

CHALLENGES OF MITIGATING AC INTERFERENCE RISKS IN A 107 KM MULTI-PIPELINE CORRIDOR

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ABSTRACT

An initial AC interference study and mitigation design was performed prior to construction, on the subject NPS 36, 107 km long pipeline (Pipeline A) installed in 2016. The subject pipeline is collocated with an NPS 30 pipeline (Pipeline B) constructed in 1999, for the entire route, and several other pipelines in some areas, all owned by the same operator and with shared cathodic protection systems. Five areas of powerline collocation were identified and modeled in the AC Interference study.

During the commissioning survey, elevated AC voltages were recorded in areas with no identified powerlines. Furthermore, it was discovered that some pipeline bonds, existing mitigation systems and other pipelines were not modeled as per the final “as-built” installation or incorporated into the AC mitigation system. Subsequent site investigations were performed to confirm bonding, assess AC interference corrosion risks, and identify additional AC interference sources. The pipelines were remodeled to include the existing “as-built” configuration and these additional interference sources. Remodeled results were assessed based on field collected data, remotely monitored data, and In-line Inspection (ILI) data on both pipelines to develop an integrated AC mitigation and monitoring system. Several lessons were learned, that can benefit future projects. These lessons include the importance of remodeling the as-built pipeline configuration, complexities related to AC interference in multi-pipeline corridors, and the difficulty in assessing the AC corrosion risk via modeling alone. Assessment and incorporation of site and ILI data into the final AC mitigation and monitoring system design leads to a more holistic result.

Keywords: Corrosion Control; Corrosion Monitoring; Corrosion Prevention; Electrochemical Corrosion

INTRODUCTION

This case study involves an NPS 36, 107 km long pipeline (Pipeline A) installed in 2016. The subject pipeline is collocated with an NPS 30 pipeline constructed in 1999 (Pipeline B), for the entire route, and two additional pipelines near the start of its route (Pipelines C and D), all owned by the same operator.

The cathodic protection (CP) and AC mitigation system design was issued for construction (IFC) in January 2016. Five areas of powerline collocation were identified and modeled in the initial AC Interference study. The four operator owned pipelines were periodically bonded and existing cathodic protection systems were utilized to protect the new pipeline.

Commissioning of the CP and AC mitigation system was performed in June 2016, and an indirect inspection survey consisting of close-interval potential survey and DC voltage gradient survey (CIPS/DCVG) was completed in September 2017.

This paper summarizes an assessment of the effectiveness of the installed AC mitigation system and additional investigation, modeling and data analysis performed to optimize the system performance and monitoring capabilities.

Several lessons were learned through this process, related to the importance of fully modeling all pipelines in multi-pipeline corridors, modeling of the final as-built configuration when there are significant changes to the design, and relying on field and in-line inspection (ILI) data to verify the model, and the mitigation design.

BACKGROUND

Project Description

The project Pipeline A is a liquids pipeline constructed in 2016. It is 107 km in length and externally coated with fusion bonded epoxy (FBE). Pipeline A is collocated with the existing Pipeline B for the entire length, and with two additional pipelines (Pipeline C and D) for the first 24 km of the route. Refer to Table 1 for the pipeline properties and areas of collocation.

Table 1
Pipeline Collocations and Properties

Description	Year Built	NPS	Product	Length	Collocation Length	Coating Type	Coating Resistance
Pipeline A (new)	2017	36	Heavy Crude	460 km	107 km	Fusion-Bonded Epoxy (FBE)	80 kΩ-m ²
Pipeline B (existing)	1999	30	Crude Oil & Liquids	540 km	107 km	High Performance Powder Coating (HPPC)	300 kΩ-m ²
Pipeline C (existing)	2017	24	Diluent	446 km	First 24 km	Fusion-Bonded Epoxy (FBE)	80 kΩ-m ²
Pipeline D (existing)	2015	36	Crude Oil & Liquids	137 km	First 24 km	Fusion-Bonded Epoxy (FBE)	80 kΩ-m ²

The CP system design assumed that Pipeline A would be bonded to the existing pipelines every 15 km and would be connected into four (4) existing impressed current CP systems, either via direct connection to the rectifier or via bond to an adjacent pipeline. A total of 86 test stations and 29 DC coupons were installed to facilitate monitoring of CP levels.

Table 2 summarizes the five (5) high voltage AC powerline (HVAC) collocations identified in the initial AC interference study, and one distribution powerline collocation.

Table 2
Powerline Collocations

Powerline	From KP	To KP	Length	Notes
240 kV	0.0	2.0	2.0 km	Parallels existing Pipeline B only
144 kV	0.0	6.8	6.8 km	Crosses Pipeline A
144 kV	43.3	54.0	9.5 km	Crosses Pipelines A & B – installed in 2010
14.4 kV (single phase)	36.4	46.3	9.9 km	Single phase powerline – installed in 2010
138 kV	104.0	106.5	2.5 km	Crosses Pipeline A (Pipeline B not collocated here)

The AC mitigation system design was issued for construction in January 2016 and consisted of 720 m of AC mitigation wire, connected to Pipeline A via DC decouplers at three (3) locations, and continuity bonding at two stations to ensure safe touch potentials. Nine (9) AC coupons were recommended to monitor AC corrosion risks.

It was unclear from the design report whether the existing collocated lines were also to be connected into the new AC mitigation systems. The new Pipeline A also did not appear to have been connected into any existing AC mitigation systems installed on the other lines. Although Pipeline B may have been included in the model, no results were provided in the report related to this or any other existing lines.

AC MITIGATION SYSTEM ASSESSMENT

IFC Model and Commissioning

The commissioning survey for the CP and AC mitigation system was performed in June 2016, and an indirect inspection survey consisting of close-interval potential and DC voltage gradient (CIPS/DCVG) surveys in September 2017.

Elevated AC voltages were recorded at the test posts in the area between kilometer post (KP) 80 and KP 87 during the CIPS/DCVG survey, which resulted in calculated AC current densities above the operator's specified project 20 A/m² design limit and the 30 A/m² NACE⁽¹⁾ SP21424¹ limit (33 A/m²) at KP 85.9. This data is provided in Figure 1 for Pipeline A along with the data from the 2018 annual test post survey. The NACE and project current density limits are included for reference.

Additional investigation was performed at the test posts located in this area, which included additional test post measurements, waveform measurements and a visual inspection for the source of the AC interference. The waveforms indicated that the predominant frequency was 60 Hz, which is indicative of induced AC from a powerline. The collocated powerline was not initially identified by the site crew. It was later identified from site photos during a desktop review as shown in Figure 2.

The subject powerline was a 240 kV line and collocated with both Pipeline A and B for approximately 12 km from KP 73 to KP 85. The powerline was omitted from the initial AC interference study as it was located outside of the project's 100 m buffer in which powerlines were identified and considered.

⁽¹⁾ NACE International, 15835 Park Ten Place, Houston, Texas, 77084.

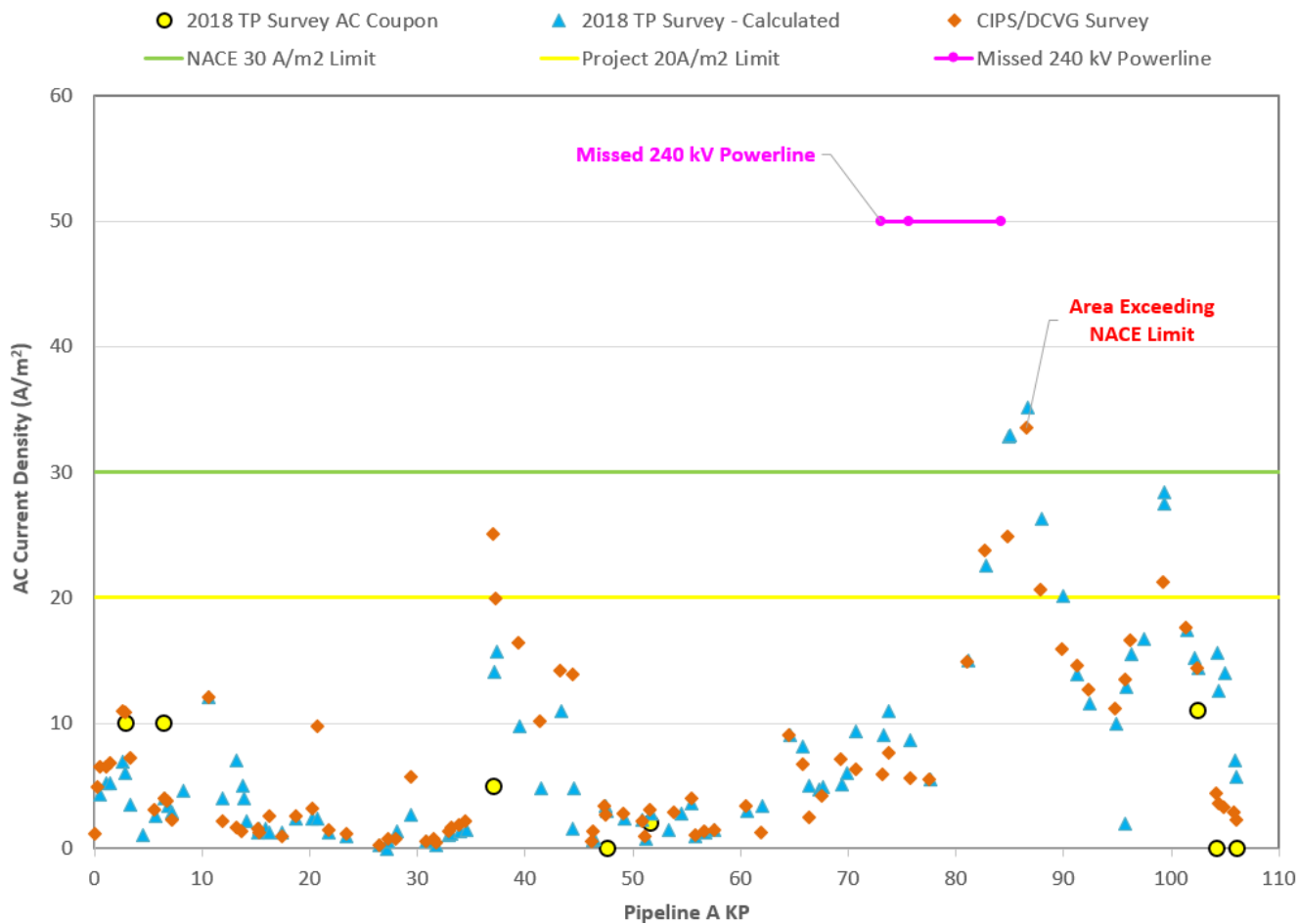


Figure 1: Project Pipeline A. Survey Data and Missed Powerline



Figure 2: Photo of Missed 240 kV Powerline at KP 82.2

Further desktop review of historical records, the initial IFC AC interference study, and the mitigation design raised these concerns:

- The missed 240 kV powerline collocated between KP 73 and KP 85.
- CP bonds between pipelines were not all installed as per the IFC design and as was modeled.
- Pipeline A did not appear to have been connected into existing AC mitigation systems.
- The existing collocated Pipeline B was not connected into the new AC mitigation systems.
- The collocated pipelines, specifically Pipeline B, did not appear to be modeled and no results were provided.

AC Interference Remodeling (Steady State)

Based on these findings, the project agreed to remodel the pipelines incorporating the following additional parameters:

- Additional 240 kV powerline between KP 73 and KP 85
- Include the existing collocated Pipeline B in the model
- Include all mitigation and bonds to other lines installed as part of the project or pre-existing on other collocated lines.
- Revise the 14.4 kV powerline in the model that was recently upgraded to a 3-phase system.

Field data was used to verify bonding and connections to existing mitigation systems. Figure 3 shows the data for Pipeline A correlated with the Pipeline B locations. Additional site investigation was performed at any locations that were considered “suspect” or that could not be verified via previous survey data.

Several bonds and interconnections were not located after further investigation and were removed from the model as indicated in Table 3. Additionally, sites with elevated AC voltages and calculated current densities outside of the “newly identified powerline” area were further investigated. This included visual investigation for potential AC interference sources, test post measurements, 24-hour AC voltage data-loggings, measurement of bond currents, and soil resistivity measurements. Given that there were no AC coupons present at these selected locations, the AC current densities were calculated for a 1 cm² holiday based on the AC voltage measured on the datalogger, and the measured soil resistivity at pipe depth.

