

GENERAL SPECIFICATION

CORROSION

GS EP COR 100

Design of cathodic protection of offshore structures

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1. Scope

This document defines the minimum requirements for the design, calculation methods, selection of equipment and alloy materials, installation and commissioning of external cathodic protection for offshore fixed structures (platforms, wharves, piers, jetties, piles, subsea templates and wells) and floating units (as FPSO, buoys).

Except if formally accepted in a written form by Company, cathodic protection shall be implemented using galvanic (or sacrificial) anodes.

Galvanic and impressed current cathodic protection systems are defined in the present document.

More detailed requirements are specified for subsea equipment in General Specification [GS EP SPS 009](#) and [GS EP SPS 029](#).

More detailed requirements are specified for cathodic protection of floating structures in General Specification [GS EP COR 103](#).

This document also defines the cathodic protection monitoring systems, gives the rules for anode distribution and the requirements to be followed to avoid negative influence induced on metallic structures by high potential alloy anodes (as magnesium alloy) or impressed current anodes.

Where more stringent, the requirements of the present document supersede those of the reference documents. Recommendations from the EN standards related to fixed or floating offshore structures and to harbour installations shall be followed when they are not in conflict with those of the present document. Other recommendations and especially those from [DNV-RP-B401](#) have also to be used in complement when necessary.

2. Reference documents

The reference documents listed below form an integral part of this General Specification.

External Documents

Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published at the effective date of this document.

Reference	Title
BS 7361-1	Cathodic protection - Part 1: Code of practice for land and marine applications
DNV-RP-B401	Cathodic Protection Design
EN 12473	General principles of cathodic protection in sea water
ISO 15589-2	Petroleum and natural gas industries - Cathodic protection of pipeline transportation systems – Part 2: Offshore Pipelines

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Total General Specifications

Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published in the applicable yearly collection.

Reference	Title
GS EP COR 102	Design of cathodic protection of sealine by sacrificial anodes
GS EP COR 103	Design of cathodic protection of offshore floating structures
GS EP COR 201	Supply of sacrificial anodes
GS EP COR 202	Monitoring systems for cathodic protection of offshore structures
GS EP COR 210	Monolithic insulating joints
GS EP COR 222	Fusion Bonded Epoxy (FBE) external coating for pipelines
GS EP COR 230	External laminated glass fibre/resin based coating for risers of sea line
GS EP COR 231	External elastomer based coating for risers of sea line
GS EP COR 350	External protection of offshore and coastal structures and equipment by painting
GS EP COR 351	External protection of structures and equipment by painting. Floating structures
GS EP COR 501	Control of cathodic protection of submerged fixed structures
GS EP ELE 141	Power transformers
GS EP EXP 311	Plant integrity - Minimum inspection requirements
GS EP SPS 009	Corrosion protection of subsea stations
GS EP SPS 029	Metallic Materials for Subsea Production Facilities

3. Qualification and Certification of Cathodic Protection specialists responsible for the design

Design of cathodic protection systems to be installed on offshore structures shall be carried out exclusively by competent and specialized personnel.

The qualification of each of the specialists working for such a design shall be demonstrated to the Owner before commencement of the design.

Therefore the verification of formal Certification of the individuals shall be carried out as follows:

- Conventional design work to be carried out by certified personnel at level 2 for all Certification schemes except for NACE International where it shall be level 3.
- Complex design work or verification to be carried out by certified personnel at level 3 for all Certification schemes except for NACE International where it shall be level 4.

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Accepted Certification schemes are AFAQ AFNOR Compétence (Seawater Application Sector), APCE (Seawater Application Sector), Institute of Corrosion, NACE International. Any other Certification scheme proposed shall be approved by Company.

Any use of non certified personnel for cathodic protection design shall be subject to the approval of Company on a case by case basis (demonstration of competence through detailed curriculum vitae and description of experience).

4. Preliminary assumptions

4.1 Definition of zones

These zones shall be defined as follows:

- Splash zone: as defined in [GS EP COR 350](#)
- Atmospheric zone: area above the splash zone
- Immersed zone: for a platform, area from the splash zone to the stability floor
- Mud line zone: for a platform, area from the bottom of the structure to 2 m above the stability floor
- Buried zones: for a platform, area where piles and conductor pipes are buried.

