THE INTERFERENCES PRODUCED BY ANTHROPIC ELECTROMAGNETIC FIELDS ON THE NATURAL ELECTROCHEMICAL SYSTEMS

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Abstract **The theoretical and practical aspects concern influence of electromagnetic field on the electrolytic systems has been studied. A few theoretical and practical aspects concern A.C. interferences by polarization of electrolytic systems are presented. Also, it were analyzed the main aspects regarding the impact of electromagnetic pollution of environment on the corrosion reactions in complex build-up media.**

Key words: electrolytic systems, A.C. polarization, D.C. stray currents, A.C. stray currents, electromagnetic induction, electromagnetic pollution.

1. INTRODUCTION

The majority of processes from nature (in biosphere) take place in wet environments, and in majority of situations, are developing by an electrochemical mechanism (for example, the redox processes from the cytoplasm interface/cellular membrane, metals corrosion in various electrolytic media etc.).

Kinetics and electrochemical processes mechanism are determined by the electric signals superposed on the reaction media, respectively electrode system (metal or membrane)/electrolyte. In this way, we can consider that any electric signal, which is superposed, on the electrolytic environments can perturb the developing of the natural electrolytic processes and consequently, is a pollutant signal [1].

The electromagnetic pollution consequences of the environment are particularly various. Pollutant electromagnetic fields disturb natural processes, both by heat effect generated in various environments, and by its electric and magnetic components. The electric component disturbs, firstly, the developing of the natural electrochemical reactions – disturbs the transit of Ca^{++} ions by human cellular membranes, and implicit, the calcium homeostasis (the probable cause of the high frequency of leukemia at the children systematic exposed to the electromagnetic radiations [2]), accelerates the corrosion reactions [3], etc. The magnetic component disturbs the biomagnetic systems, like the orientation system of the bees, which was discovered that at signals of 600 MHz ÷ 3.2 GHz, by 0.5 ÷ 1 V/m order become very aggressive and are killing each other [4], and in electromagnetic field of 600 MHz ÷ 3.2 GHz, by 0.5 ÷ 1 V/m order, get lost and they can not return to the beehouse. The cancer generating effect of mobile phone systems was demonstrated by more research reports [5÷7]. Recent medical studies have shown that long-term exposure to electromagnetic fields disrupts the immune system - explained by the redistribution of T cell type [8].

The study of signals influence in alternative current (A.C.) superposed on the electrochemical systems represents a complex theoretical problem, with especially practical importance. The theoretical complexity of the problem results from diversity of the kinetic ways for the electrode processes, but also from complexity of the electromagnetic field influence – especially of the electric component – upon the ionic atmosphere [9].

In the actual conditions of technological and industrial development, characterized by increasing of the production, and of the electric energy consumption, and implicit the enhancement of the electromagnetic pollution of natural and industrial environment with signals in A.C., very complex [1], it imposed the profoundly study of the signals influence in A.C. superposed on the electrochemical processes and reactions which take place in nature (photosynthesis, redox processes from the cytoplasm interface/cellular membrane, metals corrosion etc.) [10, 11].

The acceleration effect of corrosion of the A.C. stray currents in was been demonstrated both theoretically, and experimentally [12, 13].

Assessment of the A.C. signals in the electrode processes in industrial conditions – electrolysis in sinuous current – can presents an especially interest to performances increasing of some galvanic deposition, the galvanic obtaining of some alloys, reduction of the overvoltages, and implicit, of the voltage drops on electrolyze – so energetically optimization of the industrial electrochemical processes [14].

The purpose of this paper consists both in influence study upon the developing of electrochemical reactions of the disturbing signals in A.C. superposed on the reaction environment, and in study of nature and origin of these disturbing signals.

2. INFLUENCE OF A.C. POLARIZATION OF THE ELECTROCHEMICAL SYSTEMS

2.1. Ionic atmosphere and this deformation in electric field

Electrolytes are electroconducting environments of second species and carry on the electric current by the ions with negative charge (anions – migrate to anode) and with positive charge (cations – migrate to cathode) that are forming after dissolution in water of the substances with ionic bonds - dissociation. The solvent (water) having polar molecule (the center of positive charges is not the same with the center of negative charges), in electrolytic environments, the ions are surrounded by the oriented water molecules – ionic atmosphere (figure 1).
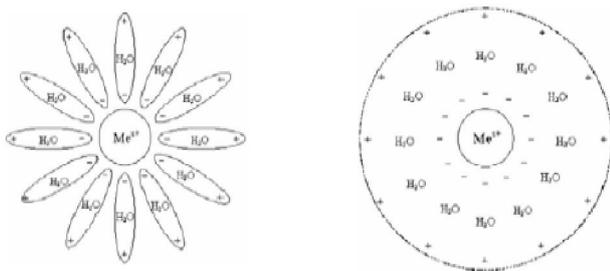
Fig. 1. Ionic atmosphere of a metallic ion with z$^+$ valence

The ionic atmosphere – the sphere of ions hydration – remains unchanged only when the electrolyte is in balance hence upon him not operate external forces, for example, an electric field which induces the ion motion by solvent [9].

