APPENDIX L
CORROSIVE EFFECTS STUDY
CASE 10-T-0139

Champlain Hudson Power Express (CHPE)

Champlain Hudson Power Express Induction Study

Report 15033-001-TL-004

Revision 1

2/7/2024

Issued for Comment

☐ Safety-Related

☒ Non-Safety-Related

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ISSUE SUMMARY AND APPROVAL PAGE

This is to certify that this document has been prepared, reviewed, and approved in accordance with Sargent & Lundy's Standard Operating Procedure SOP-0405, which is based on ANSI/ISO/ASSQC Q9001 Quality Management Systems.

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Version Log

Version	Issue Date	Notes
0	2/7/2024	Initial Issue for Comment 60% Design
1	2/2/2024	Added induced voltage results from a CDEGS HIFREQ model for the worst cases. Added reference 7.2.5. Updated Appendix A table to include results with insulating joints. Updated section 5 tables.

1. Introduction and Executive Summary

1.1. Introduction

The Champlain Hudson Power Express (CHPE) project will construct a new underground transmission line from the Astoria (NYPA) station, near the Astoria neighborhood in the New York City borough of Queens, to the Rainey (Consolidated Edison) substation, located on Vernon Boulevard. The line has been designated as the Astoria to Rainey Cable (ARC) and will be 3.5 miles long.

The proposed underground transmission line will be a three-phase 345 kV line with two conductors per phase. The proposed configuration throughout the installation is defined herein with the actual duct layout varying at some spans along the line. This study will focus on the inductive effects on the co-located infrastructure for this project.

1.2. Executive Summary

The selection of the topology and design of the CHPE 345 kV underground transmission line and the associated configuration of various duct layouts, have been considered when assessing the potential interference effects on other co-located utility services. The effects considered are:

- Electric fields
- Magnetic fields
- Induced voltages
- Corrosion effects
- Transient fault conditions
- Interference effects

After analyzing the above effects on co-located utility services, the results suggest that the proposed AC underground transmission line will have no adverse effect on any co-located utility services or infrastructure when utilizing the average horizontal spacing values for each utility. The analysis shows that if the 2 ft. horizontal separation is utilized along the entire paralleled length, then there will be touch voltages over the acceptance criteria limit, but this horizontal separation distance is not realistic.

2. Design Inputs

2.1. 345 kV 5000 kcmil Cu XLPE (2 cables per phase) Cable Dimensions

5000 kcmil HV Cable			
Component	Dimension	Value (in)	Value (ft)
Conductor (Copper)	Outside Diameter	2.48	0.2067
	Outside Radius	1.24	0.1033
Insulation (XLPE)	Outside Diameter	5.1	0.425
	Outside Radius	2.55	0.2125
	Thickness	1.20	0.10
Shield (Copper)	Inner Diameter	5.371	0.4476
	Thickness Wires	0.079	0.0066
	Thickness Total	0.079	0.0066
	Outer Diameter	5.45	0.4542
	Thickness	0.079	0.0066
Jacket (HDPE)	Thickness	0.197	0.0164

2.2. Tables 1 – 5 That Show All Nearby Utilities

The full list for each table can be found in Appendix A “Nearby Utilities Tables”

2.3. Gas Pipeline Alignment

The 345 kV duct bank parallels multiple gas pipelines. For this study the worst-case scenario per duct bank layout was analyzed, and considers the presence of insulating joints.

2.3.1. *ConEd 24” Gas Pipeline*

The pipeline parallels the 345 kV duct bank for 2492 ft. The horizontal distance from the duct bank is 14 ft. For most of this length the duct bank layout is the vertical 3x2 (3 rows by 2 columns) layout (section A).

2.3.2. *ConEd 8” to 20” Gas Pipeline*

The pipeline parallels the 345 kV duct bank for 388 ft. The horizontal distance from the duct bank varies from 4 to 46.5 ft. For most of this length the duct bank layout is the flat 1x6 layout (section C).

2.4. Sewer Pipeline Alignment

The 345 kV duct bank parallels multiple sewer pipelines. For this study the worst-case scenario per duct bank layout was analyzed.

2.4.1. *84” Sewer Pipeline*

The sewer pipeline parallels the 345 kV duct bank for 2549 ft. The horizontal distance from the duct bank varies from 15.5 to 22 ft. For most of this length the duct bank layout is the vertical 3x2 (3 rows by 2 columns) layout (section A).

2.4.2. *60” Sewer Pipeline*

The sewer pipeline parallels the 345 kV duct bank for 846 ft. The horizontal distance from the duct bank varies from 0 to 15 ft. For most of this length the duct bank layout is the flat 1x6 layout (section C).

2.5. Electrical Alignment

The 345 kV duct bank parallels multiple electrical power lines. For this study the worst-case scenario per duct bank layout was analyzed.

2.5.1. *ConEd Electrical Line*

The ConEd electrical line parallels the 345 kV duct bank for 3011 ft. The horizontal distance from the duct bank varies from 3 to 5 ft. For most of this length the duct bank layout is the vertical 3x2 (3 rows by 2 columns) layout (section A).

2.5.2. *ConEd Electrical Line*

The ConEd electrical line parallels the 345 kV duct bank for 77 ft. The horizontal distance from the duct bank varies from 0.5 ft. For most of this length the duct bank layout is the flat 1x6 layout (section C).

2.6. Telecommunication Alignment

The 345 kV duct bank parallels multiple telecommunication lines. For this study the worst-case scenario per duct bank layout was analyzed.

2.6.1. *Verizon Telecommunication Line*

The Verizon telecommunication line parallels the 345 kV duct bank for 2321 ft. The horizontal distance from the duct bank varies from 0 to 18 ft. For most of this length the duct bank layout is the vertical 3x2 (3 rows by 2 columns) layout (section A).

