AC Interference and Mitigation at Pipeline Facilities – Case Study

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ABSTRACT

An AC interference study was conducted in 2021 following a utility development with the addition of a high voltage AC powerline in Alberta, Canada. The study comprised of 11 pipelines and 4 powerlines collocating in several stretches totalling approximately 50 km of collocation, with various crossing locations.

In the unmitigated state, the modelling results indicated that mitigation under fault conditions is required at 17 pipeline facilities.

This paper discusses the strategies used to optimize the mitigation, considering the facilities specific conditions, some of the challenges faced by the install crews, and the changes to design during construction.

The optimized design approach resulted in overall less mitigation requirements, smaller number of site visits, reduced construction footprint and environmental impact, and reduction in the overall project cost.

Keywords: Pipeline and powerline collocation, AC interference, AC mitigation, AC risk assessments, safety, mitigation wire, gradient control grid, DC decoupler, monitoring.

INTRODUCTION

AC interference is a significant concern for pipeline operators, particularly when high voltage AC (HVAC) powerlines share right-of-way (ROW) with buried metallic pipelines. As energy infrastructure becomes more interconnected, the proximity of powerlines to pipelines can induce AC voltages, leading to potential safety hazards and asset integrity risks. The primary modes of interference include electromagnetic coupling and conductive coupling.[1]

In steady-state conditions, the HVAC fields surrounding powerlines can induce AC voltages on nearby pipelines, potentially resulting in AC corrosion. This occurs when AC current discharges through defects in pipeline coatings at current densities exceeding the relevant threshold. Additionally, elevated touch voltages at pipeline facilities can create dangerous conditions for operation personnel and the public.[2-7]

During powerline faults, the effects of AC interference are magnified. Line-to-ground faults generate substantial currents, which can travel through the ground and induce higher voltages on nearby pipelines. In such scenarios, touch and step voltages at exposed metallic structures can exceed safe limits, potentially causing severe electrical shocks or injuries. Fault conditions can also lead to arcing between the powerline and pipeline structures, which, while rare, can result in coating damage or even structural degradation of the pipeline.[8,9] Managing these risks requires careful analysis, mitigation design, and continuous monitoring to ensure compliance with regulatory standards.

As the global demand for energy continues to grow, the likelihood of HVAC powerline and pipeline collocation increases, making AC interference a persistent concern. Effective mitigation strategies, such as grounding systems, gradient control grids, and DC decouplers, are essential to maintain safe operations. Without proper interference management, operators risk safety violations, environmental hazards, and costly asset failures. Therefore, the development and implementation of optimized mitigation measures are critical for ensuring safe, efficient, and sustainable energy infrastructure.

STUDY BACKGROUND

In 2021, a power utility development project was initiated in Alberta, Canada to support expanding energy infrastructure. The project involved the construction of one new high voltage HVAC powerline, which would run parallel to three existing powerlines and share ROW with 11 pipelines. With a total of approximately 50 kilometers of collocation, this configuration required a detailed analysis of the interference effects between the pipelines and the powerlines under both steady-state and fault conditions. This paper focuses exclusively on the mitigation at pipeline facilities due to fault conditions. Figure 1 shows a simplified configuration of the study area.

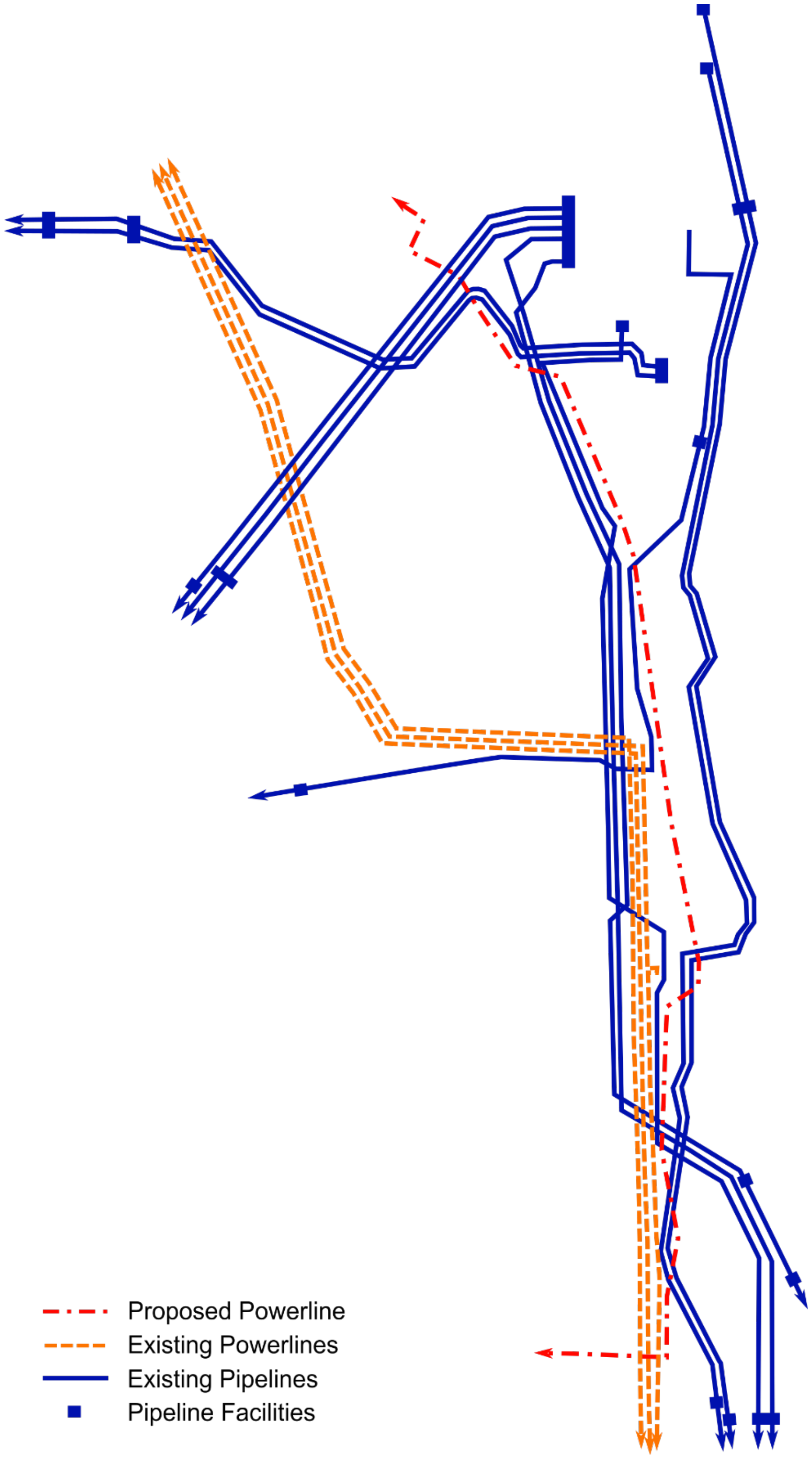

Figure 1: Simplified Pipeline and Powerline Collocation Configuration

To ensure the accuracy of the interference modelling, comprehensive data collection from both pipeline operator and powerline companies was necessary. Pipeline data included detailed information about the infrastructure, including pipeline routing, pipe sizes, coating systems, age, cathodic protection (CP) systems, and electrical isolation points. Understanding the existing electrical continuity between pipelines and their associated facilities was critical for accurate interference modelling. Table 1 summarizes the pipelines included in the project.

Table 1
Pipeline Data Summary

Pipeline	NPS	Age	Coating System
1	12	9	Fusion bond epoxy
2	10	54	Extruded polyethylene
3	12	16	Fusion bond epoxy
4	8	16	Fusion bond epoxy
5	16	55	Coal tar
6	12	4	Fusion bond epoxy

Pipeline	NPS	Age	Coating System
7	24	4	HDPE
8	30	22	Fusion bond epoxy
9	30	16	Fusion bond epoxy
10	24	6	Fusion bond epoxy
11	12	20	Extruded polyethylene

There are a total of 42 valve sites and stations located along the pipelines under study in the project scope. Field technicians conducted station surveys, including soil resistivity measurements, assessment of electrical continuity between metallic structures, site grading and electrical grounding inspection. For the majority of facilities, the pipeline mainlines were found to be electrically isolated from facility piping and grounding.

Existing AC mitigation systems were identified at three locations along the pipelines and were included in the model. Mitigation effects of existing pipeline facility grounding was considered only for stations when grounding drawings were available or for large pipeline terminals, which are typically extensively grounded. The mitigation systems were based on available as-built drawings, alignment sheets, and survey data; conservative assumptions were made where required.

On the powerline side, the utility operator supplied electrical load data, fault current parameters, conductor configurations, and structure types for each powerline segment. This information included load currents and single line-to-ground fault currents along the length of the powerlines. Additionally, critical parameters such as phase conductor arrangements, typical tower designs, shield wire types, and grounding configurations were provided to facilitate detailed modelling of interference effects. Table 2 summarizes the powerline fault data used in the study.

Table 2
Powerline Fault Data Summary

Powerline	Line Voltage (kV)	Maximum Total Fault Current (kA)*	Fault Duration (ms)	Typical Structure Type	Typical Grounding Configuration	Shield Wire
1	144	5.1	400	Wishbone	1 x 3/4" x 12’ ground rod	1 x 5/16” steel
2	144	5.1	100	Wishbone	1 x 3/4" x 12’ ground rod	1 x 5/16” steel
3	240	21.8	100	H-Frame	2 x 3/4" x 10’ ground rods	2 x 5/16” steel
4	240	17.9	100	Steel Pole	1 x 12 m foundation	2 x 3/8” steel

* Single line-to-ground fault current contributions were provided for each powerline at 0%, 25%, 50%, 75%, and 100% of the powerline route.

Site surveys were conducted along the study area, where access was possible. Due to the remoteness of many locations, access by helicopter was required and some locations could not be accessed. These surveys gathered essential field data to support the interference modelling. Key activities included:

- Soil Resistivity Measurements: Using the Wenner 4-pin method, resistivity data was collected along pipeline routes to create models with appropriate stratification. Soil resistivity values ranged between 10 to 100 Ω·m.

- Electrical Continuity Checks and Grounding Assessments at Facilities: Field technicians inspected the electrical grounding at various pipeline facilities and valve stations, evaluating the condition and configuration of grounding systems. These assessments identified existing grounding connections that could mitigate AC interference or needed upgrades. Electrical continuity testing was also performed to verify the continuity between metallic structures, such as pipelines, valves, and grounding points.

The study's objective was to ensure that AC interference risks were minimized and that all facilities complied with applicable CSA(1), AMPP(2), and IEEE(3) standards under both steady-state and fault conditions. [2-7] This required the development of a mitigation system tailored to the unique requirements of each pipeline operator, balancing effective interference reduction with minimal environmental impact and project costs. The proposed solutions included grounding systems, gradient control grids, and DC decouplers to enhance the electrical continuity between pipeline facilities while maintaining isolation for CP systems, where required.

This study's findings and mitigation design offer valuable insights into managing AC interference hazards in complex, multi-operator energy corridors. It underscores the importance of thorough planning, close collaboration between stakeholders, and the use of advanced modelling tools to ensure the safe and efficient operation of collocated power and pipeline infrastructure.

RESULTS AND MITIGATION

The AC interference study identified 17 pipeline stations and valve sites along the project's ROW as being at risk under fault conditions. These stations exhibited touch, step, and metal-to-metal touch voltages exceeding safe limits as defined by IEEE Std 80. Without mitigation, these conditions could result in electrical shocks to personnel. Table 3 shows the facility fault results in unmitigated conditions. Soil resistivity measurements were only available for five of the facilities. For all other facilities a resistivity of 10 Ω·m was conservatively used to calculate the touch and step voltage limits.

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(2) Association for Materials Protection and Performance, 15835 Park Ten Place, Houston, TX 77084, USA.

(3) Institute of Electrical and Electronics Engineers, 3 Park Ave 17th Floor, New York, NY 10016, USA.

Table 3
Predicted Voltages at Facilities

Facility	Maximum Predicted Voltage (V)	Touch Voltage Limit (V)	Metal-to-Metal Voltage Limit (V)	Step Voltage Limit (V)
A	478	371	366	385
B	456	372	366	388
C	486	567	366	1189
D	615	372	366	388
E	697	372	366	388
F	598	372	366	388
G	1816	372	366	388
H	1340	372	366	388
I	830	372	366	388
J	1449	398	366	497
K	549	454	366	726
L	486	372	366	388
M	526	372	366	388
N	560	372	366	388
O	1292	372	366	388
P	596	372	366	388
Q	573	372	366	388

The primary mitigation measures included the installation of gradient control grids with ground rods. The gradient control grids consisted of interconnected bare copper conductors and grounds rods strategically configured around above-grade appurtenances, reducing touch and step voltages to protect personnel from electric shocks. Where feasible, existing grounding infrastructure was integrated into the mitigation design, reducing the need for additional grounding installations. This approach reduced construction efforts, lowered costs, and decreased environmental impact. To maintain the effectiveness of the CP systems while ensuring AC continuity, DC decouplers were installed at all locations. Different configurations were utilized including flange-mounted DC decouplers at isolation flanges and DC decoupler junction boxes for multi-pipeline connections to electrical ground.

Table 4 summarizes the mitigation provisions used in the models to reduce AC voltages within pipeline facilities. Figures 2 and 3 illustrate the touch and step voltages, respectively, for facility A after mitigation. Ensuring AC continuity at all facilities nullified the metal-to-metal touch hazards. Similar models were generated for all facilities to ensure the effectiveness of mitigation and compliance with safety standards.

Table 4
Mitigation Provisions Summary

Facility	Mitigation Description
A	New gradient control grid and ground rods
B	Connect to existing electrical grounding and ensure AC continuity
C	Connect to existing electrical grounding and ensure AC continuity
D	New gradient control grid and ground rods
E	New gradient control grid and ground rods
F	Connect to existing electrical grounding and ensure AC continuity
G	New gradient control grid and ground rods
H	New gradient control grid and ground rods
I	New gradient control grid and ground rods
J	New gradient control grid and ground rods
K	Connect to existing electrical grounding and ensure AC continuity
L	New gradient control grid and ground rods
M	New gradient control grid and ground rods
N	New gradient control grid and ground rods
O	New gradient control grid and ground rods
P	Connect to existing electrical grounding and ensure AC continuity
Q	Connect to existing electrical grounding and ensure AC continuity

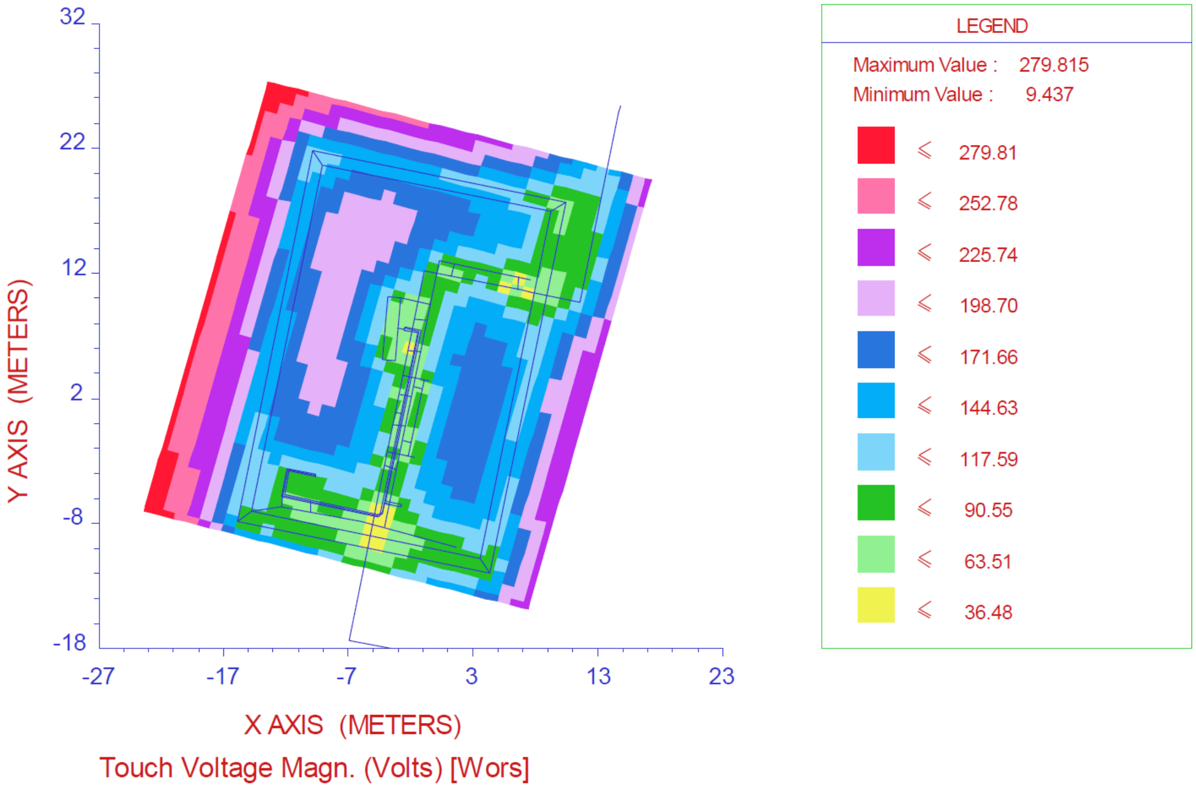

Figure 2: Station A Touch Voltages

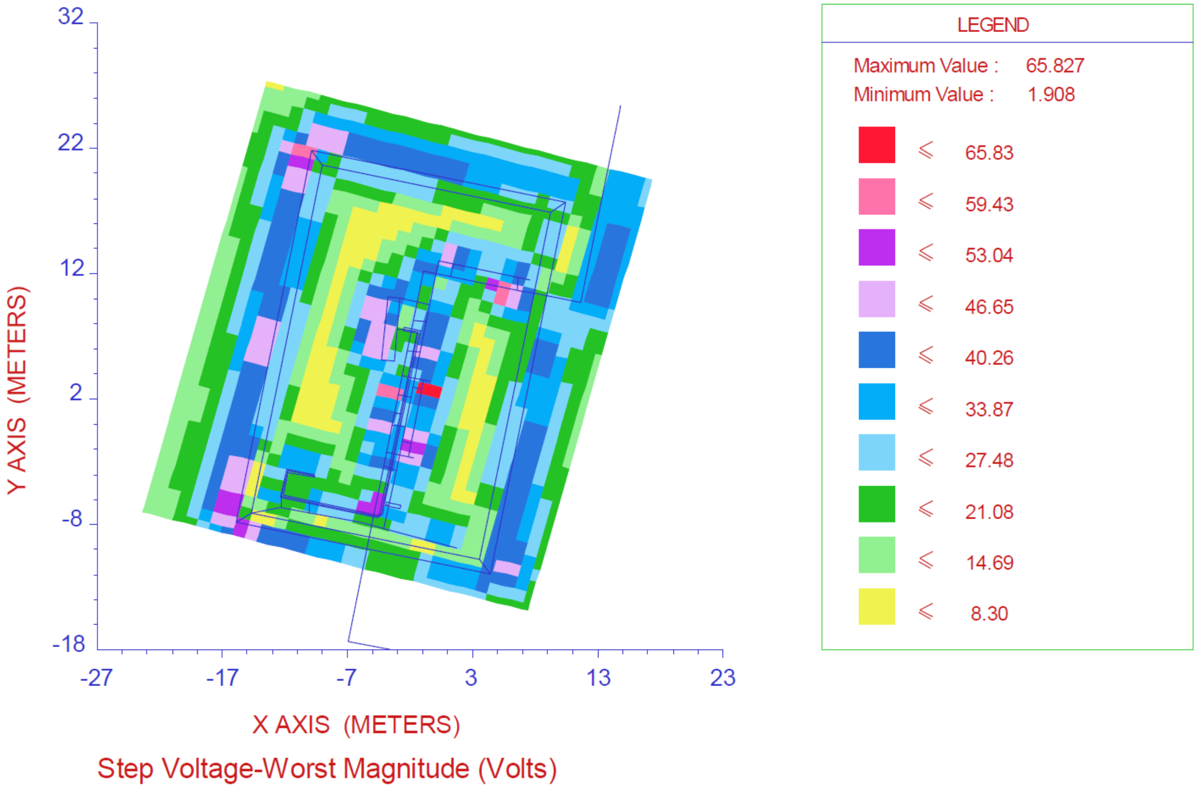

Figure 3: Station A Step Voltages

INSTALLATION CHALLENGES

Design Adjustments Due to Site Constraints:

During the project, several sites presented unforeseen congestion or extremely different access. These conditions necessitated modifications to the original design. For example, at one site, limited excavation access and material congestion required the relocation of mitigation wire to a nearby area with fewer obstacles. In another instance, contractor activities delayed hydrovac access, prompting a shift from underground to above-grade pipeline connections using pin braze methods. These adjustments were essential to maintain the project schedule and ensure efficient installation.

Electrical and Grounding Configuration Issues:

Integrating multiple grounding systems across sites presented a significant challenge. At one site, a grounding system for a pipeline was discovered during installation and it was not bonded to the adjacent fence grounding grid, which raised the risk of voltage gradients between the two. The solution involved bonding these systems together via connections through junction boxes, mitigating the potential for dangerous voltage differences and enhancing site safety.

Environmental and Access Limitations:

The project also encountered obstacles related to terrain, vegetation, and changing infrastructure ownership. Some planned installations became impractical due to dense foliage, requiring the relocation of junction boxes. In another case, the acquisition of a pipeline by a new operator led to the need for reconfiguration of connections and junction boxes. Addressing these issues promptly minimized disruptions to the project timeline.

Moisture Issues in Equipment Panels:

Moisture buildup in electrical mitigation panels was identified as a potential risk during routine inspections. The water intrusion was likely due to large, unsealed conduits in the panels. To prevent further moisture ingress and maintain system reliability, the project team recommended the installation of rainproof ventilation and the use of sealing compounds on conduits. These proactive measures ensured the longevity and functionality of the mitigation system.

Alternative Bonding Methods for Thin Structures:

Thermite welding, the standard bonding method, could not be used on certain structures due to their insufficient wall thickness. This limitation required the adoption of alternative bonding techniques. The use of band strapping provided a secure and effective solution, allowing the project to proceed without compromising the integrity of the connections. This adaptability highlighted the importance of having alternative methods available to address unforeseen structural constraints.

Limited Documentation:

Incomplete or outdated infrastructure documentation created additional challenges during installation. Some appurtenances were found to be missing entirely. In response, the project team removed unnecessary components and reconfigured connections at critical sites to avoid wasted effort and reduce costs. Notable changes to the AC mitigation design were remodelled to confirm the effectiveness of the revised design and to avoid any unintended impacts to other locations along the pipeline. This approach underscored the need for ongoing documentation reviews throughout project execution.

LESSONS LEARNED

Importance of Early Field Surveys and Site Validation:

The discovery of missing infrastructure and unforeseen site conditions reinforced the importance of conducting comprehensive field surveys before construction begins. Validating site conditions early allows teams to adjust designs proactively, preventing delays and disruptions during the execution phase.

Flexibility in Design and Installation Approaches:

Adapting to changing site conditions required a flexible approach to both design and installation. Many of the adjustments, such as shifting from underground to above-grade installations or relocating infrastructure, were facilitated through a Request-for-Information (RFI) process. Future projects could benefit from incorporating more flexibility directly into the initial designs. For example, allowing for variability in connection types and cable routing, where such changes are not expected to impact the effectiveness of the mitigation, would reduce the need for RFIs. This proactive approach could streamline project execution, minimize delays, and provide installation teams with the ability to address unforeseen challenges more efficiently.

Streamlined Scope Management and Cost Control:

Regular evaluations of the project scope ensured that redundant installations were eliminated and unnecessary costs were avoided. At one site it was discovered that fencing requiring a grounding loop was relocated further away from pipe appurtenances, so the design was adjusted to remove the extra mitigation wire after being confirmed by the design team that it was not needed. Adjusting the scope based on site conditions helped balance cost control with performance requirements, keeping the project within budget while meeting operational goals.

Collaboration and Communication among Stakeholders:

Clear and timely communication between project stakeholders, including installation teams, design teams, and project management teams, played a vital role in resolving challenges efficiently. The structured use of RFIs facilitated collaborative problem-solving, ensuring that all parties remained aligned throughout the project and that issues were addressed with minimal impact on the schedule.

CONCLUSIONS

This study demonstrates the importance of proactive management of AC interference risks in pipeline facilities, particularly in environments with shared ROW between pipelines and HVAC powerlines. Through detailed modeling and targeted mitigation efforts, the project successfully reduced touch, step, and metal-to-metal voltages at 17 at-risk facilities, ensuring compliance with safety standards. The use of gradient control grids, grounding systems, and DC decouplers enhanced the safety and operational efficiency of these facilities, preventing electrical hazards.

A key takeaway from the project was the need for flexibility in both design and installation to respond to unforeseen site conditions, such as limited access, environmental constraints, and infrastructure changes. The ability to relocate infrastructure, implement alternative bonding methods, and streamline project scope played a crucial role in maintaining the project schedule and budget. Additionally, the integration of existing grounding systems where feasible helped reduce the environmental footprint and construction costs.

The lessons learned highlight the value of thorough field surveys, early validation of site conditions, and continuous documentation review to anticipate and mitigate challenges. Effective collaboration among stakeholders ensured that decisions were made efficiently and with minimal disruption to the project timeline.

In conclusion, this case study underscores the significance of optimized AC interference mitigation strategies. The combination of advanced modeling tools, practical installation solutions, and strong inter-organizational communication are critical for AC mitigation projects, ensuring safety, cost-effectiveness, and operational resilience. As energy infrastructure continues to expand and integrate, these strategies will be critical to managing interference risks while supporting sustainable and efficient energy delivery.

REFERENCES

1. *CP Interference Course Manual*, (Houston, TX: NACE, 2006).

2. CSA C22.3 No. 6-13 (2022), “Principles and practices of electrical coordination between pipelines and electric supply lines” (Toronto, ON: CSA).

3. CSA Z662 (2023), “Oil and gas pipeline systems” (Toronto, ON: CSA).

4. IEEE Std 80 (2013), “IEEE Guide for Safety in AC Substation Grounding” (New York, NY: IEEE).

5. IEEE Std 2746 (2020), “IEEE Guide for Evaluating AC Interference on Linear Facilities Co-Located Near Transmission Lines” (New York, NY: IEEE).

6. NACE SP0177 (2019), “Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control Systems” (Houston, TX: NACE).

7. NACE SP21424 (2020), “Alternating Current Corrosion on Cathodically Protected Pipelines: Risk Assessment, Mitigation, and Monitoring” (Houston, TX: NACE).

8. A. Akhtar and M. Hynter, “Damage of a gas pipeline resulting from a high impedance fault on a 25 kV AC distribution powerline,” Materials Performance, Aug. 1985, pp. 21-22.

9. CEA Report 239 T817 (1994), “Powerline ground fault effects on pipelines” (Montreal, Canada: CEA).