LS POWER GROUP CALIFORNIA COLLINSVILLE INTERCONNECTION PROJECT CALPINE MONTEZUMA 8” PIPELINE

Solano County, California

AC INTERFERENCE ANALYSIS

Issued: 2/28/2024

Prepared By:

ARK Engineering & Technical Services, Inc.
639 Granite Street, Suite 200
Braintree, MA 02184
Phone: 781-849-3800

Mr. Kevin Almonacid
Project Engineer
Report Number: R-24024-CPN-R2

INTRODUCTION

ARK Engineering & Technical Services, Inc. was contracted by LS Power Group California (LS Power) to investigate AC electrical interference effects from the proposed LS Power Collinsville interconnection electric transmission circuit project on the existing Calpine Montezuma 8” Pipeline in Solano County, California.

The existing pipeline section will be subject to AC electrical interference effects from a proposed LS Power electric transmission double circuit that will be constructed within proximity to the existing pipeline route. The proposed electric transmission double circuit will be in proximity to the existing Montezuma 8” pipeline section, as shown in Figure 1-1 and outlined in Table 1-1.

Figure 1: Overview of Proposed Circuit In Proximity to Pipeline Route

Table 1-1: Areas of Concern

Circuit Name	Circuit Size (kV)	GPS Location
Collinsville #1	230 kV	In Proximity: 38.080250°, -121.835980° to 38.071643°, -121.832620°
Collinsville #2	230 kV	In Proximity: 38.080250°, -121.835980° to 38.071643°, -121.832620°

FIELD DATA

The effective coating resistance used in this analysis for the pipeline section is a conservative value obtained from previous research on coating resistances for X-TRU coated pipelines.

Montezuma 8" Coating Resistance: 250,000 Ω-ft^2

The characteristics used for the pipeline section, obtained from previous research on steel pipelines, are as follows:

- Relative resistivity: 10 (with respect to annealed copper)
- Relative permeability: 300 (with respect to free space)

The characteristics used for the pipeline section, provided by Calpine, are as follows:

- Pipeline diameter: 8.625 inches
- Wall thickness: 0.188 inches
- Pipe Cover/Depth: 5 feet
- Year of Install: 1973

This AC electrical interference analysis was based on a soil resistivity measurement recorded near the pipeline. The soil resistivity measurement used in this analysis was recorded on April 18, 2024.

The soil resistivity measurement was used to derive an equivalent soil structure model for the pipeline segment. This multilayer soil model is representative of the changing soil characteristics as a function of depth. Complete multilayer soil characteristics are used to calculate the conductive and total AC interference effects. Touch voltage, coating stress voltage, and AC density calculations all use the complete multilayer soil model.

The equivalent soil model resistivity is shown in Table 2-1 below.

Table 2-1: Derived Soil Resistivity Values

Soil Resistivity Location No.	GPS Location	Resistivity at Pipeline Depth (Ω-m)	Bottom Layer Resistivity (Ω-m)
1	38.081170°, -121.833897°	3.1	1.5

MODELING DETAILS

This final report presents the predicted AC electrical interference effects on the pipeline section under study with the proposed LS Power electrical transmission circuits operating at normal loading conditions.

The results of this study indicated that AC steady state interference voltage levels on the pipeline section were calculated below the design limit of fifteen (15) Volts.

> With the LS Power Transmission Circuits in place, a maximum induced AC pipeline potential of less than one (1) Volt, with respect to remote earth, was computed by the proposed crossing at approximate GPS location: 38.071178°, -121.824030°.

AC density calculations associated with AC corrosion mechanisms were conducted for the pipeline section during normal load conditions on the proposed electric transmission circuits.

The results of this study indicated that AC density levels on the pipeline section have been calculated below the thirty (30) A/m^2 design limit.

> With the LS Power Transmission Circuits in place, a peak AC density of approximately five (5.4) A/m^2 was computed along the pipeline section at approximate GPS location: 38.071178°, -121.824030°.

Assumed single phase-to-ground fault conditions on the proposed LS Power electric transmission circuit were also simulated to determine AC inductive and conductive coupling effects to the pipeline section.

The results of the single phase-to-ground fault analysis indicate that coating stress voltages were computed to be below the design limit of five thousand (2,500) Volts for the X-TRU coated pipeline section.

> The maximum coating stress voltage was computed to be approximately fifty-eight (58.1) Volts at approximate GPS location: 38.074357°, -121.823840°.

ASSUMPTIONS

During the modeling and analysis of the AC interference effects on the proposed pipeline section, various assumptions were required. These assumptions are outlined below:

a. A coating holiday size of 1 cm^2 was used in the calculation of AC density.

b. An average pipeline depth of five (5) feet was utilized.

c. A coating thickness of forty (40) mils was utilized for the epoxy coated pipeline section.

