THOMAS B. GETZ
Direct Dial: 603.230.4403
Email: thomas.getz@mclane.com
Admitted in NH
11 South Main Street, Suite 500
Concord, NH 03301
T 603.226.0400
F 603.230.4448

McLANE MIDDLETON

June 30, 2017

Via Electronic Mail

Pamela Monroe, Administrator
New Hampshire Site Evaluation Committee
21 South Fruit Street, Suite 10
Concord, NH 03301-2429

**Re: Site Evaluation Committee Docket No. 2015-06
Joint Application of Northern Pass Transmission LLC and Public Service Company of New Hampshire d/b/a Eversource Energy (the "Applicants") for a Certificate of Site and Facility – Preliminary Interference Assessment a.k.a. Co-Location Study
Applicants' Exhibit 179**

Dear Ms. Monroe:

Enclosed for filing in the above-captioned docket as Exhibit 179, please find the Applicants' preliminary high-level AC, HVDC, and DC interference assessment for the Northern Pass Transmission Project and the Portland Natural Gas Transmission System ("PNGTS) pipeline, which the Applicants also referred to as the Co-Location Study. *See* Applicants' Objection to Motion to Compel Co-Location Study (June 26, 2017). As described therein, this submission is a preliminary assessment based on conservative assumptions, which is designed to identify interference topics that may need further assessment. The Applicant and its contractors will conduct a more detailed analysis of the potential interference issues closer to when the Issued for Construction ("IFC") drawings are completed, which is standard practice throughout the industry.

The report completes a preliminary assessment for three scenarios, which represent the worst case conditions, and do not take into account existing mitigation grounding systems that may be already installed on the pipeline. This Assessment is a starting point for future discussions with PNGTS and for conducting additional detailed assessments, including field measurements, after IFC drawings are issued. If pipeline integrity or personnel safety risks are indicated as a possibility by the detailed interference analysis, well-understood mitigation techniques are available.

During future discussions with PNGTS, the Applicants will review and assess all existing equipment on the pipeline and determine what, if any, additional equipment may be needed. All of the potential scenarios discussed in the preliminary assessment will be addressed prior to commencing construction. To the extent additional mitigation equipment is necessary, the Applicant will ensure that PNGTS properly installs all such equipment prior to completing construction on the Project.

Please contact me directly should you have any questions.

Sincerely,

Thomas B. Getz

TBG:amd

cc: SEC Distribution List

Enclosure

corrpro® an AEGION company

June 29th, 2017

Corrpro Canada, Inc.
Suite 103, 221 – 18th Street SE
Calgary, AB, T2E 6J5
Tel 403-235-6400
Fax 403-272-9508
www.corrpro.ca

Burns & McDonnell
9400 Ward Parkway
Kansas City, Missouri 64114

ATTENTION: Derrick Bradstreet, P.E.

RE: BURNS AND MCDONNELL – NORTHERN PASS HVDC PROJECT PRELIMINARY INTERFERENCE ASSESSMENT

Corrpro Canada, Inc. (CCI) has conducted a preliminary AC, HVDC, and DC interference assessment of the possible effects from the proposed Northern Pass HVDC transmission line, and relocation of the existing O154 115 kV AC transmission line on the Portland Natural Gas Transmission System (PNGTS) pipeline.

The purpose of this initial assessment is to identify interference topics that may need further assessment by working closely with the pipeline owner PNGTS. This project has always planned on an additional, more detailed analysis closer to the Issued for Construction (IFC) stage of the Northern Pass HVDC Project. It is worth mentioning that this approach is a standard practice on high-voltage transmission lines throughout the industry.

BACKGROUND

The proposed Northern Pass HVDC transmission line, and relocated O154 115 kV AC transmission line parallel an existing Portland Natural Gas Transmission System (PNGTS) pipeline in northern New Hampshire for about 12 miles. There are multiple instances of crossings between these power lines and subject pipeline throughout the study area, as shown in Figure 1 through Figure 3.