In the case of overlapping of a continuous electric field with electrolytic system, the ion moves and, due to the friction force, the sphere of ion hydration cripples, modifying, firstly, the distribution of electric charges, and implicit, localization of the ion in hydration sphere (figure 2).
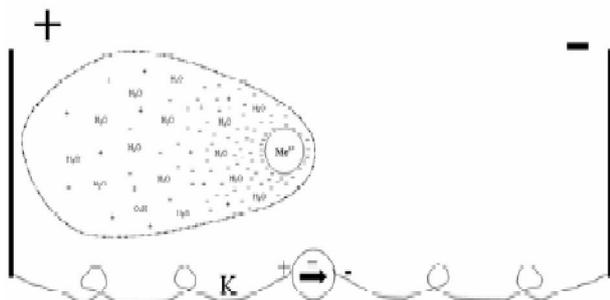
Fig. 2. Deformation of the ionic atmosphere on action of a continuous electric field (the K switcher is closed)

Obviously, to discontinuance of the electric filed action (opening of K from figure 2), the ion inclines to remake its ionic atmosphere, reverting to initial spherical shape (figure 1).

In the case of overlapping of an alternative electric field with electrolytic system, deformations of the ionic atmosphere follow the periodicity of the disturbing signal

(figure 3).
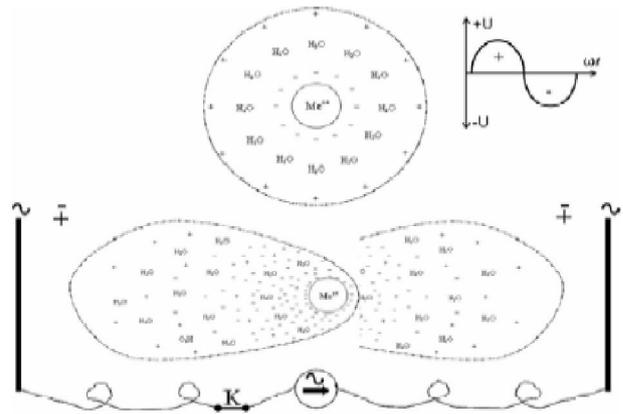
Fig. 3. Evolution of ionic atmosphere deformations upon the action of an alternative electric filed

Deformation and rehabilitation of ionic atmosphere is developing with different speeds (determined, firstly, by ion nature and size of hydration sphere), hence the rehabilitation is achieved staggered in time, named relaxation time. The relaxation time - t - of a hydrated ion [14] is inverse proportional with concentration and equivalent conductivity of the electrolyte, respectively with ion valence, namely (1):

$$t = k_r / c \cdot z \cdot \Lambda \qquad (1)$$

where: k_r - proportionality constant; c - molar concentration of the ion; z - ion valence; Λ - equivalent conductivity of the electrolyte.

2.2. Polarization overvoltage in A.C. The polarization impedance

Electrodes polarization takes place not only to the passing of the continuous current, but also by electrode/electrolyte resistances of an alternative current. In case of a linear sinusoidal alternative current signal, polarization overvoltage - η - fluctuates in time [15] by relation (2):

$$\eta = Zp \cdot Iv \cdot \sin(\omega \cdot t - \delta) \qquad (2)$$

where: Zp - polarization impedance, parameter determined by the capacity of the double electric layer and by the series resistances (ohmic polarization) and parallel resistances (Faraday polarization) from equivalent circuit of electrode/electrolyte system; Iv - peak intensity (density) of the A.C. overposed current; δ - difference of phase determined by the capacitive component of the electrolytic system.

Detailed studies regarding the equivalent circuit of the polarization impedance (figure 4) were published by E.A. Ukse [16].

In the case of overlapping with the electrolytic system of an electromagnetic field, due to the A.C. electric component, this will disturb the ionic atmosphere only if the vibration period is bigger than the relaxation time, the perturbation measure being determined by the superposed signal frequency.
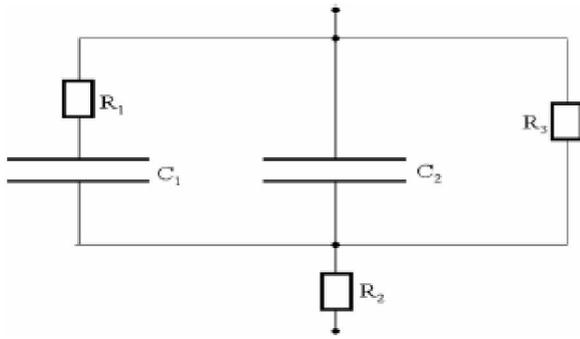
Fig. 4. Equivalent circuit of the polarization impedance: R_1 and C_1 - capacity and resistance that characterizes a partial stage (for example, ion dehydrating); C_2 - capacity of the double electric layer of the electrode; R_2 - electrolyte resistance; R_3 - resistance of the charge transfer

At small vibration periods (high frequencies of the superposed electric signal), deformation of the ionic atmosphere no more occurred, in consequence appears a increasing of the equivalent conductivity (Debye – Falkenhagen effect [9]). In these conditions, it can determine that the minimum limit frequency – f – at which takes place the disappearing of the ionic atmosphere deformation, is (3):

$$f = 1/t = c \cdot z \cdot \Lambda / k_r \qquad (3)$$

In conclusion, it can affirm that:
- deformation of the ionic atmosphere carry on to the decreasing of the equivalent conductivity of the solutions;
- deformation is so much bigger, so the electric signal frequency is lower and relaxation time is bigger;
- at frequencies sufficiently high, when a period duration of A.C. signal is smaller than the relaxation time of the ionic atmosphere or equally, the equivalent conductivity of the electrolyte trends towards a maximum value.