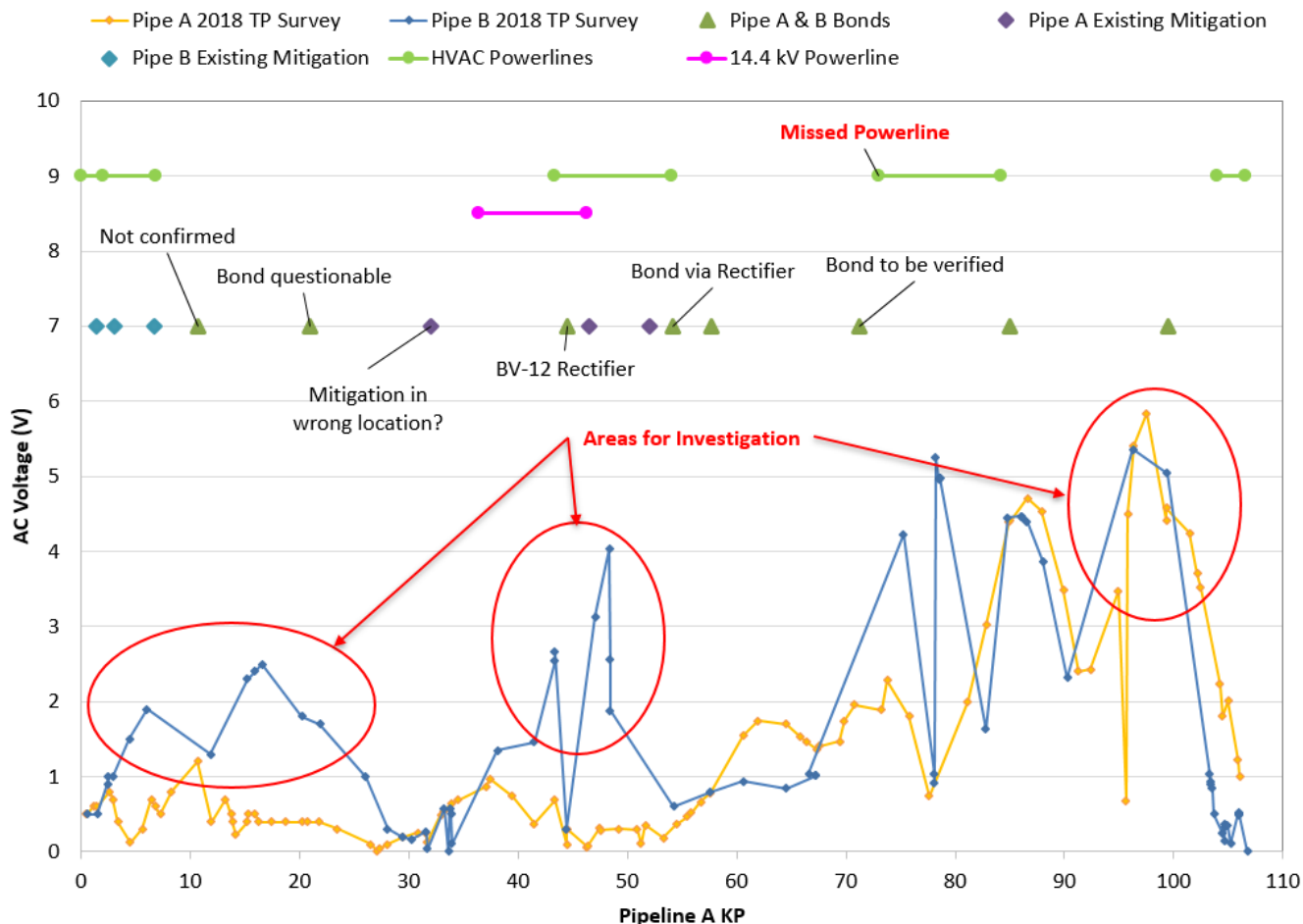


Figure 3: Field Data Analysis to Verify Bonds and Mitigation

Table 3
Field Investigation Summary

Pipe	KP	Datalogger (Max ACV)	Resistivity (ohm-cm)	Datalogger (Max A/m ²)	Summary
A	10.7	1.2	n/a	n/a	No bond found
A	20.6	0.33	n/a	n/a	Bond confirmed: 167 mAAC bond current.
A	37.0	1.30	9.39	31.30	Distribution powerline identified in photos.
A	70.6	n/a	n/a	n/a	Annual Survey data - site visit not performed due to difficult access. Bond confirmed: 180 mAAC bond current.
A	95.6	6.19	19.79	65.40	AC voltage does not vary significantly. Only small distribution powerlines in the area.
A	96.8	6.16	44.19	28.81	AC voltage does not vary significantly. Only small distribution powerlines in the area.
A	98.7	6.19	n/a	n/a	Bond confirmed: 1.15 AAC bond current
B	110.1	2.45	10.88	86.66	No powerlines in area. 3.08 Vrms on waveform, predominantly 60 Hz (approx. 20% is 180 Hz).
B	136.6	3.51	18.38	49.16	HVAC and distribution line confirmed. Rectifier tie-in location. 3.5 Vrms according to waveform.
B	141.0	4.45	16.70	55.26	Many powerlines, including distribution. 5.9 Vrms on waveform, predominantly 60 Hz (approx. 20% is 180 Hz)