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Challenges in Mitigating Ac Interference in Remote Areas

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ABSTRACT

An AC interference study was conducted in 2015 following the installation of a new 240 kV powerline in a remote area of Alberta, Canada.

The calculations indicated severe risk of AC corrosion for the paralleling pipelines and safety hazards for pipeline personnel, especially under fault conditions.

A mitigation system was designed, consisting of more than 10 km of bare copper mitigation wire; however due to site conditions (i.e. winter access only) it was impossible to install the system prior to powerline energization.

This paper describes both the challenges and the solutions in this project, including the design and optimization of a temporary mitigation system allowing energization of the powerline at reduced power.

Keywords: AC mitigation, AC corrosion, powerline load currents, mitigation wire, mitigation rods, existing test station, access by helicopter

INTRODUCTION

An AC Interference Study was initiated in December 2014 to evaluate the negative effects on seven existing pipelines in northern Alberta due to the construction of a new 240 kV powerline. The pipeline system consisted of two mainlines, and five laterals connected to these mainlines. The area of co-location extended for a length of approximately 70 km, at a typical separation distance of 75 m.

The study results issued in February 2015 indicated that unmitigated AC induced voltages under steady-state conditions were above the 15 volts' safety limits for nearly the entire co-location. The unmitigated AC current densities were well above the 50 A/m^2 design criteria, with values as high as 972 A/m^2.

The unmitigated touch voltages under fault conditions were also well above the safety limits, with values up to 5290 V. Slightly lower values (i.e., up to 3033 V) were predicted on the pipelines laterals.

An extensive mitigation system was subsequently designed, consisting of more than 10 km of bare copper conductor distributed across 10 sites. Over 100 regular test stations required conversion to dead-front configuration. Gradient control grids and/or surface stone were specified at affected valves, metering, and compressor stations. AC bonding was required at affected stations to eliminate hazardous metal-to-metal touch potentials. Where necessary, a fence grounding loop was installed and bonded to the pipeline through DC decoupler.

AC MITIGATION INSTALLATION CHALLENGES

The powerline energization was planned for June 2015.

With the time constraints (i.e., five months), the installation of the AC mitigation system required for this project appeared impossible to achieve, since any ground disturbance requires environmental inspections and applications. In addition, the wetland and environmental conditions made access with heavy vehicles extremely difficult.

The environmental inspection was conducted on May 2015, and the results from the field indicated that all ten sites (Sites 1 - 10) for mitigation work appeared to have winter access only due to ground conditions and muskeg areas. Additional information from the company's operations staff indicated that site access may be feasible in August 2015 for some areas, but the majority of the areas would only be accessible starting from January 2016. Even sites with high-grade roads were in poor condition needing mats in place for vehicles to transport equipment. Other limitations included the migratory bird window and caribou protection period.

Leaving the pipelines without mitigation with an active power line until the winter access season in 2016 was not considered a viable solution, primarily due to the risk of a pipeline leak or rupture due to AC corrosion at AC current densities of almost 1000 A/m^2. As noted in numerous investigations into AC corrosion, current densities in excess of 1000 A/m^2 pose a significant corrosion risk[1]. Even if no leak or rupture occurred, the pipeline integrity after this interval without mitigation would have to be validated using digs or other methods.

PROPOSED INTERIM SOLUTION

The system was remodelled for various powerline loadings, to determine the maximum admissible loading level, assuming no mitigation was installed along the pipelines. The results indicated that even at 5% of the projected maximum loading, AC current densities over 150 A/m^2 are expected. Subsequently, even at this minimal loading, some degree of mitigation would be required to address AC corrosion concerns.

A meeting was held with the powerline utility in order find the best solutions to avoid safety and integrity risks to the pipeline. During the meeting, it was explained that postponing the energization of the powerline was not a viable option. However, it was clarified that the initial loading of the powerline may range from 7% to 11% of the forecasted maximum loading.

At this loading, temporary mitigation measures were required, in order to protect the pipeline systems for the period of time between powerline energization and installation of the permanent mitigation system.

The proposed solution was the installation of numerous interconnected copper ground rods at specific locations to mitigate the electrical safety and AC corrosion risks to acceptable levels. These ground rods would be connected to the pipelines via DC decouplers, and would be recovered during installation of the permanent mitigation system. The system also had the added benefits of being transportable via helicopter/ATV, and could be installed with minimal environmental disturbance, resolving the site access and environmental difficulties.

