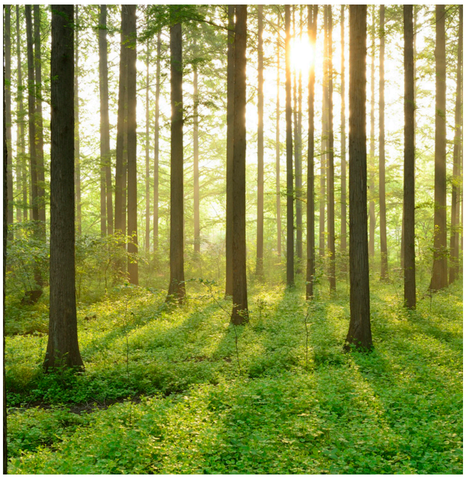
CORROSION IN EARTHING NETWORKS IN NUCLEAR POWER PLANTS

REPORT 2017:397



NUCLEAR

GRID INTERFERENCE ON NUCLEAR POWER PLANT OPERATIONS

Energiforsk

Corrosion in Earthing Networks in Nuclear Power Plants

Literature study

LENA SJÖGREN

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Foreword

A copper grounding grid is placed underneath the entire nuclear power plant, including the substation. The purpose of the grounding grid is to serve the dual purpose of carrying currents into the earth without exceeding the operating tolerances of any protected equipment while assuring that personnel in the vicinity are not exposed to electric shock as would result from excessive step or touch potentials. Similar designs are used in substations in the grid.

The grounding grid was installed upon the construction of the nuclear power plants, some 40-50 years ago. Given that the grid is buried under ground, it is difficult to inspect to verify if there are corrosion attacks. This pre-study was initiated to summarize previous work done on corrosion in grounding grids, to estimate the likelihood of corrosion attacks in grounding grids in nuclear power plants. It was performed by senior researcher Lena Sjögren at Swerea KIMAB. In a parallel project, non-destructive testing methods to verify the integrity of the grounding grid have been mapped. The results are found in Energiforsk report 2017:397.

The pre-study is part of the Energiforsk R&D program Grid Interference on Nuclear power plant Operations, GINO, financed by Vattenfall, Sydkraft Nuclear/Uniper, Teollisuuden Voima, Fortum, Skellefteå Kraft, Karlstads Energi and The Swedish Radiation Safety Authority.

Monika Adsten, Energiforsk

Sammanfattning

I jordningssystem för svenska kärnkraftverk används generellt koppar, beroende på dess höga ledningsförmåga och låga korrosionshastighet i jord. Korrosionsfrågor för kopparjordning omfattar korrosion av marklinenätet i jord inklusive effekter av inhomogent fyllnadsmaterial, korrosion av jordtag p.g.a. åska och felströmmar, läckströmskorrosion p.g.a. närliggande katodiskt skyddade objekt eller andra källor, ökad resistans hos kontaktövergångar, korrosion av svetsar.

Även om denna litteratursökning i första hand avser koppar ingår även en kort redovisning av korrosion i jord av andra material använda för t.ex. marklinor.

Enligt resultat från egna undersökningar eller resultat presenterad i litteraturen, förväntas inte korrosion i jord eller inverkan från åska ha någon större inverkan på jordningssystemet under rimlig tid. Ett undantag är dock korrosion p.g.a. luftningsceller som kan bildas i inhomogen jord p.g.a. dålig markpreparering eller för jordtag som går igenom både sand vid ytan och t.ex. lerjord längre ner. Detta kan leda till lokala angrepp, angrepp som enligt vissa uppgifter kan bli omfattande. Långtidsdata för både utbredd och lokal korrosion saknas dock (provmaterial exponerat i jord i över 30 år finns).

Tillfälliga felströmmar bedöms inte ge någon omfattande korrosion då varaktigheten är kort och det är fråga om växelström. Utjämningsströmmar mellan ställverk beroende på variationer i jordningsförhållanden, kan däremot ge omfattande växelströmskorrosion av jordtag eftersom dessa strömmar är permanenta.