2.3. The diffusion overvoltage due to A.C. polarization of the metal/electrolyte system

Under the influence of the alternative electric field, near to the electrode, the concentration of the ionic species, which maintain the electrode reactions, is changed periodically. Due to the periodic variations of the concentration produced by the variable electric field, the concentration gradient, which it establishes, is smaller than that due to a polarization in D.C. In the presence of overposed A.C. signals on the electrolytic systems, it produces a modification of the ionic species concentration, which assist in electrode process, fact that can modifies the kinetics of the respective electro-chemical reactions. In these conditions, it can affirm that, in case of the natural electrochemical processes, the electromagnetic fields overposed on the natural electrolytic systems, can disturb the developing of the electrochemical (redox) reactions, and therefore are pollutant.

For analyses of an A.C. signal influence superposed on the electrode/electrolyte system upon the diffusion overvoltage, are proposed two limit cases [17], respectively:

Limit case I – the current in A.C. that passes by system it is consumed integral in the electrode process. It is the case of the supervoltages lower than $R \cdot T / z \cdot F$, when the current that passes by system produces almost integral the Faraday processes (and produces the modification of the concentrations at the electrode surface), all partial processes and charge transfer are rapidly – the only slow stage (determined by the speed) being the diffusion. In this case, the diffusion flow of the charge carriers to the electrode surface is equally with the current, which passes by system. In the case of a sinusoidal (linear) A.C. current, the current density $i_\sim$ will be (4):

$$i_\sim = i_{v\sim} \cdot \sin \omega \cdot t \qquad (4)$$

where i_v is the peak value of the current density. In conditions of a linear diffusion, we have (5):

$$i_{v\sim} \cdot \sin \omega \cdot t = z \cdot F \cdot D \left(\frac{\partial c}{\partial x} \right)_{x=0} \qquad (5)$$

where: z - valence; F - Faraday number; D - diffusion coefficient; c - concentration; x - distance.

In these conditions, the concentration gradient near to the electrode becomes (6):

$$\left(\frac{\partial c}{\partial x} \right)_{x=0} = \frac{i_{v\sim}}{z \cdot F \cdot D} \cdot \sin \omega \cdot t \qquad (6)$$

In the established limit conditions, solving the differential equation afferent to the second law of Fick for a linear diffusion, it computes the evolution of the diffusion overvoltage in time - $\eta_{d(t)}$ (7):

$$\eta_{d(t)} = \frac{R \cdot T}{z^2 \cdot F^2 \cdot c_0 \sqrt{D \cdot \omega}} \sin \left(\omega \cdot t - \frac{\pi}{4} \right) \qquad (7)$$

where: c_0 - concentration of the ionic species which participates in process at the electrode surface.

From the analyses of the (7), results that, in the presence of a superposed A.C. signal, the diffusion overvoltage is determined both of the maximum density value of the alternative current which passes by system, and of this frequency. The diffusion overvoltage is dephased with – $\pi/4$ towards the superposed A.C. – capacitive difference of phase for diffusion – difference of phase, which is due firstly to the modifications in the charges distribution of the species which participate in process and not due to the capacity of the double electric layer. In these conditions, the peak value of the diffusion overvoltage - $\eta_{d\sim}$ - corresponding to the peak current - $i_{v\sim}$ - is (8):

$$\eta_{d\sim} = i_{v\sim} \cdot \frac{R \cdot T}{z^2 \cdot F^2 \cdot c_0 \sqrt{D \cdot \omega}} \qquad (8)$$

From the analyses of (8), it determine that, at a known density of the peak current for superposed A.C., the diffusion overvoltage due to this decreases to increasing of the superposed signal frequency.

By comparison of the overvoltage value produced by the passing by electrochemical system of an alternative

current ($\eta_{d\sim}$) with the adequate value of the overvoltage - $\eta_{d=}$ - produced by the passing of a D.C. of the same density ($i_{v\sim} = i_=$), it obtain (9):

$$\frac{\eta_{d\sim}}{\eta_{d=}} = \frac{i_{dl}}{z \cdot F \cdot c_0 \sqrt{D \cdot \omega}} = \frac{\sqrt{D}}{\delta_c \sqrt{\omega}} \qquad (9)$$

where: i_{dl} - limit of diffusion current; δ_c - limit of diffusion layer.

It determined that the diffusion overvoltage produced of an A.C. is much smaller than that produced by a continuous current of same density, thing that is explained by the fact that, due to the cyclic variations (produced by the A.C. passing) of the ionic species concentration which participates in the electrode process, these diffusion is limited al small distances towards the electrode surface.

Limit case II – the A.C. current which passes by system it consumes integral at the charging of double electric layer, when it considers an electrode perfect polarizable at which the current that passes by system change only the charging of the double electric layer, and not participates in the Faraday processes. In these conditions, the charge transfer is strongly slow down (slow stage, determined by the speed), and electrode/electrolyte system can be assimilated with an capacitor – C – at whom terminals the passing of an alternative current – $i_{\sim cap}$ – produces a voltage drop - $\Delta\eta_{\sim cap}$ – in accordance with relation (10):

$$\Delta\eta_{\sim cap} = -\frac{i_{\sim cap}}{\omega C} \cdot \cos\omega \cdot t \qquad (10)$$

The limit cases I and II represent extreme cases, which are not found in practice. In the real cases, the current that passes by system produced both Faraday processes (charge transfer between electrode and electrolyte), and modification of the double electric layer charging. In these conditions, the total alternative current - i_t - that passes by system is the sum of the partial currents which produce the charging of the double electric layer - $i_{\sim cap}$ - and - i_{cc} - current which participates in the Faraday process, therefore produces the modification of the ionic species concentration which participates in process, respectively (11):

$$i_{t^\sim} = i_{\sim cap} + i_{\sim cc} \qquad (11)$$

By comparison of the (8) and (10), it obtains (12):

$$\frac{i_{\sim cap}}{i_{\sim cc}} = \frac{R \cdot T \cdot C\sqrt{\omega}}{z^2 \cdot F^2 \cdot c_0 \cdot \sqrt{D}} \qquad (12)$$

From (11) and (12) relations, results that in the diluted electrolytes (c_0 has small values), the weigh of the capacitive current is relatively high and increases with the increasing of the frequency of overposed A.C. signal, and inverse, the weigh of the Faraday current increases to the increasing of the ionic species concentration which

participates in process and to decreasing of the frequency of the applied A.C.

