SLOVENSKI STANDARD
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Ovrednotenje verjetnosti nastanka korozije vkopanih cevovodov - Uporaba pri katodno zaščitenih cevovodih

Evaluation of a.c. corrosion likelihood of buried pipelines applicable to cathodically protected pipelines

Beurteilung der Korrosionswahrscheinlichkeit durch Wechselstrom an erdverlegten Rohrleitungen - Anwendung für kathodisch geschützte Rohrleitungen

Évaluation du risque de corrosion occasionnée par les courants alternatifs des canalisations enterrées protégées cathodiquement

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English Version

Evaluation of a.c. corrosion likelihood of buried pipelines applicable to cathodically protected pipelines

Évaluation du risque de corrosion occasionnée par les courants alternatifs des canalisations enterrées protégées cathodiquement

Beurteilung der Korrosionswahrscheinlichkeit durch Wechselstrom an erdverlegten Rohrleitungen anwendbar für kathodisch geschützte Rohrleitungen

This European Standard was approved by CEN on 5 July 2013.

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This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

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Foreword

This document (EN 15280:2013) 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of an identical text or by endorsement, at the latest by February 2014 and conflicting national standards shall be withdrawn at the latest by February 2014.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes CEN/TS 15280:2006.

With this document, CEN/TS 15280:2006 is converted into a European Standard.

The main modification concerns the criteria assumed in the presence of a.c. interference on a pipeline. While CEN/TS 15280:2006 represented a collection of various experiences in the field of a.c. corrosion, this European Standard has incorporated these criteria and thresholds together with experience gained from the most recent data. Various European countries have a different approach to the prevention of a.c. corrosion depending primarily on the d.c. interference situation. These different approaches are taken into account in two different ways:

— either in the presence of “low” ON-potentials (less negative than -1,2 V CSE), which allows a certain level of a.c. voltage (up to 15 V),

— or in the presence of “high” ON-potentials (more negative than -1,2 V CSE ; with d.c. stray current interference on the pipeline for instance) which requires the reduction of the a.c. voltage towards the lowest possible levels.

This European Standard gives also some parameters to consider when evaluating the a.c. corrosion likelihood, as well as detailed measurement techniques, mitigation measures and measurements to carry out for commissioning of any a.c corrosion mitigation system. Note that Annex E proposes other parameters and thresholds that require further validation based on practical experiences.

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

1 Scope

This European Standard is applicable to buried cathodically protected metallic structures that are influenced by a.c. traction systems and/or a.c. power lines.

In this document, a buried pipeline (or structure) is a buried or immersed pipeline (or structure), as defined in EN 12954.

In the presence of a.c. interference, the protection criteria given in EN 12954:2001, Table 1, are not sufficient to demonstrate that the steel is being protected against corrosion.

This European Standard provides limits, measurement procedures, mitigation measures and information to deal with long term a.c. interference for a.c voltages at frequencies between 16,7 Hz and 60 Hz and the evaluation of a.c. corrosion likelihood.

This European Standard deals with the possibility of a.c. corrosion of metallic pipelines due to a.c. interferences caused by inductive, conductive or capacitive coupling with a.c. power systems and the maximum tolerable limits of these interference effects. It takes into account the fact that this is a long-term effect, which occurs during normal operating conditions of the a.c. power system.

This European Standard does not cover the safety issues associated with a.c. voltages on pipelines. These are covered in national standards and regulations (see EN 50443).

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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 13509:2003, *Cathodic protection measurement techniques*

EN 50443, *Effects of electromagnetic interference on pipelines caused by high voltage a.c. electric traction systems and/or high voltage a.c. power supply systems*

EN 61010-1, *Safety requirements for electrical equipment for measurement, control and laboratory use — Part 1: General requirements (IEC 61010-1)*

3 Terms and definitions

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

3.1
a.c. electric traction system
a.c. railway electrical distribution network used to provide energy for rolling stock

Note 1 to entry: The system can comprise:

- contact line systems;
- return circuit of electric railway systems;
- running rails of non-electric railway systems, which are in the vicinity of, or conductively connected to, the running rails of an electric railway system.