Läckströmmar från närliggande katodiskt skyddade objekt skulle kunna ge mycket höga korrosionshastigheter men bedöms osannolikt då all utrustning normalt är jordad.

Läckströmmar från HVDC-överföringar med närliggande elektroder kan ge läckströmskorrosion beroende på lokala förhållanden, främst under perioder med monopolär drift. I inhomogen jord kan läckströmmar ge upphov till lokala korrosionsangrepp. Potentialkartering kan användas för bedömning av risker för läckströmskorrosion.

För jordtag i havsvatten förväntas betydligt kortare livlängd än i jord. Detta beror dels på högre korrosionshastigheter i saltvatten än i flertalet jordar, dels på saltvattnets låga resistivitet vilken leder till att förekommande läckströmmar och utjämningsströmmar i högre utsträckning kommer att ta denna väg.

Vid värdering av korrosionsstatus hos jordningssystemet bör åldringsegenskaperna hos kontakter, förbindningar och svetsar ingå. Tillförlitlighet och livslängd hos dessa beror, förutom på material och eventuella ytskikt, även på konstruktion och utförande.

Summary

For nuclear power plants, copper is generally used for the earthing system, due to its high electrical conductivity and generally low corrosion rates in soil. Corrosion issues for copper earthing (grounding) networks are corrosion of the copper material (mesh of stranded wires or rods) in soil including effects of inhomogeneities, corrosion of earth electrodes from lightning strikes, fault and equalizing currents, stray current corrosion of copper wires induced by cathodically protected objects or by other sources, as well as deteriorated electromechanical connections and corrosion of welds.

The literature review primarily covers corrosion of copper even if corrosion in soil also of other materials used for conductors in soil is briefly covered.

According to results from previous investigations and results reported in the literature, uniform copper corrosion in soil and corrosion induced by lightning strikes is estimated to be of minor importance for earthing systems for Swedish nuclear power plants. Soil conditions resulting in aeration cells from poor ground preparation or earth electrodes pressed through the sand fill into e.g. clay soil may however result in local corrosion that may possibly be extensive. For both uniform and localized corrosion, long term data is however lacking (specimens exposed for over 30 years do exist).

Occasional fault currents are not considered a major cause of corrosion. Stray currents due to differences in grounding conditions for different electrical substations may however cause extensive AC current corrosion of the earth electrodes at substations with low grounding resistance, such as at nuclear power plants, such currents being permanent. If parts of the copper mesh are in low resistivity water or soil, also the copper wires would corrode

Stray current from cathodically protected objects may cause very high corrosion rates but is considered unlikely since all equipment should be grounded.

Stray current corrosion from HVDC transmission may occur depending on local conditions Stray current corrosion from HVDC transmission may occur depending on local conditions, primarily during periods with monopolar transmission. Risks for stray current corrosion may be estimated by potential mapping.

Expected life length for earth electrodes in seawater is much shorter than in soil due to both higher corrosion rates and the low resistivity of seawater resulting in a large portion of the current being transmitted to earth at this point.

When considering corrosion of an earthing system, conditions of crimp connections and of welds should be included. Reliability of connections does not only depend on materials and possible coatings but also on design and workmanship.

List of content

1 Introduction and scope

For nuclear power plants, copper is generally used for the earthing system, due to its high electrical conductivity and generally low corrosion rates in soil. Corrosion issues for copper earthing (grounding) networks are corrosion of the copper material (mesh of stranded wires or rods) in soil including effects of inhomogeneities, corrosion of earth electrodes from lightning strikes and fault currents, stray current corrosion of copper wires induced by cathodically protected objects or other sources, deteriorated electromechanical connections, corrosion of welds.