3. ORIGIN AND INTENSITY OF STRAY CURRENTS

The source for all disturbing electrical signals of the natural electrochemical process is the chain / transport / distribution and utilization of the electrical energy system. The electrolytic environments (soil, ground water, wet concrete, etc.) are electrical conducting media of second type, having a rather low electrical conductivity that present an electric resistivity in range $0.1\Omega m \div 100\Omega m$. In these conditions, the current lines of a field that are applied to these media generate the changing of ionic atmosphere and of ion transport phenomenon that are described in [19]. In case that in this natural electrolytic environment (soil, ground water etc) or in industrial electrolytic environments are posed metallic structures (underground metallic pipes, steel in concrete etc) these current lines are focused on high conductivity ways, on the shortest current way, that mean by metallic structures fixed in these environments, that have a resistivity below 10^{-6} Ωm. In this situation, the current lines cross (at least twice) the metal / electrolyte interface with all the consequences on the mechanism and corrosion reactions kinetic.

3.1. D.C. stray currents

The most frequent sources of the stray currents in continuous current that may cause important damages by corrosion are railways of the trams underground, as well as the industrial platform of with the equipments supplied with D.C..

Unlike industrial platforms that produce stray currents having a relatively stabile intensity in time, the D.C stray currents that are produced by urban electrical traction, present by their specificity (starting and stopping successively, carriages circulation), having big fluctuations in time of the intensities.

The simplified drawing of stray currents forming in D.C. from tram railways, for a single motion carriage and for a single adjacent metallic structure (metallic pipe) is shown in figure 5.
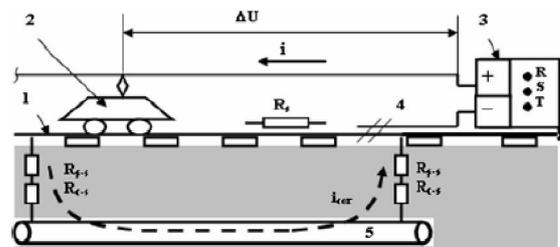
Fig. 5. The simplified scheme of the D.C. stray currents produced by the trams: 1 - tram railways; 2 - tram carriage; 3 - rectifying station for trams; 4 - return cable for tramline; 5 - metallic pipe; $R_{\text{ş-s}}$ - rail/soil resistance; R_{c-s} - pipe/soil resistance; R_s - resistance of the tram rail; i_{cor} - stray current; ΔU - voltage drop on the rail; i - traction current.

From the analysis of figure 5, it observes that the traction current i (which actuates the tram engine) produce, on the tram rail with $R_ş$ resistance (between the connector place of the return cable "–" and tram position), a direct current voltage drop ΔU.

Generally the disturbed metallic structure is a long underground metallic pipes and of the urban utilities supply networks). This structure can be disturbed by stray currents that are produced by several trams that are simultaneously in motion. In this situation, the galvanic perturbation effects are overlapping.

The railway (rails/traverses system) being on the soil, by chain of resistances series (rail/soil, soil/pipe, pipe, pipe/soil and soil/rail), ΔU produces a stray current i_{cor}, of which intensity is determined by:

- voltage drop on the railway, ΔU;
- rail/ soil dispersion resistance;
- resistivity (the electric resistance) of soil;
- dispersion resistance of the metallic pipe/soil,

firstly, by anticorrosive insulation resistance of the metallic structure (organic layers applied on the pipe – when is the case).

In the large city area, where coexist the trams and subway, the disturbances by D.C. stray currents, in conformity with figure 6, are very complex.
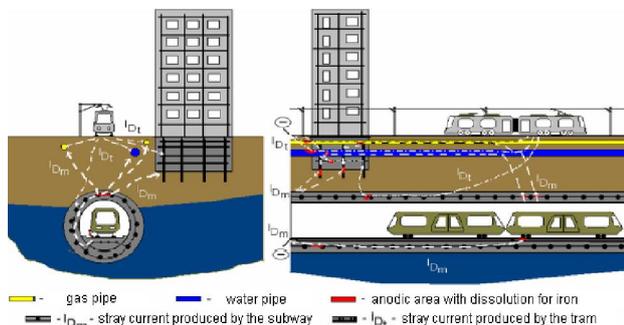
Fig. 6. The scheme of stray currents circulation in a complex system, formed by subway, underground metallic structures, resistance structures from steel concrete and trams railway

3.2. A.C stray currents

Unlike the system generating of stray current in D.C., in A.C., the disturbing signals rise from the system of transport, distribution and utilization of the electric power by:

- induction (situations in which the underground metallic structure is in the region of aerial power lines, situation presented in figure 7);
- due to the disequilibrium currents which crossing between the grounding settings of the three-phase energetic system (presented in figure 8);
- ohmic voltage drops which appear on the railways lines with A.C. traction and/or of the interactions among different metallic structures from the same environment (figure 9).
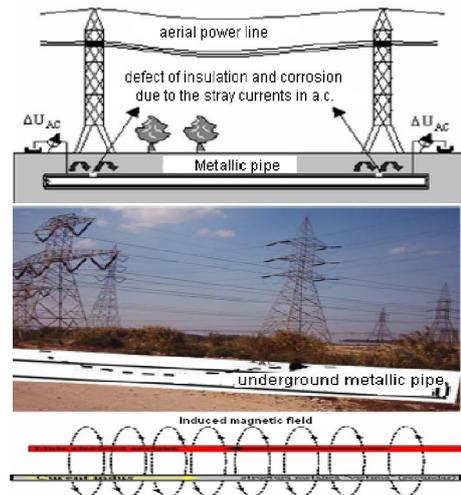
Fig. 7. The scheme of the A.C. stray currents induction from a power line: ΔU_{AC} – A.C. voltage between metallic pipe and soil
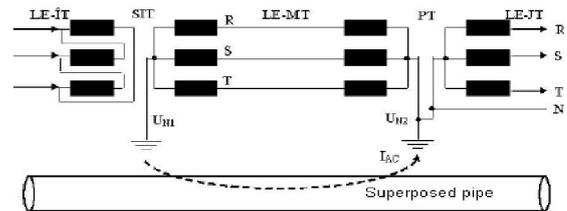
Fig. 8. The scheme of the A.C. stray currents due to the disequilibrium's from the three phase energetic system: I_{AC} - disequilibrium current that passes between grounding settings for of high/medium voltage station and of transformer plant of medium/ high voltage; $U_{N1, N2}$ - disequilibrium voltages; LE - power line; IT - high voltage; MT - medium voltage; JT - low voltage; SIT - high/medium voltage station; PT - transformer plant.
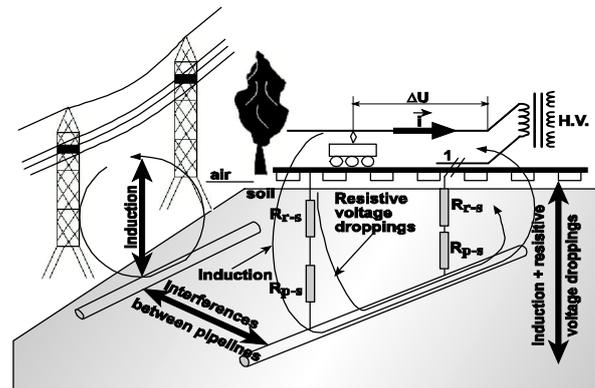
Fig. 9. AC stray currents interferences within a power line, electrified railroad and pipelines: R_{r-s} - rail/soil resistance; R_{p-s} pipelines/soil resistance; H.V.- high voltage station; 1 - cables/rail contact.

3.3. Composed stray currents

In practice, in the conglomerate urban environments, the natural electrochemical processes are disturbed by the stray currents, which have the origin in various sources. Thus, over the signal component of 50 Hz from the transport/distribution/utilization chain of the electric

energy – from the three-phase energetic system (figures 7, 8, 9) are superposed:

   - harmonics (especially those odd) of the 50Hz basic due to the system non-linearity;

   - transients produced by the commutations from the system and electric drive with solid state devices;

   - high frequency components produced by industrial generators and commutation power supplies;

   - radio-frequency signals in 100 kHz ÷ 15 GHz spectrum produced by the broadcast, TV emitters, radio-communications systems, GSM telephony etc;

   - D.C components and its variations, produced by the urban electric traction (figures 5 and 6);

   - D.C. components, relatively constants in time, rise from the industrial equipment supplied in D.C. (especially electrolysers).

It turns out that, in these conditions the disturbance current which polarizes the natural electrochemical systems is a composed current, and the shape of the disturbance signal is very complex.

4. THE IMPACT OF THE STRAY CURRENTS ON THE KINETICS OF ELECTROCHEMICAL PROCESSES

Generally, an oxidation process (13) or reduction process (14) that is developing by charge transfer (electrochemical) can be written as:

$$R \rightarrow O^{z+} + ze^{-} \qquad\qquad 3)$$

$$O^{z+} + ze^{-} \rightarrow R \qquad\qquad 4)$$

where R is the reduced specie, O^{z+} is oxidized specie, and ze^{-} represents the number of exchanged elementary charges (electrons).

In the case in which the process speed (13) is equally with the process speed (14), the system is in equilibrium (15), to whom it correspond an equilibrium potential E_0.

$$R \leftrightarrow O^{z+} + ze^{-} \qquad (15)$$
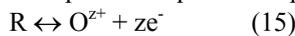
The D.C. polarization of the electrochemical system that is in equilibrium (315), has as effect the motion of the electrochemical potential of the system to values more negative than E_0 in the case of cathodic polarization E_k (16), respectively to values more positive in case of anodic polarization E_A (17)

$$E_k = E_0 - \eta_k \qquad\qquad (16)$$

$$E_A = E_0 - \eta_A \qquad\qquad (17)$$

where, η_k represents the cathodic overvoltage (18), and η_A the anodic overvoltage (19):

$$\eta_k = a_k - b_k \cdot \ln j_k \qquad\qquad (18)$$

$$\eta_A = a_A + b_A \cdot \ln j_A \qquad\qquad (19)$$

where, a_k si a_A are the Taffel constants, b_k and b_A are the Taffel slopes – specific for the electrochemical

systems, and j_k and j_A represents the densities of the cathodic, respective anodic polarization current.

