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Stray Currents and Pollution of the Environment

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Abstract

Stray currents, similar to noise level or electromagnetic wave emission, belong to physical factors affecting the state of the natural environment. Hazards to the natural environment have been shown, which can be caused by corrosion breakdowns of industrial structures caused by stray currents. Issues connected with stray currents have been discussed. Their sources and the corrosion hazard caused by these currents have been characterized. Anticorrosion protection methods of metal structures subject to the harmful interaction of stray currents are presented.

Keywords: corrosion, stray currents, cathodic protection, ecology

Introduction

The increasing population of our planet, the progress of civilization, development of industry and urbanization cause changes in the natural environment. The media frequently informs us of ecological disasters and the degradation of some regions. Pollution of the natural environment is a challenge for humanity at the turn of the century. It is generally known how serious effects are caused by pollution, how conditions of existence in our ecosystem are deteriorated, how pollution affects the health of people and animals, the climate, nature, soil, water, harvests etc. United Europe is facing not only the necessity of counteracting the effects of pollution, but also the necessity for unified evaluation of pollution of the environment, determination of the responsibility for the caused contamination, and correlation of economic development of regions with admissible pollution restrictions. The resulting investment decisions have to be based on scientific evidence, including that connected with corrosion. This circumstance is continuously underestimated and ignored in light of the need for decreasing financial losses, as well as of pollution of the natural environment. Decisions concerning the natural environment should be based on knowledge of corrosion problems.

Pollution of the natural environment usually is discussed in the following fields [1, 2]:

• pollution of the atmosphere,

- of natural origin: formed as the result of volcanic eruptions, forest fires, sandstorms, hurricanes, decomposition processes of organic matter (e.g., in swamps),
- of antropogenic origin connected with the activity of man: dust and gases (their main sources are electric power stations, thermal-electric power stations, coking plants, gas-works, metallurgical, chemical, electric and machine construction, building element industries, mechanical vehicles, boiler houses and house furnaces).

The main gas pollution elements of air are: sulphur compounds (SO_2, SO_3, H_2S), nitrogen compounds (NO, NO_2, N_2O, NH_3), carbon oxides (CO, CO_2), and hydrocarbons (C_xH_y).

Dust is formed by particles from 0.001 to 100 micrometers. It can be toxic (for example, dust containing heavy metals such as Hg, Cd, As, Zn, Pb, radioactive dust, asbestos dust), it can cause pneumoconiosis or allergy (dust containing silica SiO_2, wood and cotton dust, aluminosilicates), as well as an irritant (ferrous, limestone, gypsum, carbon dust).

- pollution of the environment by gathered waste material (industrial post-production, household-municipal waste),
- pollution of the environment by untreated sewage (hou sehold, industrial, rainfall),
- purity of waters (natural, artificial, biological, chemical contamination),
- the state of forests (they regulate ecological conditions of the environment).

Apart from hazards of chemical or biological nature, physical factors affecting the state of the natural environment also exist. The noise level or emission of electromagnetic waves are such physical factors with introduced legal regulations. Stray currents also can be treated as a physical factor affecting the state of the natural environment. This type of hazard is less known, nevertheless of equal importance as factors mentioned earlier. The aim of this work is to present the main sources of stray currents and their properties, as well as methods of limiting their harmful action. Propagation of problems related to stray currents can lead to a future situation in which limitation of their harmful activity will be affected by not only corrosion specialists, but also by specialists in other fields such as designers of industrial infrastructure, designers of power lines or electrified railway routes. Positive effects of such a situation could be felt by all of us.

Sources of Stray Currents

Apart from rare cases, when stray currents are formed in the earth's external crust as a result of natural phenomena connected with solar activity (the so called telluric currents or geocurrents), they are the effect of human activity. Stray currents are defined as currents flowing into electrolytic environments (soil, water) from electric circuits inadequately insulated from the environment. From the corrosion point of view DC current industrial devices remain the most hazardous sources of stray currents for metal structures. AC stray currents pose a much smaller hazard. According to Baeckmann [3] the corrosion loss caused by a 0.5 Hz frequency current is 30 times smaller, while that caused by a 50 Hz current is 100 times smaller in comparison with losses caused by a DC current of the same intensity. Thus, in world literature and industrial practice stray currents are treated as DC stray currents. This also is in accordance with definitions of the Polish standard [4].