2.6.2. *Verizon Telecommunication Line*

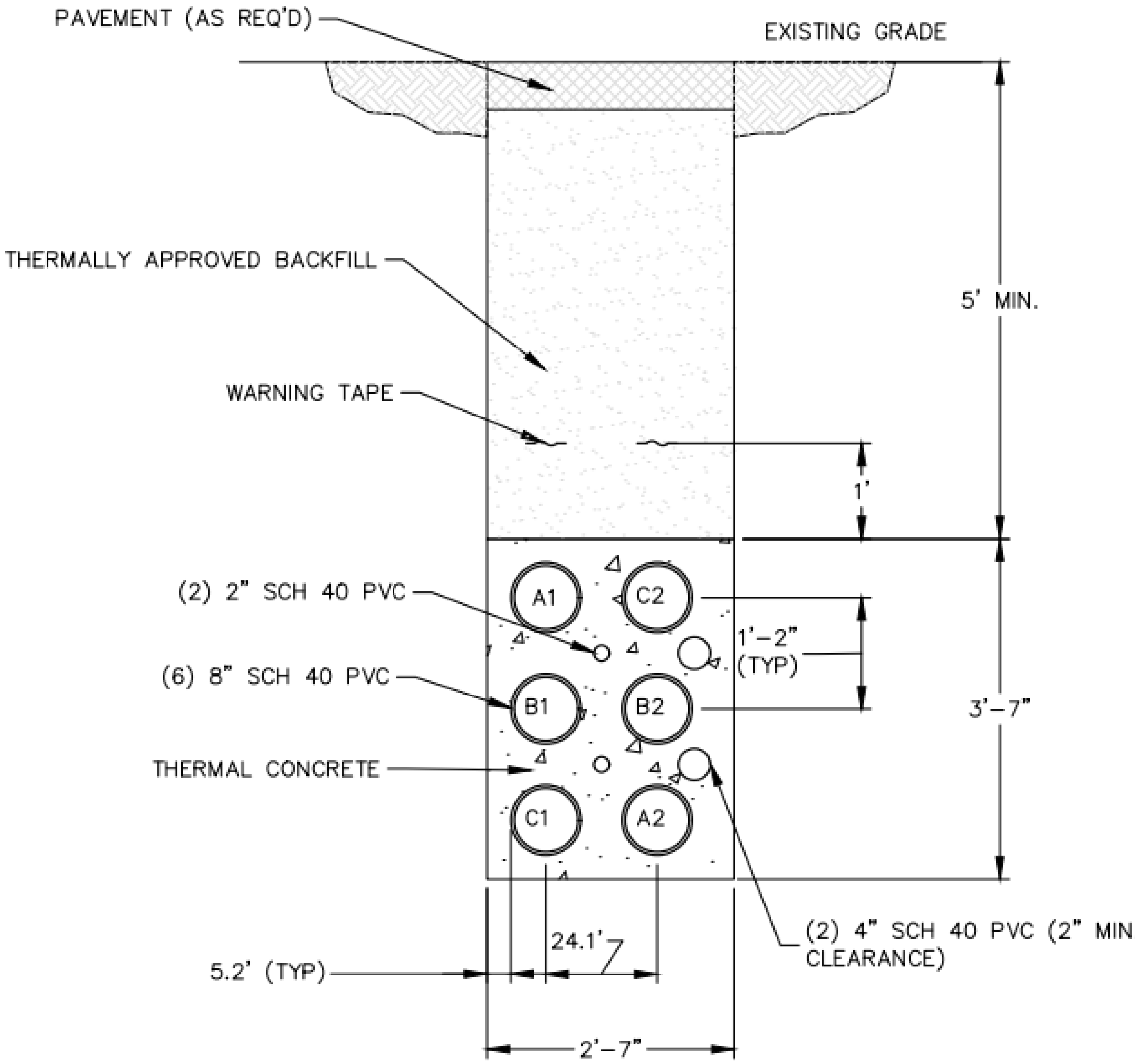
The Verizon telecommunication line parallels the 345 kV duct bank for 188 ft. The horizontal distance from the duct bank varies from 13 to 22.5 ft. For most of this length the duct bank layout is the flat 1x6 layout (section C).

2.7. Circuit Steady State Current

The duct bank is designed to carry a load current of 2325 A at 345 kV.