Like it determines from the relations (13÷19), the evolution of electrode potential in an electrochemical system in function of the D.C. polarization current can be illustrated by plotting of the polarization curves E = $f(j)$ (figure 10).
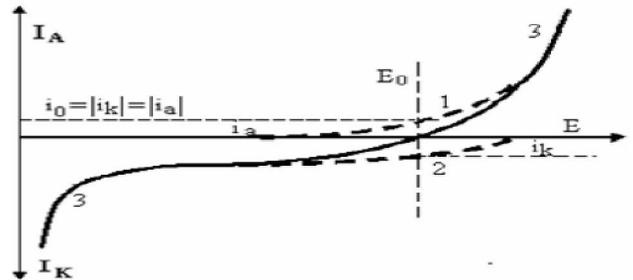
Fig. 10. Polarization curves which characterize the electrode/electrolyte systems:
1 - polarization curve specific to partial anodic process; 2 - polarization curve specific to partial process; 3 - global polarization curve; i_a - partial anodic current; i_k - partial cathodic current; i_0 - the change current specific to the system; I_A - global anodic current; I_K - global cathodic current; E_0 - equilibrium potential; E - potential of the electrode/electrolyte system.

From the figure 10 analysis result that, at the equilibrium potential E_0, the partial anodic current - the measure of the process speed (13) - is equally with, the partial cathodic current (the measure of the process speed (14)), namely $|i_a| = |i_k| = i_0$ - change current (the intensity of the charge exchanges to equilibrium).

The size of the change current i_0 is determined by the nature of electrolytic system and is (20):

$$i_0 = zFk_1 C_{Me} \exp\left[-\frac{U_a^0 - \alpha zF\varepsilon_e}{RT}\right] =$$
$$= zFk_2 C_{Me^{z+}} \exp\left[-\frac{U_k^0 + (1-\alpha)zF\varepsilon_e}{RT}\right] \qquad (20)$$

where, k_1 - equilibrium constants of the anodic partial reaction, k_2 - equilibrium constants of the cathodic partial reaction, C_{Me} - concentration of the reduced specie, and $C_{Me^{z+}}$ - concentration of the oxidized specie, U_a^0 - activation energy of the partial anodic reaction, U_k^0 - activation energy of the partial cathodic reaction, α - transfer coefficient, ε_e - equilibrium potential, E_0, R - gases universal constant, T - absolute temperature.

Considering the electrochemical corrosion process, the reduced specie R is metal Me that corrode itself, and oxidized specie O^{z+} is the formed corrosion product, the metallic ion Me^{z+} having valence Z, because the re-deposed metal in partial cathodic reaction (14) can not present the physical-chemical properties similar with those of dissolved metal in the partial anodic process (13), we notice that measure of metal corrosion natural rate v_{cor} is just the change current specific to the

mentioned electrochemical current, respectively $i_0 = i_{cor}$.

Also analyzing figure 10, we observe that, by anodic polarization of the metal in electrolyte (for example by D.C. stray currents) the metal corrosion is strengthening and the dissolving rate - V - (21) will be determined by anodic current intensity I, by Faraday relation (22), respectively (23).

$$V = \frac{D_m}{t} \qquad (21)$$

$$D_m = I \cdot t \cdot \frac{M}{zF} \qquad (22)$$

$$V = \frac{D_m}{t} = \frac{M}{z \cdot F} \cdot I \qquad (23)$$

It also noticed that at cathodic polarization of the metal with a current having higher intensity than i_K (respectively than i_0), the corrosion of the metal is thermo- dynamic impossible (in compliance with principle of anticorrosive active-cathode protection).

The first theoretical studies regarding the A.C. signals impact overposed on electrode /electrolyte systems was carried out by Erdey – Gruz and Devay [17]. Their studies was focused only on sinusoidal and linear signals superposed on equilibrium processes, analyzing the change current evolution and of equilibrium potential function of the electrochemical system nature, the A.C. signals applied to equilibrium systems can generate significant increase of the change currents and consequently of the corrosion rate.

Many studies and case analysis have emphasized the very high corrosion accelerator effect of the A.C. stray currents, both the underground metallic pipes [13], [19] (even to those cathodic protected against corrosion) and also to, steel concrete structures [20] that are burial [21] and/or apparent [22].

Among these studies, we can underline the remarks of E. BINNI [19] from 1997 that affirm followings: "*Until now, some tenth of cases of heavily interfered pipelines have been reported în Europe. As a result, more than 700 corrosions have been reported, with a total of 4 gas leaks. Most probably, many other AC corrosion cases will be discovered as soon as the operators will focus their attention on this relatively new phenomenon*".

From BINNI [19] remarks we can conclude that the operators and the specialists of the underground metallic structure administrators (transport and supply networks for urban utilities, natural gases or liquid hydrocarbons transport pipes etc) do not know yet or are not familiarized with the specific aspects of the accelerated corrosion due to the A.C. stray currents this thing can be explained as this energy form is relative new being more frequent in the last two or three decades, when as consequence of industrializing and technological development, the production and demand of electric energy has considerable increase, especially in the west Europe countries.

Also in this time, due to a technological development, using of magnetic amplifiers in electrical operating was completely surrendered, being replaced by the acting systems realized with electronic montages based on "solid state" devices (especially controlled rectifier diodes – "thiristors").