4.2 Risers - Insulating joints - Appurtenances

Risers of sea lines are normally not electrically insulated from the platform except when either the pipelines or the jackets are cathodically protected by impressed current. In this case, a job specification shall be established specifying the nature of the insulating joint and its location.

Insulating joints shall comply with Company General Specification [GS EP COR 210](#).

If the pipeline is protected by sacrificial anodes, the cathodic protection calculation for the jacket shall include the riser.

Utility risers, J-tubes, sump caissons, etc. shall be included in the cathodic protection design of the jacket.

Except if otherwise stated for specific structural reasons, mud mats are considered useful only for the installation of the jacket and are not supposed to be fully protected for the whole lifetime of the platform. However, they have to be taken into consideration for the design of the CP system over the full design life as they will consume current.

Cathodic protection of SCRs (Steel Catenary Risers) is designed as per the associated pipelines in accordance with [GS EP COR 102](#).

4.3 Painting-Coating

Marine structures shall be coated in the following areas:

- Atmospheric zone
- Splash zone
- Mud line zone.

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Additionally, all parts in the splash zone and immersed zone shall be coated for:

- Risers
- Utility risers, J-tubes, sump caissons, etc.

A job specification shall define all additional elements to be coated such as Conductor pipes.

Painting application methods and painting systems to be used are given in [GS EP COR 350](#) (fixed structures) or [GS EP COR 351](#) (floating structures). For conductor pipes, FBE coating as per [GS EP COR 222](#) (without girth weld coating) is the preferred solution.

Other coating or painting systems may be submitted to Company for approval (see section 5.5).

5. Calculation of cathodic protection

5.1 Protection criteria

For carbon steel, the following potential criteria shall be reached on the structures:

- More negative than -800 mV/Ag-AgCl-seawater in aerated seawater
- More negative than -900 mV/Ag-AgCl-seawater in a seawater environment with a potential high content of sulphate reducing bacteria and for the lower side of the mud mats
- For carbon steel with SMYS greater than or equal to 550 MPa, the potential shall remain more positive than -1100 mV/Ag-AgCl-sea water.
- For other materials, potential requirements shall be in accordance with [ISO 15589-2](#) Table 1 and material requirements shall be in accordance with [GS EP SPS 029](#) § 6 to avoid hydrogen embrittlement.

5.2 Current density

The current density to be used for the cathodic protection of carbon steels shall be as per [DNV-RP-B401](#) (January 2005), Annex A.

For stainless steel or other alloys, the same current densities shall be used, as long as such CRAs are not electrically insulated from the rest of the structure and have no dedicated cathodic protection system.

The calculation methodology shall be as per [DNV-RP-B401](#) (January 2005), § 7.

The anode design shall fulfill both the total anode weight requirement (based on the mean current density) and the final (or initial) current output requirement.

Nonetheless, the driving parameter for the design shall be the anode weight (mean current requirement) and the anode size shall be adapted accordingly.

The current density shall be increased by 10% in the splash zone.

The current density for the mud line zone shall be the same current density as for the immersed zone.

For equipment such as risers operating at elevated temperatures, the current density shall be increased by 1 mA per °C above 25°C.

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The current drain to wells shall be 6 A per well for the lifetime of a drilling platform, and 8 A per well for the lifetime of a subsea well, except if otherwise specified.

5.3 Resistivity

The resistivity of seawater as a function of geographic location shall be as given below.

Mean resistivity of seawater							
Geographic area	Cameroon Nigeria	Congo Gabon Angola Italy	The Netherlands	Norway Argentina	Gulf Of Mexico	Libya	Indonesia Persian Gulf
Resistivity (Ω.m)	0.22	0.20	0.29	0.33	0.20	0.23	0.19

For structures laid into mud, the average resistivity value shall be 1 Ω.m.

Generally, it is assumed that resistivity is constant as a function of depth. In case of significant variations, especially for deepwater designs (water depth over 100 m), the project specification shall document these variations.

For deepwater structures in West Africa a seawater resistivity of 0.30 Ω.m shall be used.

5.4 Surface to be protected

The surface to be protected shall be divided in different zones (splash zone, immersed zone, mud line zone and buried zone). Calculations shall be carried out separately for each zone.

The structure shall also be divided into different zones (levels) as a function of depth. The calculations shall be done separately for each level.