The main sources of stray currents are as follows:

- DC electric tractions (tram, railway, metro),
- DC industrial devices,
- High voltage DC (HVDC) power lines,
- cathodic protection systems.

Electric Tractions

These are the largest and best recognized sources of stray currents [5, 6]. Statistical studies show that currents from these sources are the cause of 90% of cases of electrolytic corrosion of underground infrastructure in towns [7].

Leakage of stray currents takes place from rails, which are an element of the return circuit of traction currents [8]. There are two types of electric traction, so-called "heavy" (applied mainly in underground railways) and "light" [9] tractions. In the first system the DC current is delivered from the so-called contact system to the motor in each train by a third rail (placed next to two traffic rails), whilst the second system utilizes an overhead traction conductor over the vehicle. The current is led away to the power substation through the return network - traffic rails and return conductors. A part of the return current leaks out of rails and returns to the source through the ground and underground metal structures neighbouring with the traction. The magnitude of the leakage depends on the voltage drop in the rail (as a function of the current flowing in the rails and the resistance of the rails) and the resistance of rails in relation to the ground [10]. It is estimated [7] that for rail circuits in working order approximately 95% of return currents return to the power substation through the rails, while the remaining part flows to the ground. Each electric discontinuity of rail circuits increases the leakage of stray currents (even up to 50% of return currents) and their instantaneous intensity in the ground can reach hundreds of amperes. Traction stray currents are dynamic in character: their intensity and flow direction continuously change, depending on the traction load and location of electric locomotives in relation to the power substation. Dynamic potential changes of underground structures and their random periods of anodic (corrosion) and cathodic polarization (lack of corrosion) are a consequence of this.

Industrial Devices

The following are sources of stray currents belonging to this group: welding machines, electrolytic plants, galvanizing plants, accumulator plants. Stray currents are generated by these devices when they are not properly grounded. If grounding is carried out through other metal structures, then a significant hazard caused by electrolytic corrosion is introduced to these objects. Stray currents formed during welding on vessels pose a great problem in shipyards - cases have occurred, when these currents reached values of several hundred amperes [11].

HVDC Transmission Lines

High voltage direct current transmission HVDC lines are used to transmit energy over long distances [12]. These systems can be either monopolar or bipolar [13]. The monopolar system transmits energy in a single cable and uses the ground as a return conductor. Such lines transmit a direct current of the order of several kiloamperes. Bipolar systems transmit energy using two or more conductors, while only compensation currents flow in the ground [14]. They can be of the order of several to several hundred amperes. Currents from HVDC lines flowing in the ground can cause electrolytic corrosion of metal structures, especially long structures (pipelines, telecommunication cables, earthing systems). The places of corrosion are on the ends of structures located nearer to the cathode, to which currents flow through the ground.

Cathodic Protection Systems

If another metal structure is in an electric field connected with the flow of a protective current from anodes to the protected structure, then it can be exposed to electrolytic corrosion (interference of cathodic protection). Cathodic protection systems generate a DC current of several hundred milliamperes to over ten amperes. Their functioning is practically continuous and working parameters remain virtually constant. For these reasons stray currents generated by these sources are most frequently static in character — the intensity and flow direction do not change in time. To detect them, measurements are carried out during cyclic interruption of the functioning of the protection system.

Hazards Caused by Stray Currents

Corrosion processes occur on external surfaces of metal underground structures, which due to the character of the environment, are qualified as so-called earth corrosion [16, 17]. Steel structures are prone to many hazards resulting from the action of the environment and external factors. The following factors affect the kinetics of corrosion processes [18]:

- different chemical and structural composition of soil,
- differentiated oxygenation of different fragments of the structure,
- application of various galvanically connected metals,
- installing new pipeline sections in old installations,
- presence of bacteria, mould, fungus,
- constant and variable stress formed during (amongst other times) pumping of media,
- material faults of pipelines and insulation,
- design, construction and repair errors,
- presence of current interference (stray currents).

Stray currents flow in the field in the direction to the negative pole of their source. On their way they can flow through metal structures, such as underground pipelines and cables. Places in which currents flow out from the structure to the electrolyte are attacked by corrosion, defined as electrolytic corrosion [19]. Stray currents pose a great corrosion hazard to underground infrastructure. In municipal agglomerations they are the most frequent cause of failures of such constructions as gas, heat, oil, and water pipelines; telecommunication cables, underground tanks, etc. Depending on the magnitude and time of flow of stray currents, corrosion of structures may cause substantial measurable and immeasurable consequences; for example: interruptions in the delivery of water or energy, lack of telecommunications, gas explosions, fires, hazards to human life, or pollution of the environment. For the above mentioned reasons it is extremely important to identify phenomena connected with stray currents: how they are generated, how they can be detected, what corrosion effects they cause to metal structures, how they can be reduced, and how their harmful interaction can be eliminated.

The intensity of stray currents in towns with tram tractions reaches hundreds of amperes, leading to catastrophic corrosion of underground infrastructures. In a dense network of structures the current flows between the structures causing electrolytic corrosion of each of them. If the place of outflow of stray currents from the structure to the ground is of a small area (thus leading to a current of high density), then in a very short time perforation of the walls occurs causing a corrosion breakdown. Many examples of such destruction can be found in world literature and on the Internet [20].

Protection from Stray Currents

Control of the hazard of stray currents can be obtained mainly by:

- preventative actions in current sources (limitation of leakage to the ground) [8],
- application of electrochemical protection of endangered structures [15, 21],
- sectioning of long structures (insulation of short sections from each other) [22, 23],
- coatings.

Control of Stray Current Sources

The following actions are performed as part of prophylactic activities limiting outflow of currents from return circuits of **electric traction** [8, 24]:

- welding of rails (decreases the resistance to the flow of return currents).
- application of insulation separators between rails and sleepers (increases the resistance of rails in relation to the ground).
- maintaining of a minimum 3 cm distance between the flanges of rails and the ballast of the track (increases the resistance of rails in relation to the ground).
- installation of rail bonds (decreases the resistance of the rail network and maintains an equal potential between rails).

Stray currents from **industrial devices** can be completely eliminated by their correct use (with no grounding through other metal structures).

Minimizing the hazardous interaction of stray currents connected with the functioning of a monopolar HVDC power line is based on application of earth (marine) electrodes of possibly low resistance [11]. For the above reason they have large dimensions and they are located in an environment of low resistance. Bipolar systems should be used in such a way so that leakage of equalizing currents to the ground does not occur.

In cathodic protection systems the effect of interaction of stray currents on neighbouring structures can be decreased by [15]:

- locating of anodes in soil of small resistivity, in which a minimal gradient of electric field is formed or the interference in relation to other structures is limited.
- instead of impressed current protection - application of sacrificial anode protection, if the required protection effect can be achieved by this method,
- in endangered places - connection of the endangered structure with the protected structure through a resistor.

Electrochemical Protection

Electrochemical protection from electrolytic corrosion caused by stray currents is called "active protection", contrary to the methods described above called "passive protection". Near electric tractions it is realized first of all in the form of electric drainage (polarized and amplified) [7]. Their action is based on the controlled draining of stray currents from the underground structure with an electric conductor to the source of their formation. By this method a harmful phenomenon is eliminated of outflow of currents through the .external surface of the structure to the ground.

Polarization of the protected structure with a cathodic protection installation is another form of protection. Due to variations of potential caused by changes of the intensity of stray currents, systems are most frequently used with an automatic regulation of cathodic protection station parameters. If the demand for protective current is not high then for protection polarized sacrificial anodes are used, i.e. connected with the structure through diodes and transistors.

Preventative Activities

The electrolytic corrosion hazard can be limited already in the design phase. For example, for pipelines a route is chosen far from sources of stray currents. In the case of traditional hot water pipelines their correct execution is very important (tightness of channels, efficient draining) and exploitation (drowning of channels is impermissible, drying is essential).

Summary

Corrosion also should be treated as a source and factor causing pollution of the natural environment. Stray currents pose a great hazard to underground metal structures transporting or storing aggressive media. Their presence cannot be eliminated as they are inseparably connected with the exploitation of industrial devices in an industrial society; nevertheless, the level of stray currents can be limited.

It is possible to limit the harmful corrosive effects of stray currents on metal structures, with the use of passive and active protection. Knowledge of these problems by specialists in different fields can lead to the limiting of huge financial losses, but also a decrease in pollution of the natural environment. It should be noticed that stray currents affect the state of the natural environment in two ways. On one hand they have a direct effect connected with the leakage of current from the installation and the resulting increase of corrosion aggressiveness. On the other hand stray currents have an indirect effect on the natural environment. Stray currents as the cause of corrosion failures and damage (for example of oil pipelines, fuel tanks or other such installations) can cause ecological disasters.

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