VGB/BAW Standard
Corrosion Protection for Offshore Wind Structures
Part 1: General

3rd edition, 2018

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VGB/BAW Standard

Corrosion Protection for Offshore Wind Structures

Part 1: General

(3rd edition, 2018)
VGB-S-021-01-2018-04-EN

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Preface

The growing number of wind turbines in Europe and the world raise new challenges to operators. To reduce the cost of installation and operation and to increase operating reliability, a coordinated and joint analysis of operating experience is an absolute necessity. Apart from exchanging information and experience, the participating companies mainly strive to promote standardisation (best practice). To this end, VGB PowerTech e.V. and Bundesanstalt für Wasserbau (BAW – Federal Waterways Engineering and Research Institute) have decided jointly to draw up a VGB/BAW standard on corrosion protection for offshore structures (e.g. offshore stations).

The aim of this standard is to ensure that the considerable investments in offshore structures are safeguarded by appropriate corrosion protection systems. In this context, coating systems, for instance, are to protect the steel structures of offshore units from corrosion damage, during their entire service life – which is normally at least 25 years – and without requiring any expensive repair work. Robust systems are therefore required which, while involving calculable manufacturing costs (CAPEX), can keep the operating costs (OPEX) at a predicable and low level in the long term. Repair work at sea is to be avoided, as the cost of such offshore repair work can exceed the cost of onshore repairs by a factor of as much as 100.

VGB/BAW Standard VGB-S-021-01-2017-06-EN published in June 2017, is replaced by the VGB/BAW Standard published in April 2018:

Like the previous standard, this modified Part 1 “General” explains various corrosion protection options, provides information about planning, the design of steel surfaces, as well as about the stress zones within the scope covered by the standard.

Part 2 describes requirements for coating systems. Part 3 defines the application of initial coating, and Part 4 the design, operation and monitoring of galvanic and impressed-current protection systems. Parts 5 and 6 are currently in preparation and will be concerned with the topics of coating system repair and in-service inspection and monitoring.

This VGB/BAW standard is made available for use free of charge. It has been written to the best of our knowledge, but cannot fully reflect the state of the art for every conceivable case. Any liability, also for the factual presentation of the contents, is excluded. Also, the users themselves are responsible for clarifying the situation regarding patents and other property rights. The VGB/BAW standard is not in itself binding. Its application must be explicitly agreed between the contracting parties.

Proposed changes can be sent to the email addresses vgb.standard@vgb.org and info@baw.de. To enable unambiguous allocation of the contents, the subject line should contain a brief designation of the document concerned.
The following institutions and associations submitted comments on topics addressed by this standard, which were adopted in the process of editing this standard:

- Bundesamt für Seeschifffahrt und Hydrographie (BSH – German Maritime and Hydrographic Agency), authority responsible for approving offshore structures in Germany within the exclusive economic zone
- Bundesverband Korrosionsschutz (BVK – Federal Association for Corrosion Protection)
- Verband der deutschen Lack- und Druckfarbenindustrie (VDL – German Paint and Printing Ink Association)
- Arbeitsgemeinschaft Offshore-Windenergie (AGOW – Offshore Wind Power Consortium)
- Fachausschuss für Korrosionsfragen (Committee for Corrosion Issues) of Hafentechnische Gesellschaft (HTG-FAKOR)
- DNV GL
- WAB Windenergieagentur (WAB)

and other interested parties.

In cases of doubt, the current German version shall apply.

Essen, April 2018
Karlsruhe, April 2018

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A grey bar at the side indicates changes compared to the 2nd edition 2017.
Revised pages in this document: pp. 7, 8
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# Part 1 - General

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1 General

Unprotected steel corrodes in the atmosphere, in water and in soil, possibly giving rise to damage. To avoid such corrosion damage, steel structures are protected so that they can withstand corrosion stresses during the required service life, usually at least 25 years.

The offshore structures are exposed to strong corrosive influences over a long period, while the conditions for maintenance and repair are poor. Along with corrosion protection systems that must meet the highest demands, the idea of a corrosion protection strategy must be taken into consideration. This means, among other things, that the specific stresses in the various areas of offshore structures, but also the cooperation of several methods of protection, e.g. coatings, duplex systems (passive corrosion protection), cathodic protection (active corrosion protection) and corrosion allowance (see DIN 50929-3 Supplement 1) in submerged areas, must also be taken into consideration.