Additional safety risks under powerline fault conditions would be mitigated through the use of dead-front test heads, and the use of lock-out bags, where dead-front conversion was not practical. The use of dead-front equipment would be in compliance with applicable regulatory associations.[2]

The use of lock-out bags has been observed in lock-out-tag-out procedures, commonly used in electrical maintenance and servicing work. The bags are typically made of rugged canvas or other heavy material, and were placed over the affected test posts, so as to render them inaccessible until appropriate mitigation measures were in place.

At above-grade valves and assemblies, washed rock would be installed to increase ground surface resistivity, and DC decouplers would be installed to mitigate metal-to-metal touch voltage hazards across insulating kits at flanges.[3] At locations where the installation of these provisions was not practical, high voltage personal protective equipment (PPE) would be provided in mounted boxes on-site.

Remote monitoring equipment would be installed at strategic test points, to monitor AC and DC potentials to ensure that the temporary system would be working effectively.

NEW AC MITIGATION MODEL

With this design philosophy, a new scenario was explored based on the initial powerline loading, and a new model was conceptualized. A new study was completed, and a “temporary” mitigation system was designed. The modelling and design was completed using specialized electromagnetic interference modelling software.

Prior to any mitigation, the predicted pipeline AC voltages under steady-state conditions were above the 15 V safety limit, reaching a maximum value of 25.1 V_{AC}. The modeled voltage profile is given in Figure 1.