3.2
a.c. power supply system
a.c. electrical system devoted to electrical energy transmission and including overhead lines, cables, substations and all apparatus associated with them

3.3
a.c. power system
a.c. electric traction system or a.c. power supply system

Note 1 to entry: Where it is necessary to differentiate, each interfering system is clearly indicated with its proper term.

3.4
copper/copper sulphate reference electrode (CSE)
reference electrode consisting of copper in a saturated solution of copper sulphate

3.5
a.c. voltage
voltage measured to earth between a metallic structure and a reference electrode.

3.6
interfering system
general expression encompassing an interfering high voltage a.c. electric traction system and/or high voltage a.c. power supply system

3.7
interfered system
system on which the interference effects appear

Note 1 to entry: In this European Standard, it is the pipeline system.

3.8
pipeline system
system of pipe network with all associated equipment and stations

Note 1 to entry: In this European Standard, pipeline system refers only to metallic pipeline system.

Note 2 to entry: The associated equipment is the equipment electrically connected to the pipeline.

3.9
earth
conductive mass of the earth, whose electric potential at any point is conventionally taken as equal to zero

[SOURCE: IEC 60050 826-04-01]

3.10
operating condition
fault free operation of any system

Note 1 to entry: Transients are not to be considered as an operating condition.

3.11
fault condition
non intended condition caused by short-circuit to earth, the fault duration being the normal clearing time of the protection devices and switches

Note 1 to entry: The short circuit is an unintentional connection of an energised conductor to earth or to any metallic part in contact with earth.

3.12
conductive coupling
coupling which occurs when a proportion of the current belonging to the interfering system returns to the system earth via the interfered system or when the voltage to the reference earth of the ground in the vicinity of the influenced object rises because of a fault in the interfering system, and the results of which are conductive voltages and currents

3.13
inductive coupling
phenomenon whereby the magnetic field produced by a current carrying circuit influences another circuit; the coupling being quantified by the mutual impedance of the two circuits, and the results of which are induced voltages and hence currents that depend for example on the distances, length, inducing current, circuit arrangement and frequency

3.14
capacitive coupling
phenomenon whereby the electric field produced by an energised conductor influences another conductor, the coupling being quantified by the capacitance between the conductors and the capacitances between each conductor and earth, and the results of which are interference voltages into conductive parts or conductors insulated from earth, these voltages depend for example on the voltage of the influencing system, distances and circuit arrangement

3.15
interference
phenomenon resulting from conductive, capacitive, inductive coupling between systems, and which can cause malfunction, dangerous voltages, damage, etc.

3.16
disturbance
malfunction of an equipment losing its capability of working properly for the duration of the interference

Note 1 to entry: When the interference disappears, the interfered system starts again working properly without any external intervention.

3.17
damage
permanent reduction in the quality of service, which can be suffered by the interfered system

EXAMPLE coating perforation, pipe pitting, pipe perforation, permanent malfunction of the equipment connected to the pipes, etc.

Note 1 to entry: A reduction in the quality of service could also be the complete cancellation of service.

3.18
danger
state of the influenced system which is able to produce a threat to human life

3.19
interference situation
maximum distance between the pipeline system and a.c. power system for which an interference is considered

3.20
interference voltage
voltage caused on the interfered system by the conductive, inductive and capacitive coupling with the nearby interfering system between a given point and the earth or across an insulating joint

3.21
***IR* drop**
voltage, due to any current, developed in an electrolyte such as the soil, between the reference electrode and the metal of the structure, in accordance with Ohm's Law

3.22
***IR* free potential ($E_{IR\ free}$)**
structure to electrolyte potential measured without the voltage error caused by the IR drop due to the protection current or any other current

3.23
OFF-potential (E_{OFF})
structure to electrolyte potential measured immediately after synchronous interruption of all sources of applied cathodic protection current

3.24
ON-potential (E_{ON})
structure to electrolyte potential measured with the cathodic protection current flowing

3.25
spread resistance
ohmic resistance through a coating defect to earth or from the exposed metallic surface of a coupon to earth

Note 1 to entry: This is the resistance which controls the d.c. or a.c. current through a coating defect or an exposed metallic surface of a coupon for a given d.c. or a.c. voltage.