Figure 1: Northern Pass HVDC – Crossing Area No. 1 (Source: Burns & McDonnell)

APP63352

Figure 2: Northern Pass HVDC – Crossing Area No. 2 (Source: Burns & McDonnell)

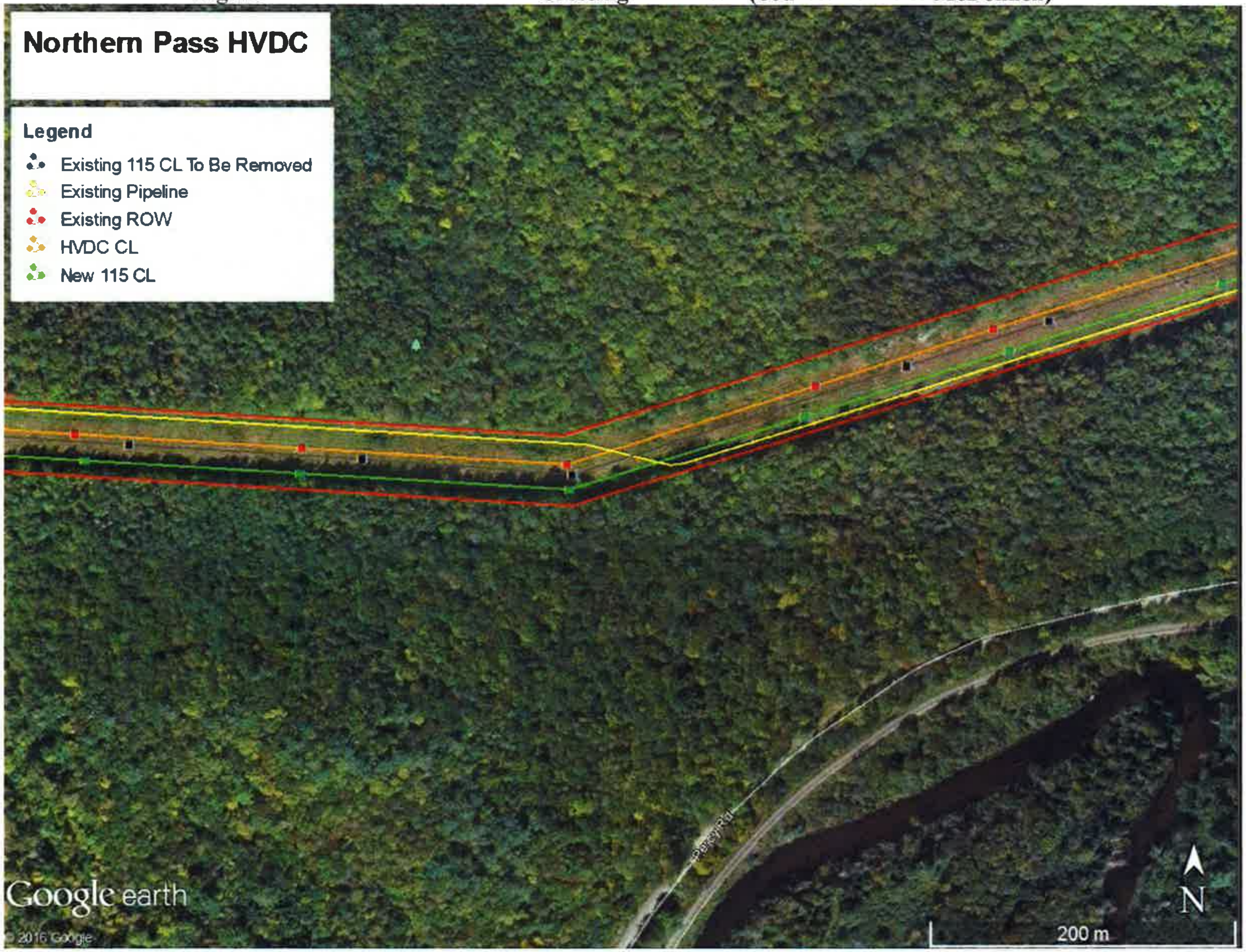
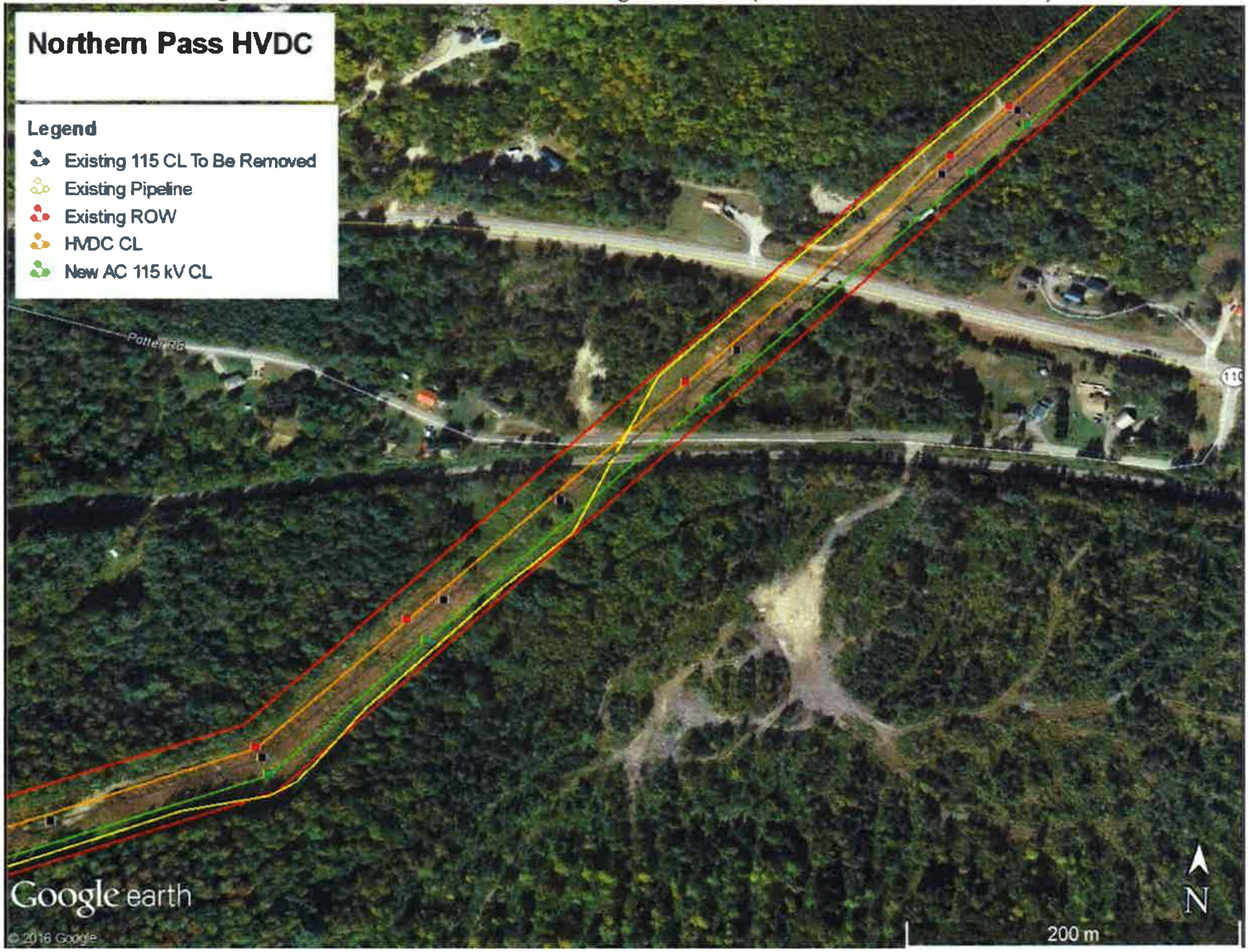