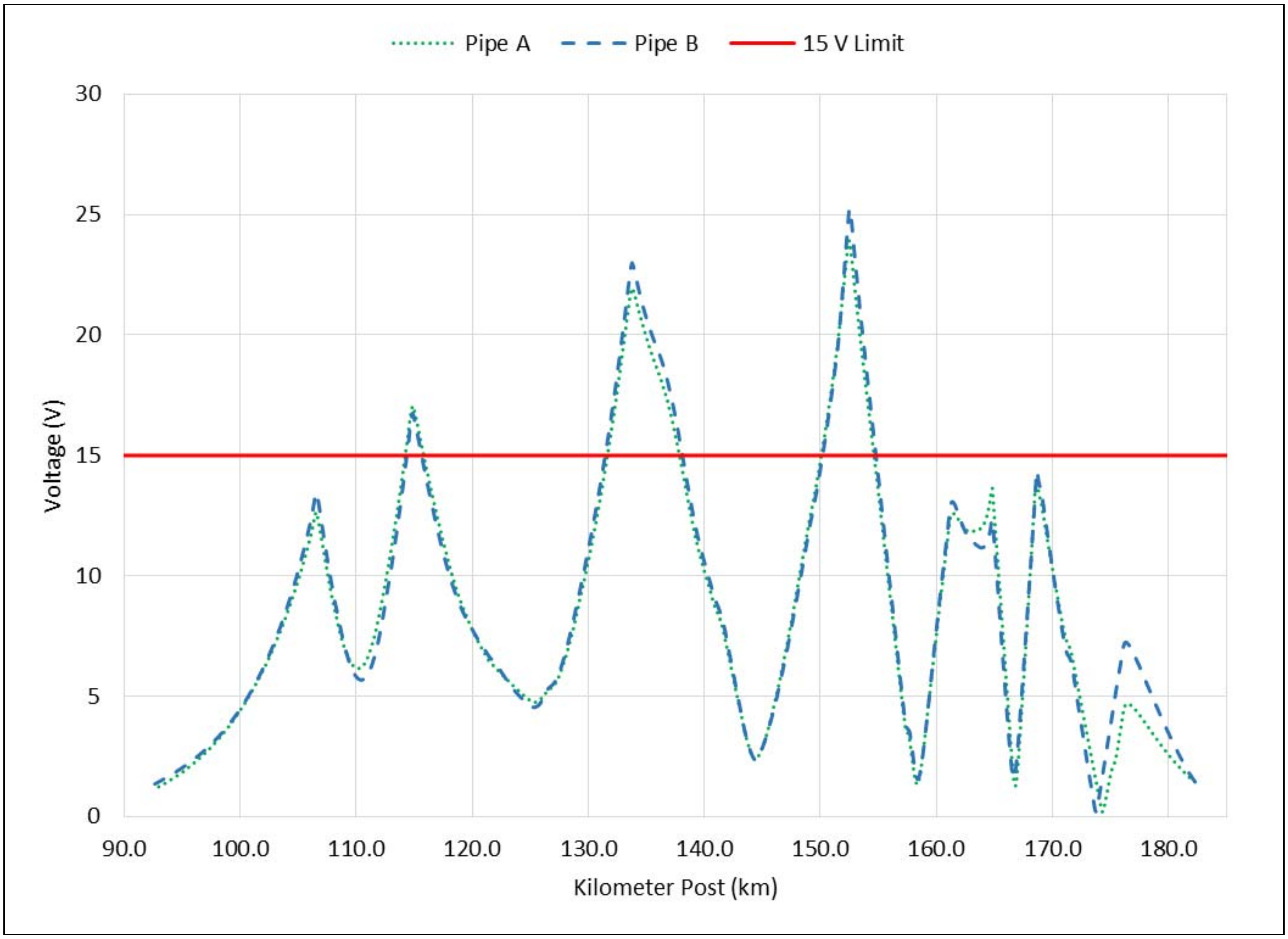

Figure 1: AC Voltages under Initial Loading Conditions – Before Mitigation

Using the soil resistivities measured along the pipeline right-of-way, the corresponding AC current densities were above the recommended 50 A/m^2 design criteria, reaching a maximum value of 301 A/m^2. The modeled current density profile is given in Figure 2.