Typical to these electrical drive systems, besides all the technical-economical advantages, is the fact that they are strong transient generators so the non linear component content of the supplied electric energy significantly increase and, as a consequence increase the level of disturbing nonlinear A.C. stray currents.

It was demonstrated by experimental testing that the corrosion accelerator effect of the A.C. disturbing signals in disturbing conditions is considerably higher than for signals in nonlinear system [20].

The influence of disturbing A.C. signals superposed on the electrode process can be represented by applying a sinusoidal signal in the equilibrium potential of the system (figure 11) - or in case of pre-polarized systems in D.C., in anodic (figure 12) or cathodic (figures 13 and 14) dynamic potential.
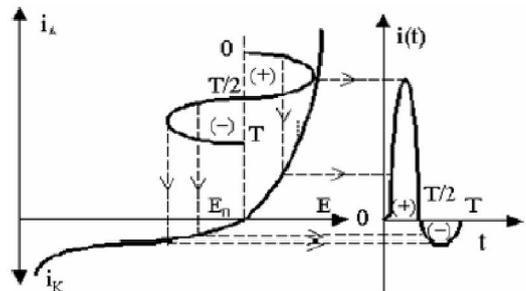
Fig. 11. The influence of superposed A.C. signals on electrode/electrolyte interface in equilibrium (E₀) and the response of the electrochemical system
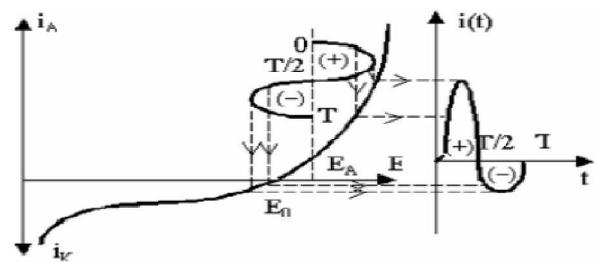
Fig. 12. The influence of a superposed A.C. signal on an anodic prepolarised (E_A) electrode/ electrolyte interface and the response of the electrochemical system
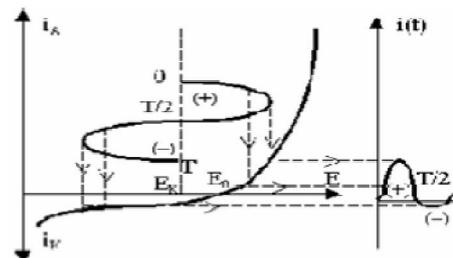
Fig. 13. The influence of a superposed A.C. signal with relatively high amplitude on an cathodic prepolarised (E_K) interface and the response of the electrochemical system
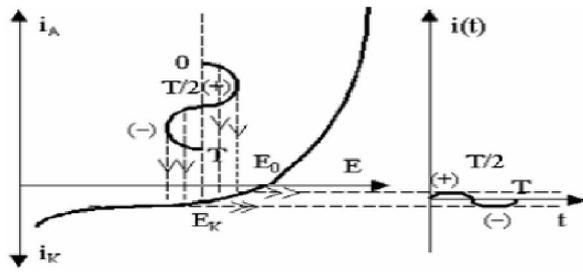
Fig. 14. The influence of a relatively low amplitude (under 0.5 V$_{pp}$) A.C. signal superposed on an cathodic protected (E$_K$) metal surfaces and the response of the electrochemical system

Analyzing figures 11÷14 we notice that, excepting the cases where the electrochemical system is cathodic pre-polarized and the disturbing signal has low amplitude (values up to RT/zF, that means up to 0.05 V$_{RMS}$- figure 14), the response of the electrolytic system to the A.C. disturbing signals is a deformed A.C. for which the positive (anodic) semi-period contribution is higher than negative semi-period, so the system is preponderantly anodic polarized.

This effect is very accentuated for anodic pre-polarized systems (Fig 12). In this situation, for metallic structures that operate in electrolytic environments (soil, ground water, wet concrete), the risk for damage by corrosion is extremely high.

It has also been observed that even in case of metallic structures protected against corrosion by cathodic protection (cathodic pre-polarization that are disturbed by pollutant A.C. signals at relatively high amplitude (above 0.05 V$_{RMS}$) it arise the risk for corrosion degradation that is higher in case signals above 0.5V$_{pp}$ [23].

5. THE IMPACT OF A.C. AND D.C. STRAY CURRENTS ON THE CORROSION FROM THE COMPLEX BUILD-UP MEDIA

World has firstly been confronted with depreciation by accelerated corrosion due to D.C. stray currents at the beginning of XX. Centery, when following the technical revolution, at the trams in Los Angeles, hypo traction was replaced by D.C. electric traction (1906). In two years only it has appeared significant damages in drinkable water supplying network, and in 1910 it was just reported the existence of the first mobile auto-laboratory, specialized in investigation and establishing of D.C. stray currents (figure 15).

Fig. 15. Mobile auto-laboratory designed for stray currents monitoring (Los Angeles 1910).

In the absence of implementing a proper protective technical solutions and/or of conception and un properly make of a build-up complex systems, the intensity of the D.C. stray currents is high (for example, at under underground train in Bucharest it have been determined stray currents, up to 800 A [21] and consequently their afferent damages are considerably. (figures 16÷19).