Figure 3: Northern Pass HVDC – Crossing Area No. 3 (Source: Burns & McDonnell)



APP63354

This high-level preliminary assessment is divided into three different scenarios:

- Scenario #1: AC Interference – Steady State and Faults

  In this scenario, the potential impact of steady state inductive potentials, and fault state total interference touch potentials and integrity effects, were evaluated. Since PNGTS pipeline was constructed in an existing AC corridor, a comparison between potential effects introduced by existing and relocated O154 115-kV AC transmission line was the main objective in this scenario. Please note that existing AC mitigation grounding system was not considered in this preliminary assessment.

- Scenario #2: HVDC Interference – Faults

  This scenario examines the potential effects of fault state total interference touch potentials and integrity risks on PNGTS pipeline from the proposed Northern Pass HVDC transmission line.

- Scenario #3: HVDC Interference – Steady State

  In this scenario, the potential effects associated with stray current interference during steady state operation of the proposed Northern Pass HVDC transmission line was introduced and evaluated.

Power transmission lines can couple in three ways to parallel conductors (i.e. pipelines, railways, etc.): through mutual capacitance, mutual inductance, and through direct conduction.

Capacitive Coupling: Capacitive coupling results when the electric field of the power line interacts with a parallel conductor that is not grounded. This is most commonly encountered during the construction phase of a pipeline near overhead transmission lines or on ungrounded (isolated) above grade piping near overhead transmission lines.

Inductive Coupling: Inductive coupling occurs when a parallel conductor is influenced by the alternating magnetic fields set up by the transmission of alternating currents (AC). In three phase systems, each phase current, and therefore each magnetic field, is out of phase by 120° from its neighbor. This tends to have some cancellation effects on the coupling of parallel conductors. The phase conductors, however, are not typically equidistant from a buried pipeline, so there is always a resultant net induction. The magnitude of this effect increases if one phase carries more current than the other two, or if the currents are not exactly 120° out of phase from one another. This is called imbalance. For induction to cause high voltages on an underground pipeline, generally, the pipeline coating should provide reasonable electrical isolation from the soil. The pipeline also should be relatively close to the phase conductors or parallel them for a considerable distance. Induced potentials can be generated on parallel pipelines when a single phase to ground (SLG) fault occurs at a power line structure. This induced potential is a result of unbalanced current flow on the power line and circulating currents in the shield wire.

Conductive Coupling: When a single phase to ground (SLG) fault occurs at a power line structure, the fault current injected into the soil by the transmission tower increases the local soil potential. If there is no induction, the pipeline remains at a relatively low potential due to its coating resistance. As a result, the local soils around the pipeline will be at relatively high potentials with respect to the pipeline steel potential. The magnitude of the conductive interference decreases with increasing distance away from the faulted power line structure. With a high enough discharge current, and a close enough proximity to nearby pipelines, there is a potential for soil path arcing to the pipeline wall.

Soil Path Arcing: Soil path arcing occurs when the fault state voltage difference between an energized transmission structure ground and an adjacent pipeline is large enough to ionize the soil between the two objects and cause an electrical arc. The risk of an arc to a pipeline occurs where fault current enters the earth, typically at energized supporting structure's designed grounding system.

One method for determining the safe separation distance between an energized grounded structure and a pipeline, is presented by Sunde[1]. The Sunde equation shown below is based on the soil resistivity at pipe depth being more than 1000 Ω-m, and relates to arcing due to lightning. Therefore, the current variable in the equation relates to the lightning current injected into the earth at a tower footing during a lightning strike. As a worst case, one could conservatively consider a lightning current of 100 kA. Please note that the assumed lightning current of 100 kA is a very conservative assumption, and the calculated arcing distance should be confirmed during a detailed interference analysis using measured soil resistivity values.

$$Sustainable\ Arc\ Distance\ (m) = (0.047)\sqrt{(I_f)(\rho)}$$

Equation B-1: Arc Distance (ρ > 1000 Ohm-m)

Where:
I_f = maximum injected tower footing current (kA)
ρ = soil resistivity (Ohm-m)

DISCUSSION

Scenario #1: AC Interference – Steady State and Faults

During power line steady state operation, there can be a risk to human safety from induced AC potentials on pipelines exceeding 15 V_{AC}[2] which is an industry standard limit. The main risk is at above-grade pipeline appurtenances (including, but not limited to, stations, block valves, and test posts), however normally inaccessible sections of pipe (i.e. buried) may pose a concern if the pipeline is excavated for maintenance work.

As with steady-state induction, high currents flowing in the phase wires and shield wires due to faults can induce high voltages on parallel pipelines. Further, this voltage can combine with the local soil Ground Potential Rise (GPR) from currents flowing in the earth next to the pipeline to produce what is referred to as the total interference voltage. This total interference voltage can cause step and touch voltage concerns for facilities along the length of the pipeline(s). The definition and magnitude of acceptable touch and step

[1] E.D. Sunde, "*Earth Conduction Effects in Transmission Systems,*" New York: Dover Publications, 1968.
[2] Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control Systems, NACE International Standard Practice SP0177-2014.

potentials are defined by IEEE Standard 80 2013[3].

