The Influence of Interference Currents from Lightning-Rod Cables of Grid Steel Power Lines on the Corrosion Process of Tower Foundations

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ABSTRACT

With the increasing growth of several areas in the modern society, become raising the necessity to generate and carry electrical energy to the great downtons. Because of that it was necessary to heigten the generation and transport of electrical energy to the big towns.
To carry the energy we usally use power towers with steel structure foundation with zinc coating protection (galvanic coating). This foundation is undergrounded on the soil and because of that it may cause a high rate of corrosion, usually detected by a conventional potential measurement, utilizing a CuSO4 reference electrode.
It is belivied that corrosion resulted from the action of stray currents that flow throught the ground to close the loop between neigboring towers. Stray currents originate in the lightning rod cables of the power line towers, induced by the strong eletromagnetic and electric fields of the energized power lines.
The intensity and direction of those currents were measured, indicating substantial values of both AC and DC components.
The potential of the tower ground system, measured in the perpendicular direction of the main axis of the power line, was plotted as a function of the distance to the tower base.
The results clearly indicated the propensity to corrosive attack in the anodic towers as reflected by the slope of the plot, whereas no signs of corrosion could be found in the reverse slope, confirming the visual inspection of the foundation.
The profile of the potential plots could be changed providing the electric insulation of the lightning rod cable.

1. INTRODUCTION

Outstanding industrial development requires the transport of considerable amounts of energy through long distances, which enhances the importance of the power lines as an essential link between generators and consumers of energy. With the increase of the voltage in the lines in order to minimize resistive losses, wooden and concrete structures are no longer adequate, and have been progressively replaced by galvanized metal ones. Galvanized structures are designed to last up to 12 years in aggressive environments or even 24 years in the country side (2) (3) (4) (6). Their foundations are usually of grid-like built with the same ironware used to assemble the remaining components of the tower. The structure is then buried in the ground, and therefore, subjected to different corrosion processes, characteristic of different types of soil.

Tower foundations are susceptible to corrosion due to a myriad of contributing factors, such as differential aeration, pH, soil moisture, and the presence of stray currents. The latter expedites corrosion in the foundations, particularly in high-voltage lines, such as 525 kV lines. Burnett *et al* (5) have theoretically demonstrated that, as a line is energized, a DC current associated with its electric field, along with an AC -

60 Hz component, *Ix* and *Iy* respectively, are induced in the top cables. The AC - 60 Hz current, *Iy* consists of two components, *i.e.*, a *circulation component* (Icirc.comp.) and a *ground return component* (Ig.r.c.), which act together closing loops between adjacent towers, as is illustrated in Fig.1 (5).

The objective of the present investigation was to address the effect of stray currents on the corrosion process of tower foundations. This study has been carried out in the power lines of *Empresa Transmissora de Energia Elétrica do Sul do Brasil S. A. – ELETROSUL* (Southern Brazil Power Company), maintainer of 8,566 km of power lines connected mainly by metal towers of 69 kV, 138 kV, 230 kV, and 525 kV. Most of the towers have grid-like steel foundations manufactured from a zinc coated steel (2) having a protective layer of average thickness 80 ?m. The distributor supplies energy to 11.1% of the Brazilian consuming market including Southern and Midwestern states of *Rio Grande do Sul*, *Santa Catarina*, *Paraná*, and *Mato Grosso do Sul*.

Upon energizing the lines, electrical currents consisting of both an AC and a DC component is generated in the lightning rods. Monitoring those currents indicated that the direction of their DC component affected the magnitude of the corrosive process taking place at the foundations (1) of anodic towers. As a corrective action, the lightning-rods have been insulated from the power lines. This step also allowed a systematic study of the influence of DC-currents on the corrosion of high voltage towers.