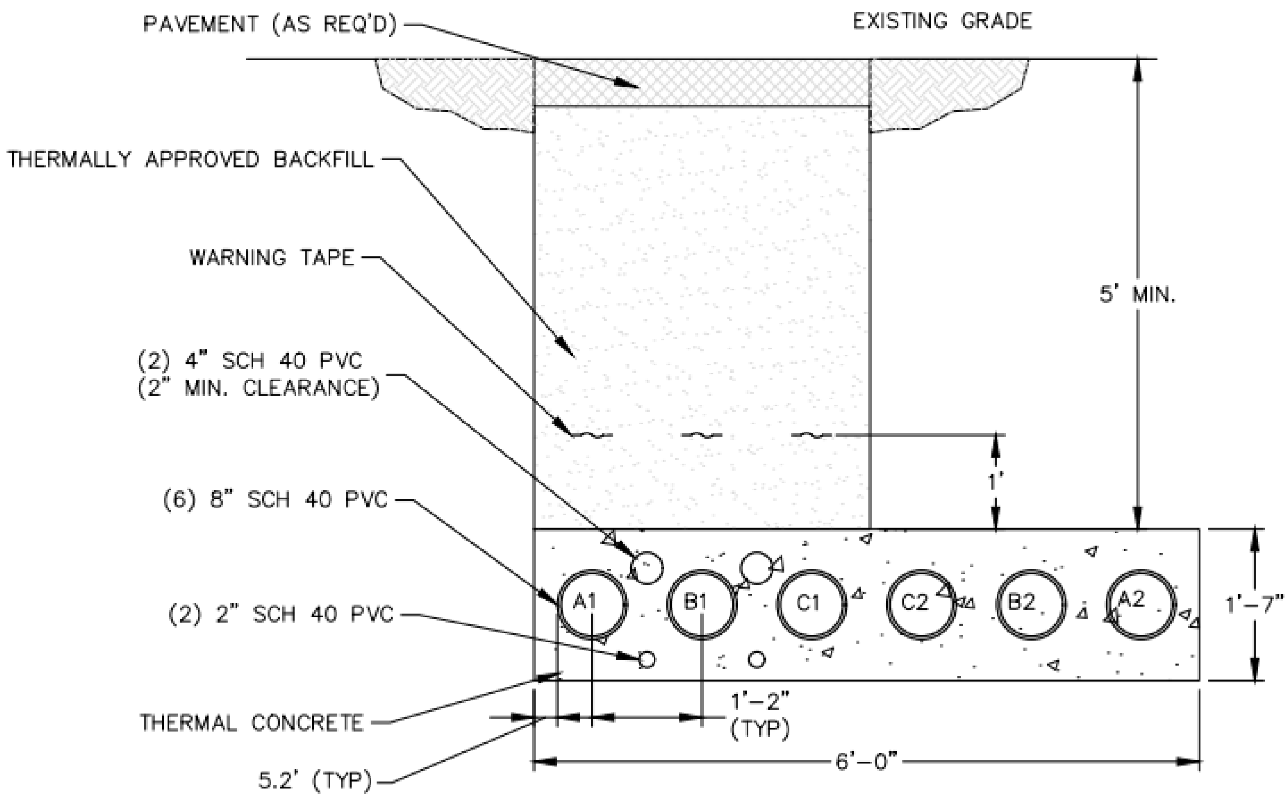
2.8. Conduit Layout

The following arrangement, Section A, is followed for most of the duct bank sections (Ref. 7.1.1).



SECTION A: VERTICAL DUAL CIRCUIT DUCT BANK
(PRIMARY ALIGNMENT)

The following arrangement, Section C, is the second most common (Ref 7.1.1).



SECTION C: DUAL CIRCUIT DUCT BANK

3. Assumptions

Assumption not requiring verification

3.1. Balanced Current
For the purpose of this calculation, the currents in the 345 kV cables are considered balanced.

3.2. Electrical Utilities
The voltage level of the analyzed parallel power line is 15 kV. The line is modeled as a single cable with an aluminum core, EPR insulation, and a PVC jacket.

3.3. Telecommunication Utilities
The telecommunication lines are assumed to be MCMH-210 and ALAW-100 cables. It is assumed that the conductors for telecommunication lines are tightly twisted together, and that the receivers are designed so that they nearly only respond the difference in voltage between the two conductors in a pair (transverse voltage) and are almost totally insensitive to the voltage appearing along the length of conductor (longitudinal voltage).

3.4. Utility Crossings
The worst case induced voltage on a crossing/parallel utility presents itself when the utility parallels the underground transmission line for a long distance. Therefore, it is assumed during this analysis that utility crossings will not result in an induced voltage that violates the acceptance criteria.

Assumptions requiring verification

3.5. Sewer Utilities
While the sewer pipes are likely made of concrete, this analysis assumes they are steel pipes with a polyethylene coating, representing a worst-case scenario. The coating is assumed to be a polyethylene with $1*10^{14}$ ohm-m resistivity. The coating is assumed to be in good condition and 0.25-inch thick.

3.6. Water and Gas Pipeline Utilities
It is assumed that the water and gas pipelines have an epoxy coating that is in good condition with a resistivity of $2*10^{10}$ ohm-m. For the purpose of calculating the coating resistivity, the coating is assumed to be 0.01-inch thick or 0.00083 ft. It is also assumed the pipe material is steel. Furthermore, for the gas pipelines that insulating joint spacing is not provided, it is assumed that an insulating joint exists every 100 ft.

3.7. Fault Current
A 63 kA fault current is assumed for the single line to ground fault scenarios. This is conservative as it is anticipated the actual L-G through fault current will be less than 20 kA.

4. Methodology

4.1. Nearby Utilities Review

Plan and profile view drawings that identify the utilities that cross and parallel the 345 kV line were reviewed. A complete list of the utilities near the 345 kV line was created based on these drawings. The list noted horizontal distance from the 345 kV line, angle the utilities cross the line, the type of utility, size of pipes, and other details as available. Tables 1 through 5 in Appendix A list all these utilities.

4.2. Scenarios Studied

Given the numerous electric, sewer, gas, water, and telecommunications lines that cross and parallel the 345 kV underground line, this analysis focuses on the worst-case scenarios for each utility type. Worst case scenarios pertain to utilities that parallel the new 345 kV line for the longest length and maintain the smallest horizontal distance between the new line and the utility. For each utility type, two predominant section layouts exist: Section A and Section C layout. The utilities analyzed are those in Design Input sections 2.2 to 2.5.

4.3. AC Cable Effects on Co-located Infrastructure

The selection of the topology and design of the CHPE 345 kV transmission line and associated layout of the underground AC cables have been taken into effect when assessing any interference effects on other co-located utility services. The effects considered are as follows:

4.3.1. Electric fields

This refers to the electric field between any high voltage conductor and earth. The CHPE 345 kV cable system is enclosed within an earthed metallic sheath. Therefore, there is no electric field external to the cable.

4.3.2. Magnetic fields

The AC cables will generate a magnetic field. This magnetic field will be a magnetic field that varies over time as the AC current in the cable varies with time. When the current changes over time, the magnetic flux created also changes over time.

