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Cathodic protection of offshore wind structures

Protection cathodique des structures éoliennes en mer

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 156, *Corrosion of metals and alloys*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 219, *Cathodic protection,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

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.

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 document 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.

This document does not require the CP designer to be expert in metocean data; it gives guidance on data which should be available from metocean specialists and which is required in the CP design process.

Cathodic protection of offshore wind structures

1 Scope

This document specifies the requirements for the external and internal cathodic protection for offshore wind farm structures. It is applicable for structures and appurtenances in contact with seawater or seabed environments. This document addresses:

— design and implementation of cathodic protection systems for new steel structures;

— assessment of residual life 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, and

— guidance on cathodic protection of reinforced concrete structures.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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*

EN 12496, *Galvanic anodes for cathodic protection in seawater and saline mud*

ISO 12696, *Cathodic protection of steel in concrete*

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

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

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*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

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

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

3.1
atmospheric zone
zone located above the splash zone

3.2
buried zone
zone located under the seabed or expected scour level, whichever is lower

3.3
CP design life
time for which the CP is designed to protect the structure

Note 1 to entry: This may be different to the structure design life or structure service life.

3.4
doubler plate
plate welded onto a member to locally reinforce it or to isolate it from further welding work

3.5
electrolyte
medium in which electric current is transported by ions. In the context of this document, seawater or seabed

3.6
frequently wetted zone
FWZ
water level, WL(t), plus significant wave height, H_{mo}

Note 1 to entry: See Annex B for details.

3.7
free board level
FBL
water level for floating structures

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

3.8
HAT
highest astronomical tide
level of the highest astronomical tide

3.9
hybrid cathodic protection system
system comprising both impressed current and galvanic anodes

3.10
inspection
examination of equipment to determine its continued performance characteristics, whether undertaken on a regular program basis or carried out as a simple operation

3.11
IR error
error in measured steel to electrolyte potential caused by the protection current or any other current flowing through the resistive environment

3.12
jacket structure
multi-legged lattice braced structure

3.13
J-tube
curved tubular conduit designed and installed on a structure to support and guide cables

3.14
LAT
lowest astronomical tide
level of the lowest astronomical tide

3.15
marine sediments
top layer of the seabed composed of water saturated solid materials of various densities

3.16
metocean data
meteorological and oceanographic data, often given as hourly statistics

3.17
monitoring
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.

3.18
monopile
foundation element driven or drilled into the seabed to support a transition piece and/or tower

3.19
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

3.20
owner
structure owner, or developer or operator, all or any of which may have responsibility for matters related to corrosion protection

3.21
primary steel
primary load carrying elements (monopile, jacket, hull and other steel structures)

3.22
re-polarization
situation where the steel is polarized after a depolarization event

3.23
retrofit cathodic protection
provision of CP equipment, either as a complete or a partial system, to an existing structure either to remedy CP performance deficiencies or to extend the CP system life

3.24
salinity
quantity of inorganic salts dissolved in the seawater

Note 1 to entry: The standardised measurement is based on the determination of the electrical conductivity of the seawater.

Note 2 to entry: Salinity is expressed in grams per kilogramme (g/kg) or as parts per thousand (ppt or ‰).

3.25
scour
removal of seabed soils by sea currents and waves or caused by structural elements interrupting the natural flow regime above the sea floor

3.26
seabed
interface between seawater and solids of the *buried zone* (3.2) including the *marine sediments* (3.15)

3.27
secondary steel
steel which is not primary steel, hence used for access (boat landing, ladders, decks and support for equipment)

3.28
shallow water
water of such depth that surface waves are noticeably affected by bottom topography

Note 1 to entry: Typically, this implies a water depth equivalent to half the wavelength[33]. For all practical purposes in this document, it is understood as depth less than –30 m LAT

3.29
significant wave height
H_{mo}
mean level of the third largest waves in open sea

3.30
splash zone
external region of support structure that is frequently wetted due to the wave and tidal variations. A more detailed definition of splash zone is given in IEC 61400-3-1[15]. In this document the frequently wetted zone is included as the upper boundary to which current demand for CP shall be included

3.31
structure service life
anticipated life of the windfarm structure.

Note 1 to entry: This includes a period for storage, transport, installation, operating the wind farm and a possible period for decommissioning

3.32
suction bucket
foundation element that is sucked into the seabed

3.33
surveying
process of carrying out inspection using a defined procedure

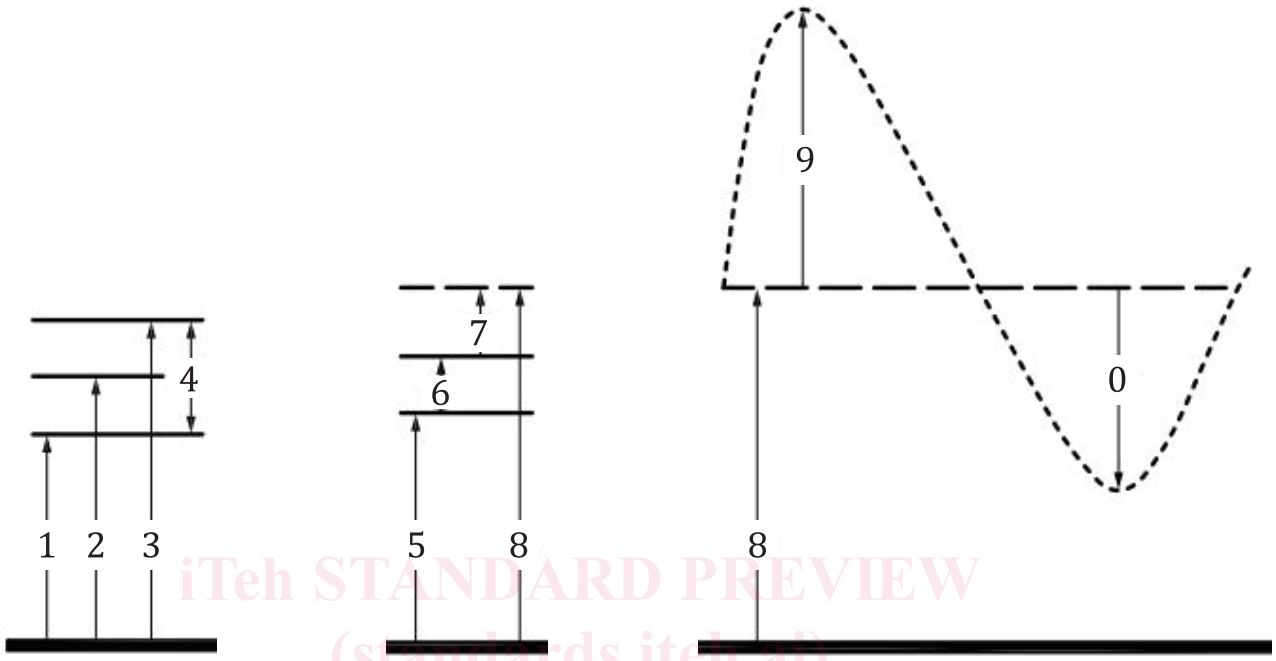
Note 1 to entry: In this document surveying is also used to describe the process of taking cathodic protection measurements, not using fixed and data logged sensors, but using a defined procedure

3.34
tidal zone
zone located between LAT and HAT

3.35
transition piece
intermediate structure between the monopile and the tower

3.36
wave crest and trough
height of seawater above and depth of below still water level due to waves

Note 1 to entry: See Figure 1 below.



a) Tides b) Tide+storm surge=still water level c) Wave profile superimposed on water level

Key

Key to distance elevation				**Key line types**	
1	lowest astronomical tide (LAT)	6	tide associated with storm (shown positive but may be positive or negative)	▬	seafloor
2	mean sea level (MSL)	7	storm surge (shown positive but may be positive or negative)	——	tide levels
3	highest astronomical tide (HAT)	8	still water (or "storm water") level	— —	surge or surge+tide levels
4	tidal range	9	crest elevation	·····	wave profile
5	tidal datum (commonly LAT or MSL but may be other)	0	trough elevation		

Figure 1 — Water depth, tides and storm surges, from ISO 19901-1[10]

4 Symbols and abbreviations

4.1 Symbols

A	Area, m^2
C	Anode cross section periphery, m
c	Coating degradation, %

ΔU	Driving potential, V
f_c	Coating breakdown factor
I	Current, A
$I_{\text{anode(initial)}}$	Initial current output of an individual galvanic anode material, A
$I_{\text{anode(final)}}$	Final current output of an individual galvanic anode material, A
I_{max}	Maximum protection current demand for a CP zone, A
$I_{\text{total(initial)}}$	Total current required for polarization of the structure, A
$I_{\text{total(final)}}$	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. In this document resistivity may be of an electrolyte (sea or seabed) or a conductor material
R_a	Anode resistance to remote earth, Ω. In the context of this document, remote earth will be in seawater or seabed
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	Flow velocity (m/s)
u	Utilisation factor for CP design calculations
V_{initial}	Initial net volume of anode alloy (excluding the steel insert), m^3
V_{insert}	Volume 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
m_{anode}	Net mass of an individual galvanic anode material, kg
m_{total}	Minimum total net mass of galvanic anode material, kg

4.2 Abbreviations

ABS	Area Below Seabed
AC	Alternating Current
BEM	Boundary Element Method
CA	Corrosion Allowance
CP	Cathodic Protection
CP design life	Cathodic Protection design life
CPS	Cable Protection System
CSPE	Chlorosulfonated Polyethylene; alternatively abbreviated to CSP
DC	Direct Current
DO	Dissolved oxygen
EMF	Electromotive Force
EPR	Ethylene Propylene Rubber
ER	Electrical Resistance
FAT	Factory Acceptance Test
FBL	Free Board Level
FEM	Finite Element Method
FWZ	Frequently Wetted Zone
GACP	Galvanic Anode Cathodic Protection
HAT	Highest Astronomical Tide
HDPE	High Density Polyethylene
HMMPE	High Molecular Mass Polyethylene
HSC	Hydrogen Induced Stress Cracking
ICCP	Impressed Current Cathodic Protection
IEC	International Electrotechnical Commission
IMCA	International Marine Contractors Association
IP	Ingress Protection Rating
ISO	International Organization for Standardization
ITP	Inspection and Test Plan
LAT	Lowest Astronomical Tide
MIC	Microbially Influenced Corrosion