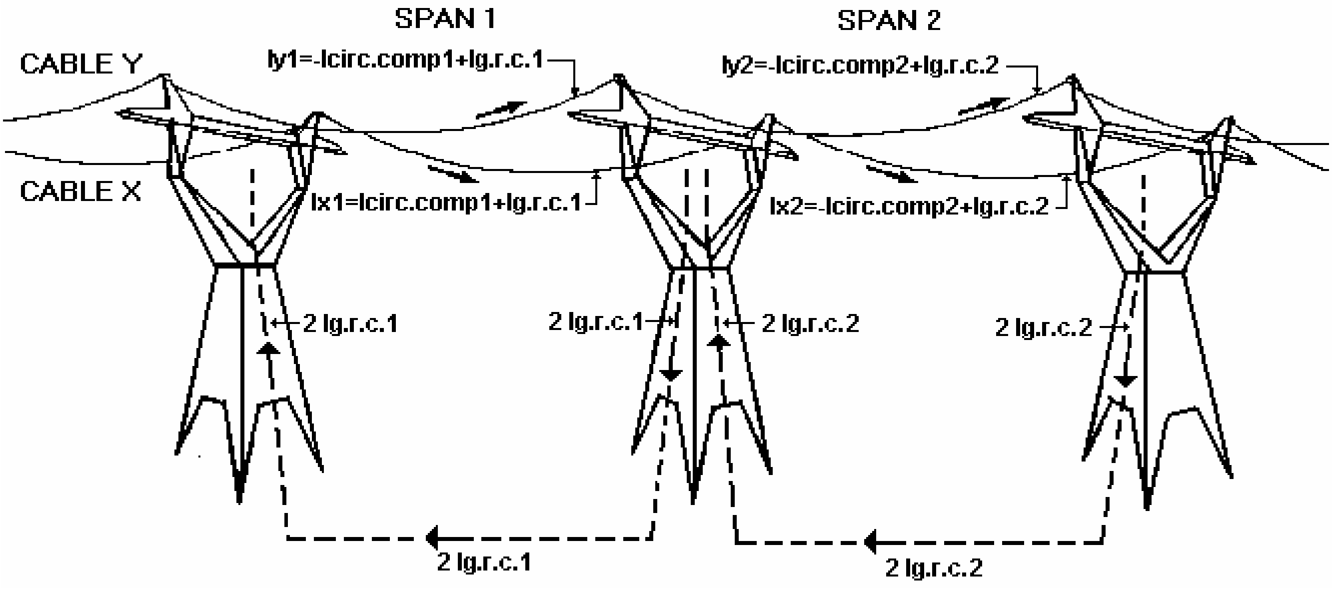

Fig.1 — Illustrative representation of stray currents, according to Burnett *et al* (5)

2. EXPERIMENTAL PROCEDURE

The presence of stray currents in energized power was detected under normal operation conditions, *i.e.*, with the power line equipped with 3/8 EHS galvanized lightning rods, and energized to 525 kV (6). The shape of both the potential and current signals measured at the base of the towers, upon disconnecting and connecting the rods to the structure, are shown in Fig.2 (6).

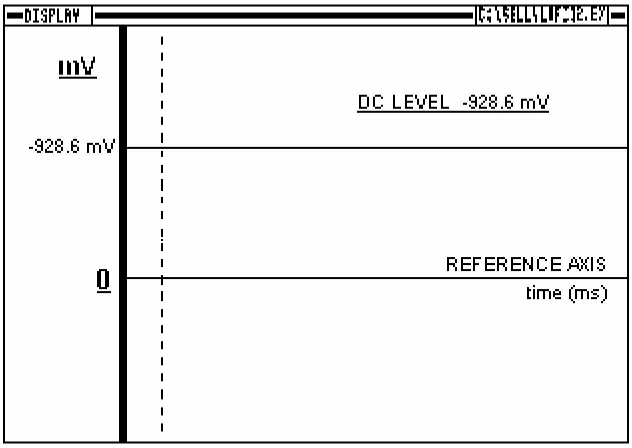

Fig.2 — DC component measured with rods and tower disconnected.

