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# Electrochemical characterization of the steel wire used as reinforcement in the conductors transmission networks electricity nitride by ion implantation

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**Abstract.** The power company feature infrastructure, which are generally shaped so the transmission and distribution lines, here is why it is necessary to characterize the process of electrochemical corrosion of these components. In this case the steel wire coated with zinc or aluminium, as it is undergoes the rigor of corrosive environments. Given the geographical diversity and different climatic environments, atmospheric corrosion carried affecting service life of structures. For example in very humid environments such as coasts and high altitudes, wetting time (TOW), parameter that meets the conditions of temperature and relative humidity, it affects large proportion, accelerating the corrosion of ferrous materials. Given the importance of establishing mechanisms that lessen the impact on degradation in transmission and distribution lines of both the reliability and the availability of the same. This paper presents the implementation in nitride steels as an alternative or complement to zinc coating.

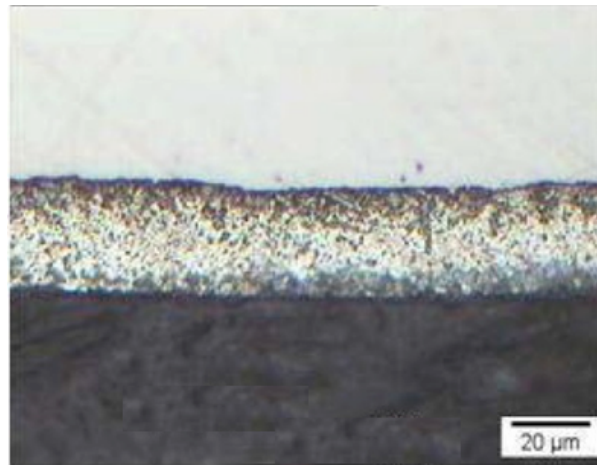
## 1. Introduction

The power companies have made infrastructure, in general, for the transmission and distribution lines [1]. The stability of the supply system and electricity distribution is affected by the deterioration of basic infrastructure components; in this case the most critical is the steel wire, [2] which works not only as a support but is exposed to highly corrosive environments. Traditionally to increase corrosion resistance wire that is coated with aluminium or zinc (galvanized)[3]. Considering potential advantages (such as lightning, reduced size, increased resistance to hydrogen permeation, adhesion and surface hardness greater) [4,5] it was considered as an alternative treatment ion implantation.

## 2. Experimental procedure

Steel core samples of a commercial wire ACSR 2/0 (according to the NTC 461 has the following chemical composition: Carbon 0.50 to 0.88%, manganese 0.50 to 1.10%, 0.035% maximum phosphorus, 0.045% maximum sulphur and 0.10 to 0.35% silicon). The length of the specimens was 70mm long, this in order that upon immersing the samples shielded saline in 3.5% NaCl is exactly a contact area of 300mm<sup>2</sup>, for testing electrochemical impedance spectroscopy (EIS). According to NTC 461 standard wire corresponds to class A. In Figure 1, the zinc layer is shown generated by galvanizing a thickness of 20 microns is equivalent to about 210g/m<sup>2</sup>, equivalent to approximately 240g per 100m length of wiring.





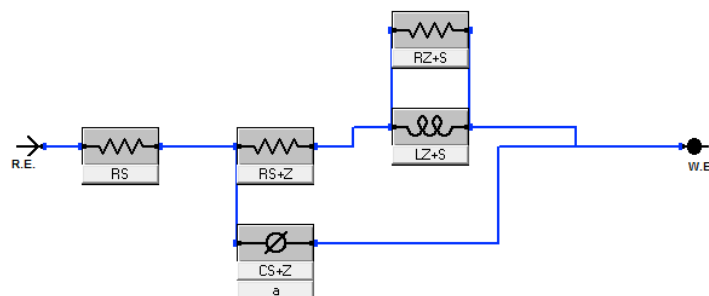
**Figure 1.** Zinc coating microscopy.

Using the software, it was determined as the optimal amount of 15 specimens, for experimental design, we proceeded to divide into three groups as follows: uncoated wire, zinc coated steel (galvanized) and nitrated steel cable. The nitrating was performed by high voltage electrical discharges at low pressures JUPITER device, using nitrogen as a working gas, a range of pressures comprised between 0.83 and 0.85Pa. The discharge pulses were 20kV, 30Hz, 0.25ms pulse width, and a total treatment time of 30 minutes [3,6].

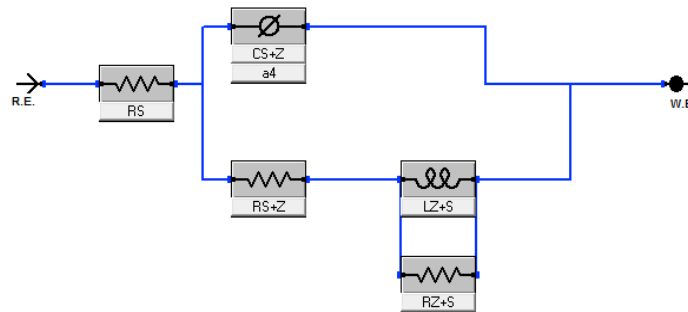
The electrochemical characterization was performed on a Gamry PCI-4 model, using techniques Electrochemical Impedance Spectroscopy (EIS) at room temperature using a cell composed of the working electrode with an exposed area of  $300\text{mm}^2$ , a reference electrode of Ag/AgCl and a wire as a counter electrode graphite, all immersed in a solution of sodium chloride (NaCl 3.5%w/v) prepared with distilled water, this solution was chosen because it simulates a marine solution also forming active metals corrode metal chlorides on. Bode plots were obtained and Nyquist performing frequency sweeps in the range of 0.001Hz to 100kHz using an amplitude of the sinusoidal signal of 10mV [7,8].