Calculations shall include any metallic surface in electrical continuity with the protected structure and considered as current consumers.

5.5 Coating breakdown factors

Coating breakdown factors are based on the principles given in the Recommended Practice [DNV-RP-B401](#) § 6.4. This factor (f_c) is a function of coating properties, operational parameters, and time.

$$f_{c-mean} = k_1 + k_2 \cdot (t_{final} / 2)$$

$$f_{c-final} = k_1 + k_2 \cdot t_{final}$$

However coating categories differ from those of [DNV-RP-B401](#) with three further coating types (categories IV, V and VI):

- Category I One layer of epoxy paint coating, minimum 50 μm nominal DFT.
- Category II One or more layer of marine paint coating (epoxy, polyurethane or vinyl based), with total nominal DFT minimum 250 μm.

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- Category III Two or more layer of marine paint coating (epoxy, polyurethane or vinyl based), total nominal DFT minimum 300 µm.
- Category IV One layer of primer coat, plus minimum three layers of intermediate/top coats, minimum 450 µm DFT.
- Category V Fusion bonded epoxy (FBE), nominal DFT 300 µm minimum.
- Category VI Three layer polyethylene or polypropylene coating.

k_1 and k_2 for calculation of coating breakdown factors

	Cat. I	Cat. II	Cat. III	Cat. IV	Cat. V	Cat. VI
k_1	0.1	0.05	0.02	0.02	0.01	0.01
k_2	0.075	0.025	0.014	0.012	0.009	0.004

For risers coated with GRE or elastomers in accordance with **GS EP COR 230** and **GS EP COR 231** respectively, the coating breakdown factor shall be:

- Initial value 0.2%
- Mean value 0.5%
- Final value 1%.

In the buried zone, the coating breakdown factor shall be:

- 50% for initial, mean, and final value, whatever the coating category.

6. Cathodic protection by sacrificial anode systems

6.1 Sacrificial alloy

The same anode alloy shall be used for the protection of the whole structure (except for underside of mud mats).

As a general rule, indium activated aluminium alloy anodes shall be used.

Zinc alloy anodes may be used for the protection of the underside of mud mats.

Notes:

- For structures sensitive to hydrogen embrittlement (for instance subsea Christmas-trees in 13% chromium stainless steel, high strength steels, duplex or superduplex stainless steels, etc.), specific precautions shall be taken regarding metallurgic aspects. They shall be in accordance with recommendations of the **GS EP SPS 029**.
- Aluminium anodes unit weight shall be of 3 kg minimum.

The compositions, quality requirements, and inspection requirements for aluminium and zinc alloy anodes are given in **GS EP COR 201**.

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6.2 Characteristics of the sacrificial alloy

The cathodic protection calculation shall use the potential and practical consumption (m) values guaranteed by the anode Supplier and verified during the qualification procedure.

If these values are unknown at the time of calculation, the following conservative values shall be used:

- Practical consumption (m):
 - 3.6 kg/A/year for aluminium-zinc-indium alloy anode ($C = 2433 \text{ A.h/kg}$)
 - 11.2 kg/A/year for zinc alloy anode ($C = 782 \text{ A.h/kg}$)
- Temperature effect on the electrochemical capacity (C) of the aluminium-zinc-indium alloy shall be considered using the following formula:

$$C = 2433 - 27 (T - 20) \quad \text{with } C = 8766 / m$$

- Close circuit potentials:
 - -1050 mV/Ag-AgCl-seawater for aluminium indium alloy anode
 - -1000 mV/Ag-AgCl-seawater for zinc alloy anode.

6.3 Utilisation factor u

The utilisation factor shall be as follows:

- Anodes stand-off made by continuous casting $u = 0.95$
- Anodes stand-off made by traditional mould casting $u = 0.90$
- Half shell bracelet anodes $u = 0.85$
- Segmented bracelet anodes $u = 0.75$
- Short flush-mounted anodes $u = 0.80$
- Long flush-mounted anodes $u = 0.85$

Note: Anodes performance becomes unpredictable for u values higher than these given above.

6.4 Installation and location of anodes

6.4.1 Insert

Inserts diameter and thickness shall be defined as a function of the weight of the anode, the environmental conditions and the installation conditions of the structures.

Minimum requirements are given in [GS EP COR 201](#).