CONCLUSIONS AND RECOMMENDATIONS

As outlined in Chapter 3 of this report, ARK Engineering's modeling analysis indicated that induced AC interference effects to the existing pipeline section, under normal conditions on the proposed electric transmission circuit were computed below the design limits outlined previously in this report.

ARK Engineering does not recommend any AC mitigation for the pipeline section.

It is recommended that upon installation and energization of the proposed electric transmission circuit, AC pipeline potentials are recorded at each of the pipeline test stations.

If an increase in pipeline AC induced potentials or AC density is recorded over time, additional analysis may be required.

Please call the author if you have questions or require additional information regarding this report.

APPENDIX A: METHODOLOGY

A.1 A Brief Perspective on Electromagnetic Interference Mechanisms

The flow of energy transmitted by electric power is not totally confined within the power conductors. However, the spatial density of energy in the environment surrounding these circuits decreases sharply with an increase in distance from the conductors. Metallic conductors such as pipelines that are located near electric transmission circuits may capture a portion of the energy encompassed by the conductors' paths, particularly under unfavorable circumstances such as long parallel exposures and fault conditions. In such cases, high currents and voltages may develop along the conductors' lengths. Energy may also flow directly from power installations to pipeline installations via conductive paths common to both.

The electromagnetic interference mechanisms at low frequencies have been traditionally divided into three (3) categories: capacitive, inductive, and conductive coupling. These categories and their possible effects are illustrated in Figure 1-1.