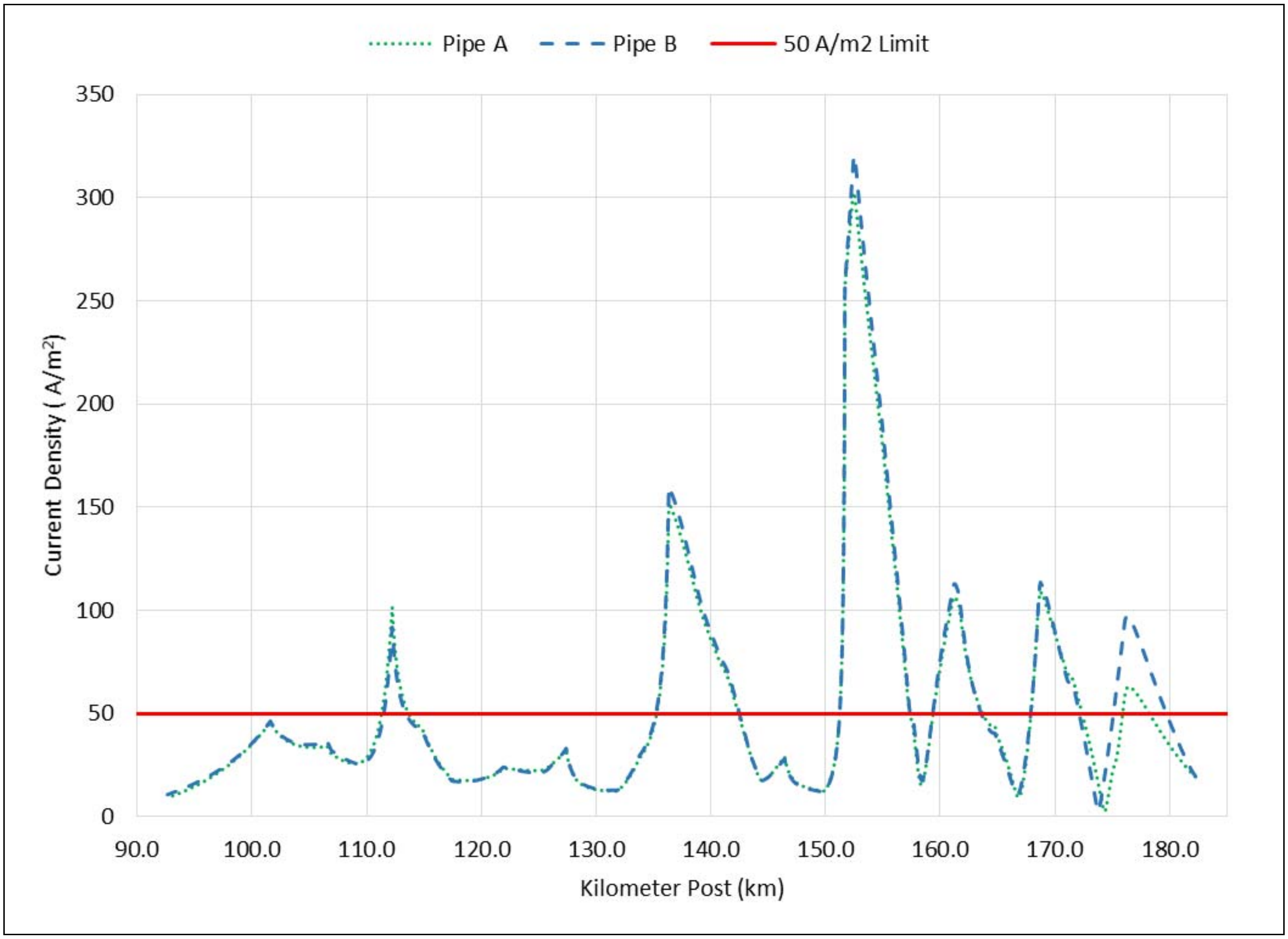

Figure 2: AC Current Densities under Initial Loading Conditions – Before Mitigation

Additionally, under powerline fault conditions, the predicted touch voltages along the pipelines greatly exceeded the safety limit for test posts, valves, and other appurtenances at fenced facilities. Voltages up to 5290 V_{AC} were calculated, which exceed the 402 V_{AC} and 1793 V_{AC} limits (safety limit without, and with a gravel layer, respectively). A sample of the pipeline voltage profiles under fault conditions are given in
Figure 3. The location and corresponding safety limit at fenced facilities are also marked for reference.

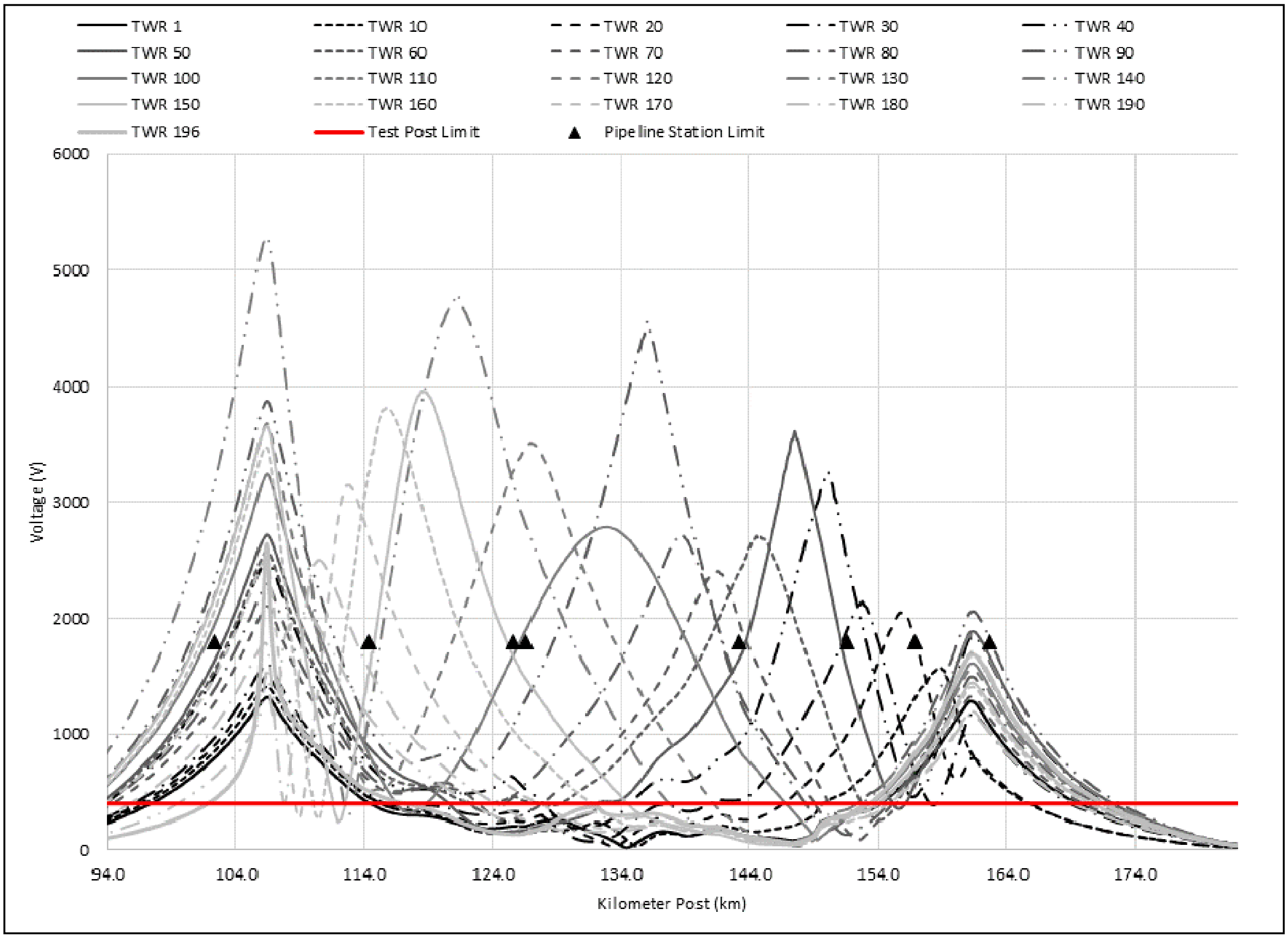

Figure 3: AC Voltages under Powerline Fault Conditions – Before Mitigation

To reduce these elevated AC voltages, a mitigation system, consisting of a total of 560 ground rods, was designed. These ground rods would be interconnected in groups of 60 to 100, across nine locations, typically coinciding with the modeled AC voltage peaks, and were designed to provide a target grounding resistance ranging from approximately 0.2 Ohm to 0.8 Ohm. Remote monitoring units would be included to monitor AC current to the ground rods, as well as AC and DC potentials.

After installation of the ground rods, the predicted pipeline AC voltages under steady-state conditions were below the 15 V safety limit, reaching a maximum value of 12.7 V_{AC}. The modeled voltage profile is given in Figure 4.