Complementary to an Energiforsk project “Survey of methodologies to verify that the outer earthing line network in the nuclear power plants is intact”, Swerea KIMAB has been assigned to conduct a short literature survey on corrosion issues for the earthing network. The literature survey covers previous Elforsk projects, other projects and consultancy assignments that are relevant, and information in readily available literature on corrosion of earthing conductors and earth electrodes. Since the earthing network and earth electrodes of Swedish nuclear power plants are of copper, the literature survey focus on copper.

2 Earthing system

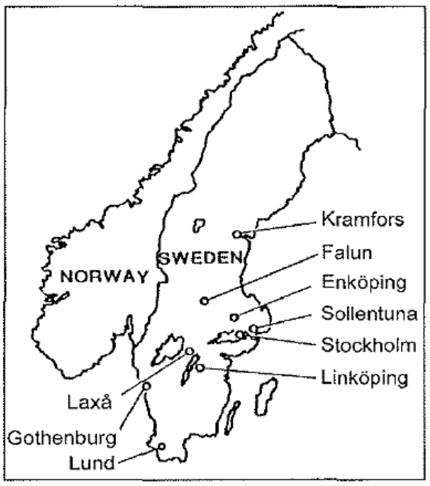
An earthing system (system for potential equalization and for transferring fault currents and current induced by lightning the ground) for power plants normally consist of a copper wire mesh, or a mesh of copper rods (earthing grid), with deep earth electrodes (rods or sheets) in the periphery, acc. to Svenska Kraftnät requirements [1], minimum one per corner, down to a depth of minimum 3 m if possible. There may also be potential grading electrodes which, similar to the mesh, consist of wires. Deep earth electrodes shall be dimensioned so that the maximum current density anticipated is 200 A/mm^2 for 1 s duration (for copper, to avoid melting) [1]. It is assumed that similar conditions are valid for nuclear power plants and that only copper is used for the earthing grid.

3 Corrosion

3.1 CORROSION OF COPPER IN SOIL

3.1.1 Uniform corrosion

Corrosion rates of copper in soil have been measured in previous projects conducted by the Swedish Corrosion Institute [2], [3]. Copper panels (triplicate panels of deoxidized copper, min 99,85%) were exposed at two levels, above and below the water table, including in sand fill, at exposures sites representing soil types common in Sweden, Figure 1.



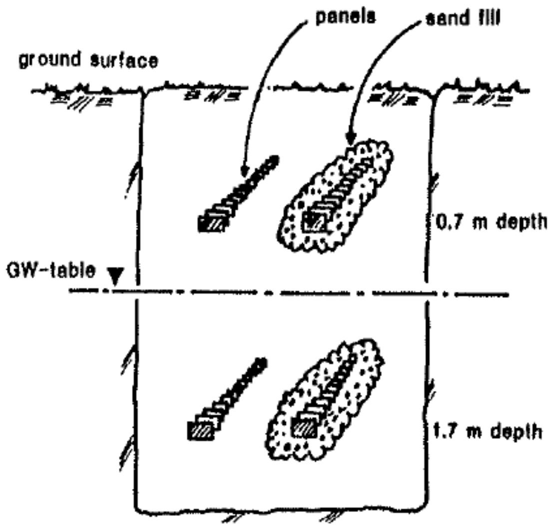


Figure 1 – Exposure sites in soil **- Position of test panels in trenches**

First year corrosion rates vary between < 0,1 and 7,7 µm/year. The corrosion rate decreases with time; corrosion rates between < 0,1and 3,3 µm/year were obtained as average for seven years exposure, Figure 2.