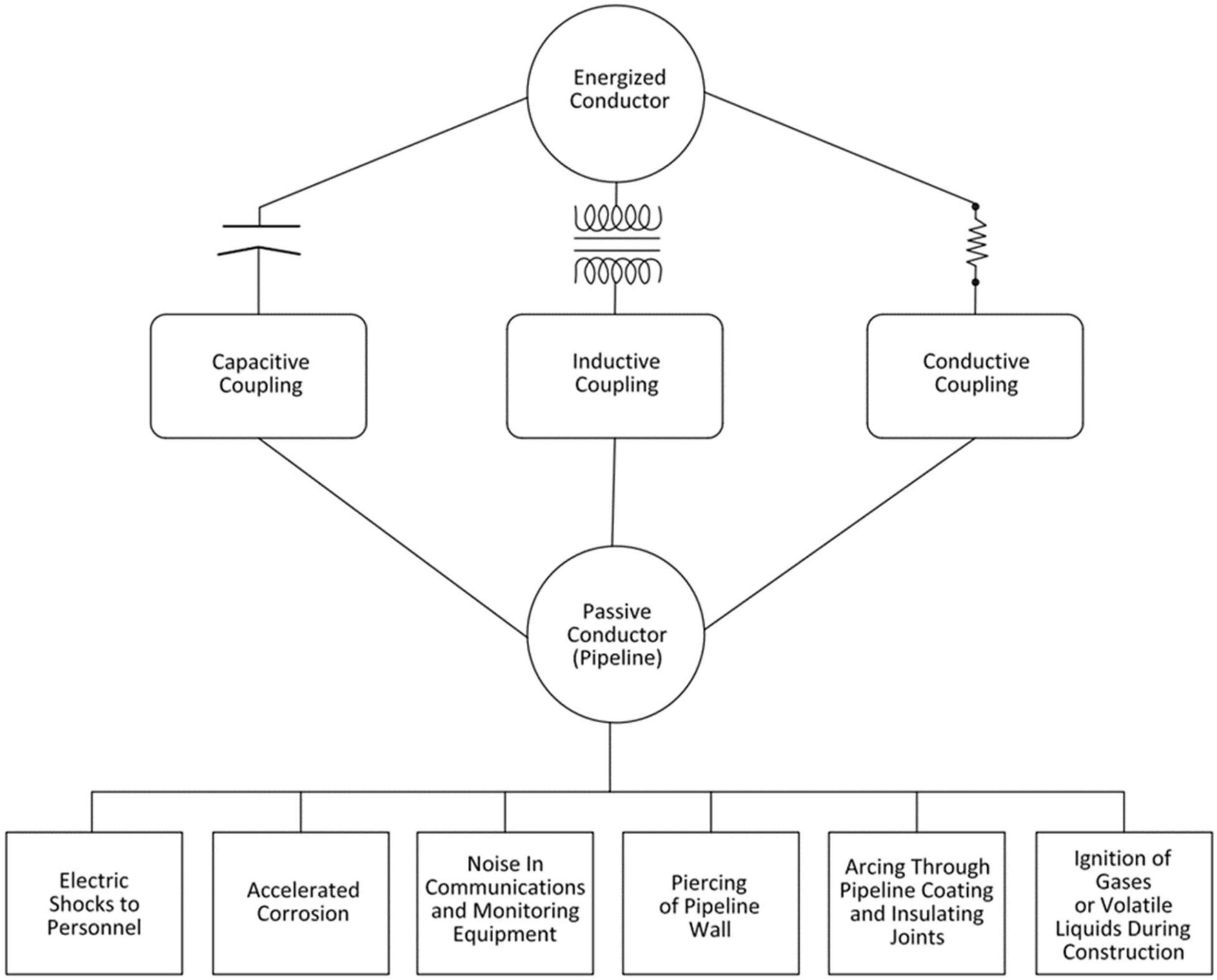


Figure 1-1: Interference Mechanisms and Effects on Pipeline

A.1.1 Capacitive Coupling

Mechanism:

Electrostatic or capacitive coupling results from the electric field gradient established between energized transmission circuit conductors and the earth. When the transmission circuit voltage is very high, a significant electric field gradient exists in the transmission circuit. Large conductors, which are near and parallel to the transmission circuit and insulated from the earth, are liable to accumulate a significant electric charge, which represents a very real danger for personnel. Typically, such conductors include equipment isolated from the earth, vehicles with rubber tires, aboveground pipelines, or pipelines under construction in dry areas when no precautions have been taken to establish adequate grounding for the pipeline lengths not yet installed in the ground. Hazards range from slight nuisance shocks to ignition of nearby volatile liquids with the accompanying risk of explosion, or electrocution of personnel.

Mitigation Measures:

Buried pipelines are relatively immune to interference due to capacitive coupling because, despite even an excellent coating, the length of exposure to the surrounding soil makes for an adequate ground to dissipate any significant charge that might otherwise accumulate. Aboveground pipelines, including pipelines under construction (which may or may not be buried in part) do not naturally have this protection. One means of protection is periodic grounding to earth, via ground rods, or other ground conductors judiciously placed to be unaffected by ground currents emanating from nearby towers during a fault.

A.1.2 Inductive Coupling

Mechanism:

Electromagnetic or inductive interference in a passive conductor (pipeline) result from an alternating current in another energized conductor (power line), which is parallel to the first. This level of interference increases with decreasing separation and angle between the conductors, as well as with increasing current magnitude and frequency in the energized conductor. The combination of high soil resistivity and passive conductors with good electrical characteristics (good coating, high conductivity, and low permeability) also result in high-induced currents.

Steady-state potential values occur at discontinuities in either the energized or the passive conductor. When a transmission circuit and a pipeline are interacting, such discontinuities take the form of rapid changes in separation between the pipeline and transmission circuit, termination of the pipeline or an insulating junction in the pipeline (which amounts to the same thing), sudden changes in pipeline coating characteristics, a junction between two (2) or more pipelines or transposition of transmission phase conductors. Note that the induction effects on pipelines during normal power line operating conditions are small compared to the induction effects experienced by a pipeline during a power line fault. The most severe kind of fault is a single-phase-to-ground fault during which high currents circulate in one of the power line phases and are not attenuated by any similar currents in other phases. Hence, mitigation methods, which suffice for single-phase fault conditions, are often adequate for other conditions. It must be noted, however, that the longer duration of the resulting potentials in the pipeline during steady state conditions makes the problem important to investigate from the perspective of human safety.

Unlike conductive interference, which tends to be a rather local phenomenon, inductive interference acts upon the entire length of the pipeline that is near to the power lines. Note, however, that conductive interference can involve long section of a pipeline if several towers adjacent to the faulted tower discharge a significant portion of the fault current, or if a ground conductor connected to the pipeline (anode) and located near a faulted tower, picks up current from the soil.

The large potentials induced onto a pipeline during a fault can destroy insulated junctions, pierce holes in lengths of coating, and puncture pipeline walls. Equipment electrically connected to the pipeline, such as cathodic protection devices, communications equipment, and monitoring equipment can be damaged, and personnel exposed to metallic surfaces, which are continuous with the pipeline, can experience electrical shocks. Accelerated corrosion is another possible result. Implementing appropriate mitigative measures, as discussed below, can prevent this situation.

Although a pipeline equipped with mitigative measures appropriate to deal with phase-to-ground faults does not usually present a great safety hazard during normal conditions, several problems can still exist due to low magnitude induced alternating currents. Accelerated corrosion of steel can result if not offset by increased cathodic protection. This may mean a shortened life for sacrificial and impressed current anode beds. Small amounts of AC can also render impractical the use of a pipeline as a communication channel for data such as pressure and temperature readings to pumping and compressor stations.