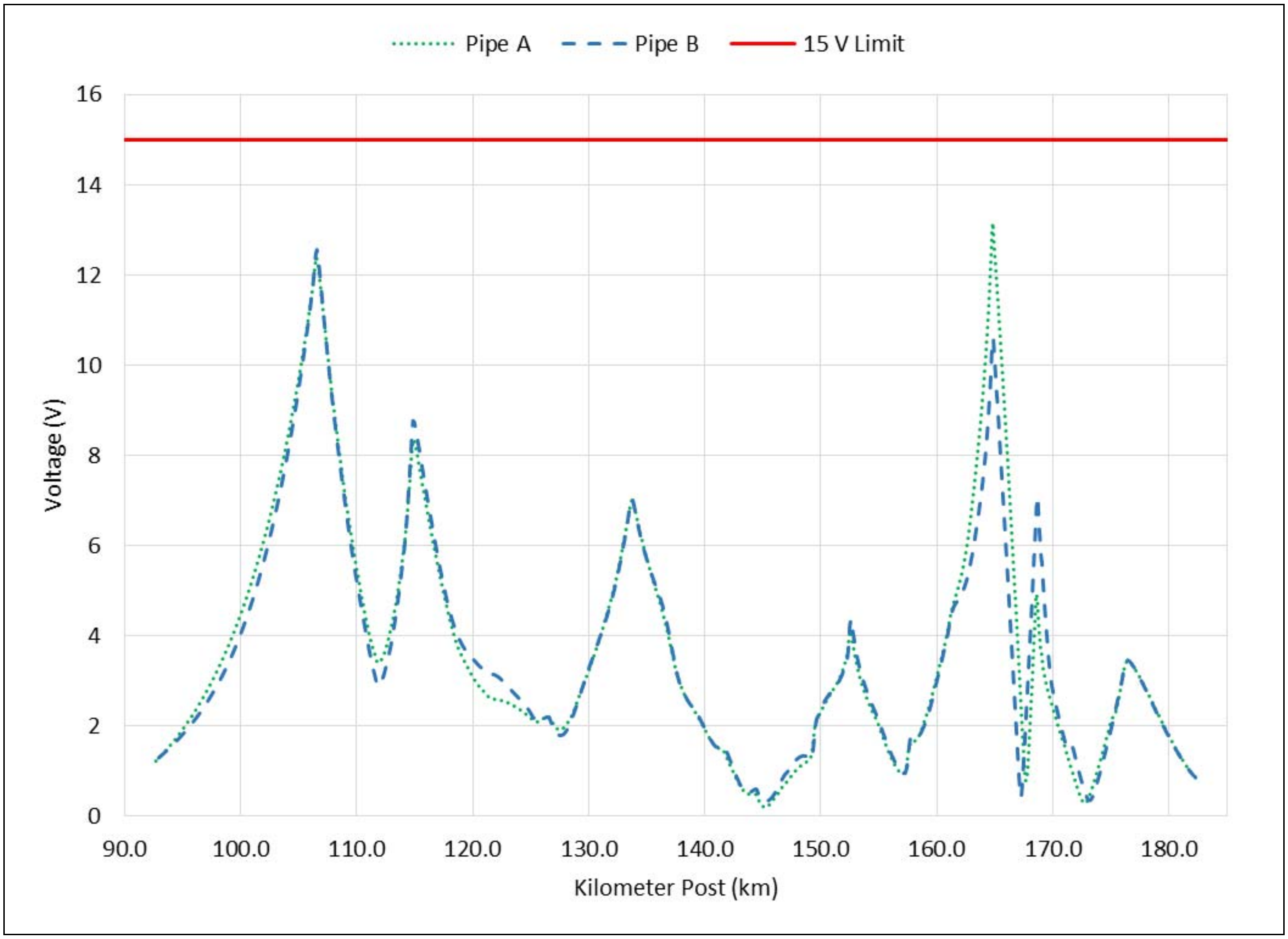

Figure 4: AC Voltages under Initial Loading Conditions – After Mitigation

The calculated AC current densities were above the recommended 50 A/m^2 threshold, at two locations, but remained mostly below 50 A/m^2. The maximum AC current density was calculated to be 55 A/m^2. The modeled current density profile is given in Figure 5.

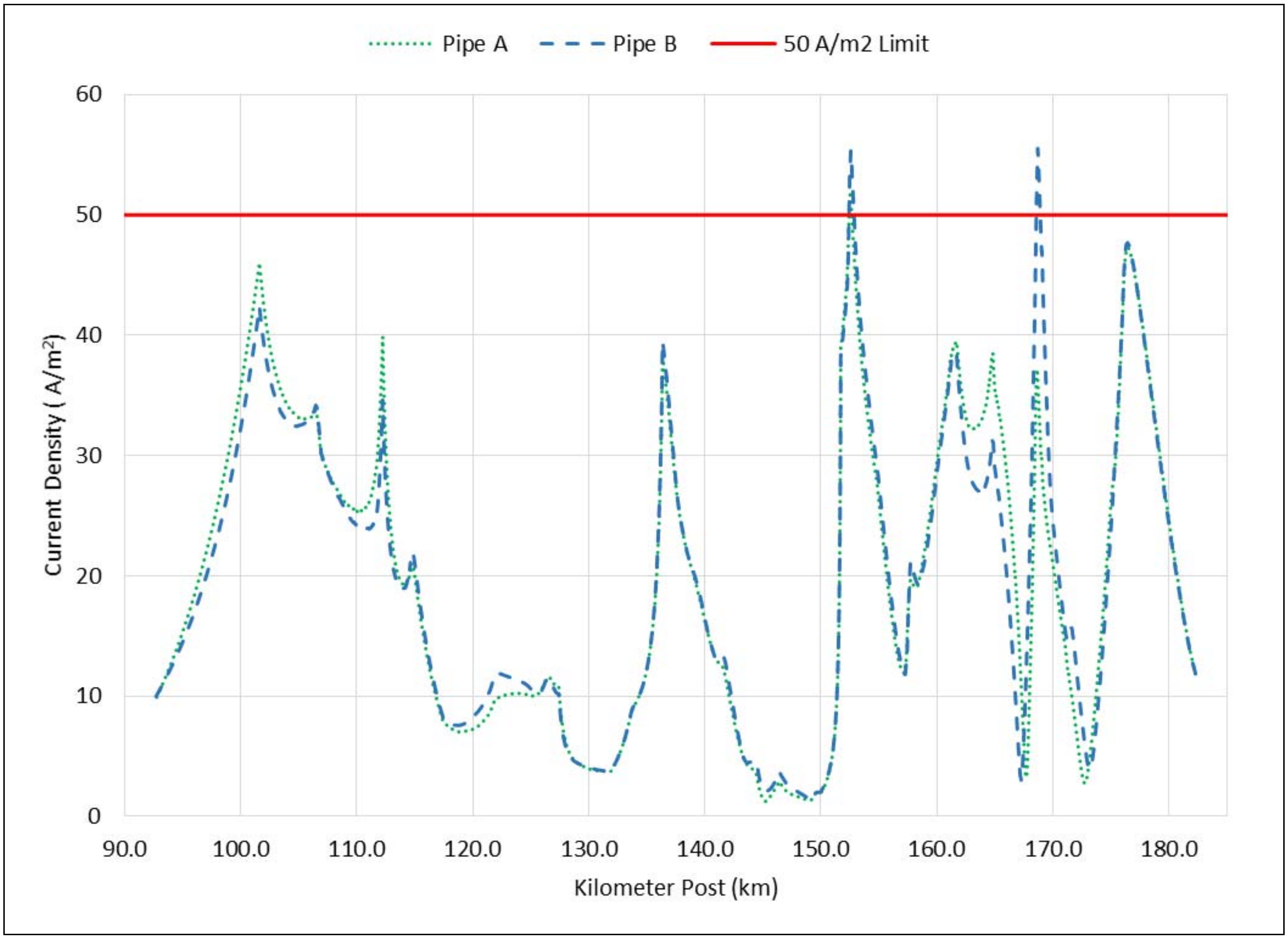

Figure 5: AC Current Densities under Initial Loading Conditions – After Mitigation

Under powerline fault conditions, the predicted touch voltages along the pipelines still exceeded the safety limit for test posts, valves, and other appurtenances at fenced facilities. Voltages up to 3895 V_{AC} were calculated, which exceed the 402 V_{AC} and 1793 V_{AC} safety limits. A sample of the pipeline voltage profiles under fault are given in Figure 6.