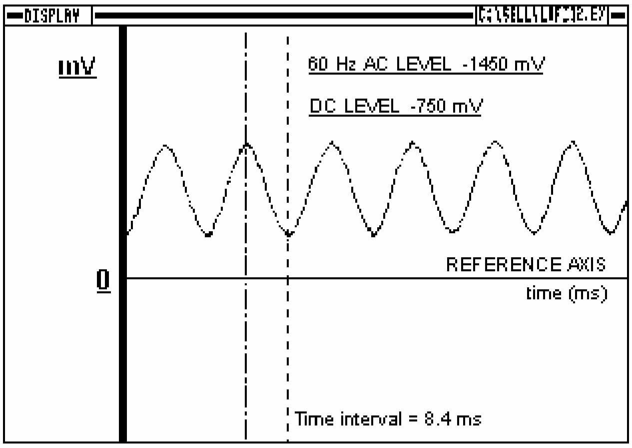

Fig.3 — DC and AC components measured with rods and tower connected.

The presence of AC and DC components originated from the electric and magnetic fields of the energized line (6) could be detected. They flowed from the lightning rod to the tower and acting as voltage and current sources. The levels of current and voltage obtained suggested extensive corrosion of the towers as a result of stray currents (7). This assumption was later confirmed by visual inspection of the base of the respective towers. Potential tests were also carried out at the towers energized to 525 kV using a $Cu/CuSO_4$ reference electrode, as illustrated in Fig. 4 (7).

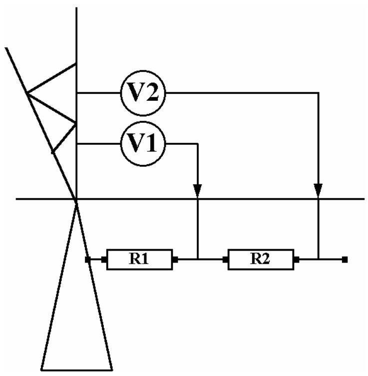

Fig. 4 – Schematic representation of potential measurements carried out at tower base as a function of the distance using a $Cu/CuSO_4$ electrode

The potential was measured at pre-established distance intervals $\mathbf{x_1}$ = 1.5 m for $\mathbf{V_1}$ and $\mathbf{x_2}$ = 3.0 m for $\mathbf{V_2}$. To that end, an Engro MD 820a digital multimeter was used at a 2000 mV_{cc} full scale along with a $Cu/CuSO_4$ reference electrode. The value of $\mathbf{x_1}$ was chosen to account for voltage fluctuations caused by surface current density lines (8) (9) near to and around tower foundations As such currents flow through a resistive volumetric conductor (ground), a surface voltage distribution turns out (8) (9).

The grid-like configuration characteristic of the tower foundations reported herein was considered as grounding vertical pole, acting not only as a structural component, but also driving lightning discharges to the ground and accounting for "flash-over" currents originated along the lines and discharged by the lightning rods.

Considering that the foundation works a pole, the resistance of the pole/ground system can be obtained either by a 3-point method or by the Wenner approach (four points) (8) (9), and the result is expressed in terms of **R (?).** Fig.5 illustrates a pole/ground R (?) plot (8) (9).

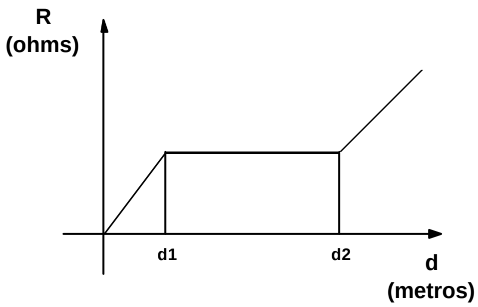

Fig.5 – R(?) plot of pole/ground system

The **R** and **d** axes intersect at the pole/ground system (grid). In the range from zero to $\mathbf{d_1}$**,** the plot is roughly linear. The distance d_1 corresponds to the value, in meters, of approximately twice the height of the pole (foundation), which is the minimum distance necessary to stabilize the resistance of the pole/ground system. Full stabilization occurs between 2 to 5 meters away from the pole. As the distances measured, 1.5 and 3.0 m, correspond to less than twice the height of the pole, measurements were taken in the linear region of the pole/ground system (Fig. 4).