4.3.3. Induced voltages

Faraday's Law states that the electromotive force around a closed path is equal to the negative of the time rate of change of magnetic flux enclosed by the path. In this study the co-located metallic utility service is assumed to be the enclosed path with magnetic flux changing over time. This will result in induced voltage or current. It is noted that the voltage induced is proportional to the length of the metallic utility that runs in parallel to the power circuit.

4.3.4. Corrosion effects

AC-induced corrosion stems from pipeline coating imperfections where leakage current lead to corrosion over time. This type of corrosion is also a risk at areas of the pipeline that do not have protective coating. AC corrosion is not expected at current densities less than 30 A/m^2. Since corrosion is a long term process, the risk of corrosions is asses using the transmission line steady state currents.

4.3.5. Transient fault conditions

During fault conditions the magnetic fields generated increase proportional to the increase in current. This results in higher induced voltage before the breakers open to clear the fault.

4.4. Telecommunication Lines

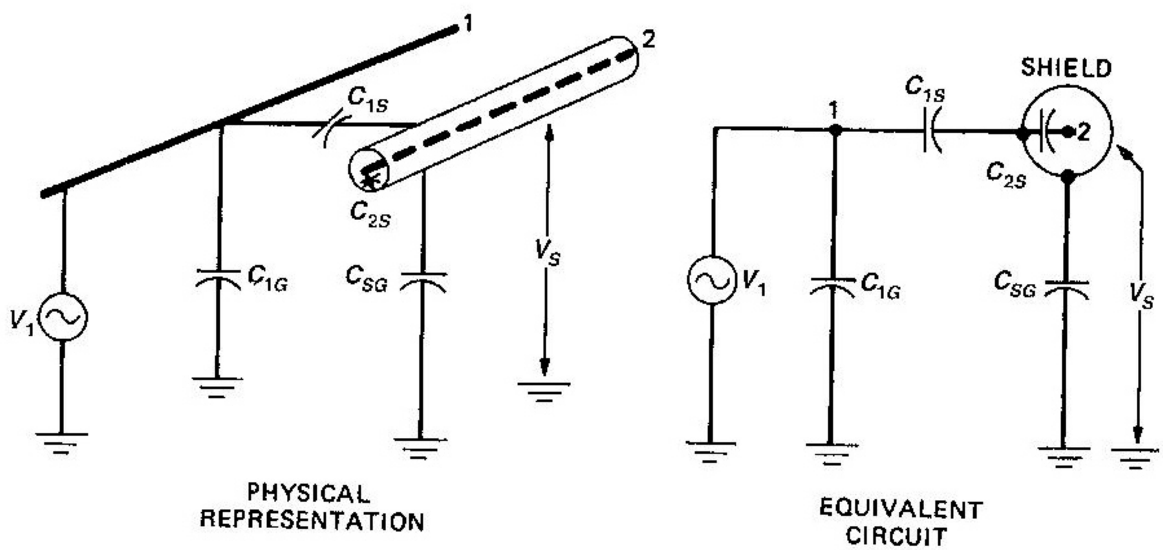
The telecommunication lines can be either fiber optic lines for digital transmission or copper cables for analogue or digital transmissions. Since the cable type is not known, this study assumes the cables are copper cables since fiber optic cables are vastly more resilient to electromagnetic interference than copper cables.

4.4.1. Fiber Optic Communication Cables

There is no electromagnetic impact on fiber optic cables.

4.4.2. Copper Communication Lines

The telephone cable runs in the vicinity of the 345 kV underground line and will therefore have mutual capacitances between the 345 kV line and the conductors in the telephone cable. As the voltage on underground line changes, a voltage will be introduced into the telephone cables by capacitive coupling. Like most industrial category cables, the telephone cables in this case are assumed to equipped with a shield around the operating conductors. Because the shield surrounds all the operating conductors, the interference from the nearby power cables will be induced in the telephone cable shield. The telephone conductors are only coupled to the shield, which extends beyond the region where the cable is exposed to the other (interfering) cables. The conceptual arrangement is shown in the following schematic:



It is normal practice to ground the shield. This forces the voltage of shield to be zero and since the voltage of the shield is zero, nothing will be induced into the telephone conductors by capacitance between the telephone cable shield and the telephone cable conductors (capacitor C_{2S} above). It should be noted that the impedance of the connection between the shield and ground becomes significant if its length exceeds one twentieth of the wavelength at the frequency of the interfering voltage. Because most potential sources of interference have low operating frequency, this is not a significant factor in this installation.

A second factor that suppresses interference is the fact that the telephone conductors are assumed to be tightly twisted together. This results in the two conductors in a pair being at nearly equal distances from the interfering conductors on average, so the difference in the voltage between the two conductors in a pair will be very small. The telephone receivers are designed so that they nearly only respond to the difference in voltage between the two conductors in a pair (transverse voltage) and are almost totally insensitive to the voltage appearing along the length of conductor (longitudinal voltage).

The twisted pair construction also greatly suppresses the voltage induced in the signal cables by the magnetic field produced by the interfering circuits. First, there is little area between the two conductors of a pair due to the tight twisting. Because the induced voltage is proportional to the enclosed flux, the small area between the conductors guarantees that the enclosed flux will be small. Secondly, the twisting means the voltage induced in adjacent turns cancels. This is promoted by the uniform twists of category cable. Thirdly, any induced voltage will be almost the same in both conductors. Therefore, the transverse (conductor to conductor) component of the induced voltage will be very low.

It was observed as early as the 1920's that harmonic currents on power lines can cause audible distortion on telephones. Table B-1 from IEEE 519 (Ref 7.3.3) provides an empirical weighting factor for the range of harmonics in the human hearing range. The weightings are a product of a person's sensitivity to audible interference at that frequency and the fact that higher frequencies tend to have a greater coupling factor.