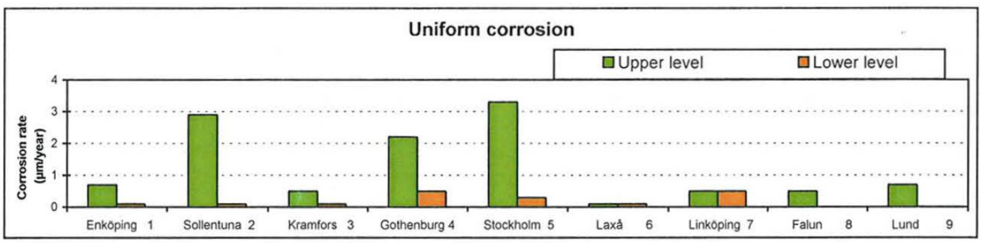


Figure 2 – Uniform corrosion rates at the different exposure sites, presented as average for seven years exposure

Maximum local corrosion rate was measured to between 1 and 30 µm/year as average for seven years. Also local corrosion rates were found to be substantially higher during the first year. Highest corrosion rates were found for aerated soils, especially for clay soils with high organic content, accompanied by increased levels of sulphides, sulphates and/or chlorides and low pH-values. Corrosion rates are generally higher at the higher exposure level, above the water table. Sand fill, common procedure for pipes in soil, did improve the situation in clay type soils, primarily for the upper level (over the water table) concerning uniform corrosion.

In sand soil and sand fill, more relevant to conditions for a nuclear plant earthing grid, uniform corrosion rates were generally low, under 1,5 µm/year as average for seven years but local corrosion rates could still be high. Pit growth rates of over 30 µm per year, as average for seven years, was measured at a site with sandy moraine soil. High local corrosion rates are probably caused by micro-aeration cells due to inhomogeneous sand, sand fills and till soils. For strands in an earthing grid of 50 mm^2 seven stranded wire, each strand is about 3 mm. A corrosion rate of 1,5 µm per year will result in a remaining wire diameter of 2,7 mm after 100 years. Uniform corrosion would thus be no cause of concern. As for local attack, up to 0,2 mm deep pits have been measured for sand filling after seven years, extrapolation to longer durations is however difficult due to lack of data from long term exposures[1].

To conclude, for a copper conductor of size used for earthing grids, uniform corrosion would not be an issue in soil without any influence of current. The life expectancy would be well over 100years.

3.1.2 Differential aeration cells

In case the sand fill used is not uniform, parts of the copper wire mesh may be located in dense soil holding water while other parts are located in more aerated areas in sand. Under such circumstances an aeration cell may form resulting in corrosion of copper in areas with limited air supply (wet or dense soil as mud) while the cathodic reaction occurs in more aerated areas. This effect is considered to be one of the most probable mechanisms controlling localized corrosion of copper wires in soil, i.e. extensive local corrosion after only three years in soil [4], to be compared with the over 100 years life expectancy stated above. Since information in the literature on corrosion and corrosion rates due to aeration cells is scarce and there is no information on local conditions in the case mentioned [4], relevancy of the extensive local attack after the very short time is not known. There could be alternative explanations such as stray current corrosion, see sections 3.4-3.6.

Conditions similar to those described above would occur with a deep earth electrode pressed through the sand fill into denser soil underneath, thus resulting in corrosion of the lower part of the electrode.

[1] There are additional panels still in soil at the exposure sites.

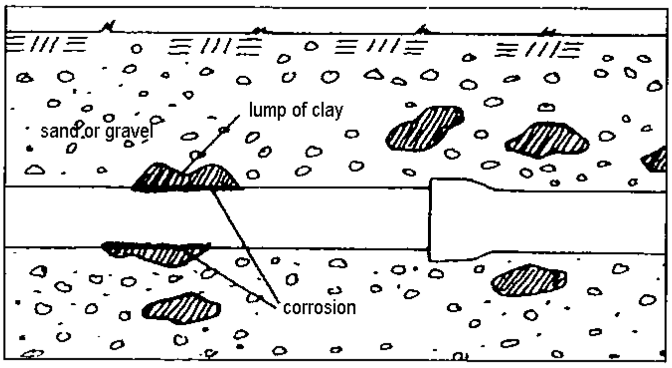


Figure 3 - Differential aeration cell - corrosion under a lump of clay, here illustrated for a pipe, from [5]

3.2 CORROSION OF COPPER IN SEAWATER

In some installations, earth electrodes are installed in seawater. Expected corrosion rate of copper in seawater is 20-50 µm per year [5]; rates as high as 50 µm expected during the initial period only.