Mitigation Measures:

Pipeline Coating Resistance - The coating resistance of the pipeline should be chosen as low as corrosion considerations permit. Pipeline coating resistance plays an important role in determining pipeline potentials during a fault condition. During a fault condition, on an electric transmission circuit, the pipeline coating conducts significant amounts of current and should be regarded more as a poor grounding system than an insulator. When this perspective is assumed, it is seen that lowering pipeline coating resistance and bonding grounded conductors to the pipeline steel are two (2) applications of the same principle.

Pipeline Length - In theory, the potential induced electromagnetically in a pipeline insulated at both ends is roughly proportional to the length of the exposed region. When this relationship no longer holds, the pipeline is said to have exceeded its characteristic length. The maximum potential value in a section (with respect to remote ground) occurs at each extremity with roughly the same magnitude and opposite phase. This means that each insulating junction is subjected to a stress voltage that is double the steady-state value in the section. If insulating junctions are inserted frequently enough along a pipeline, then the section size is kept to a minimum, and consequently, so are the steady-state voltages in the pipeline. This constitutes one possible mitigation method. However, this thorough segmentation can result in very high construction and pipeline cathodic protection costs.

Grounding - Grounding of a pipeline, as a protection against the significant voltages that appear during an electrical fault condition, is one of the most effective mitigation measures available. A pipeline should be grounded at appropriate locations throughout its length. Typical grounding locations include: all termination points, both extremities of a segment which is grounded at both ends by an insulating junction, just before and just after a pipeline crosses a power line at a shallow angle, and any other important point of discontinuity likely to result in high induced voltages during a fault condition. Such points include locations where the passive conductor:

- Suddenly veers away from the power line.
- Suddenly changes coating characteristics.
- Emerges from the earth or returns to the earth.

Other locations where high-induced voltages are likely are points where power line phases are transposed and points where two (2) or more pipelines meet.

In order not to load cathodic protection installations significantly, grounds should be made of an adequate sacrificial material such as zinc or should be made via solid-state-isolator or polarization cells. These DC decoupling devices (DCD) should be properly sized, spaced and physically secured to withstand the current resulting during a power line fault. Caution should be taken to locate grounds far enough away from any nearby power line structure, so that the soil potential near the ground does not rise to undesirable values during a power line fault condition. Soil potentials drop off rather quickly around a faulted structure injecting currents into the earth, so this is not an extremely difficult proposition.

Buried Mitigation Systems - A highly effective means of mitigating excessive AC pipeline potentials is the installation of gradient control wires or matting. These methods reduce both inductive and conductive interference. These gradient control wires consist of one or more bare conductors which are buried parallel and near to the pipeline, and which are regularly connected to the pipeline. These wires provide grounding for the pipeline and thus lower the absolute value of the pipeline potential (i.e., the potential with respect to remote earth). They also raise earth potentials in the vicinity of the pipeline such that the difference in potential between the pipeline and local earth is reduced. As a result, touch voltages are significantly reduced.

A.1.3 Conductive Coupling

Mechanism:

When a single phase-to-ground fault occurs at a power line structure, the structure injects a large magnitude current into the earth raising soil potentials near the structure. If a pipeline is located near such a faulted structure, then the earth around the pipeline will be at a relatively high potential with respect to the pipeline potential. The pipeline potential will typically remain relatively low, especially if the pipeline coating has a high resistance. The difference in potential between the pipeline metal and the earth surface above the pipeline is the touch voltage to which a person would be subjected to when standing near the pipeline and touching an exposed metallic appurtenance of the pipeline.

If the pipeline is perpendicular to the power line, then minimal induction effects may occur, and the conductive component described above will constitute the entirety of the touch voltages and coating stress voltages appearing on the pipeline. If the pipeline is not perpendicular to the power line, then an induced potential steady state will appear in the pipeline near the fault location. Based on previous interference studies, the induced potential steady state in the pipeline is typically on order of one hundred and fifty-five degrees (155^{o}) out of phase with the potential of the faulted structure and therefore with the potentials of the soil energized by the structure. Thus, the pipeline steel potential due to induction is essentially opposite in sign to the soil potentials due to conduction. Therefore, inductive and conductive effects reinforce each other in terms of coating stress voltages and touch voltages.

Mitigation Measures:

The magnitude of the conductive interference is primarily a function of the following factors:

i) GPR of Transmission Circuit Structure. Soil potentials and touch voltages due to conductive coupling are directly proportional to the ground potential rise (GPR) of the transmission circuit structure. This GPR value is a property of the entire transmission circuit system.

ii) