers a situation where the steel polarizes after a depolarization

4.21
retrofit cathodic protection
the provision of CP equipment, either as a complete or a partial system, to an existing structure, typically, either to remedy CP performance deficiencies or to extend the CP system life

4.22
salinity
the quantity of inorganic salts dissolved in the seawater. The standardised measurement is based on the determination of the electrical conductivity of the seawater. Salinity is expressed in grams per kilogramme (g/kg) or as parts per thousand (ppt or ‰)

4.23
scour
removal of seabed soils by currents and waves or caused by structural elements interrupting the natural flow regime above the sea floor

4.24
secondary steel
Steel which is not primary steel, hence used for access (boat landing, ladders, decks and support for equipment)

4.25
shallow water
Water of such depth that surface waves are noticeably affected by bottom topography.

Note 1 to entry: Note to entry: Typically, this implies a water depth equivalent to half the wavelength (CIRIA Beach management manual CIRIA report 153,[1]. For all practical purposes in this document it is understood as depth less than –30 m LAT

4.26
Significant wave height, Hmo
In open sea approximately equivalent to the mean level of the third largest waves

4.27
splash zone
external region of support structure that is frequently wetted due to the wave and tidal variations

Note 1 to entry: A more detailed definition of splash zone is given in IEC 61400-3-1, [2]. In this document the frequently wetted zone is included as the upper boundary to which current demand for CP shall be included

4.28
structural service life
the anticipated life of the windfarm structure. This includes a period for storage, transport, installation, the operating lifetime of the wind farm and a possible period for decommissioning

4.29
submerged zone
zone including the buried zone, the immersed zone, the tidal zone and the splash zone.

Note 1 to entry: In this document the frequently wetted zone is included as the upper boundary to which current demand for CP shall be included

4.30
suction bucket
a foundation element that is sucked into the seabed

4.31
surveying
the process of carrying out inspection using a defined procedure

4.32
tidal zone
zone located between LAT and HAT

4.33
transition piece
intermediate structure between the monopile and the tower

4.34
wave crest and trough
see Figure 1 below