This standard is concerned with offshore structures made of steel. In its various parts it takes into account all essential factors having significance for appropriate corrosion protection.

Project owners, ordering parties, planners, advisors, firms carrying out corrosion protection measures, supervisory personnel for corrosion protection work and manufacturers of coating systems require state-of-the-art information on corrosion protection through corrosion protection systems, in condensed form, to protect steel structures effectively against corrosion. Such information must be as complete as possible and unambiguous and easy to understand as well so that complications and misunderstandings are avoided between the parties involved in carrying out the protective measures.

In regard to the minimum requirements for corrosion protection concepts, reference is made to the BSH Standard “Mindestanforderungen an die konstruktive Ausführung von Offshore-Bauwerken in der ausschließlichen Wirtschaftszone (AWZ)” (Minimum requirements for the design of offshore structures within the exclusive economic zone) as amended from time to time.

This standard defines additional requirements supplementing the standards and codes of practice cited in chapter 8 hereinafter.

In addition to this standard, the minimum requirements, rules and regulations applicable on the federal state level to the locations of wind turbines, wind farm components and other offshore wind structures must also be considered for the design of the corrosion protection. For the area of the German exclusive economic zone, the minimum requirements and regulations stipulated by the Bundesamt für Seeschifffahrt und Hydrographie (BSH) are applicable.
2 Scope

This standard, “Corrosion Protection for Offshore Wind Structures – Part 1: General”, specifies requirements for the corrosion protection of the following water- and atmospherically loaded components of the primary steel structure according to the area shown in the schematic diagram.

The components are hereinafter referred to as offshore structures.

Schematic diagram: Scope exemplified by various offshore structures (Source: BSH Standard Design)

These include the locally fixed connections to the seabed (foundation elements such as piles or suction cups), as well as the supporting structures of the offshore wind turbines (substructure and tower up to the transition to the nacelle) and the offshore stations (including the bottom side of the top deck).

Parties may agree on the application of this standard for secondary steel construction.

3 Stress zones

The corrosion protection systems of the steel structures should protect these structures from corrosion damage for the service life, normally at least 25 years. Corrosion protection systems must withstand a variety of loads such as exposure to underwater conditions, fluctuating water levels, splash water in a marine atmosphere, extreme temperature fluctuations, strong ultraviolet exposure or ongoing mechanical damage and abrasion.
Depending on location and environmental influences, for offshore structures four different stress zones are defined in relation to the water level. The stress zones are shown using a monopile as example; see Figure 1 and Table 1.

The interior of the offshore structure in Zone 2 (Fig. 1) above the airtight deck can be considered as Zone 4.

---

Fig. 1: Stress zones of an offshore structure (for example monopile) (Source: BAW)
Table 1: Stress zones and corrosive stress areas

<table>
<thead>
<tr>
<th>Zone</th>
<th>Corrosive stress areas</th>
<th>Adapted from the corrosivity categories set out in DIN EN ISO 9223 and DIN EN ISO 12944-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Atmosphere, internal</td>
<td>C4</td>
</tr>
<tr>
<td>3</td>
<td>Atmosphere, external</td>
<td>C5/CX</td>
</tr>
<tr>
<td>2</td>
<td>Splash zone (SZ)</td>
<td>Im2/CX</td>
</tr>
<tr>
<td></td>
<td>Tidal zone (TZ)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low water zone (LWZ)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>external and internal</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Underwater zone (UWZ), external and internal</td>
<td>Im2/Im4</td>
</tr>
<tr>
<td></td>
<td>Seabed, external and internal</td>
<td>Im3/Im4</td>
</tr>
</tbody>
</table>
4 Corrosion protection plan and concept

An optimised, economical, ecologically compatible corrosion protection concept, including repairs, for the corrosion protection of offshore structures is to be drawn up by the contractor upon submission of its tender. The concept must satisfy the official requirements. Corrosion protection concepts make allowance for passive and active corrosion protection or a combination of both.

The corrosion protection must be calculated and designed to at least the service life so that a complete renewal of the systems during the useful life is not necessary.

The structural requirements for the steel structure remain unaffected by this standard. The corrosion protection plan provides the basis for execution. For the passive corrosion protection, the plan is to be drawn up by the contractor based on DIN EN ISO 12944, Part 8, Table 1 and 2, and presented to the principal/owner for approval just-in-time before the work is performed.

