



Exploration & Production

GENERAL SPECIFICATION

CORROSION

GS COR 100

Design of cathodic protection of offshore structures

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01	10/02	General revision - Calculation method revision - Requirement of certification of specialised personnel
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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 of offshore fixed structures (platforms, wharves, piers, subsea templates and wells) and floating units (as FPSO, buoys).

Except if formally accepted in a written form by the OWNER, 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 the General Specification [GS SPS 009](#).

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

The requirements of the present document are superseding those of the reference documents, which have to be used when necessary in addition. 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. Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published at the EFFECTIVE DATE of the CONTRACT.

Standards

Reference	Title
ISO 8044	Corrosion of materials and alloys - Basic terms and definition
EN 12473	General principles of cathodic protection in sea water
EN 12495	Cathodic protection for fixed steel offshore structures
EN 13173	Cathodic protection for steel offshore floating structures
EN 13174	Cathodic protection of harbour installations
IEC 227	Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V
IEC 146	Semiconductors convectors



Professional Documents

Reference	Title
DNV RP-B401	Cathodic Protection Design
NACE RP-0176	Corrosion control of Steel Fixed Offshore Platforms associated with Petroleum Production
NACE RP-0169	Control of external corrosion on underground or submerged metallic piping systems
NACE RP-0286	The electrical isolation of cathodically protected pipelines
BS 7361 - Part 1	Cathodic protection - Part 1: Code of practice for land and marine applications

Regulations

Reference	Title
Not applicable	

Codes

Reference	Title
Not applicable	

Other documents

Reference	Title
Not applicable	

Total General Specifications

Reference	Title
GS COR 102	Design of cathodic protection of sealines by sacrificial anodes
GS COR 201	Supply of sacrificial anodes
GS COR 202	Supply of cathodic protection monitoring system
GS COR 204	Supply of a device for checking cathodic protection characteristics of a jacket
GS COR 210	Insulating joints
GS COR 230	External laminated glass fibre/resin based coating for risers of sea-line
GS COR 231	External elastomer based Coating for Risers of Sea Line
GS COR 240	Fusion bonded epoxy based coating for conductor pipes of drilling platforms

Reference	Title
GS COR 350	External protection of off-shore and related structures and equipment by painting
GS COR 351	External protection of structures and equipment by painting - Floating structures
GS COR 501	Control of cathodic protection of submerged fixed structures
GS ELE 079	Electric apparatus for explosive gas atmosphere
GS SPS 009	Corrosion protection of subsea stations

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 specialised personnel. The qualification of each of the specialists working for such a design shall be demonstrated to the OWNER before commencement of the job. Therefore the verification of the formal Certification of the individuals shall be carried out as follows:

- Conventional design work to be carried out by level 2 certified personnel
- Complex design work or verification to be carried out by level 3 certified personnel.

Accepted Certification schemes are AFNOR Compétence (Seawater Application Sector), APCE (Seawater Application Sector), Institute of Corrosion, NACE International. Any other Certification scheme should be approved by the OWNER.

Any use of non certified personnel for cathodic protection design shall be subject to the approval of the OWNER 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 are defined in the [EN 12495](#) with the following deviations:

- Atmospheric zone: for a platform, this zone is defined in [GS COR 350](#) as: area between the level located at 0.5 m below the first horizontal wind bracing level and the top of the structure
- Splash zone: for a platform, area just under the atmospheric zone defined above and the tidal datum minus the value of the annual swell trough
- 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 only for piles and conductor pipes under the bottom of the structure.

4.2 Risers-Insulating joints - Appurtenances

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

If the pipeline is protected by sacrificial anodes, the riser cathodic protection calculation shall be included in the jacket cathodic protection calculation.

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. However they have to be taken in consideration for the design of the CP system as they will consume current.

Cathodic protection of SCRs (Steel Catenary Risers) is designed in the frame of the associated pipelines in accordance with **GS COR 102**.

4.3 Painting-Coating

The following parts of marine structures shall be coated:

- Atmospheric zone
- Splash zone
- Mud line zone (closest to seabed),

and all the submerged length of the following parts:

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

A job specification shall define all the additional elements to be coated.

The painting application methods and painting systems are given in **GS COR 350**.

Other coating or painting systems may be submitted for the OWNER's approval (see different categories in section 5.5).

5. Calculation of cathodic protection

5.1 Protection criteria

For mild steel, the requirement at the potential achieved by the structure shall be in accordance with the following values:

- More negative than -800 mV/Ag/AgCl/sea water in aerated seawater
- More negative than -900 mV/Ag/AgCl/sea water in a seawater environment with a high content of sulphate reducing bacteria
- More positive than -1100 mV/Ag/AgCl/sea water in sea water if the structural steel is carbon steel having a yield strength of maximum 550 MPa.