Table B-1—Weighting values (W_f)

FREQ	W_f	FREQ	W_f	FREQ	W_f	FREQ	W_f
60	0.5	1020	5100	1860	7820	3000	9670
180	30	1080	5400	1980	8330	3180	8740
300	225	1140	5630	2100	8830	3300	8090
360	400	1260	6050	2160	9080	3540	6730
420	650	1380	6370	2220	9330	3660	6130
540	1320	1440	6560	2340	9840	3900	4400
660	2260	1500	6680	2460	10340	4020	3700
720	2760	1620	6970	2580	10600	4260	2750
780	3360	1740	7320	2820	10210	4380	2190
900	4350	1800	7570	2940	9820	5000	840
1000	5000						

The total telephone influence factor (TIF) can be found be determined by finding the weighted sum of the various harmonic currents that are on the power line. This method was developed for arial distribution level lines and is not immediately applicable to the duct bank under questions for several reasons. First, the TIF method involves measuring harmonics on the power line, which is not possible as the 345 kV cables are not yet installed. Secondly, the 345 kV cables have a cable shield and are installed in underground ducts that will both contain the electrical field of the conductors. Thus, it is expected that any interferences would be solely due to magnetic fields and the TIF weightings will overestimate the influence of the power cable current and voltage.

Despite these inconsistencies we can still use the TIF weighting to provide an estimate of the audible interference. Table 4 from IEEE 519 (Ref 7.3.3) provides the limits for harmonic current on 345 kV lines. For conservatism, an I_{SC}/I_L of greater than 50 is used in this analysis.

Table 4—Current distortion limits for systems rated > 161 kV

Maximum harmonic current distortion in percent of I_L						
Individual harmonic order (odd harmonics)[a, b]						
I_{sc}/I_L	$3 \leq h < 11$	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h \leq 50$	TDD
< 25[c]	1.0	0.5	0.38	0.15	0.1	1.5
$25 < 50$	2.0	1.0	0.75	0.3	0.15	2.5
≥ 50	3.0	1.5	1.15	0.45	0.22	3.75

[a]Even harmonics are limited to 25% of the odd harmonic limits above.

[b]Current distortions that result in a dc offset, e.g., half-wave converters, are not allowed.

[c]All power generation equipment is limited to these values of current distortion, regardless of actual I_{sc}/I_L.

where

I_{sc} = maximum short-circuit current at PCC

I_L = maximum demand load current (fundamental frequency component) at the PCC under normal load operating conditions

Based on the above values, the TIFF is calculated in the following table up to the 25th harmonic. Above this range the harmonic content is small. Table B-2 in IEEE 519 (Ref 7.3.3) states that for TIFF I-T values up to 10,000 interference is unlikely. The results show that well below this value at ~205.

Calculated

Harmonic	Frequency	Harmonic Content Limit (Table 4)	Single Frequency Current	TIFF Weight (Table B-1)	TIFF Summation
1	60	100%	2325	0.5	0.25
3	180	3%	69.75	30	0.81
5	300	3%	69.75	225	45.5625
6	360	3%	69.75	400	144
7	420	3%	69.75	650	380.25
9	540	3%	69.75	1320	1568.16
11	660	3.00%	69.75	2260	4596.84
12	720	1.50%	34.875	2760	1713.96
13	780	1.50%	34.875	3360	2540.16
15	900	1.15%	26.7375	4350	2502.50063
17	1020	1.15%	26.7375	5100	3439.8225
18	1080	1.15%	26.7375	5400	3856.41
19	1140	1.15%	26.7375	5630	4191.91503
21	1260	1.15%	26.7375	6050	4840.68063
23	1380	1.15%	26.7375	6370	5366.29503
24	1440	1.15%	26.7375	6560	5691.1936
25	1500	0.45%	10.4625	6680	903.6036
TIFF - square root of the sum of the squares:					204.407469

4.5. <u>Model Overview</u>

The CDEGS module TRALIN is used to create a model which includes cross-section description of the underground transmission line, gas pipelines, electric lines, telecommunication lines, sewer lines and water lines. The data for this file was built from the information in the plan and profile drawings and data provided by the utilities. The locations of the transmission line, duct banks and utilities were provided in References 7.1.1, 7.2.3, and 7.2.4.

The soil is modeled as uniform with a resistivity of 100 ohm-m.

The sewer pipelines are modeled as steel tubes with a thin polyethylene coating layer. The water and gas pipelines are modeled as steel tubes with an epoxy coating. The depth of water lines Is modeled at 4’-6”. The gas line is modeled at a depth of 3’-0”. Lastly, the sewer lines are modeled between a 6’ to 7’ depth.

The electric power lines analyzed are modeled as 15 kV cable with an aluminum core, EPR insulation, and a PVC jacket. It should be noted that for higher voltage cables the results would be similar to the 15 kV cable.

The telecommunication cables are modeled as MCMH-210 and ALAW-100 cables.

The XLPE cables have concentric neutral conductors composed of 90 #12AWG cables. Since only the continuous screen rather than the concentric neutrals can be modeled in TRALIN, the concentric neutrals should be converted to the continuous sheath which provides the same internal and external impedances. To do this the concentric neutral can be modeled as a solid conductor having the equivalent area as the 90 neutral conductors.

From basic geometry, the area of the shield is calculated as follows:

$$Area_{Shield} \coloneqq \pi(Radius_{Outer}^2 - Radius_{Inner}^2)$$

From this, the thickness required for a conductor area equivalent to the 90 conductors is determined. Adding this calculated area equivalent thickness to the thickness of the copper sheath the total thickness of the sheath is calculated to be 0.0346 in.

The result of this exercise is a file that is a detailed cross section of the underground cables and nearby utilities. Having this data allows us to calculate the induced electromagnetic voltages onto the nearby utilities.

