**SLOVENSKI STANDARD**
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**Katodna zaġļ ita kompleksne zgradbe**

Cathodic protection of complex structures

Kathodischer Korrosionsschutz komplexer Anlagen



Protection cathodique des structures complexes



**Ta slovenski standard je istoveten z: EN 14505:2005**

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# Cathodic protection of complex structures

Protection cathodique des structures complexes

Kathodischer Korrosionsschutz komplexer Anlagen

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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# Contents

# Foreword

This European Standard (EN 14505:2005) has been prepared by Technical Committee CEN/TC 219 “Cathodic protection”, the secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by October 2005, and conflicting national standards shall be withdrawn at the latest by October 2005.

It may be difficult to obtain complete cathodic protection of certain structures when following the general guidelines in EN 12954. This may be due to an electrical connection to one or more metal structures (electrodes) situated in the same electrolyte as the structure, which is to be protected. In particular, the structure may be earthed in order to mitigate electrical hazards or the connection to the other structures may be dictated by construction or operational requirements.

An electrical connection to a foreign structure can result in a significantly increased cathodic protection current demand, since the current flows not only to the structure to be protected but also to the foreign structure. This unwanted increased current demand is enhanced when the foreign structure consists of a metal, which is more noble (having a more positive resting potential) than the metal in the structure to be protected. Connection to a copper earthing electrode or to the steel reinforcement in a concrete structure are examples of the latter.



These difficulties can mean that a significantly increased cathodic protection current is required because of structures electrically connected to the structure to be protected, resulting in inadequate cathodic protection, current distribution and shielding effects.



For this reason, the term “complex structure” has been used. It does not refer to the complexity of the structure or to the complexity of the cathodic protection system.

In such conditions the prerequisites, the criteria and the methods described in the present document expand those given in EN 12954.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

## 1 Scope

This European Standard applies to the cathodic protection of complex structures. It is applicable to structures, which are to be cathodically protected, but cannot be electrically isolated, whether for technical or safety reasons, from foreign metallic structures situated in the same electrolyte as the structure to be protected. Such a structure is referred to as a “complex structure”.

This European Standard is not applicable to structures that can be protected in accordance with EN 12954. When contacts with foreign structures or defective isolation from foreign structures exist, but can be corrected, EN 12954 is applicable instead of this document. As an example pipeline network distribution systems are not considered to be complex structures

It is assumed in this document that the design, installation, commissioning, inspection and maintenance are entrusted to adequately trained, experienced, competent and reliable personnel in order to achieve effective and efficient cathodic protection.

Annexes A and B show the principle scheme of a complex structure with examples.

## 2 Normative references

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



EN 12954:2001*, Cathodic protection of buried or immersed metallic structures — General principles and application for pipelines.*

EN 50162, *Protection against corrosion by stray current from direct current systems*.



## 3 Terms and definitions

For the purposes of this European Standard, the terms and definitions given in EN 12954:2001 and the following apply.

NOTE For other definitions related to corrosion, refer to EN ISO 8044:1999.

**3.1**
**complex structure**
structure composed of the structure to be protected and of one or more foreign electrodes, which, for safety or technical reasons, cannot be electrically separated from it

**3.2**
**foreign electrode**
electrode (anode or cathode), in contact with the structure under consideration

NOTE a foreign anode is a foreign electrode, which has a more negative potential than the structure, a foreign cathode is a foreign electrode, which has a more positive potential than the structure.

## 4 Criteria for the cathodic protection of complex structures

For complex structures, the cathodic protection criteria defined in EN 12954 should be used where possible. Indeed, the characteristics of complex structures and the special influential factors (see Clause 5) which can occur means that it is not always possible on every part of the complex structure to determine by measurement whether these criteria of cathodic protection are met. In this case alternative methods of verification may be selected to ensure an adequate reduction of the corrosion rate. Particular attention should be paid to the selection of these alternative methods, and these will depend upon the structure and the soil characteristics.

The following three alternative methods may be used as criteria. They are based upon practical experience and are widely used. All structure to electrolyte potential measurements are stated with respect to a copper/saturated copper sulphate reference electrode.

a) Potential measurement method

An on potential $E_{on}$ equal to or more negative than –1,2 V, if the measuring point is outside the area of influence of the large foreign cathode (e.g. reinforced concrete or copper earthing system) and if the soil resistivity is sufficiently low (less than about 100 Ω·m) with the exception that an on potential $E_{on}$ more negative than –0,8 V could be acceptable at entries to, and in the vicinity (within 0,5 m) of large foreign cathodes (demonstrating that the effect of a galvanic cell with the large foreign cathode is mitigated).

b) Current method

The purpose of this method is to demonstrate that current is able to enter the structure at critical locations either:

1) directly (i.e. when the protection current is switched on, a negative shift from the free corrosion potential $E_n$ by at least 0,3 V indicating that probably sufficient current is entering the structure); or

2) by means of either current density or potential shift measurements at test probes or coupons.

NOTE A critical location is location where the probability to have an anodic current leaving the structure to be protected is high (e.g., vicinity of foreign cathode due to galvanic couple, heterogeneity of the soil or shielding effect).



c) Depolarisation measurement method



A positive shift (depolarisation) on test probes or coupons of at least 0,1 V measured from immediately after disconnection ($E_{off}$) to 1 h after disconnection from the structure indicates that the structure is polarized. These test probes/coupons are disconnected only for measurements.

One of these alternative criteria shall be used as a minimum. More than one of these alternative criteria may be required to verify adequate protection over the entire complex structure. Other criteria can be used if they can be shown to reduce the external corrosion rate to an acceptable level.

# 5 Prerequisites for the application of cathodic protection to a complex structure

## 5.1 General

The cathodic protection system depends on the size and shape of the complex structure, the type of coating, the aggressive action of the soil and its resistivity, d.c. and a.c interference, national regulations, and also on the technical and economic criteria.

To achieve cathodic protection, the conditions given in 5.2 to 5.4 should be satisfied.

## 5.2 Electrical continuity

In the case of a complex structure, all metallic parts of the structure to be protected should be electrically continuous. Foreign electrodes should also be electrically continuous.

## 5.3 Electrical isolation

For the cathodic protection system to be properly designed, the form and extent of the structure should be clearly defined in terms of its location and electrical isolation from foreign structures.

If the electrical isolation is ineffective and cannot be restored to its original condition, then the extent of the complex structure should be revised to take this into account.

### 5.4 External coating

Protective coatings are not always applied to components in a complex structure (e.g. earthing systems). Uncoated components significantly increase protection current demands and thus add to the difficulties of the application of cathodic protection and increase the risk of interference. Wherever possible, buried metallic components should be suitably coated.

## 6 Base data for design

### 6.1 General

In addition to following the principles laid out in EN 12954, other specific data, as given in 6.2 to 6.8, should be used when dealing with complex structures.

### 6.2 Structure details

The surface area of all buried or immersed components of a complex structure should be ascertained as well as the status of the coating (if any).

### 6.3 Coatings



Types of the different coating applied on all components of a complex structure should be taken into account.

### 6.4 Environment



Depending on the composition of some parts of a complex structure, particular environmental conditions should be considered, for example, the chloride content of the electrolyte when an integral part of a complex structure is made of stainless steel, or reinforcement steel in concrete (rebar).

### 6.5 Shielding

All relevant information should be obtained on any feature that might act as a shield to the cathodic protection current or its distribution, e.g. reinforced concrete foundations, pits, ducts, any geotextiles, and pipe sleeves. The location of the anodes with respect to the shields should be selected such that shielding is minimized.

A shield can be either conductive or non-conductive.

A conductive shield can be either a part of the complex structure itself or a foreign structure such as steel sleeves for pipes, large conducting structures (sheet piling and reinforced concrete foundations) close to the structure to be protected.

Non-conductive shields can be either a non-conductive object (e.g. plastic or a well coated steel sleeve pipe) or a mechanical protective material or a localized area with a higher resistivity (e.g. drained sands, gravels, sealed concrete).

### 6.6 Electrical isolation

The location and efficiency of electrical isolation should be taken into account at the defined complex structure limits and, if necessary, within the complex structure.

For example, isolation is ineffective if it is bypassed by metallic components or equipment that provide a parallel electrical path. Electrical earthing systems, instrumentation and/or telemetry cables, control pipework, and supporting structures are examples of possible parallel paths. Electrical isolation is also ineffective when pipelines carrying low resistivity liquids (e.g. brine) are equipped with inappropriate isolating joints.

NOTE Details concerning isolating joints are given in EN 12954.

### 6.7 Foreign electrodes

Details of the type, location and other detailed characteristics of foreign electrodes should be obtained.

In a complex structure, the presence of foreign electrodes which act as an anode (e.g. zinc or zinc-coated (galvanized) steel) or as a cathode (e.g. steel reinforcement in concrete (see Annex C), copper, stainless steel or silicon iron in carbonaceous backfill earthing systems) increases the protection current demand.

Zinc earthing systems should be used because they consume less current from the cathodic protection system than copper, stainless steel or silicon iron.

Electrical earthing systems associated with complex structures should utilize zinc or zinc-coated (galvanized) steel electrodes.

NOTE The connection of copper or cathodic earthing systems to buried steel not only increases cathodic protection current demand but, if cathodic protection is not applied, it will increase the corrosion risk to the buried steel.

### 6.8 Interference assessment

Interference:



- from any d.c. operated equipment to the complex structures or

- from the complex structure to foreign structures

should be assessed in accordance with EN 50162.



If necessary, appropriate measures should be taken to mitigate the effects of interference to maintain effective cathodic protection of the complex structure.

Particular attention should be paid to interference that can occur between the cathodic protection system(s) of the complex structure and the incoming/outgoing pipelines. Pipelines in the vicinity of the complex structure and their cathodic protection should be taken into account both in the design and the commissioning of the cathodic protection system of the complex structure to limit, or preferably, eliminate adverse interference effects.

## 7 Design and prerequisites

### 7.1 General

Complex structures include foreign electrodes that are often large cathodic surfaces (such as reinforcement steel and earthing systems). The result is that the cathodic protection current requirement is high and the effective distribution of the current is difficult to obtain.

Even though all known influences are taken into account in the design of the cathodic protection system, experience has shown that subsequent adjustments and additional cathodic protection installations can be necessary after the system has been switched on and a certain polarization time has elapsed. This is due to the characteristics of the structure to be protected, shielding effects and interference with foreign structures. For these reasons, the protection current requirements and current distribution cannot always be accurately determined during the design stage.

When a complex structure includes reinforcement steel in concrete that is bonded to the structure to be protected, efficient current distribution can be achieved by the application of an insulating coating to the buried concrete surface at entries or points of close proximity of the protected structure to the reinforced concrete (see 7.2 item b) and Annex D). This method may be applied whether local anodes to increase the soil potential are used or not.

A coating is used to reduce the effect of the local voltage gradient from the reinforced concrete structure and improve the current distribution.

The coating should extend on the concrete surface at least 1 m around the protected structure (e.g. pipeline) and up to the soil surface.

If pipelines are laid in soil parallel to steel reinforced concrete foundations and the spacing is less than twice the pipe diameter or less than 0,5 m, the coating should extend for the length of the parallelism from 1 m below the bottom of the pipe to ground level.

Test stations connected to reinforcement steel should be located in these areas (see also 7.8).

## 7.2 Cathodic protection methods for complex structures

To achieve the protection criteria detailed in Clause 4, cathodic protection can be achieved by three methods. The choice of the method depends on the complex structure in question.

a) By the use of impressed current groundbed(s) sufficiently remote from the complex structure to be protected (conventional groundbed). By using this method, high levels of cathodic protection current are often required because all components of the complex structure receive and consume current.



b) By the use of distributed or continuous groundbed(s) located along and close to the structure to be protected. The purpose of this method is to localize the application of cathodic protection current to the structure to be protected. (Complementary information is given in Annex D).



c) By a combination of the above two methods.

Effective cathodic protection is usually achieved by a combination of these methods. Complex structures vary considerably in size and complexity and it is not possible to be prescriptive as to which single method will be successful.

NOTE Annex E covers groundbed data.

## 7.3 Electrical isolation of structures

If electrical isolation from the adjacent structures exists or is planned, this information should be used to determine the extent and limits of the complex structure.

Isolating joints in incoming or outgoing pipelines should be located outside the zone of influence of the cathodically protected complex structure so that unacceptable interference by the cathodically protected complex structure (due to voltage gradient) is avoided.

## 7.4 Safety

### 7.4.1 General

The design should not cause any additional hazards, (e.g. explosion, safety, personnel and interference).

### 7.4.2 Electrical earthing systems

Generally, earthing systems are electrically connected directly to the structure to be protected and are part of the complex structure. In order to prevent excessive drain of cathodic protection current to copper earthing systems, they can be separated from the structure to be protected by the use of decoupling devices.

#### 7.4.3 Electrical safety bonding

##### 7.4.3.1 Permanent bonding

Structures such as building frames, reinforcement steel in concrete, access platforms and stairways are often bonded to the complex structure to be protected and therefore become a part of the complex structure.

Permanent bonding should be taken into account when designing the cathodic protection system.

##### 7.4.3.2 Temporary bonding

Temporary bonds are made when vehicles (road/rail) or ships are engaged in loading or unloading hazardous products.

All necessary safety precautions should be taken before transfer operations start e.g. equipotential bonding which may be by conductive hoses or cables (see EN 50162).

Temporary bonding should be taken into account when designing the cathodic protection system.

In hazardous installations, current may be flowing in both buried and above ground sections of pipework and so to avoid possible sparking when pipework modifications are made, the cathodic protection system should be switched off and a heavy duty cable bond should be applied across the pipe section to be separated. The bond should be maintained until the pipe is reconnected or the area declared safe.

### 7.5 Electrical continuity



Metallic bonds are installed to ensure electrical continuity of the complex structure and also to avoid interference and excessive voltage drops in the cathodic protection circuit.



### 7.6 Negative connections

To achieve optimum current distribution in the complex structure, several transformer rectifiers and/or several negative connections should be used.

### 7.7 Transformer–rectifiers

The rating of transformer–rectifiers should be designed with sufficient capacity to allow for the initial higher current requirement during the polarization period and for changing conditions. The output voltage should be kept as low as possible to help limit the interference levels (see also 7.9).

### 7.8 Test stations and measuring points

Test stations and measuring points should be located at sufficient locations to adequately represent the cathodic protection status of the structure.

Where measuring points are located in concrete or gravel areas, provision should be made for reference electrode contact to the soil beneath the concrete/gravel.

Measuring points should be located at critical points, permanently marked to ensure reproducible measurements. These critical points should take into account the presence of:

a) sleeve pipes;

b) sheet piling;

c) reinforced concrete structures;

d) entries to reinforced concrete structures;