By analogy with ZTV-ING Part 4, Section 3, a description of the corrosion protection measures with drawings and texts is to be made prior to performing the corrosion protection work.

A sample description of the corrosion protection measures for certification and plausibility checking purposes is contained in Annex 1.

5 Design of steel structures and their surfaces

To achieve the protection period required of coating systems for offshore structures, DIN EN ISO 12944-3, DIN EN ISO 8501-3, DIN EN 10163 and ZTV-ING – Part 4, Section 3 already must be taken into account during planning and design and allowance made for the possibility of repair or renewing coating systems.

If components for new-build structures are being coated, for edges, welds and other areas of steel surfaces which exhibit surface imperfections, preparation grades P3 according to DIN EN ISO 8501-3 shall be provided. For edges, as alternative to DIN EN ISO 8501-3 triple chamfering of the edges is permissible; refer also to DIN EN 1090-2.

Components which are subject to corrosive stresses and are no longer accessible for corrosion protection measures after erection must get corrosion protection that is so effective that structural safety is ensured during the service life of the offshore structure. If this cannot be achieved with corrosion protection systems, other steps must be taken (e.g. manufacture of components from corrosion-resistant material, replaceability of components, or definition of a rust allowance).
6 Explanations regarding thermal spraying and hot dip galvanising

If the thermal spraying and hot dip galvanising methods are applied, the relevant qualifications, approvals and requirements for the companies performing the work must be taken into account:

- DIN EN ISO 12690 Thermal spray coordination,
- DIN EN ISO 14918 Approval testing of thermal sprayers,
- DIN EN ISO 14923 Characterization and testing of thermally sprayed coatings, and
- DIN EN ISO 1461 Hot dip galvanized coatings on fabricated iron and steel articles – Specifications and test methods

In the thermal spray process the applied Zn/Al layer is provided with a sealer (DIN EN ISO 2063) and the layer structure then completed with intermediate and top coats. The companies performing the work must present a certificate of suitability. For protection system approval, the layer structures must be subjected to the tests which apply also to the usual, described coating systems – see VGB/BAW Standard VGB-S-021-02-2018-04-EN (Part 2).

If parts of the structure are hot dip galvanised or sprayed with zinc, then these coatings are treated like primer coats in respect to their structure. The build-up of further coats must be system-compatible.

7 Explanations regarding cathodic protection

Cathodic protection (CP) systems provide active protection by means of an appropriately calculated protective current and the protective potential which this generates in areas in contact with water (zones 1 and 2), and so prevent corrosion on offshore structures, but also hydraulic steel structures and the steel fittings of hydraulic structures.

A distinction is made between the following CP systems:

- impressed-current system, see Figure 2
- galvanic protection system, see Figure 3
Fig. 2: Principle of an impressed-current system (Source: MKKS)
Fig. 3: Principle of a galvanic protection system (Source: MKKS)

The two systems differ mainly in their technical design. By the impressed-current system, a stream of electrons is directed into the protected steel component by means of a rectifier. By special long-lived inert anodes, an ionic protective current in the electrolyte (in this case the water wetting the structure) closes the circuit. The principle of a galvanic protective current system is comparable with that of an impressed-current system. The difference is that in the galvanic system the electrons are introduced through direct contact of an anode with the protected component, involving the corrosion/consumption of the (baser, relatively to carbon steel) metallic anode material.

The combination of active and passive corrosion protection generally results in smaller power consumption in the CP system. Furthermore, the combination of active and passive protection leads to/enables a more homogeneous distribution of the protective current in the structure. In addition, “hybrid CP systems” made up of a combination of an impressed-current CP system and galvanic anodes are conceivable. These hybrid systems usually find use when offshore structures are cut off from a power supply for a longer period of time during the installation phase. In this phase it is the galvanic anodes that first provide for cathodic protection; after the power supply is connected, they then do this in combination with an impressed-current system.

The prerequisite for efficient corrosion protection is continuous monitoring of the maintenance of specified potentials. Overpotentials (i.e. potentials that have been lowered too far) can result in immediate damage to the coating. CP systems must be equipped with measurement, monitoring and control systems for central monitoring.
and control of the essential system parameters; this applies particularly to impressed-current systems. For systems using galvanic anodes, monitoring systems are recommended, e.g. for early detection of possible anode passivation.
8 Standards and codes of practice

This standard defines additional requirements supplementing the following series of technical rules, some of which are cited in this standard:

Standards:

DIN 50929-3 Corrosion of metals – Probability of corrosion of metallic materials when subject to corrosion from the outside – Part 3: Buried and underwater pipelines and structural components; Supplement 1: Corrosion rates of structural components in water

DIN 81249 Corrosion of metals in sea water and sea atmosphere

DIN EN 1090-2 Execution of steel structures and aluminium structures – Part 2: Technical requirements for steel structures

DIN EN 10163 Delivery requirements for surface condition of hot-rolled steel plates, wide flats and sections

DIN EN 10204 Metallic products – Types of inspection documents

DIN EN 12473 General principles of cathodic protection in seawater

DIN EN 12474 Cathodic protection for submarine pipelines

DIN EN 12495 Cathodic protection for fixed steel offshore structures

DIN EN 12496 Galvanic anodes for cathodic protection in seawater

DIN EN 13173 Cathodic protection for steel offshore floating structures

DIN EN 13509 Cathodic protection measurement techniques

DIN EN 15257 Cathodic protection – Competence levels and certification of cathodic protection personnel

DIN EN 61400-3 Wind turbines – Part 3: Design requirements for offshore wind turbines

DIN EN ISO 1461 Hot dip galvanized coatings on fabricated iron and steel articles – Specifications and test methods

DIN EN ISO 2063 Thermal spraying – Metallic and other inorganic coatings – Zinc, aluminium and their alloys

DIN EN ISO 8501-3 Preparation of steel substrates before application of paints and related products – Visual assessment of surface cleanliness – Part 3: Preparation grades of welds, edges and other areas with surface imperfections
<table>
<thead>
<tr>
<th>Standard Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIN EN ISO 9223</td>
<td>Corrosion of metals and alloys – Corrosivity of atmospheres – Classification, determination and estimation</td>
</tr>
<tr>
<td>DIN EN ISO 12690</td>
<td>Metallic and other inorganic coatings – Thermal spray coordination – Tasks and responsibilities</td>
</tr>
<tr>
<td>DIN EN ISO 12944-2</td>
<td>Paints and varnishes – Corrosion protection of steel structures by protective paint systems – Part 2: Classification of environments</td>
</tr>
<tr>
<td>DIN EN ISO 12944-3</td>
<td>Paints and varnishes – Corrosion protection of steel structures by protective paint systems – Part 3: Design considerations</td>
</tr>
<tr>
<td>DIN EN ISO 12944-5</td>
<td>Paints and varnishes – Corrosion protection of steel structures by protective paint systems – Part 5: Protective paint systems</td>
</tr>
<tr>
<td>DIN EN ISO 12944-8</td>
<td>Paints and varnishes – Corrosion protection of steel structures by protective paint systems – Part 8: Development of specifications for new work and maintenance</td>
</tr>
<tr>
<td>DIN EN ISO 13174</td>
<td>Cathodic protection of harbour installations</td>
</tr>
<tr>
<td>DIN EN ISO 14713-2</td>
<td>Zinc coatings – Guidelines and recommendations for the protection against corrosion of iron and steel in structures – Part 2: Hot dip galvanizing</td>
</tr>
<tr>
<td>DIN EN ISO 14918</td>
<td>Thermal spraying – Approval testing of thermal sprayers</td>
</tr>
<tr>
<td>DIN EN ISO 14923</td>
<td>Thermal spraying – Characterization and testing of thermally sprayed coatings</td>
</tr>
<tr>
<td>ISO 20340</td>
<td>Paints and varnishes – Performance requirements for protective paint systems for offshore and related structures</td>
</tr>
</tbody>
</table>
Codes of practice (in the current version):

BAW Guidelines for the testing of coating systems for the corrosion protection of hydraulic steel structures

BAW Liste der zugelassenen Systeme II (für Meerwasser und Böden, Im 2/3)

BSH-Standard Mindestanforderungen an die konstruktive Ausführung von Offshore-Bauwerken in der ausschließlichen Wirtschaftszonen (AWZ)

DASst Richtlinie 022 Deutscher Ausschuss für Stahlbau (DASst), Feuerverzinken von tragenden Stahlbauteilen

DNV GL RP-0416 Corrosion protection for wind turbines

GfKORR Richtlinie für die Zertifizierung von Personal und Akkreditierung von Zertifizierungsstellen auf dem Gebiet der Korrosion und des Korrosionsschutzes

MKKS BAW-Merkblatt Kathodischer Korrosionsschutz im Stahlwasserbau (MKKS); www.baw.de

TL/TP-KOR-Stahlbauten Technischen Lieferbedingungen und Technischen Prüfverfahren für Beschichtungsstoffe für den Korrosionsschutz von Stahlbauten


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ZTV-ING
Part 4, Section 3
Zusätzliche Technische Vertragsbedingungen und Richtlinien für Ingenieurbauten, Teil 4 Stahlbau, Stahlverbundbau, Abschnitt 3 Korrosionsschutz von Stahlbauten

ZTV-W 218
Zusätzliche Technische Vertragsbedingungen – Wasserbau (ZTV-W) für Korrosionsschutz im Stahlwasserbau (Leistungsbereich 218)

Other:
Safety data sheets, technical data sheets

9 Literature
10 **Annex**

A template for the project-specific description to be submitted to the BSH for the 2\textsuperscript{nd} approval phase can be downloaded from www.baw.de. The following example is provided for illustration purposes.
**Date:** ___________________
**Name of project:** _____________________

**BSH approval phase:**
- [ ] First
- [ ] Second

**Construction [number]:**
- [ ] WT
- [ ] Offshore Station
- [ ] Other

**Foundation:**
- [ ] Monopile
- [ ] Jacket
- [ ] Gravity Base
- [ ] Other

**Site:**
- [ ] North Sea
- [ ] Baltic Sea

**Planned corrosion protection measure(s) at the foundation:**
- [ ] Organic coating
- [ ] ICCP
- [ ] Galvanic anodes [total weight: ______kg]
- [ ] Thermally sprayed coating
- [ ] Remote-ICCP
- [ ] Other

**Detailed corrosion protection measures:** *(filled with examples)*

<table>
<thead>
<tr>
<th>Construction element</th>
<th>Outside / inside</th>
<th>Hight related to LAT or MSL [m]</th>
<th>Zone 1-4</th>
<th>Cath. corrosion protection</th>
<th>Coating [from substrate to top]</th>
<th>Other</th>
<th>Source (related to column)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monopile submerged</td>
<td>Outside</td>
<td>-6.0 -36.2 m</td>
<td>Zone 1</td>
<td>ICCP</td>
<td>-</td>
<td>3x 200 µm EP</td>
<td>-</td>
</tr>
<tr>
<td>Monopile floor</td>
<td>Outside</td>
<td>-36.2 -43.9 m</td>
<td>Zone 1</td>
<td>ICCP</td>
<td>-</td>
<td>-</td>
<td>Stripe coating DOK-123.pdf (3) ICCP-815.pdf (5) COAT-789.pdf (8)</td>
</tr>
<tr>
<td>Monopile Grout zone</td>
<td>Outside</td>
<td>+2.5 +2.0 m</td>
<td>Zone 2</td>
<td>-</td>
<td>-</td>
<td>3x 200 µm EP</td>
<td>Grout, corrosion allowance [1.2 mm] DOK-123.pdf (3) COAT-789.pdf (7) COAT-789.pdf (8) DES-101.pdf (8)</td>
</tr>
<tr>
<td>Transition piece</td>
<td>Outside</td>
<td>+21.2 -7.0 m</td>
<td>Zone 2</td>
<td>Al-anodes</td>
<td>-</td>
<td>3x 200 µm EP 1x 80 µm PUR</td>
<td>-</td>
</tr>
<tr>
<td>Sec. Steel</td>
<td>Outside</td>
<td>n.a</td>
<td>Zone 1-2</td>
<td>-</td>
<td>1x 100 µm TSZ (Zn/Al 15) with 40 µm Sealer or 1x 100 µm HDG</td>
<td>3x 200 µm EP 1x 80 µm PUR</td>
<td>-</td>
</tr>
</tbody>
</table>

**Column explanation for table:**
1) e.g.: Monopile grout zone, Jacket submerged, Pile bottom, Transition piece, Secondary Steel etc.
2) Full description of outside and inside corrosion protection measures from tower to tip of pile
3) According to zone 1-4 in Fig. 1 (VGB-S-021-01)
4) Galvanic anodes with alloy specification (e.g.: Al-anodes)
5) e.g.: 1 x 120 µm TSZ
6) e.g.: 1 x 80 µm EP-Zn(R), 2 x 250 µm EP, 1 x 80 µm PUR
7) e.g.: grout, stripe coating, corrosion allowance [mm]

Appendix: Construction draft if available