

Comparing AC Study Techniques in Addressing AC Corrosion Risk

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ABSTRACT

An AC study and mitigation design was performed and installed to address corrosion risks. After a few years of operation, the site was revisited due to changing conditions and increasing AC current densities. For the second evaluation, new modeling software was used to evaluate the risk. This paper is a case study comparing the two modeling software techniques, and evaluation on the impact of the field data quality, and a lesson learned on addressing AC corrosion risk.

Key words: Corrosion control, corrosion management, cathodic protection, simulation and modeling, AC corrosion

INTRODUCTION

AC interference studies have become increasingly popular in an industry where shared right of ways have increased and there has been a better understanding of how AC interacts between pipelines and powerlines that are collocated with each other. While modeling software for AC interference studies have been developed since the 1990s, advancement in AC interference processes have occurred as more has been learned over the years. When performing an AC interference study there are three steps that need to be completed: field data collection, modeling, and mitigation design. Within this paper, we can compare a project from ten years ago to a project from today to understand the developments that have been made over the course of time to improve the way we develop our mitigation designs. Over the past ten years we have learned how to improve the quality of field data we collect, shown advancements in what is offered by modeling software's, and developed mitigation designs that more efficiently meet our clients needs.

In 2011 and 2013, EN was commissioned by a client to perform an AC interference study along a 16" natural gas pipeline with a wall thickness of 0.25" and Fusion Bonded Epoxy (FBE) coating that runs for about 8.5 miles. The pipeline had an existing cathodic protection system. The cathodic protection is a sacrificial anode system with an anode placed every 1000 feet. There is one rectifier located on the line at the north substation and two bonds. One bond is located on the southern end of the line and connects to an 8" pipeline that runs from the southern substation. The second bond is connected to a 16" pipeline that runs west from the center of the pipeline. The pipeline is collocated with three

powerlines. Two powerlines are 138kV lines that parallel the entire pipeline. The third powerline is a 345kV line that parallels half of the pipeline. An image of the area being studied can be seen in **Figure 1**.

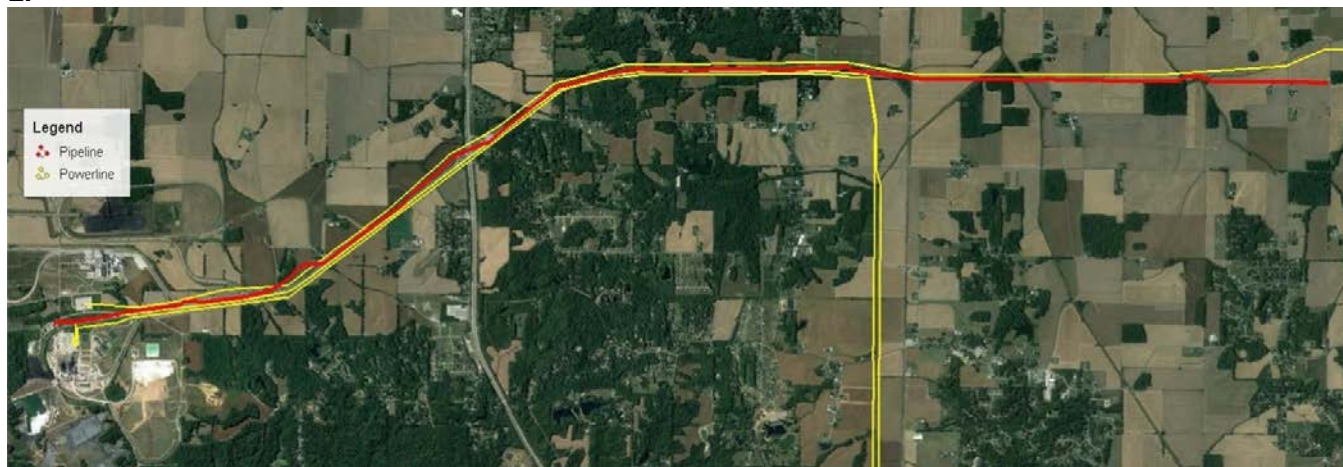


Figure 1: “Overview of Study Area: The pipeline (red) is collocated by three HVAC powerlines (yellow).”

At the time, field data collection was done, modeling was performed, and a mitigation system was designed for the line. Almost ten years later, in 2021, the same client recommissioned EN to update the mitigation design for the same pipeline due to changing soil conditions and increasing AC current densities found while taking annual readings along test stations. During the 2021 AC interference study additional mitigation was designed based on the new field data collection and modeling.

There are three types of phenomena that are related to AC power systems: inductive coupling, resistive coupling and capacitive coupling. Inductive coupling is of the most concern during AC interference studies and what will be discussed throughout this paper. Inductive coupling is due to the interaction of the magnetic field generated by overhead powerlines and any parallel metallic object. The longitudinal flow of AC current within the powerlines will magnetically couple with a second conductor due to a long length of exposure.

When designing preliminary AC mitigation systems, the goals are to reduce steady-state voltages below 15 V_{AC} and minimize AC current densities below 30 A/m².¹ Any steady-state touch voltages of 15 V_{AC} or higher with respect to local earth is considered a shock hazard. The likelihood of AC corrosion risk is predicted based on AC current density. Any AC current density between 30 A/m² and 100 A/m² is determined to be a medium risk for corrosion as its unpredictable. Any current density above 100 A/m², corrosion is a high risk and corrosion is expected to occur.² It is also important to study the fault conditions of the powerlines that are collocated with the pipeline. The goals are to reduce fault conditions for coating stress and reduce the risk of power-arc coupling.

EXPERIMENTAL PROCEDURE

For the purpose of discussion, the case study will be broken down into three areas to be discussed for comparison: field data, modeling, and design.

Field Data

Field data collection was performed in 2011, 2013, and 2021. Different field plans were developed in 2011 and 2013, than in 2021. Over the course of ten years, field data processes have become more efficient and show a more complete look at what is occurring in the area of the pipeline. In 2011 and 2013, the field plan included soil resistivity measurements, AC current density measurements, AC potential readings, and placing data loggers at areas along the pipeline with expected peaks in AC

voltage. In 2021, the field plan included soil resistivity measurements, AC and DC current density measurements, AC and DC potential readings, and placing data loggers along the pipeline.

Equipment

While the field plans have changed over the course of ten years, developments in equipment have also improved. In 2011 and 2013, the soil resistivity measurements were taken using an MC Miller Soil Resistivity Box. In 2021, the soil resistivity measurements were taken using an AGI Ministing. Advancements in equipment technology are now able to calculate noise errors, change the output current, average continuously after each cycle to provide more accurate measurements, and be able to complete a variety of different types of measurements for soil resistivity.³

Another development in equipment over the past ten years, is an AC-10 portable AC/DC coupon probe. The coupon probe allows technicians to collect AC current densities at the time of the reading while out in the field rather than using a calculation that does not take any DC interference into effect.⁴ The AC-10 portable probe is a rod with a 10cm² conical tip that should have good soil contact when taking readings to achieve the most accurate current density readings.

Soil Resistivity Measurements

Soil resistivity measurements are used to predict levels of AC current that may be coupled to the pipeline from the powerlines. The soil data was collected using the Wenner Four-Pin Method in accordance with ASTM G57.⁵ After the collection of data, soil resistivity calculations are done using the Barnes-Layer calculation. This calculation can break the soil down into layers and determine when the soil resistivity changes at different depths of soil.

$$\rho = 191.5AR$$

$$\begin{aligned}\rho &= \text{soil resistivity } (\Omega\text{-cm}) \\ A &= \text{distance between pins (feet)} \\ R &= \text{soil resistance } (\Omega)\end{aligned}$$

Equation 1: “Barnes-Layer Calculation”⁵

Between 2011 and 2013, twenty-nine (29) soil readings were taken along the pipeline. During these years, Wenner Four-Pin readings were taken at 5-foot and 10-foot spacings. These readings were generally taken in clusters at areas where high AC voltages were predicted and did not extend to areas of the pipeline that low AC voltages were not expected to occur. Barnes-Layer calculations for 0-5 feet depths and 5-10 foot layers were determined for this study. The Barnes-Layer calculation determined that the 0-5 feet layer was calculated to be 5,104 Ω -cm. The 5-10 feet layer was calculated to be 4,371 Ω -cm.

In 2021, nine (9) soil readings were taken along the pipeline. Wenner Four-Pin readings were taken at 2.5-foot intervals from 2.5 feet to 20 feet depths at least every ½ mile along the collocation corridor. About every two miles a “deep” reading would be taken with an additional four readings at 20-foot intervals from 20 feet to 100 feet depths. Soil readings are no longer only taken at areas along the pipeline that are predicted to have high AC voltages and are now taken uniformly across the entire pipeline to find a true representative of the soil along the entire length of the pipeline being studied. Barnes-Layer calculations are done during this study for 2.5 feet layers up to 20 feet. Modeling capabilities have advanced in the past ten years and within the SEStech CDEGS software suite, RESAP software can be used to calculate more accurate soil layers that do not need to be defined like with the Barnes-Layer calculations. Both the Barnes-Layer calculation and RESAP results are used to

determine the most accurate soil representation across the length of the pipeline. The Barnes-Layer calculations can be seen in **Table 2**. The RESAP results can be seen in **Figure 2**.

Barnes Layer Analysis						
Depth	Avg Ω	Avg ρ (Ω -cm)	StDev Ω	StDev ρ	95% CI	Average Soil Resistivity
0 to 2.5 ft	8.82	4224.15	2.67	1280.62	793.72	4224 $\pm$ 794
2.5 to 5 ft	4.11	3676.26	1.29	1184.38	734.07	3676 $\pm$ 734
5 to 7.5 ft	2.94	4939.66	0.99	2054.42	1273.32	4940 $\pm$ 1273
7.5 to 10 ft	2.18	4018.43	0.68	1057.62	655.51	4018 $\pm$ 656
10 to 12.5 ft	1.81	5081.71	0.53	1116.82	692.20	5082 $\pm$ 692
12.5 to 15 ft	1.53	4731.30	0.42	955.83	592.42	4731 $\pm$ 592
15 to 17.5 ft	1.31	4429.74	0.33	727.43	450.86	4430 $\pm$ 451
17.5 to 20 ft	1.21	7855.36	0.31	2797.04	1733.59	7855 $\pm$ 1734

Table 1: Barnes-Layer Analysis 2021

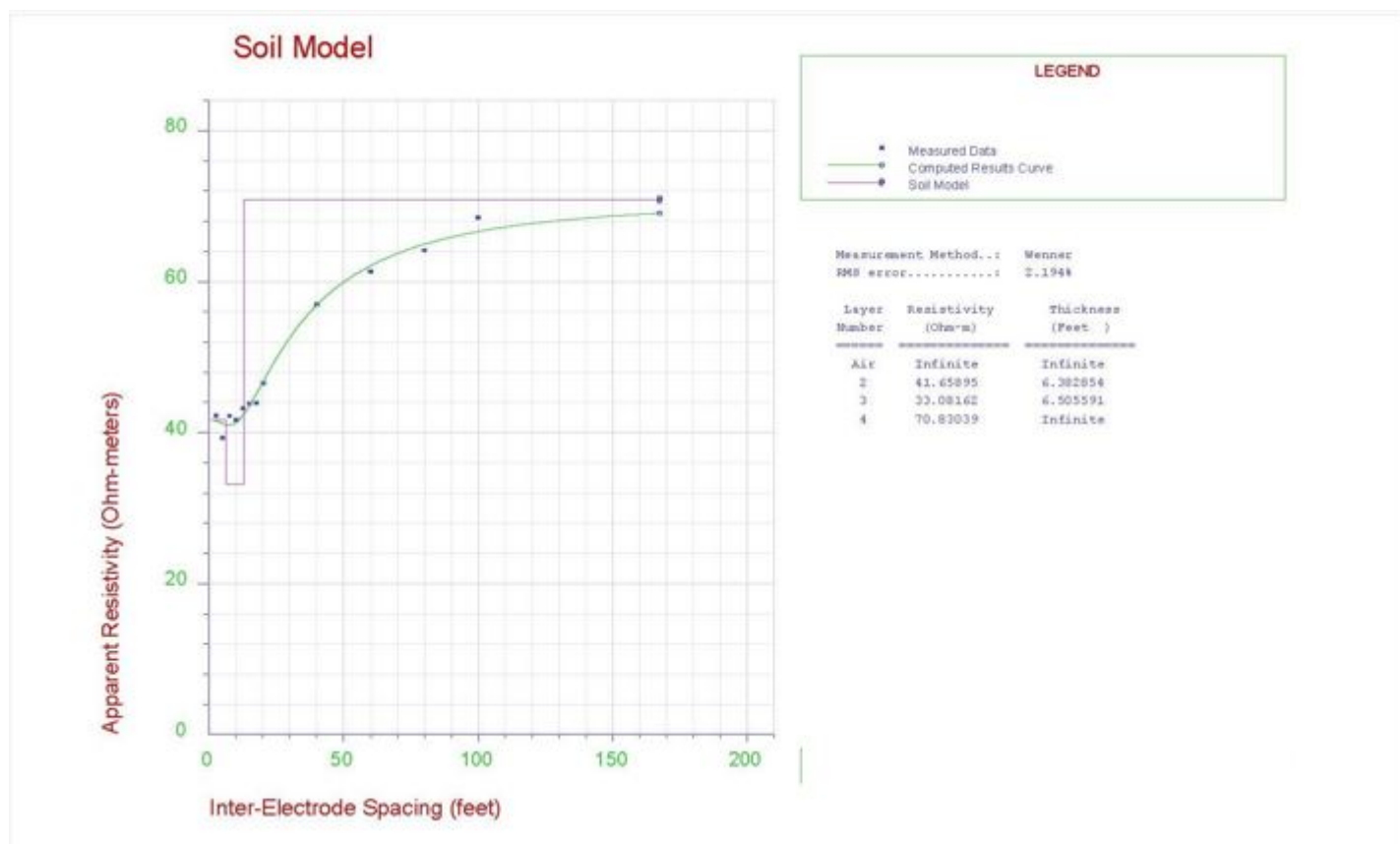


Figure 2: Soil Analysis using RESAP software

The soil measured in earlier years and in 2021 can both be determined to have low resistivity and be corrosive. However, having an increased number of soil layers from the Barnes-Layer equation allows us to have more accuracy in measurements at different depths along the pipeline.

Potential Readings

Pipe-to-soil readings are taken at test stations along the pipeline to understand where peaks in voltages are occurring along the pipeline in the field. These readings are also used to compare what was found in the modeling results with what is occurring in the field. In 2011 and 2013, AC voltages were only recorded during field data collection for the AC interference study. In 2021, DC and AC voltages are