3.26
coupon
representative metal sample with known dimensions

Note 1 to entry: A coupon may be electrically connected to the pipeline.

Note 2 to entry: Examples of coupons are given in Annex B.

3.27
probes
device incorporating a coupon that provides measurements of key parameters to assess the corrosion risk

Note 1 to entry: Examples of probes are given in Annex B.

4 Cathodic protection personnel competence

Personnel who undertake the design, supervision of installation, commissioning, supervision of operation, measurements, monitoring and supervision of maintenance of cathodic protection systems shall have the appropriate level of competence for the tasks undertaken.

EN 15257 constitutes suitable methods of assessing competence of cathodic protection personnel, which may be utilised.

Competence of cathodic protection personnel to the appropriate level for the tasks undertaken should be demonstrated by certification in accordance with qualification procedures such as EN 15257 or any other equivalent scheme.

5 Assessment of the a.c. influence

5.1 General

This European Standard is applicable to all metallic pipelines and all high voltage a.c. traction systems and high voltage a.c. power supply systems and all major modifications that can significantly change the a.c. interference effect.

The effects considered within EN 50443 are the following:

a) danger to people who come in direct contact or contact through conductive parts with the metallic pipeline or the connected equipment;

b) damage of the pipeline or to the connected equipment;

c) disturbance of electrical/electronic equipment connected to the pipeline.

Electrical/electronic systems installed on a pipeline network shall be chosen such that they will neither become dangerous, nor interfere with normal operating conditions, because of short term voltages and currents, which appear during short circuits on the a.c. power system.

Long term a.c. interference on a buried pipeline can cause corrosion due to an exchange of a.c. current between the exposed metal of the pipeline and the surrounding electrolyte.

This exchange of current depends on an a.c. voltage whose amplitude is related to various parameters such as:

— the configuration of a.c. power line phase conductors;

— the presence and the configuration of the earthing conductor;

— the distance between the a.c. power line / traction system and the pipeline;

— the current flowing in the a.c. power line / traction system phase conductors;

— the average coating resistance of the pipeline;

— the thickness of the coating;

— the soil resistivity;

— the presence of earthing systems;

— the voltage of the a.c. railway system or the a.c. power line system.

5.2 Assessment of the level of interference

Calculations can be carried out according to EN 50443 by mathematical modelling to determine the earthing requirements necessary to maintain touch voltages within acceptable safe levels. Their results can also be used to determine voltages necessary to reduce the a.c. corrosion likelihood.

During the design phase of new influencing systems (electricity power line or railway line) or a new influenced system (pipelines), an estimation of the level of a.c. voltage on the pipeline should be calculated. Calculations can be carried out by mathematical modelling to determine the level of voltage produced on the pipeline. In the case of existing structures, field measurements can also be used as an option to calculation.

According to the results of calculations or field measurements, relevant mitigation measures should be installed on the influencing systems and/or the influenced system to limit the relevant a.c. voltage to reduce the a.c. corrosion likelihood (see Clause 7).

Guidance on calculating the a.c. voltage on a structure caused by an a.c. power system was published in CIGRE's Technical Brochure No. 95 in 1995 [1]. The algorithm determines the worst case conditions for the input parameters used for the calculation.

Due to inconsistent load demands on a.c. power systems, the magnitude of operating currents in power lines varies. The fluctuations depend on daily and seasonal changes. Input data for calculation purposes should be based on the realistic operating conditions or the maximum power load of the influencing system.

NOTE Carrying out calculations with input data based on both approaches (i.e. at realistic operating loads and maximum power load) is a help to estimate the range between both results and to choose the best method of mitigation.

6 Evaluation of the likelihood of a.c. corrosion

6.1 Prerequisite

6.1.1 General

The a.c. voltage on a pipeline is the driving force for the a.c. corrosion processes taking place on the steel surface at coating defects. Among other things, corrosion damage depends on a.c. current density, level of d.c. polarisation, defect geometry, local soil composition and resistivity (Annex D).

There are three different approaches to prevent a.c. corrosion: one to limit the a.c. current flowing through a defect, one to control the cathodic protection level, and the other to ensure that any coating remains defect free. These approaches are not mutually exclusive.

The evaluation of a.c. corrosion likelihood should be performed by evaluation of some or all of the following parameters:

- a.c. voltage on the structure,
- ON-potential,
- IR-free potential,
- a.c. current density,
- d.c. current density,
- a.c./d.c. current density ratio,
- soil resistivity,
- corrosion rate.

Annexes B, C and E provide further information.

6.1.2 A.c. voltage on the structure

The acceptable a.c. voltage thresholds (see Clause 7 and Annex E) depend on the chosen strategy to prevent a.c. corrosion. Hence, a given interference situation on the pipeline can influence the decision regarding the applicable strategy.

6.2 A.c. and d.c. current density

6.2.1 General

The a.c. and d.c. current density on a coating defect controls both the cathodic protection level and a.c. corrosion process. Therefore it is a more reliable parameter for the evaluation of the a.c. corrosion likelihood than the ON-potential or the a.c. voltage. However, in contrast to the voltages present on the pipeline, the current density cannot be readily determined. In principle the current density can be calculated from the spread resistance and the geometry of the coating defect and the a.c. voltage. This calculation is generally not possible, since the geometry of the coating fault and its surface area are not always known. Moreover, the application of cathodic protection can significantly change the spread resistance and therefore the current density at a given voltage.

The current density can only be estimated by means of coupons or probes. When evaluating the a.c. corrosion likelihood by means of a coupon or probe, it is important to consider the limitations of this technique. The calculation of the current density based upon the metallic coupon or probe surface area and on the current measured on a coupon or probe the current is averaged over the entire coupon or probe surface. However, the current distribution on the coupon or probe can vary depending on its geometry. Typically, current densities at the edges of the coupon or probe are larger than the current averaged over the entire surface. Moreover, the often observed formation of chalk layers can decrease the effective coupon or probe surface area. Again, this effect results in an under estimation of the current density.

6.2.2 A.c. current density

The a.c. current density results in anodic and cathodic charge transfer. A detailed explanation of the charge transfer process is given in Annex A. This current can be consumed in charging of the double layer capacitance at the steel surface, in the oxidation of hydrogen (resulting in a decreasing pH), in the oxidation of corrosion products and the oxidation of the metal. The oxidation of the metal results in corrosion. Generally, an increasing a.c. current density results in a larger amount of metal oxidation and higher corrosion rates. However, the anodic current is not the only current that can affect the corrosion process. Cathodic current can reduce oxide layers formed and increase the pH on the metal surface.

High a.c. current densities do not necessarily cause a.c. corrosion if the charge passed through the metal surface can be consumed in reactions other than metal oxidation and oxide film reduction. This is the case in the presence of low cathodic d.c. current densities. As a consequence, the judgment of the a.c. corrosion likelihood based on the a.c. current density requires the additional consideration of the cathodic d.c. current density.

Nevertheless, there is an empirically determined lower limit for the a.c. current density below which the probability for a.c. corrosion is extremely low (see Clause 7).

6.2.3 High cathodic d.c. current density

A high d.c. current density results in more negative cathodic protection levels and the formation of a high pH at the pipeline surface. However, the formation of a high pH-value, the decrease of the spread resistance, and the increased reduction of surface oxide films can result in an acceleration of the corrosion rate under simultaneous a.c. interference. Nevertheless, a sufficiently high d.c. current density can prevent any anodic metal oxidation and therefore the occurrence of a.c. corrosion.

Annexes A and E give detailed explanations about this process.

6.2.4 Low cathodic d.c. current density

A low d.c. current density results in a limited increase of the pH value at the metal surface, does not significantly change the spread resistance, and has less reductive effect on metal oxides on the pipeline surface. Therefore, the a.c. corrosion likelihood significantly decreases with decreasing d.c. current densities. However, low d.c. current densities can result in an insufficient level of cathodic polarisation of the metal surface as stated in EN 12954.