6.4.2 Stand-off and flush-mounted anodes

For stand-off anodes, the distance between the centre line of the anode's insert and the structure shall be 300 to 500 mm.

Zinc anodes located underneath mud mats shall be flush-mounted.

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Flush-mounted anodes are recommended for the protection of piers, wharves. The side of the anode facing the structure shall be coated to prevent high anodic current density and preferential consumption.

For floating units, either flush-mounted or stand-off anodes can be considered.

6.4.3 Gussets - Doubler plates

When necessary for mechanical requirements, anodes shall be welded to doubler plates with additional reinforcement by gussets if necessary. Minimum requirements are given in **GS EP COR 201**.

6.5 Calculation of cathodic protection

As indicated in section 5.2, the calculation is based on the current requirement (I_t) at mid-life to determine the minimum total weight of anodes.

The current requirement (I_t) for the entire structure shall be the sum of the currents required for protecting each individual part taking into account each zone (splash, immersed, mud-line, buried):

- Current requirement for uncoated surfaces (structure, piles, chains, etc.)
- Current requirement for coated surfaces
- Current drain for the maximum number of wells that can be physically installed
- Current requirement for the conductor pipe surfaces from sea level down to and including the buried zone.

6.5.1 Total weight of alloy to be installed

The minimum total weight M_t (kg) of anodes to be installed in order to protect the structure for the design life D (years) is given by:

$$M_t(\text{kg}) = \frac{I_t \times D \times m}{u}$$

6.5.2 Total number of anodes

The minimum total number of anodes to be installed (N_t) is obtained by dividing the total weight of anodes by the individual anode net weight (M):

$$N_t = \frac{M_t}{M}$$

The final number of anodes shall be adjusted to meet the required protection level at initial and final stages (section 6.7).

In general, Supplier's standard anodes shall be preferred.

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In case of indium activated aluminium alloy, the anode weight shall be selected according to the criteria given in the table below:

Weight of an indium activated aluminium alloy anode

D	M
0 - 10 years	$M \leq 150 \text{ kg}$
10 - 20 years	$150 \leq M \leq 300 \text{ kg}$
20 - 40 years	$300 \leq M \leq 600 \text{ kg}$

If the structure is completely coated the anode weight shall be less than that indicated in the table above.

6.5.3 Distribution and location of anodes

6.5.3.1 Distribution

Based on the theoretical number of anodes required for the different zones of the structure, practical distribution of the anodes shall take into consideration the following aspects:

- Anodes shall be uniformly distributed on the structure
- Anodes for the splash zone shall be located between the LAT and the first submerged level
- Anodes for the buried zone of the jacket including piles and underside of mud mats (if not protected by flush-mounted zinc anodes) shall be located between the two lowest immersed levels
- Anodes shall be located as symmetrically as possible on the structure
- Anodes shall be located nearer complex and critical points such as node areas
- Anodes protecting conductor pipes shall be uniformly distributed between the different levels on the conductor guide frames
- Anodes corresponding to the current drain from wells shall be uniformly distributed all over the submerged part of the structure.

6.5.3.2 Location

The anodes shall be positioned on the surface they are meant to protect according to the following guidelines:

- In the permanently submerged zone
- On legs, the anodes shall face the centre of the structure
- On diagonal bracings, the anodes shall be alternately placed on the upper and lower surface if more than one anode is required

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- On horizontal bracings at different levels, the anodes shall be installed alternately facing upwards and downwards with the exception of the uppermost level where they shall be mounted facing downwards.

In case the anodes located on the conductor guide frame present an obstruction for installation of the conductor pipes after launching, the anodes shall be tilted 45° upwards and downwards (every other anode).

Cathodic protection of tendons of TLPs (Tension Leg Platforms) is carried out by anodes located only on the bottom structures or the hull of the TLP. When necessary, modeling of the CP system has to be carried out as indicated in the following note.

Note: When necessary (in case of any doubt on the right location of anodes on complex or elongated structures, turret, etc.), modeling of the zone shall be carried out demonstrating that a right level of potential will be reached at each location during the whole design lifetime using a software approved by Company (e.g. PROCOR, BEASY, or equivalent).

6.6 Cathodic protection monitoring

Two monitoring systems shall be used to monitor the operation of the cathodic protection system.

The complete monitoring arrangements to be installed are described in [GS EP COR 202](#).

The use of the most complex systems is limited to geographic locations new to Company or new platform designs.

In both cases the monitoring systems shall consist of two anodes located on the same member and installed at a specific distance apart from each other which corresponds exactly to the distance used in the calculation. The distance between the two anodes reflects the surface area to be protected by one anode.

For coastal facilities, the monitoring system shall be composed of a test facility permanently accessible from the surface with one or several reference electrodes at different levels.

If possible monitored anodes shall be installed.

6.6.1 Number of monitoring systems

In general the number of monitoring systems shall be as follows:

- Between 0 and 60 m one system
- Between 0 and 120 m two systems
- For each additional 60 m one system
- For jetty piles, one minimum at each expansion loop
- For other kinds of structures, one minimum.

6.6.2 Reference electrodes

At least one zinc electrode shall be used per monitoring system.

The electrode shall be completely isolated from the structure and located as far as possible from the sacrificial anodes.

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Reference electrodes shall be zinc alloy with a chemical composition complying with Z2 type in accordance with [GS EP COR 201](#) paragraph 3.1.2.2. Potentials of different reference electrode potentials are given in [EN 12473](#) – Annex A.

6.7 Verification of the protection

The suitability of the chosen anode size, dimensions, and quantity shall be verified for the entire life of the structure.

Note: The anode resistance formula R is given in the Recommended Practice [DNV-RP-B401](#) paragraph 7.9.

6.7.1 Verification of cathodic protection at beginning of life (polarisation)

The purpose is to verify that the chosen anode is capable of supplying sufficient current at the beginning of life so that the structure will be satisfactorily protected in a few months.

The condition is as follows:

$$E_s = E_A + R_o \cdot I_{A0} \leq -800 \text{ mV/Ag-AgCl-seawater}$$

I_{A0} = Initial anode current output at the beginning of life, using polarisation current density and initial coating breakdown factors for coatings (if any)

R_o = Initial anode resistance, with Φ_o = initial diameter of anode

6.7.2 Verification of protection at end of life

The purpose is to verify that the potential at the end of life conditions is at an acceptable level so that the structure is still satisfactorily protected.

The condition is as follows:

$$E_s = E_A + R_f \cdot I_{Af} \leq -800 \text{ mV/Ag-AgCl-seawater}$$

I_{Af} = Final anode current output, using repolarisation current density and final breakdown factors for coatings (if any)

R_f = Final anode resistance, calculated from the theoretical weight loss during polarisation and maintenance periods and resulting diameter assuming no reduction in length.

For slender anodes, the final diameter of anode is given by:

$$\Phi_f = \sqrt{(\Phi_o^2 - \Phi_{ins}^2)(1 - u) + \Phi_{ins}^2}$$

6.8 Protection of mud mats by zinc anodes

When the integrity of mud mats is required for the whole service life, the cathodic protection shall be provided by flush mounted zinc alloy anodes installed underneath.

The procedure for calculations of the cathodic protection shall be performed as described in chapter 6.5 and separated from the rest of the structures.

The potentials in start-of-life, and end-of-life conditions shall be verified, according to chapter 6.7, to be more negative than -900 mV/Ag-AgCl-sea water.

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6.9 Summary result table

The main results of the cathodic protection study shall be presented in a summary result table.

The initial and final anode characteristics and the potentials of the structure shall be given.

Furthermore, the following data shall be highlighted:

- Total weight of indium activated aluminium alloy
- Characteristics of the aluminium-zinc-indium anodes chosen (weight, diameter, length)
- Total number of aluminium-zinc-indium alloy anodes
- Total number and weight of zinc alloy anodes.

6.10 Measurements after structure installation

A series of measurements shall be performed, according to [GS EP COR 501](#), in the first three to six months of operation after commissioning. The results shall demonstrate the effectiveness of the cathodic protection system.

The subsequent schedule of routine inspections shall be as per [GS EP EXP 311](#).

7. Cathodic protection by impressed current systems

7.1 Definition of impressed current anodes

The calculations for defining the maximum output of impressed current anodes are based on the greatest value obtained for the current requirement (I_i) between the current density at the beginning of the life, at mid-life and at the end of life.

