

A Right Way to Calculate CP Potential Attenuation

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ABSTRACT

Pipeline polarized potential attenuation is supposed to be IR-free pipe-to-soil potential distribution along a pipeline. Currently, most of the potential attenuation calculations in published documents or in CP training manuals are either a pure IR drop attenuation or attenuation that contains IR drop^{1, 2, 3, 4, 6}. Polarization and IR drop are caused by applying current to the pipe surfaces. When current density distribution along a pipeline is determined, the attenuation of cathodic polarization (IR free potential shift) can be established. Current density is restrained by both pipe to soil resistance and pipe polarization resistance. This article uses current density attenuation and polarization resistance to determine the polarization (IR-free potential shift) attenuation.

Key words: Attenuation, Polarization resistance, IR-free potential

INTRODUCTION

Shown on Figure 1 is a typical impressed current CP diagram. When the rectifier is first turned on, i.e. time $t=0$, there is no polarization yet. At that moment, the applied DC voltage is fully consumed by IR drops at anode (IR_{a0}) and cathode (IR_{c0}), plus original potential difference between anode and pipe ($E_{oca} - E_{occ}$). When $t=0$, the current is at the greatest value. Over time when polarization kicks in, due to adding polarization resistance, the current is gradually reduced. Figure 1 indicates that both IR drop and polarization resistance have significant impacts on the current (density), hence both IR drop and polarization resistance should be considered in current density attenuation calculations. This article provides a method to calculate the attenuation of ΔE_p with the assistance of current density attenuation and polarization resistance. Currently, published documents only provide attenuation calculations for

the moment of $t=t_0$ which does not even include polarization or only provide the apparent potential shift (ΔE_{app}) attenuation which includes both IR drop and polarization.

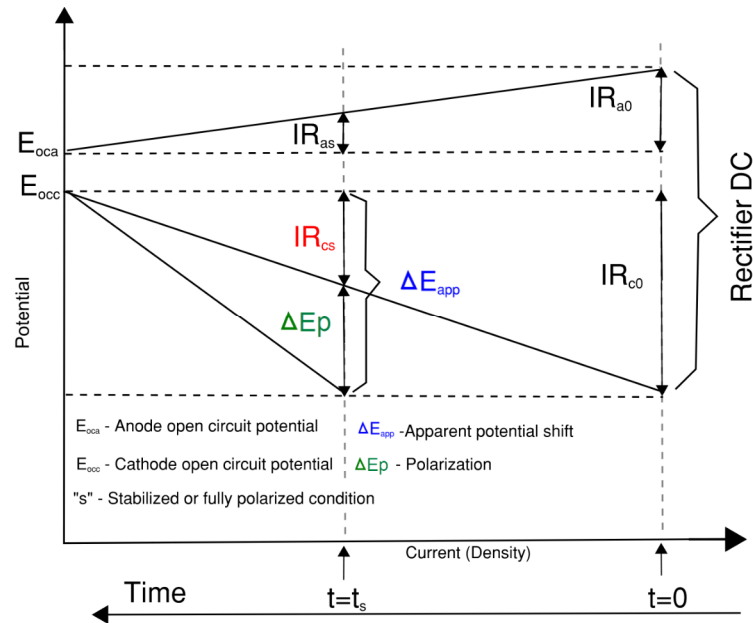


Figure 1. Cathodic Protection Diagram

Following are a brief review of some ISO 15589 as a example. The approaches from other published documents are similar.

ISO 15589 uses the following equation to calculate pipeline potential attenuation:

$$E_x = E_0 \times \frac{\cosh \alpha (L - x)}{\cosh \alpha L}$$

Table 1 shows the definitions of equation parameters based on the 2004 edition and 2015 edition of ISO 15589.

Table 1. Definitions from ISO 15589

	ISO 15589, 2004	ISO15589, 2015
E_0	“pipe-to-electrolyte potential at drain point”	“Pipe-to-electrolyte potential shift” (with respect to remote earth) at drain point
E_x	“pipe-electrolyte potential at a distance of x”	“Pipe-to-electrolyte potential shift (with respect to remote earth) at a distance of x”

It can be seen from Table 1, ISO 15589 tried to get the definitions corrected in 2015 edition by making changes from “potential” to “potential shift”, but a potential shift with respect to remote earth contains IR drop.

In both 2004 and 2015 editions of ISO 15589, The leakage resistance in attenuation constant (α) contains only pipe-to-electrolyte insulation resistance (R_0). So, if using the equations from ISO 15589, you will not get the IR free pipe-to-electrolyte potential attenuation. Since the attenuation constant (α) contains only pure electrical insulation resistance, the calculated potential attenuation will not reflect the polarization, i.e., the result may only apply to the situation when $t=0$ as indicated in Figure 1.

Other published documents such as Reference 3, 4, and 6 along with the references attached to ISO 15589-2, 2004 have the same problem. Since cathodic protection criteria are about IR free pipe-to-electrolyte potential or polarized potential, it may not be appropriate to use any potential attenuation that contains IR drop to determine if cathodic protection criteria have been met.

The following sections will show a right way to calculate pipe-to-soil IR free potential attenuation. The key focus will be on adding polarization resistance to the attenuation constant (α) and on working from current density attenuation.

CURRENT DENSITY AND POLARIZATION RESISTANCE

Cathodic protection current density is typically determined by soil resistivity in real cathodic protection design practices. A minimum 300 mV cathodic polarization is supposed to be achieved under the determined current density^{1,2, 6}. Table 2 shows the relationship between current density and soil resistivity. Polarization resistance is defined as the polarization (300mV) divided by corresponding current density.

Table 2. Cathodic Protection Current Density VS Soil Resistivity

Pipe Depth Resistivity (ohm-cm)	Minimum Design Current Density CD_{min} (mA/m ²)	Polarization Resistance-Bare Steel R_p (ohm*m ²)
Less than 2,000	30	10
2,000 to 5,000*	20	15
5,000 to 10,000	10	30
10,000 to 50,000	5	60

* 3,000 ohm*cm will be used for demonstration

PIPE COATING CONDUCTANCE AND COATING BREAKDOWN FACTOR

Figure 2 shows the relationship between coating conductance and coating breakdown factor³. The original chart in the referenced article was based on the data obtained from a test site⁷. This chart shown on Figure 2 may need to be modified to better suit the field and coating conditions. The straight line in the logarithmic chart can be represented by the equation (g_{cs}) below:

$$g_{cs} = 10^{(0.8796 \cdot \log(100 \cdot fcb) + 4)} * 10^{-6} \frac{1}{ohm \cdot m^2}$$