A preliminary AC steady state and fault analysis based on provided information and conservative assumptions, indicates some potential safety concerns at above grade sites throughout the study area. It is worth mentioning that these inferences are based on worst case scenario assumptions and assumed coating quality and soil resistivity values, which require further evaluation through a detailed AC interference analysis. While it is likely that existing mitigation measures may be in place, please note that an existing AC mitigation grounding system was not considered in this preliminary assessment. Given that this pipeline is located in an existing AC transmission line right of way, it is possible that there is mitigation already installed at above ground appurtenances. These appurtenances and the mitigation details from the initial pipeline construction should be reviewed and evaluated during a detailed interference analysis.

For well insulated pipelines, a potential difference exists across the coating of the pipeline from the difference in local soil ground potential rise (GPR) and the pipe metal potential. This potential difference is defined as the coating stress voltage, and could become hazardous to the coating integrity at values over 3,000 V_{ACRMS} for fusion bond epoxy (FBE) and polyethylene (PE) coatings according to NACE International Standard Practice SP0177-2014[2].

The results from a preliminary analysis conducted based on provided data and conservative assumptions show minimal coating stress risks to PNGTS pipelines throughout the area of influence. Please note that these high-level findings are based on assumed coating quality and soil resistivity values, which play a significant role in determining coating stress voltages. It is strongly recommended that field measurements followed by a detailed AC interference study be conducted, to better evaluate the associated risks.

The safe separation distance from a lightning arc can be calculated using the Sunde[1] equation as shown below. Elevated risk of soil arcing may exist if the separation distance between a pipeline and the closest location of the structures effective grounding system is less than this calculated distance. The following assumptions were made for the calculation:

1. Maximum injected tower footing current, I_f (kA)
   A lightning current of **100 kA** was assumed as the maximum injected tower footing current.
2. Soil resistivity value, ρ (Ohm-m)
   An average soil resistivity value of **1000 Ohm-m** was assumed. This is based on a representative measurement from a recent project in proximity to the study area.

$$Sustainable\ Arc\ Distance\ (m) = (0.047)\sqrt{(I_f)(\rho)} \cong 14.86\ m \cong 48.75\ ft$$

Please note that the assumed lightning current of 100 kA is a very conservative assumption, and the calculated arcing distance should be confirmed during a detailed interference analysis using measured soil resistivity values which the project team has indicated will occur closer to the IFC timeframe. There may be deviations from actual values, which are difficult to determine without performing soil resistivity

[3] IEEE Guide for Safety in AC Substation Grounding, Institute of Electrical and Electronics Engineers, ANSI/IEEE Std. 80-2013.

measurements.

A comparison between the preliminary before and after scenario results for the existing and relocated O154 115 kV AC transmission lines, shows that potential risks are slightly different during both steady state and fault conditions, for existing and relocated transmission lines.

Scenario #2: HVDC Interference – Faults

During HVDC faults, the faulted pole conductor may transmit thousands of amperes of time fluctuating current. This high amplitude fluctuating current can cause significant inductive coupling. As well, these faults may inject a significant amount of current into the earth as fault current flows back to the source via the shield wire(s) and the earth. Although faults on HVDC lines are rare, they can occur anywhere along the transmission line, but at a supporting structure is the most common location.

High currents flowing in the pole conductor and shield wires due to faults will induce potentials on parallel pipelines. Further, this voltage can combine with the local soil GPR from currents flowing in the earth next to the pipeline to make the total interference touch potential voltage lower or higher depending on the respective phase angles of the currents. This total interference touch potential voltage can cause step and touch voltage hazards for facilities along the length of the pipeline. Safety thresholds are defined by IEEE Standard 80 2013[3] and IEC 60479 Standard Parts 1[4]& 2[5].

A preliminary HVDC fault analysis based on provided information and conservative assumptions, indicates some potential safety concerns at above grade sites throughout the study area. It is worth mentioning that these inferences are based on worst case scenario assumptions and assumed coating quality and soil resistivity values, which require further evaluation through a detailed HVDC interference analysis. While it is likely that existing mitigation measures may be in place, please note that an existing AC mitigation grounding system was not considered in this preliminary assessment. Given that this pipeline is located in an existing AC transmission line right of way, it is possible that there is mitigation already installed at above ground appurtenances. These appurtenances and the mitigation details from the initial pipeline construction should be reviewed and evaluated during a detailed interference analysis.