The current requirement (I_i) for the entire structure is the sum of the currents for each individual parts:

- Current requirement for uncoated surfaces (structure, piles, chains, etc.)
- Current requirement for coated surfaces
- Current requirement for the maximum number of wells that can be installed in the conductor guide frame
- Current requirement for the conductor pipe surfaces from sea level down to and including the buried zone.

Individual impressed current anodes deliver higher electrical currents than sacrificial anodes. Therefore either dielectric shields or larger anode to structure separation shall be used to prevent localised over-polarisation and improve the electrical current distribution to the structure.

The surface of the structure to be protected shall be divided into different zones (splash zone, submerged zone, mud line zone and buried zone) and each of them shall be calculated separately.

The structure shall also be divided into different zones as a function of depth and the calculations shall be done for each zone.

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In order to compensate for a less efficient current distribution (small number of anodes), the impressed current cathodic protection system shall be designed to provide 1.25 to 1.5 times the current requirement (I_i).

7.2 Choice of impressed current anodes

Due to high output currents, only inert anodes shall be chosen. The inert anodes are made of platinum coated (or clad) titanium, niobium or tantalum with a thin layer of platinum applied to the substrate or of mixed metals oxides activated titanium.

For a design life of 20 years, platinum shall be applied in a thin (about 10 to 15 microns) layer on the various substrata.

The loss of one impressed current anode may significantly reduce the performance of the cathodic protection system. Therefore, the output current for an impressed current unit anode shall not be more than 10% of the total current requirement (I_i).

Impressed current anodes shall be designed to withstand all forces that can reasonably be expected during transport, installation and operation.

Impressed current anodes shall be designed to be replaced either from the surface or with subsea means (diver or ROV).

7.3 Dielectric shields

Liquid applied coatings, prefabricated plastic, composite (SVR), or elastomeric sheets shall be used on the structure adjacent to the anode or incorporated into the anode assembly.

This dielectric shield shall be inert with regards to the electrochemical reactions occurring at the anode and structure surfaces (corrosive products, chlorine or hydrogen gases, etc.).

Dimensions for the dielectric shields shall take into account the recommendations of the [BS 7361-1](#) - Section 7 Standard.

7.4 Transformer Rectifiers

7.4.1 Transformers

Supply and installation of transformers shall refer to [GS EP ELE 141](#) and be in accordance with recognised international standards listed as reference documents in the present specification.

Minimum IP rating for indoor installation shall be IP31 for overall construction and shall consist of dry type transformer.

For outdoor installation, minimum IP55 applies and transformers shall be of the oil cooled type.

7.4.2 Rectifiers

The rectifier stack shall be of the silicon diode type, connected for full-wave rectification.

Silicon diode shall be rated to minimum 120% of the nominal current output rating of the unit.

7.4.3 Control

Rectifier output shall be thyristor controlled.

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The output shall be continuously variable from 0-100% of rated output.

The ac ripple voltage shall be controlled in order to not to exceed 5% of dc output voltage for the range 5-100% of full output rating.

The unit shall be capable of operating in any one of the following output control modes:

- Constant current
- Constant voltage
- Constant potential (relative to potential value of a permanent reference electrode).

The transformer rectifier shall be defined for:

- An output current equal or greater than 1.25 to 1.5 times the current requirement (I_t)
- An output voltage taking into account the resistance of the electric source (cables, anodes).

It shall be installed inside a pressurised enclosure.

The control of the transformer rectifier current output may be manual or automatic. For manual control, control using tap setting shall be avoided.

When used, automatic control shall be based on potential readings from fixed reference electrodes.

Alarms indicating excessive voltage/current load on anodes and/or too negative potentials shall be included.

In the case of current requirements (I_t) greater than 500 A, the number of rectifiers shall be two or more.

7.5 Reference electrodes

Reference electrodes used to control the impressed current systems shall be installed at locations determined by calculations or experience to ensure the potential of the structure is maintained within the design set limits.

The type of reference electrodes shall be zinc alloy with a chemical composition complying with Z2 type in accordance with **GS EP COR 201** paragraph 3.1.2.

7.6 Cables

The cables and connections insulation materials shall be resistant to the environmental conditions, chlorine, hydrocarbons, and any other deleterious product that may be present. For example PVDF/HMWPE or ETFE/HMWPE double insulated cables may be used.

The cross-section of cables shall be determined in accordance with mechanical requirements, the current rating and the voltage drop for the cable length considered, with a minimum value of 16 mm².

Restrictions for routing of cables in hazardous areas shall apply.

Impressed current anodes cables shall steel armoured and adequately protected to avoid any mechanical damage. Steel dedicated conduits shall be used for this purpose.

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Reference electrodes cables shall be also mechanically protected as for anode cables, but not in the same conduits as for the impressed current anodes.

Impressed current anodes and reference electrodes cables shall be protected in the splash zone by different steel conduits able to resist waves, high currents, etc.

7.7 Junction boxes

These boxes mainly function as a marshalling point for anodic or cathodic cables at DC current sources, and shall preferably be located outside of hazardous areas so that they can always be accessed when live.

Consequently, unless a specific situation is justified by Contractor, reinforced safety boxes shall not be required. However, they shall provide a minimum of protection against shocks and water ingress, whether made of insulating material (PVC, polycarbonate, etc.) or metal (steel, cast aluminium, stainless steel). Boxes shall be of the following type:

- IP55/IK08 for outdoor locations
- IP31 for indoor locations.

Internal equipment, such as the number and sizes of copper strips, cable terminals, resistors and any other particular components, shall be defined in the detailed study.

The junction box, internal equipment, and support structure shall be selected and/or treated to withstand the specific climatic conditions.

The cables shall be easy to disconnect for measurements and their entry into the junction box shall be via cable gland of metal or insulating material, or via support pipe according to the type of box selected.

7.8 Summary result table

The main results of the cathodic protection study shall be presented in a summary result table.

Furthermore, the following data shall be highlighted:

- Number and characteristics of impressed current anodes
- Characteristics of the transformer rectifiers
- Characteristics of the reference electrodes, dielectric shields and insulating joints
- Detailed drawings of wiring.

7.9 Measurements after structure installations

A series of measurements shall be performed after starting the impressed current system:

- Measurement of the structure before starting of the transformer rectifiers
- Setting of each DC generator at the minimum to obtain the required protection level at the furthest points.

The subsequent schedule of routine inspections shall be drawn up by Contractor at the request of Company.

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8. Cathodic protection by complementary systems

Complementary systems provide protection during structure construction/installation and/or during times when the impressed current system is inoperative.

If the complementary sacrificial anode system is smaller than a conventional long term system, it requires careful design to ensure adequate amount and distribution of current.

For protection during early life of bare structures, magnesium alloy-based anodes shall be distributed on the structure in order to avoid its oxidation which may largely increase the current density required for structure polarisation. A lifetime of 6 to 12 months for this type of alloy allows to wait for the start of the impressed current anodes system and to limit the current requirement (I_i) at the value defined for maintenance or end of life.

The type of sacrificial anode shall be magnesium alloy with a chemical composition complying with M1 or M2 type according to [GS EP COR 201](#) paragraph 3.1.1.

Magnesium alloy-anodes shall be flat anodes or slender anodes with stand off and a dielectric shield, paint-based as described in [GS EP COR 350](#), shall be installed on the structure around the anode on a radius of 1 metre.

During maintenance time of bare structures, aluminium alloy anodes shall also be distributed on the structure in order to avoid its depolarisation and the damage of calcareous deposits in case the impressed current anodes system is inoperative for several months. A lifetime of 1 to 2 years for these anodes allows to delay repairs and restart of the impressed current anodes systems.

9. Quality assurance procedures

9.1 General

At the beginning of the design, a Quality Plan must be prepared by Contractor, detailing all actions related to the cathodic protection calculation, the definition of the systems to install, the procurement, checks and reception of equipment, and commissioning on site. These shall be described in detailed procedures.

All the calculations, systems, and materials used shall be approved by Company.

9.2 Equipment

In the technical part of the QA dossier, characteristics and references for some of the materials and apparatus used for the cathodic protection systems shall be specified such as:

- Impressed current DC sources, impressed current and sacrificial anodes, insulating joints, safety devices, reference electrodes, cables, junction boxes, as controlled in plant by Contractor
- Painting and coating
- Wiring plans.

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9.3 Technical file

The technical file submitted by the Contractor at the end of the work shall include:

- The characteristics of the structure to protect
- The detailed calculations of the cathodic protection
- The systems related to the installation
- The data sheets and test certificates of the materials
- The detailed drawings of the different systems
- The values obtained during the commissioning.