3. RESULTS AND DISCUSSION

Table 1 summarizes the data obtained at the base of the 525 kV towers of ELETROSUL Empresa Transmissora de Energia Elétrica do Sul do Brasil SA:

Lines of Eletrosul System (kV)	**No. of Towers ? V_1 < ? V_2**	**%**	**No. of Towers ? V_1 > ? V_2**	**%**	Total No. of Towers Measured
525	**1.014**	**80,1**	**251**	**19,8**	**1.265**
230	**729**	**80,4**	**177**	**19,5**	**906**
TOTAL	**1.743**	**80,2**	**428**	**19,7**	**2.171**

TABLE 1 – Variation of ? V1 and ? V2 along Eletrosul power lines

The voltage is closely related to the flow of the stray current through the lightning rods of the line. Proof of that was obtained connecting the rods to the tower. They acted as current sources and intensified the corrosion process at the base of the towers.
The values shown in Table 1 were fitted to a straight line, as they fall in the linear region of the plot illustrated in Fig.5. It can be seen that **82.40% of the tests carried out at the base of the towers resulted in** ? $\mathbf{V_1}$ **<** ? $\mathbf{V_2}$

Plots having a positive slope (**a=tan ?)** were associated with anodic towers. The corresponding foundations were visually inspected in an attempt to assess the situation of the corrosion process. As it can be seen from Fig.7, the foundations showed evidence of extensive corrosion. The influence of the stray current flowing in those foundations was verified measuring the voltage at the base of anodic towers in advanced stage of corrosive degradation (Fig.7) (7).

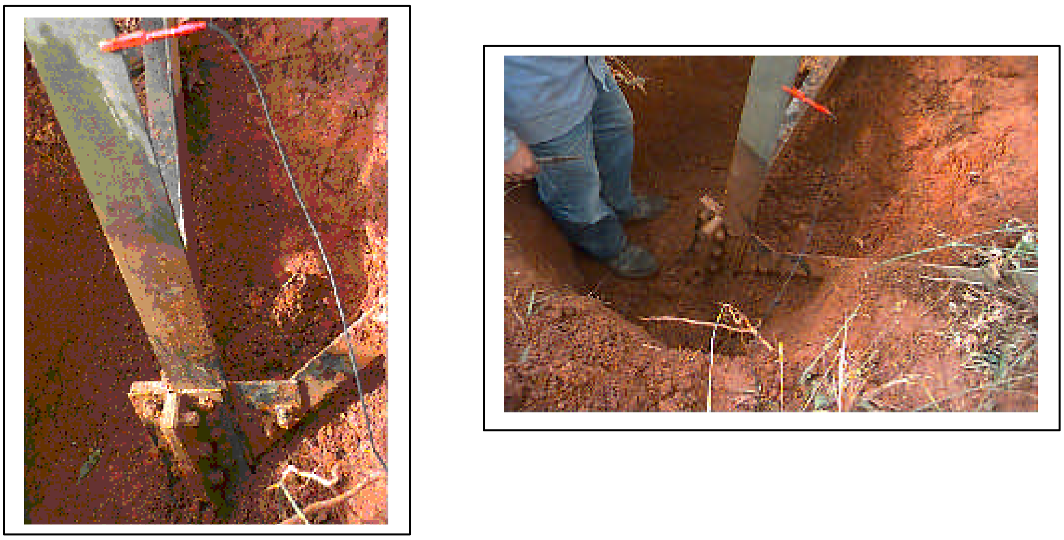

Fig.7 –Image of anodically polarized foundation

Conversely, plots with negative slope (**-a=tan ?)** suggested a cathodic process taking place at the foundations. Such towers were also visually inspected, but no signs of corrosion could be detected. Fig. 8 shows an example of a well preserved structure corresponding to a cathodic tower.

Fig.8 – Image of a cathodically polarized foundation

5. CONCLUSIONS

Significant induced currents consisting of AC and DC components flow through lightning rods of extra-high voltage cables — 525 kV. As the loop between adjacent spans is closed, the currents thus flow between towers in an electrochemical process. The counter-part of such currents is the stray current, which speeds up the corrosive process of anodically polarized towers. The effect of the stray current can be significantly reduced insulating the lightning-rod cables. Studies are still under way to verify the effect of the stray current on the resting electrode potential in an attempt to determine the conditions that lead to either anodic or cathodic processes at the tower foundation.

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