For other materials, the requirement shall be in accordance with [EN 12473](#) Table 2.

On subsea production installations different material qualities are often used. For these materials the following criteria shall apply when they are under cathodic protection:

- For CRA and high strength steel materials, the risk of hydrogen induced cracking is of main concern when cathodic protection is applied. The bare material shall be chosen to withstand a negative potential limit of -1.05 V Ag/AgCl
- For the non-welded carbon/low alloy steels, the maximum actual YS shall not exceed 950 MPa and a hardness level of 300 HV5 (307 HB or 32 HRC)
- For the welded components, the maximal allowable hardness level of the welded area shall be 300 HV5.

5.2 Current density

For submerged zone, the current density to be applied for standard structures in depths not greater than 100 m is given below. The value may be modified by a job specification adapted to the actual site.

Current densities at mid-life are used (column 3: maintenance) to calculate the minimum weight of alloy material anode in case of cathodic protection by sacrificial anodes.

The current densities at the beginning of life (before polarisation) and at the end of life are used to verify that, for a cathodic protection by sacrificial anodes, the chosen anodes are capable of supplying sufficient current at the beginning of life to polarise the structure and the additional current at the end of life required to re-polarise the structure, if necessary.

The greatest value obtained for the current requirement (I_t) between the current density at the beginning of the life, at mid-life and at the end of the life shall be used to define the characteristics of the equipment (rectifiers, anodes, etc.) in the case of cathodic protection by impressed current anodes.

Minimum current density for cathodic protection of bare steel

Area		Current density (mA/m ²)		
		Initial (Polarisation)	Maintenance	Final (Repolarisation)
North Sea (sector North of 57°N)		180	90	120
North Sea (Sector South of 57°N)		150	90	100
Mediterranean Sea		150	70	90
Gulf of Guinea	Shallow water	130	90	100
	Deep water	250	100	100
Gulf of Mexico		110	70	80
Persian Gulf		130	70	90
Indonesia		110	70	80
Buried zone (ambient temperature)		25	20	20

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 of the submerged zone.

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

The current drain to wells is 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 specifically defined.

5.3 Resistivity

The resistivity of sea water as a function of geographic location is 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 is 1 Ωm.

Generally, it is assumed that resistivity is constant as a function of depth. In case of significant variations, especially for deep water structures (water depth over 100 m), the job specification shall reflect these variations. For deepwater structures in West Africa a sea water resistivity of 0.30 Ωm shall be used.

5.4 Surface to be protected

The surface to be protected shall be divided in different zones (splash zone, submerged zone, mud line zone and buried zone). Each of these zones shall be calculated separately.

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

5.5 Coating breakdown factors

The coating breakdown factors are based on the recommendations given in the Recommended Practice [DNV RP-B401](#) paragraph 7.4. In addition two further coating types, categories V and VI, have been defined.

- Category I One layer of primer coat, about 50 µm nominal DFT (Dry Film Thickness)
- Category II One layer of primer coat, plus minimum one layer of intermediate top coat 150 to 250 µm nominal DFT
- Category III One layer of primer coat, plus minimum two layers of intermediate/top coats, minimum 300 µm nominal DFT
- 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) (300 µm minimum)
- Category VI Polyethylene or polypropylene coating (three layer) or elastomer or laminated fibre glass/epoxy 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 the risers coated with GRE or elastomers in accordance with [GS COR 230](#) and [GS COR 231](#) resp. the coating breakdown factor shall be: initial value 0.2%, mean value 0.5%, final value 1%.

6. Cathodic protection by sacrificial anode systems

6.1 Sacrificial alloy

Indium activated aluminium alloy anodes shall be utilised as a general rule. Zinc alloy anodes may be used for the protection of the mud mats facing downwards

Notes:

- If the structures are completely coated, aluminium alloy anodes shall be chosen subject to successful qualification tests (current output of 0.1 A/m² during 6 months minimum according to the Recommended Practice [DNV RP-B401](#) Appendix B). If tests fail, zinc alloy anodes shall be chosen
- For structures sensitive to hydrogen embrittlement (for instance subsea Christmas-trees in 13% chromium stainless steel, high strength steels, etc.), special precautions must be taken. As a minimum precaution, zinc anodes shall be used instead of aluminium anodes to protect such sensitive steels.

The compositions and quality requirements and control of the aluminium and zinc alloy anodes are given in [GS COR 201](#).

6.2 Characteristics of the alloy sacrificial

The cathodic protection calculation shall take into account the potential and practical consumption (m) values guaranteed by the anode SUPPLIER and verified during the qualification procedure. If the values are unknown at the time of calculation, a conservative value shall be chosen:

- Practical consumption:
 - 3.6 kg/A/year for aluminium indium alloy anode
 - 11.2 kg/A/year for zinc alloy anode.
- Potential:
 - 1050 mV/Ag/AgCl/sea water for aluminium indium alloy anode
 - 1000 mV/Ag/AgCl/ sea water for zinc alloy anode.

6.3 Utilisation factor u

The utilisation factor is given below:

- Anodes stand-off made by continuous casting u = 0.95
- Anodes stand-off made by traditional mould casting u = 0.90
- Bracelet half shell anodes u = 0.85
- Bracelet segment anodes u = 0.75
- Short flush-mounted anodes u = 0.80
- Long flush-mounted anodes u = 0.85

Note: The performance of anodes becomes unpredictable if utilisation factor value is above those given below.

6.4 Installation and location of anodes

6.4.1 Insert

The insert diameter and thickness are defined as a function of the weight of the anode, the environmental conditions and the installation conditions of the structures.

The minimum requirements are given in **GS COR 201**.

6.4.2 Stand-off

The distance between the centre line of the anode's insert and the structure shall be 300 to 500 mm for all aluminium anodes.

Eventual zinc anodes located underneath mud mats shall be flush-mounted.

Flush-mounted anodes may be recommended for the protection of piers, wharves and floating units.

6.4.3 Gussets - Doubler plates

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

6.5 Calculation of cathodic protection

As indicated in Section 5.2, the calculation is based on the current requirement (I_i) at mid-life.

The current requirement (I_i) for the entire structure is the sum of the currents for the 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.

6.5.1 Total weight of alloy to be installed

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

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

6.5.2 Total number of anodes

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

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

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

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

Weight of an aluminium-indium 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	$300 \leq M \leq 600 \text{ kg}$

In case 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 defined by the current requirement calculation of the different zones of the structure, practical distribution of the anodes shall take into consideration the following factors:

- Anodes shall be uniformly distributed on the structure
- Anodes for the splash zone shall be located between the LAT and the first submerged level that is practicable
- Anodes for the buried parts of the jacket including piles and underside of mud mats (if not directly 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 at the different levels in their immediate proximity on the conductor guide frames
- Anodes corresponding to the current drain of wells shall be uniformly distributed over all the submerged part of the structure.

6.5.3.2 Location

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

- On legs, the anodes shall face the centre of the structure
- On diagonals, the anodes shall be alternately placed on the upper and lower surface if more than one anode is required
- On horizontal bracings at different levels, the anodes shall be installed alternately facing up and down 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° up and down (every other anode).

Cathodic protection of tendons of TLPs (Tension Leg Platforms) is carried out from anodes located only on the bottom structures or the hull of the TLP. When necessary, modelling of the CP system has to be carried 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), modelling 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 the OWNER (e.g. PROCOR, Corrocean).

6.6 Cathodic protection monitoring

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

The monitoring arrangements to be installed are described:

- For the monitoring of anodes, in [GS COR 202](#)
- For the monitoring of anodes and cathodes, in [GS COR 204](#).

The use of the latter system is limited to new geographic locations or new platform designs.

In both cases the monitoring systems shall consist of two anodes located on the same member and installed a specific distance apart 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.

6.6.1 Number of monitoring systems

In general the number of monitoring systems is calculated as follows:

- Between 0 and -60 m one system
- Between 0 and -120 m two systems
- For each additional 60 m one system

6.6.2 Reference electrodes

At least one zinc electrode shall be located at each level of the submerged part of the jacket. The electrode shall be completely isolated from the structure and located as far as possible from the sacrificial anodes.

The types of zinc electrode and their compositions are given in [GS COR 202](#) and [GS COR 204](#).

6.7 Verification of the protection

The suitability of the chosen anode size, dimensions and number must be verified all along the life of the structure.

Note: The anode resistance formula R is given in the Recommended Practice [DNV RP-B401](#) paragraph 7.7.

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:

$$E_s = E_A + R_o \cdot I_{Ao} \leq -800 \text{ mV/Ag/AgCl/sea water}$$

I_{Ao} = Initial anode current output at the beginning of life, using polarisation current density and initial coating breakdown factors for eventual coatings

R_o = Initial anode resistance, with Φ = 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:

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

I_{Af} = Final anode current output, using repolarisation current density and final coating breakdown factors for eventual coatings

R_f = Final anode resistance, calculated with $\Phi_f = \sqrt{(\Phi_o^2 - \Phi_{ins}^2)(1-u) + \Phi_{ins}^2}$ and Φ_f = hypothetical diameter of anode at the end of life.