In several cases, the TRALIN model will conservatively overestimate the effective induced voltage on a nearby utility. In such cases, a more detailed model of the configuration is constructed in the HIFREQ module of CDEGS software.

4.6. Acceptance Criteria

4.6.1. Pipeline Induced Voltage (Steady State Condition)

The steady state AC Pipeline voltages should be less than 15 V to remote ground during maximum steady state loading conditions (Ref 7.3.2).

4.6.2. Pipeline Leakage Current (Steady State Condition)

The steady state leakage current of the pipeline should be no greater than 30 A/m^2 to be at no risk of corrosion due to induction effects. For current densities between 20 A/m^2 and 100 A/m^2 the probability is unpredictable (Ref 7.3.2).

4.6.3. Tolerable Touch Voltages (Short Circuit Condition)

The tolerable touch voltage is a function of the body weight of the person being shocked, the resistance of the body, and the contact resistance between the person's two feet and the ground. The methodology is described in Sections 5 to 8 of (Ref. 7.3.1). A body weight of 50 kg (about 110 lb) is assumed in accordance with the recommendations of (Ref. 7.3.1).

4.6.4. Pipeline Coating Stress (Short Circuit Condition)

The coating voltage stress of the pipelines should be below 10 kV to avoid damage to the coating (Ref. 7.3.4).

4.6.5. Electrical Line Induced Voltage (Steady State Condition)

The study documents the voltage induced onto nearby electrical power lines.

4.6.6. Electrical Line Induced Voltage (Short Circuit Condition)

The study documents the voltage induced onto nearby electrical power lines during fault conditions.

4.6.7. Telecommunication Lines Analogue Interference (Steady State Condition)

While there are no set standards on the level of acceptable voltage, Kimbark (Ref. 7.3.5) provides a limit of 55 mV as the limit of longitudinal induced noise from a single source.

4.6.8. Telecommunication Lines Digital Interference (Steady State Condition)

Assuming the use of twisted pair data wiring and design techniques used in terminal equipment that rejects common mode voltage, it is expected that any induced noise will not have a significant impact on the performance of digital transmissions on the circuit.

4.6.9. Telecommunication Lines Analogue Interference (Short Circuit Condition)

Voltages that can cause a telephone to ring are between 40 volts AC and 90 volts AC.

5. Simulation Results

5.1. Gas Pipes

Induced voltage, coating holiday current density, touch voltage, and coating stress voltage is calculated and summarized in the following tables:

Results for Gas Section A Layout | 2492 ft. Parallel Model Created in HIFREQ			
Steady State Current of 2325 A			
	Result 11 ft. Separation	**Result 2 ft. Separation**	**Acceptable Level**
Pipeline Induced Voltage	7.34 V	11.17 V	15 V
Pipeline Coating Holiday current Density	16.51 A/m^2	25.12 A/m^2	< 30 A/m^2
Fault Current (SLG) at 63 kA			
24" Pipeline Touch Voltage	7022 V	8504 V	188.65 V
Coating Stress Voltage	7.022 kV	8.5 kV	10 kV

Results for Gas Section C Layout | 388 ft. Parallel			
Steady State Current of 2325 A			
	Result 5 ft. Separation	**Result 2 ft. Separation**	**Acceptable Level**
Pipeline Induced Voltage	2.81 V	2.77 V	15 V
Pipeline Coating Holiday current Density	23.27 A/m^2	22.86 A/m^2	< 30 A/m^2
Fault Current (SLG) at 63 kA			
8-20" Pipeline Touch Voltage	465.9 V	487.57 V	188.65 V
Coating Stress Voltage	0.47 kV	0.49 kV	10 kV

As shown in Attachment A, the 2492 ft parallel pipeline is a transmission pressure line that is electrically continuous throughout the co-location.

A more detailed model is constructed in the HIFREQ module of CDEGS software to better model the induced voltage of the pipeline and to account for capacitive leakage current to the soil and the impact of the ground conductors and cable shield on the magnetic fields produced by the cable conductors

5.2. Water Pipes:

Appendix A Table 2 includes the induced voltage levels for electrically continuous pipes and pipes with an assumed 100 ft insulating joint spacing. Metallic water pipes are typically constructed of cast iron or ductile iron, and are joined with gasketed bell and spigot joints that provide an electrical break between sections. Consideration of these electrical breaks demonstrate that induced voltage is within acceptable limits. Water pipelines constructed of steel may have electrically continuous welded joints and as shown in Attachment A may experience induced voltage above acceptable limits. Note that water pipes constructed of non-metallic materials such as PVC, HDPE, another plastic, or terra cotta will have no induced voltage on them. Induced voltage, coating holiday current density, touch voltage, and coating stress voltage is calculated and summarized in the following tables. Induced voltage during a fault is proportional to the fault current and the length of electrically continuous pipe; the induced voltage during a fault are expected to be about 1/10 as shown in the tables below if a typical water pipe length of 20 ft (1/5 of 100 ft) and a fault current half as large are considered. This results in induced fault currents below the acceptable touch voltage limit.

Results for Water Section A Layout | 3021 ft. Parallel Effective insulating Joints every 100 ft			
Steady State Current of 2325 A			
	Result 10 ft. Separation	**Result 2 ft. Separation**	**Acceptable Level**
Pipeline Induced Voltage	0.7 V	4.68 V	15 V
Pipeline Coating Holiday current Density	1.57 A/m^2	10.53 A/m^2	< 30 A/m^2
Fault Current (SLG) at 63 kA			
8" Pipeline Touch Voltage	415.77 V	521.74 V	188.65 V
Coating Stress Voltage	0.42 kV	0.52 kV	10 kV

Results for Water Section C Layout | 127 ft. Parallel			
Steady State Current of 2325 A			
	Result 5 ft. Separation	**Result 2 ft. Separation**	**Acceptable Level**
Pipeline Induced Voltage	2.95 V	5 V	15 V
Pipeline Coating Holiday current Density	6.64 A/m^2	11.25 A/m^2	< 30 A/m^2
Fault Current (SLG) at 63 kA			
16" Pipeline Touch Voltage	529.25 V	579.79 V	188.65 V
Coating Stress Voltage	0.5 kV	0.6 kV	10 kV

5.3. Sewer Pipes

Induced voltage, coating holiday current density, touch voltage, and coating stress voltage is calculated and summarized in the following tables:

Results for Sewer Section A Layout | 2549 ft. Parallel			
Steady State Current of 2325 A			
	Result 15 ft. Separation	Results 2 ft. Separation	Acceptable Level
Pipeline Induced Voltage	8.99 V	19.9 V	15 V
Pipeline Coating Holiday current Density	20.23 A/m^2	44.78 A/m^2	< 30 A/m^2
Fault Current (SLG) at 63 kA			
84" Pipeline Touch Voltage	9350.39 V	10787.73 V	188.65 V
Coating Stress Voltage	9.4 kV	10.8 kV	10 kV

Results for Sewer Section C Layout | 846 ft. Parallel			
Steady State Current of 2325 A			
	Result 8 ft. Separation	Result 2 ft. Separation	Acceptable Level
Pipeline Induced Voltage	13.64 V	14.77 V	15 V
Pipeline Coating Holiday current Density	30.69 A/m^2	33.2 A/m^2	> 30 A/m^2
Fault Current (SLG) at 63 kA			
16" Pipeline Touch Voltage	2365.65 V	2396.42 V	188.65 V
Coating Stress Voltage	2.4 kV	2.4 kV	10 kV

Appendix A Table 3 includes the induced voltage levels with an assumed 100 ft insulating joint spacing.

It should be noted that the study assumes the sewer pipes are steel with a polyethylene coating and the gas and water pipes are assumed to use an epoxy coating. The sewer pipes are expected to be non-metallic pipes thus their induced voltage would be negligible. These analysis results are provided to show a worst-case scenario if conditions in the field are different. Depending on the coating used the acceptable coating stress voltage can vary from 3.5 kV to 100 kV+. Considering the stress coat voltages calculated during this analysis, utilities should confirm the coating utilized for sewer, gas, and water pipes and compare their acceptable coating stress voltage to the calculated touch voltages in this analysis.

5.4. Electric Utilities

The induced voltage on the longest parallel electric power line has been computed, with the results presented in the following table:

Results for Electric Line Section A Layout | 3011 ft. Parallel		
Steady State Current of 2325 A		
	Result 3 ft. Separation	**Result 2 ft. Separation**
Induced Voltage	73.65 V	85.8 V
Fault Current (SLG) at 63 kA		
Induced Voltage	13644.73 V	13959.58 V

Results for Electric Line Section C Layout | 77 ft. Parallel	
Steady State Current of 2325 A	
	Result 2 ft. Separation
Induced Voltage	1.07 V
Fault Current (SLG) at 63 kA	
Induced Voltage	355.52 V

Voltages calculated during steady state condition are a small percentage, 0.49%, of the assumed distribution level voltage of 15 kV (at 3 ft separation). During short circuit conditions, the induced voltage on the electric utility can be as high as 13.64 kV (at 3 ft separation). Considering the magnitude of this induced voltage during short circuit conditions, a more detailed analysis is needed for this interaction.

5.5. Telecommunication Utilities

The results of the computer simulations are summarized in the tables below. The results show that the MCMH-210 cable will have an unweighted induced voltage of 0.136 volts/mile and the ALAW-100 will have and unweighted induced voltages of 0.136 volts/mile

TRALIN Model Results

			TRALIN Result (induced volts/mile)		Reduction per Harmonic Content		-60 db due to twisted pair	
Frequency	% Content I_{SC}/I_L >50	% Content I_{SC}/I_L <25	MCMH-210	ALAW-100	MCMH-210	ALAW-100	MCMH-210	ALAW-100
60	100.00%	100.00%	113.03	113.033	113.030	113.033	0.113	0.113
300	3.00%	1.00%	566.338	566.338	16.990	16.990	0.017	0.017
420	3.00%	1.00%	793.41	793.41	23.802	23.802	0.024	0.024
660	1.50%	1.00%	1248.16	1248.16	18.722	18.722	0.019	0.019
780	1.50%	0.50%	1475.79	1475.79	22.137	22.137	0.022	0.022
900	1.50%	0.50%	1703.59	1703.59	25.554	25.554	0.026	0.026
1020	1.50%	0.50%	1931.51	1931.51	28.973	28.973	0.029	0.029
1140	1.50%	0.38%	2159.57	2159.6	32.394	32.394	0.032	0.032
1380	1.50%	0.38%	2616.04	2616.04	39.241	39.241	0.039	0.039
Square root of sum of the square of each frequency (volts/mile):							**0.136**	**0.136**
Excluding 60 Hz:							**0.076**	**0.076**
Using I_{SC}/I_L <25 Harmonic Values:							**0.025**	**0.025**

The total interference for each section is summarized in the table below. The worst case shows an induced voltage of 0.06 volts. If the 60 Hz contribution is neglected (since telephone systems are designed to filter out interference at this frequency), the worst-case voltage becomes 0.04 volts for the highest level of harmonics, and 0.01 volts for the lower limits.

Section	Length	Total Volts		Total Volts w/o 60 Hz		Total Volts w/o 60 Hz and $I_{SC}/I_L < 25$	
		MCMH-210	ALAW-100	MCMH-210	ALAW-100	MCMH-210	ALAW-100
A	0.44	0.06	0.06	0.04	0.04	0.01	0.01
C	0.036	0.0	0.0	0.0	0.0	0.0	0.0

The results show that the total steady state induced voltage on the telephone cables of 0.06 volts will be within the cable and connected devices ratings.

The calculated voltages of 40 mV for high levels of harmonics, and 10 mV for I_{SC}/I_L < 25 levels of harmonics are below the 55 mV value for analogue interference. It should be noted that IEEE 519 also requires that the TDD (Total Demand Distortion) be less than 1.5 for I_{SC}/I_L <25. The harmonic content used in the TRALIN results in a conservative TDD of ~2.0%.

Lower harmonic content that meets a TDD of <1.5%, especially in higher frequencies with greater coupling, could result in induced voltage below the 55mV limit. However, since there are no standards ensuring that future equipment installed on the grid meets these lower levels at the most impactful frequencies, it is conservative to use the values provided.

In addition to analogue voice signals, the telephone cables may carry digital information carried as a transverse voltage on the twisted conductor pair. Other than for stray capacitances there is no path for the longitudinal voltage that contains almost all the noise. The digital information will be input to an assumed integrated circuit that will be very effective at rejecting any common mode voltage. Therefore, due to the use of balanced shielded twisted pair data wiring and the design techniques used in the terminal equipment, it is expected any induced noise will not have a significant impact on the performance of digital transmissions on the circuit.

In addition to steady state current, the model was also ran simulating a 63 kA single phase fault in the 345 kV cables. Due to the current unbalance and less cancelations, this fault will have the greatest level of interference. The TRALIN model shows an induced longitudinal voltage of ~10 volts once mitigation due do the twisted pair is considered. This voltage will have a short duration and is less than voltage applied to cause a telephone to ring, which can be up to 90 volts AC.

6. Conclusions

For 2 ft. separation it is observed during this analysis that the acceptable touch voltage criteria for gas, water, and sewer pipes is not met, however, it is unrealistic to assume the longest utilities will parallel the underground transmission line at a constant 2 ft. horizontal separation distance. Therefore, the conclusion of this analysis focuses on the scenarios where horizontal separation is greater than 2 ft.

Gas
The results demonstrate that during steady state conditions it is not expected that the gas utilities will exceed the 15 V criteria for induced voltage. In addition, the holiday current is below levels that would cause AC corrosion.

For short circuit conditions, the induced voltage on the gas utilities do exceed the 188.65 V safe touch voltage acceptance criteria at several locations, however the coating stress voltage remain within acceptable levels.

As the pipelines are located below grade, elevated voltages due to a fault on the transmission line are expected to be acceptable due to typical safe work practices for maintaining the pipelines take induced voltages into account. The pipelines are in areas with several other existing high voltage cables, so no new hazards are introduced. In particular, ground potential grids are expected to be provided where a pipe or equipment connected to the pipe is exposed (e.g. at a valve station or vault). The grids are connected to the pipe so that the potential of the earth near the equipment is forced to be nearly the same as the potential of the pipe. Portable gradient control mats should be used for temporary grounding and to control potential differences in the area where an exposed pipe is being worked on. Where laterals off the main gas line exist it is expected that insulating flanges have been installed to provide electrical isolation for the laterals.

Water
The results demonstrate that during steady state conditions water utilities will not exceed the 15 V criteria for induced voltage. In addition, the holiday current is below levels that would cause AC corrosion.

For short circuit conditions, it is expected that for a pipe length of 20 ft the induced voltages during a fault will be within acceptable limits. Furthermore, as the water pipes are below grade and inaccessible to the public. Since the pipelines are in areas with several other existing high voltage cables no new hazards are introduced and it is expected that any laterals coming off a water main will have sufficient insulating material to maintain electrical isolation of the water pipe.

Sewer
Sewers in the area are expected to be constructed of non-metallic material and will not be susceptible to induced voltages. Lateral metallic sewer pipes coming off the parallel will not experience significant induced voltages.

Telecommunications
The results of the telecommunication line interference section show that there will not be significant analogue interference. The calculated value of 40 mV is below the 55 mV acceptable value. During short circuit conditions the calculated induced voltage is ~10 V. This is below the 40 V to 90 V value where a telephone might inadvertently ring. As discussed in Section 4, the use of shielded twisted pair cables will prevent interference with digital communication circuits. Fiber optic cables are inherently immune from EMF interference.

7. References

7.1. Drawings

7.1.1. Drawing Set for CHPE Astoria Rainey Cable Project PDF, "2023-07-05 Drawing Set"

7.2. Technical Data

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7.2.2. Cables Report PDF, "Cable Model From ARC amp calc"

7.2.3. E&T Design Basis PDF, "E&T Design Basis 345 kV Cable Project Rev A"

7.2.4. ARC Line – Nearby Utilities Spreadsheet, "ARC Line - Nearby Utilities"

7.2.5. ConEd excel document containing information on insulating joint spacing, "RFI 4 - ARC Y19 Line - Nearby Utilities 60 Gas"

7.3. Technical Reference

7.3.1. IEEE Std 80 - 2013, "Guide for safety in AC Substation Grounding"

7.3.2. IEEE Std 2746 - 2020 "Guide for Evaluating AC Interference on Linear Facilities Co-Located Near Transmission Lines"

7.3.3. IEEE Std 519 – 2022 "IEEE Standard for Harmonic Control in Electric Power Systems"

7.3.4. A/C Interference Guideline Final Report PDF, "AC-Interference-Guidelines-Final-Report-FOR-PUB."

7.3.5. Kimbark, Edward Wilson "Direct Current Transmission, Volume 1" 1971.

7.4. Software

7.4.1.1. CDEGS Software Version 17.1.09971, Run on computer AD9026 in Windows 10 Environment