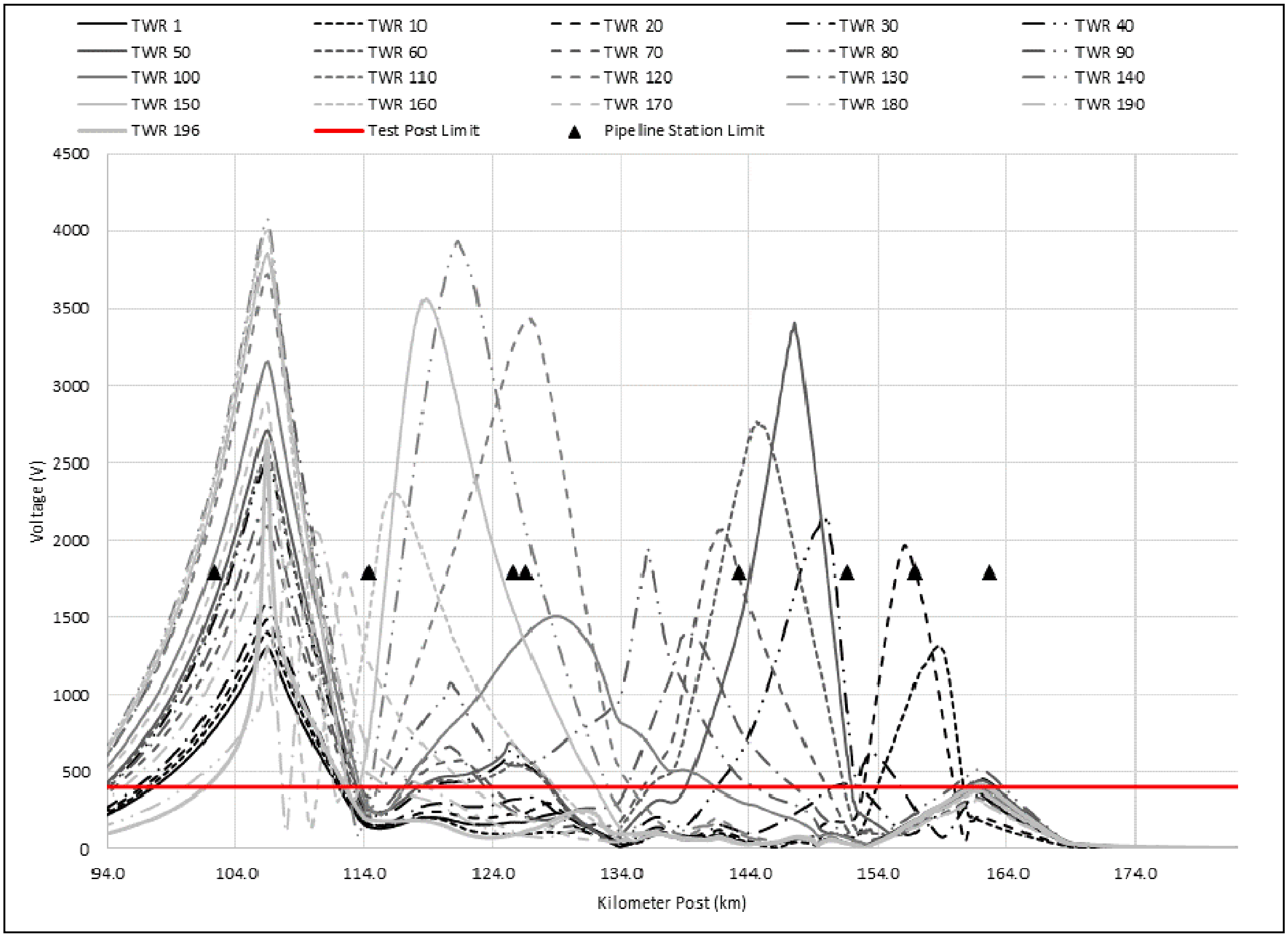

Figure 6: AC Voltages under Powerline Fault Conditions – After Mitigation

The remaining safety concerns under fault conditions were addressed by using 100 dead-front test heads, installing a 150 mm layer of washed rock at three station facilities, and installing seven DC decouplers to mitigate metal-to-metal touch voltages. As specified in the design philosophy, lock-out provisions were specified where conversion to dead-front test heads was impractical and high voltage PPE were to be provided in mounted boxes on-site.

The calculated coating stress voltages approached the upper limit of the 3-5 kV limit specified by applicable standards.[4] However, it should be noted that these limits have been found to be conservative for short-duration faults.[5]

Remote monitoring equipment was selected to be installed at twenty existing test post locations, to monitor AC and DC potentials to ensure that the temporary system would be working effectively.

RESULTS

The designed system was installed during the summer of 2015. AC pipeline potentials at each ground rod installation site were recorded, prior and after installation. AC currents and DC potentials were recorded after installations.

A sampling of the collected data is given below in Table 1.

Table 1 Field Data at Ground Rod Installation Locations

Ground Rod Installation Location	Pipe V_{AC}, Before	Pipe V_{AC}, After	AC Current Density at Coupon	AC Current to Ground Rods	Coupon V_{DC}, ON	Coupon V_{DC}, OFF
	[V_{AC}]	[V_{AC}]	[A/m^2]	[A_{AC}]	[V_{CSE}]	[V_{CSE}]
Location 1	2.9	1.0	6.8	1.80	-1.474	-1.193
Location 2	3.3	0.6	5.9	1.72	-1.217	-1.029
Location 4	4.6	0.9	3.6	1.41	-1.447	-1.185
Location 5	1.1	0.1	1.9	5.65	-1.605	-1.239
Location 6	6.5	1.0	4.4	2.50	-1.311	-1.121
Location 8	3.6	0.4	0.8	2.25	-1.371	-0.754
Location 9	3.6	0.7	0.8	2.96	-1.423	-1.068

At the locations shown, the installation of the ground rods contributed to an approximate AC voltage reduction of 65% to 88%. The measured AC voltages were significantly below the 15 V_{AC} safety limit, and the calculated AC current densities were also significantly below the 50 A/m^2 threshold. The majority of DC pipe-to-soil potentials were also at acceptable levels, indicating that the copper ground rods are properly DC-isolated from the pipeline.

The “temporary” mitigation system remained in place until the installation of the “permanent” mitigation system. The installation of the “permanent” mitigation system was completed during the winter of 2016, and was accompanied with the removal of all 560 ground rods, and lock-out bags at test posts.

CONCLUSIONS

Given the timeline, site access, and environmental constraints, the proposed “temporary” mitigation system was an effective method to mitigate severe AC interference in accordance with the safety and regulatory requirements set forth by the applicable standards associations. The data collected after the installation suggests that the system was successful in meeting these design criteria.

For future projects with similar conditions or constraints, this method may be considered as a viable option to mitigate personnel safety and pipeline integrity risks, for a short-term duration.

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