Data from the literature are generally for warmer locations. In natural seawater in Port Hueneme, California, Mansfield et.al. [6] have measured a copper corrosion rate of about 35 µm/year for three months exposure. In tropical seawater, Núñez et.al. have measured corrosion rates between 19 and 28 µm (six sites) after one year exposure and about 12 µm after two years exposure (three sites). Corrosion rates measured after six months are two to three times as high as the average for two years exposure. In the Dechema Corrosion Data Sheets (1976), copper corrosion rates of 10-70 µm are given, 10 µm per year as average for 15 years for the Panama Canal.

Copper corrosion rate in seawater are thus substantially more than in the low corrosivity soil expected at electrical substations.

3.3 CORROSION OF CONDUCTORS AND EARTH ELECTRODES, OTHER THAN COPPER, IN SOIL

3.3.1 Copper clad conductors

Corrosion rate of copper clad steel conductors is very difficult to estimate since any pore or damage in the copper clad would result in accelerated corrosion of the steel at the site of the damage. This local corrosion will result in deteriorated tensile strength and may cause broken wires in case the conductor is exposed to tensile stress after installation, e.g. from soil movements in the spring, from flooding or other reasons. For this purpose, a thick copper cladding, minimum 250 µm, is required by Svenska Kraftnät for both conductors and earth electrodes [9], [10]. For earth electrodes, some suppliers use a nickel intermediate coating for additional protection.

For copper clad steel earth electrodes, life estimates should be based on dimensions of both the cladding and the steel core, with a reduction due to expected flaking off of the copper cladding. According to corrosion rates given above for copper in low corrosivity soil (paragraph 3.1.1), the copper cladding would be completely corroded away after 160 years. In practice, expected life time is shorter due to pore corrosion of the steel accompanied by local flaking of copper, or due to overheating caused by the lower conductivity after corroding away a large portion of the copper.

3.3.2 Zinc coated steel conductors

The conductivity of zinc coated earth electrodes is about 8,6% of that of copper electrodes [11].

For steel with a thick zinc coating, 200 μm, life expectancy for the coating is 10-20 years in soil [11]. In sand soil, life expectancy is longer; zinc corrosion rates of 3,5 μm/year would correspond to 50 years corrosion protection, however with local exposure of the steel. To be added is the life expectance of the steel i.e. corrosion allowance considering acceptable increase in resistance. Steel corrosion rates measured in sand soil and sand filling after 7 years are 3-30 μm per year. In sand soil (Linköping above the water table) and sand fill, soil types more relevant here, uniform corrosion rates of 5-20 μm per year of have been measured after 7 years [12]. Local corrosion rates are higher, 25-106 μm per year as average for 7 years exposure [12]. For steel and zinc coated steel, contact with copper will result in substantially higher zinc and steel corrosion rates due to bimetallic corrosion. There should thus be no contact between steel conductors and copper. Zinc plated steel conductors are thus not believed to be used in the earthing network for nuclear power plants.

3.3.3 Aluminium and aluminium coated steel

Aluminium has about half the conductivity of copper. Aluminium has low uniform corrosion rates but is sensitive to pitting corrosion and may thus break if stress is applied. Local corrosion depths of up to 3,6 mm after 7 years exposure have been measured in Swedish soils. Use of aluminium conductors is excluded in many earthing regulations, due to limited corrosion resistance and risks for high resistance in connections. [11]

3.3.4 Stainless steel

Stainless steel has low conductivity, for steel type 304 the conductivity is 2,4% of that of copper. Corrosion rates for stainless steel in soil are generally low. If chlorides are present there is a risk for pitting corrosion resulting in reduced tensile strength for conductors. Risks for pitting corrosion and stress corrosion cracking vary greatly between alloys. In exposures, a martensitic stainless steel with 16% chromium and 2% nickel showed local corrosion rates of 240 μm per year, as average for 25 years, while there was virtually no pitting on an austenitic steel with 17% Cr and 12% Ni and on a duplex steel with 18% Cr, 5%Ni, 2,5% Mo and 1,2% Mn. [11]

3.4 CORROSION OF EARTH ELECTRODES

The function of an earth electrode is to carry current between the earthing grid and soil. To pass current from an earth electrode to soil there must be an electrochemical reaction at the surface of the earth electrode. At the anode the reaction will be metal dissolution, for high voltages in parallel with oxygen evolution. With alternating fault currents; both anode and cathode reactions will occur.

The amount of metal corroded is determined by the distribution between the different reactions, current transferred to the earth and the duration of the periods with current. It is thus dependent on the frequency, duration and strength of the fault currents as well as on the frequency and polarity of the current induced in the system and whether it is DC (lightning strike) or AC (fault currents).

Earth electrodes may be rods or plates, also the buried earthing conductor grid acts as an earth electrode. Earth electrodes are commonly copper, copper clad steel or copper embedded in concrete. Dimensioning earth electrodes is based on the resistance to soil, primarily depending on the resistivity of the surrounding soil and the area of contact. Requirements on earth resistance vary; according to Svenska Kraftnät [10], earth resistance for individual towers for high voltage power transmission should be below 100 Ω.

Corrosion of copper in soil when no current is passing is described in section 3.1. Copper clad steel suffers bimetallic corrosion in damages from driving the rod into soil. Copper rods embedded in concrete may suffer damages from passing high fault currents causing water to boil thus breaking the concrete and/or from the electrochemical reactions resulting in hydrogen evolution (cathode reaction) or oxygen evolution (anode reaction). Copper electrodes embedded in concrete may also suffer stress corrosion cracking from ammonia. Urea as a source of ammonia is reported for urea-based antifreeze used in cement [13].

Metal loss from transferring short fault currents and lightning strikes etc. cannot readily be estimated. Observations of no extensive corrosion, only pitting, of copper plates used as earth electrodes for lightning conductors for 50 years [14] indicate that at least "normal" lightning should not be expected to cause any metal loss of importance. Fault currents expected would be AC-current. Exposure to AC current may cause AC current corrosion but primarily for metals with protective passive films, as stainless steel and aluminium. For intermittent fault currents, AC current corrosion is normally not expected to pose a problem.

Even if AC current corrosion for copper is lower than for some other metals, it is not zero. For copper, the AC corrosion is less than 1 % of what is obtained with an equal DC current. According to Faradays law this equals 0,1 kg/ampere-year. AC currents are always running in the top wire of power lines. These currents can be the result of equalizing currents between substations, or more frequently due to induction from the phases. These AC currents are grounded at power pylons or at substations. Due to different earthing conditions, locally high currents can occur, in the magnitude of several amperes. The earthing grid under substations is normally installed in gravel. This will result in the stray current being transmitted to earth via the earth electrodes. Since this current is permanent, a metal loss of 1 kg/year will occur if the current is 10 A, resulting in premature failure of the earth electrodes.

Expected life length for earth electrodes in seawater is much shorter than in soil due to the low resistivity of resulting in a large portion of the current being transmitted to earth at this point.

3.5 SECONDARY EFFECTS FROM CATHODICALLY PROTECTED OBJECTS

If there are cathodically protected objects in the vicinity, the earthing network may suffer stray current corrosion. If the potential field of the anode for the cathodic protection extends to the earthing network, the current will enter the copper mesh close to the anode and leave the mesh close to the protected object, see Figure 4. The copper grid will suffer corrosion where the current leaves the grid. According to the standard EN 50162, risks for stray corrosion are small for positive potential shifts (potential difference with and without cathodic protection) of maximum 1,5*[soil resistivity in Ωm] mV, 0,3 V for steel in soil with a resistivity over 200 Ωm. It should be possible to use the same potential shift limits for copper. In inhomogeneous soil, stray current would give preferential attack in wet areas, as in lumps of clay, compare section 3.1. Corrosion rates for stray current corrosion may be very high, governed by the current density. An example from a different area is destroyed lead sheathed telephone cables in only a few years due to secondary effects from a cathodically protected water pipe (with imperfect coating) crossing the cable about 0,5 m over the pipe.

Since virtually all equipment at a nuclear power plant should be grounded, secondary effects from cathodically protected objects are considered unlikely.

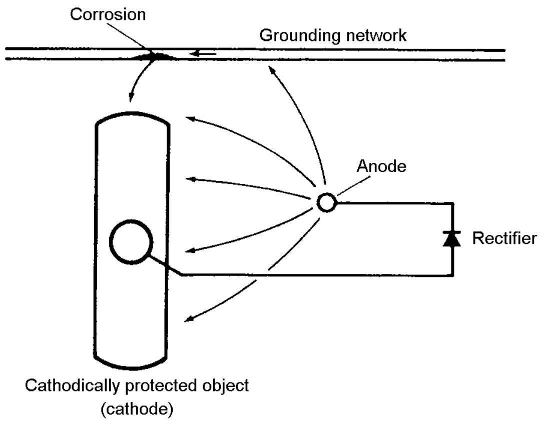


Figure 4 - Secondary effect from cathodic protection (image based on figure in [5])

3.6 CORROSION DUE TO STRAY CURRENT FROM HIGH VOLTAGE DC TRANSMISSION

A principal illustration of effects of stray current form an HVDC electrode is shown in Figure 5. As seen in the figure, risks for stray current corrosion are greatly affected by the extension of the object, long objects obtaining larger potential differences along the length; largest differences arise if the object is extended perpendicular to the potential field.

In a project investigating risks for stray current corrosion at Forsmark, the potential gradient field from the HVDC electrode at Fågelsundet has been estimated based on measurements [15]. Assuming the resistivity of the sand fill being over 200 Ωm and using the EN 50162 [16] limit for steel of 0,3 V potential shift, stray current corrosion of an earthing grid would be expected if the extension of the grid (largest distance) exceeds 600 m. Measurements performed at Forsmark at an earlier occasion however show that a local gradient field of about 1,5 V/km exists around the earthing grid of the site [17], acting as a secondary electrode relative to remote earth [15]. With a potential gradient field of 1,5 V/km, a potential difference of 0,3 V is obtained for constructions extending 200 m. During the measurements referred [17], the HVDC transmission was run as a monopole. With bipolar transmission, in reality two combined monopoles with the unbalance current transmitted by the HVDC electrodes, the potential gradient field would be lower since it is determined by the unbalance current.

To reveal risks for stray current corrosion, similar measurements could be done for power plants in the vicinity of HVDC transmission electrodes.

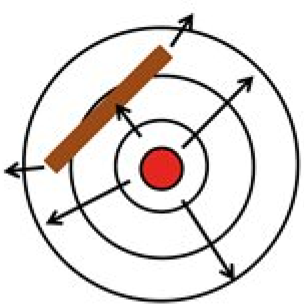


Figure 5 – Stray current corrosion caused by an electrical field in the ground. Circles indicate the potential field, arrows show current from the source (HVDC electrode, red) entering and leaving an elongated structure (corrosion on exit of the current) [15].

3.7 DETERIORATION OF JOINTS

When considering corrosion of an earthing grid, conditions of crimp connections or of other types of electromechanical contacts, and of welds, should be included. Reliability of connections does not only depend on materials and possible coatings but also on design and workmanship.