6.8 Protection of mud mats by zinc anodes

When the protection of the mud mats in contact with the mud is provided by flush mounted zinc alloy anodes, the calculation is separate from the rest of the structure. The procedure for calculations of cathodic protection is performed as described in chapter 6.5. The requirement for mud mats potential shall be -900 mV/Ag/AgCl/ sea water, instead of -800 mV/Ag/AgCl/seawater.

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.

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 structure potentials shall be given.

Furthermore, the following data shall be highlighted:

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

6.10 Measurements after structure installation

A further series of measurements shall be performed, according to **GS COR 501**, in the first three to six months of operation after commissioning. The results shall then demonstrate the effectiveness of the cathodic protection system.

The subsequent schedule of routine inspections shall be drawn up by the CONTRACTOR at the request of the OWNER.

7. Cathodic protection by impressed current anode systems

7.1 Definition of impressed current anodes

The calculations for defining the maximum output by 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 the life.

The current requirement (I_t) for the entire structure is the sum of the currents for the 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 divided zone.

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

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 metal oxide activated titanium.

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

In order to limit the direct current power source and the voltage on the vicinity of the anode, only titanium substratum shall be chosen for impressed current anodes installed on the structure or at its close vicinity.

For impressed current anodes installed far from the structure (20 to 50 m minimum), niobium substratum may be chosen.

The loss of one impressed current anode may significantly reduce the performance of the cathodic protection system. So, the output current for an unit impressed current anode shall not be more than 10% of the total current requirement (I_t). Such anodes permit to avoid a radius too big for the dielectric shield.

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 also 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 anodes or incorporated into the anode assembly. This dielectric shield shall be inert 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 Part 1](#) - Section 7 Standard.

7.4 Rectifier

The transformer rectifier or controllable direct current generator 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 local.

The control of the transformer rectifier current output may be manual or automatic.

Automatic control shall be based on potential readings from fixed reference electrodes. Alarm functions indicating excessive voltage/current load on anodes and/or too negative or too high potentials shall be included.

In the case of current requirements (I_t) more than 500 A, the number of rectifiers shall be two or even three or more, depending of the total output current.

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 in zinc alloy with a chemical composition complying with Z2 type in accordance with [GS COR 201](#).

7.6 Cables

The cable and connections insulation materials shall be resistant to the environmental conditions, chlorine, hydrocarbons, and any other deleterious that may be present.

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.

Restrictions for routing of cables in hazardous areas shall be applied.

Impressed current anodes cables should have a steel armour and are to be adequately protected to avoid any mechanical damage. Steel dedicated conduits or internally within the structure if applicable, shall be used for this purpose.

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

Impressed current anode and reference electrodes cables shall be protected at the splash zone transition into different steel conduits able to resist at 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 there is a specific situation justified by the CONTRACTOR, reinforced safety boxes shall not be required. However, they shall provide a minimum of protection against shocks and the ingress of water, whether made of insulating material (PVC, polycarbonate, etc.) or metal (steel, cast aluminium, stainless steel), and of type of:

- IP 65/IK 08 for outdoor locations
- IP 41 for indoor locations.

The 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 further series of measurements shall be performed after the starting of the impressed current anode systems:

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

The subsequent schedule of routine inspections shall be drawn up by the CONTRACTOR at the request of the OWNER.

8. Cathodic protection by complementary systems

A complementary system provides protection during structure construction/installation and/or during times when the impressed current system is inoperative.

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

For the initial life with bare structures, magnesium alloy-based anodes shall be distributed on the structure in order to avoid the oxidation of steel structure which may increase highly the current density required for structure polarisation. A lifetime of 6 to 12 months for this type of alloy permits to wait the starting of the impressed current anodes system and to limit the current requirement (I_t) at the value defined for maintenance or final time.

The type of sacrificial anode shall be in magnesium alloy with a chemical composition complying with M1 or M2 type according to **GS COR 201**.

The magnesium alloy-anodes should be flat anodes or slender anodes with stand off and a dielectric shield, paint-based described in **GS COR 350**, shall be installed on the structure around the anode on a radius of 1 metre.

For the maintenance time with bare structure, aluminium alloy-based anodes shall also be distributed on the structure in order to avoid the depolarisation of it and the damage of calcareous deposits in case of the impressed current anodes system is inoperative several months. A lifetime of 1 to 2 years for these anodes permits to delay repairs and restarting of the impressed current anodes systems.

9. Quality assurance procedures

9.1 General

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

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

9.2 Equipment

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

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

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.