For well insulated pipelines, a potential difference exists across the coating of the pipeline from the difference in local soil ground potential rise (GPR) and the pipe metal potential. This potential difference is defined as the coating stress voltage, and could become hazardous to the coating integrity at values over 3,000 V_{ACRMS} for fusion bond epoxy (FBE) and polyethylene (PE) coatings according to NACE International Standard Practice SP0177-2014[2].

The results from a preliminary analysis conducted based on provided data and conservative assumptions show minimal coating stress risks to PNGTS pipelines throughout the area of influence. Please note that these high-level findings are based on assumed coating quality and soil resistivity values, which play a significant role in determining coating stress voltages. It is recommended that field measurements followed by a detailed HVDC interference study be conducted to better evaluate the associated risks.

The safe separation distance from a lightning arc can be calculated using the Sunde[1] equation as shown

[4] Effects of current on human beings and livestock – Part 1: General Aspects, IEC TS 60479 1 4th Edition, 2005.

[5] Effects of current on human beings and livestock – Part 2: Special Aspects, IEC TS 60479 2 3rd Edition, 2007.

below. Elevated risk of soil arcing may exist if the separation distance between a pipeline and the closest location of the structures effective grounding system is less than this calculated distance. The following assumptions were made for the calculation:

1. Maximum injected tower footing current, I_f (kA)
   A lightning current of **100 kA** was assumed as the maximum injected tower footing current.
2. Soil resistivity value, ρ (Ohm-m)
   An average soil resistivity value of **1000 Ohm-m** was assumed. This is based on a representative measurement from a recent project in proximity to the study area.

$$Sustainable\ Arc\ Distance\ (m) = (0.047)\sqrt{(I_f)(\rho)} \cong 14.86\ m \cong 48.75\ ft$$

Please note that the assumed lightning current of 100 kA is a very conservative assumption, and the calculated arcing distance should be confirmed during a detailed interference analysis using measured soil resistivity values. There may be deviations from actual values, which are difficult to determine without performing soil resistivity measurements.

Scenario #3: HVDC Interference – Steady State

During steady state operation of the HVDC transmission line, there is negligible AC ripple in the HVDC signal, which will induce negligible AC potentials on any adjacent pipelines. Consequently, it is not likely to influence the risk to human safety and AC corrosion effects on adjacent pipelines during steady state operation of the HVDC transmission line.

We recommend further investigation and evaluation of DC stray current interference from the proposed HVDC transmission line during its symmetrical monopole operation, on PNGTS pipelines through field measurements and detailed DC interference analysis.

CONCLUSION

A high-level preliminary AC, HVDC, and DC interference assessment has been conducted for the impacts from the proposed Northern Pass HVDC transmission line, and relocation of the existing O154 115 kV AC transmission line on Portland Natural Gas Transmission System (PNGTS) pipeline.

This preliminary analysis was conducted based on information provided and conservative assumptions, and indicates some potential safety concerns at above grade appurtenances throughout the study area. Please note that these inferences are based on worst case scenario assumptions and assumed coating quality and soil resistivity values, which require further evaluation through field measurements and detailed interference analysis which the project team has indicated will occur closer to the IFC timeframe. It is worth mentioning that an existing AC mitigation grounding system was not considered in this preliminary assessment. Given that this pipeline is located in an existing AC transmission line right of way, it is possible that there is mitigation already installed at above ground appurtenances. These appurtenances and the mitigation details from the initial pipeline construction should be reviewed and evaluated during a detailed interference analysis, which is recommended as the next step in this process. If pipeline integrity or personnel safety risks are indicated by the detailed interference analysis, well-understood mitigation techniques are available to reduce risks to an acceptable level.

We also recommend further investigation and evaluation of DC stray current interference from the proposed HVDC transmission line, during its symmetrical monopole operation, on PNGTS pipelines through field measurements and detailed DC interference analysis.

We trust that this correspondence satisfies your request for a preliminary evaluation and feasibility assessment. If there are any questions or comments, please contact the undersigned or Levi Blumhagen at 587-747-8038.

Respectfully,

CORRPRO CANADA, INC.

Boshra Momen Nejad, M.Sc., PMP, P.Eng.
Project Engineer
Corrpro Canada, Inc.
587-747-8042
BNejad@aegion.com