3.7.1 Deterioration of electromechanical permanent contacts

Electromechanical permanent contacts, such as crimp connections, deteriorate primarily by stress relaxation and creep. Following changes in stress and/or dimensions, corrosion plays a role in isolating the contact parts from each other and/or by pressing the two surfaces apart. In electrical contacts, a permanent force pressing the two surfaces together and penetrating the surface films, e.g. corrosion protective passive films, is required. It is thus not sufficient to use materials with high corrosion resistance.

The crimp connection type specified by Svenska Kraftnät is Elpress C-sleeve [9] which is a C-shaped crimp “sleeve” with a ridge providing the required deformation of the conductor, see Figure 6. Besides design, the material in the sleeve has major effects on the performance and life of a crimp connection. The modulus of elasticity of the sleeve should be high and the strands of the conductors should have a large elongation before break. Such requirements cannot be stated separately, but a design/material/tool with proven good performance should be used. Performance may be evaluated by testing, however not by the normally performed tensile testing (high tensile strength does not necessarily imply good contact performance). Proper electrical tests in combination with ageing tests must be conducted, with requirements adapted to the application (current carrying capability in aged condition).

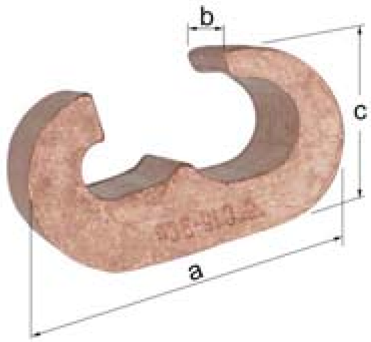


Figure 6 - Elpress C-sleeve (www.elpress.se)

3.7.2 Deterioration of welds

Performance of welds is governed by the base material, the added weld material, and the welding process. Porous welds will weaken the product and the pores may open for corrosion. A weld may show different corrosion resistance at different distances from the weld, as for welds in stainless steel where weld oxides have a major influence but also the heat affected zone.

Welds in copper, the material concerned here, may be porous, affecting mechanical properties both initially and with time, after additional dimensional changes from corrosion.

4 Conclusions

Based on previous investigations and information in the literature, uniform copper corrosion in soil and corrosion induced by lightning strikes or fault currents is estimated to be of minor importance for earthing systems for Swedish nuclear power plants. Long term data is however lacking (material that has been exposed more than 30 years does exist).

Soil conditions resulting in differential aeration cells from poor ground preparation or earth electrodes pressed through the sand fill into e.g. clay soil may result in local corrosion of importance.

Occasional fault currents are not considered a major cause of corrosion. Stray currents due to differences in grounding conditions for different electrical substations may however cause extensive AC current corrosion of the earth electrodes at substations with low grounding resistance, such as at nuclear power plants, such currents being permanent. If parts of the copper mesh are in low resistivity water or soil, also the copper wires would corrode.

Corrosion due to stray current from cathodically protected objects is considered unlikely since all equipment should be grounded.

Stray current corrosion from HVDC transmission may occur depending on local conditions, primarily during periods with monopolar transmission. In inhomogeneous soil, stray current may result in local attack. Risks for stray current corrosion may be estimated by potential mapping.

Expected life length for earth electrodes in seawater is much shorter than in soil due to both higher corrosion rate and the low resistivity of seawater resulting in a large portion of the current being transmitted to earth at this point.

Reliability of crimp and weld connections depend on materials, design and workmanship and cannot be generalized.

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CORROSION IN EARTHING NETWORKS IN NUCLEAR POWER PLANTS

For nuclear power plants, Cupper is generally used for the earthing system, due to its high electrical conductivity and generally low corrosion rates in soil.

This literature survey provides a short overview over corrosion issues for copper earthing, grounding, networks. Areas covered are corrosion of the copper material, mesh of stranded wires or rods, in soil including effects of soil inhomogeneities, corrosion of earth electrodes from lightning strikes and fault currents, stray current corrosion of copper wires induced by cathodically protected objects or other sources as well as deteriorated electromechanical connections and welds.

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