### 3. Results and discussion

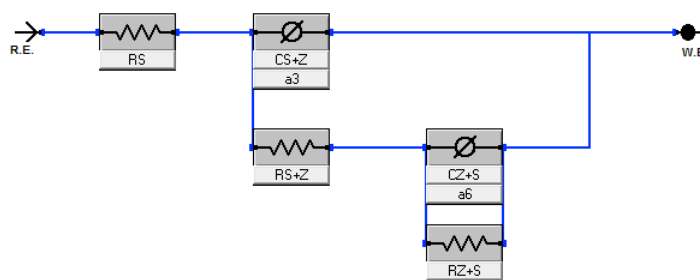
Interpreting data obtained by analogous modeling requires electrical circuits to physical system studied, also called equivalent circuit. As can be seen in Figures 2, 3 and 4, total impedance in Tables 1, 2 and 3 [9].



**Figure 2.** Bare steel wire equivalent circuit.



**Figure 3.** Nitrided specimens equivalent circuit.



**Figure 4.** Galvanized specimens equivalent circuit.

Based on these equivalent circuits may be tabulated values of total impedance as seen in Tables 1, 2 and 3.

**Table 1.** Values of the circuit elements of bare steel wire specimens.

Specimen	Bare steel wire					
	1	2	3	4	5	
RS	3,75E+00	4,39E+00	3,53E+00	3,86E+00	3,07E+00	
RS+Z	3,60E+01	5,08E+01	9,11E+00	2,31E-04	3,50E+01	
CS+Z	1,92E-04	1,33E-04	4,22E-05	1,04E-04	1,47E-04	
a	7,85E-01	8,57E-01	9,84E-01	8,41E-01	8,43E-01	
RZ+S	1,41E+01	2,86E+01	1,07E+01	4,74E+01	1,50E+01	
LZ+S	1,74E+01	2,18E+01	1,81E+00	1,68E+02	1,41E+01	
R TOTAL	5,38E+01	8,38E+01	2,33E+01	5,13E+01	5,31E+01	5,31E+01

**Table 2.** Values of the circuit elements of the samples nitride.

Specimen	Nitrided steel					
	N1	N2	N3	N4	N5	
RS	1,85E+00	1,43E+00	2,54E+00	1,81E+00	2,16E+00	
RS+Z	4,61E+01	3,68E+01	4,00E+01	1,08E+01	2,34E+01	
CS+Z	2,54E-05	2,87E-05	5,89E-05	1,77E-05	1,94E-05	
a4	9,25E-01	9,09E-01	8,90E-01	9,77E-01	9,30E-01	
RZ+S	4,49E+01	3,15E+01	2,40E+01	1,42E+01	2,10E+01	
LZ+S	2,73E+01	1,62E+01	1,62E+01	2,11E+00	9,51E+00	
R TOTAL	9,28E+01	6,97E+01	6,65E+01	2,68E+01	4,65E+01	7,08E+01

**Table 3.** Values of the circuit elements of the specimens galvanized.

Specimen	Galvanized steel					
	A	B	C	D	E	
RS	1,35E+00	1,77E+00	3,78E+00	4,53E+00	3,42E-01	
CS+Z	2,46E-04	1,38E-03	2,03E-03	1,82E-03	1,35E-03	
a3	6,83E-01	3,27E-01	7,18E-02	2,79E-01	2,98E-01	
RS+Z	1,57E+02	6,95E-01	2,69E-04	2,62E-06	3,13E+00	
CZ+S	7,30E+03	7,20E-05	8,85E-04	6,06E-05	5,84E-05	
a6	9,15E-01	8,34E-01	6,62E-01	8,53E-01	8,39E-01	
RZ+S	3,65E-09	1,86E+02	3,06E+02	6,99E+02	2,96E+02	
R TOTAL	1,59E+02	1,89E+02	3,10E+02	7,04E+02	2,99E+02	3,32E+02

As shown in the equivalent circuits, impedance equivalent circuit of the test pieces of bare steel was lower in relation to the impedance manifested circuit the nitrated samples, this is due to the implantation of nitrogen ions it has a great influence on the behaviour of the material. Implantation nitriding decreases the hydrogen in steel, so it is important to consider the possibility of using implantation as a tool to prevent corrosion and hydrogen permeation of the wire.

#### 4. Conclusions

It was observed that the impedance of the equivalent circuit increase in the specimens that had undergone the nitriding process with respect to the bare specimens. However it was less than that of galvanized steel, this mainly due to the changes undergone by the steel surface during the implantation process. Therefore it is more advisable to significantly extend the average wiring life, would perform a nitriding and then galvanized. To implement this combined technique is recommended further study.

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