Fig. 16. Advanced damages fixing element at underground train in Budapest (formed in about 2 years) due to D.C .stray currents

Fig. 17. Localized corrosion on some gas pipes due to D.C. stray currents of trams and underground train in Bucharest

Fig. 18. Advanced corrosion of a medium voltage cable in Cluj, due to stray currents caused by trams [24]
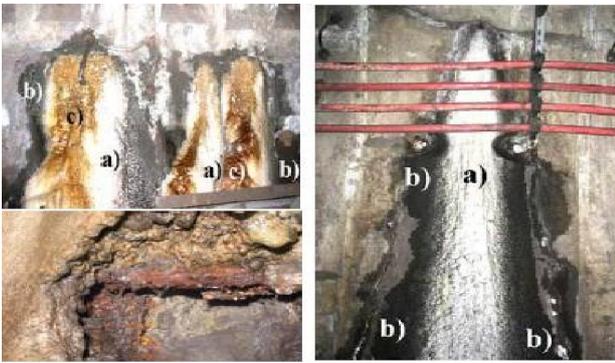
Fig. 19. Damages due to D.C. stray currents of concrete steel tubes (underground Bucharest) [21]: a) calcium levigation; b) mycromicetes colony; c) iron dissolving

Considering damages by accelerated corrosion of some metallic structures exposed to A.C. or in composed stray currents actions, these are illustrated by photos in figure 20 and figure 21.

Fig. 20. Steel concrete support elements (operating in high level electromagnetic field) degradations [22]

Fig. 21. Generalized corrosion caused by composed (D.C.+A.C.) stray currents

For prediction of degradations and localization of the areas with high risk of degradation due to the electromagnetic pollution of environment, recently were elaborated computation models, which allow impact evaluation of some transport installations, distribution or utilization of the electric energy on a representative metallic structures, respectively the computation of the currents and voltages induced in the disturbed metallic structures [25]. By applying of these computation models, for resistance structure from steel concrete of a crossing bridge for more electrified railways it determined a good concordance (figure 22) among the places with maximum values of the induced currents and physical degradations of the bridge structure [26].
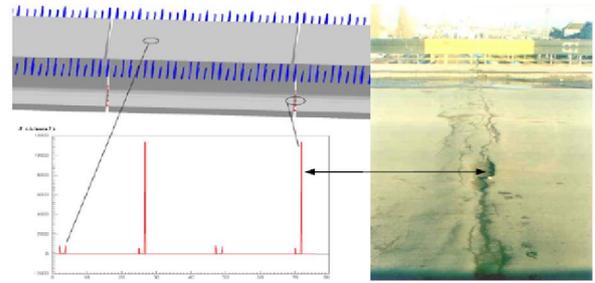
Fig. 22. The visual degradations of the bridge are in good accordance with the maximum computation values of the induced current densities [26]

Beside the effect accelerator of corrosion for the environment electromagnetic pollution, is important the fact that the A.C. voltages induced in the metallic structures "victim" (industrial or civil installations, like pipes for transport and distribution of the natural gases) from the lines of transport and distribution of the electric energy, in some cases, can have dangerous values, that – in the absence of some technical solutions of adequate protection – can damage the operators security/integrity and/or of consumers (figure 23).
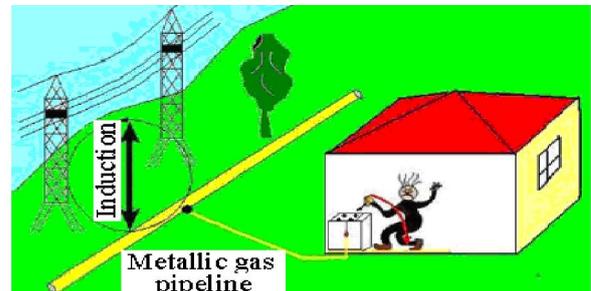
Fig. 23. The induced voltages in the "victim" metallic structures can achieve dangerous values for the servicing personal of the installations and/or of the natural gases consumers

6. CONCLUSIONS

It were analyzed the main aspects regarding the electromagnetic pollution impact of environment on the natural electrochemical reactions. From the made researches resulted that, the electromagnetic fields superposed on the electrochemical environments from biosphere produce modifications both in charge transport phenomena from electrolytes and in the mechanism and/or kinetics of the electrochemical reactions which are developed both in the biological electrochemical systems (like cytoplasm/cellular membrane system), and in natural electrolytes (soil, phreatic waters etc.). In these conditions it determines that the electromagnetic fields rise from various disturbing sources modify the natural development of the natural electrochemical processes from biosphere – so are pollutant signals.

From theoretical analysis of the A.C. interferences of the electrolytic environments resulted that the effect of the pollutant A.C. signals consist in modification of kinetic parameters of electrochemical reactions that are developing – especially the increasing of the change current.

In these conditions, we can affirm that, in case of the natural electrochemical processes, the electromagnetic fields overposed on the reaction media can disturb the natural performing of the reactions, so they are disturbing (pollutants).

Also, were analyzed the provenience sources of the electromagnetic pollution of the natural and complex build-up medium and it concluded that the source of all disturbing signals, of the D.C. and A.C. stray currents – both linear and/or nonlinear regime – is the system of transport/ distribution/utilization of the electric energy.

Of course, without electric energy, modern life on the Earth can not be conceived – so the humanity must be aware of fact that the electric energy utilization has negative effects on the environment – both on the biological environments, and on complex build-up media. Consequently, it imposes the intensification of the studies and researches which must regards on the one hand optimization/diminishing of the electric energy consumption, and on the other hand the diminishing of the electromagnetic pollution impact on environment, on both of bioelectrochemical processes from biosphere, and on the corrosion reactions from the complex build-up media.

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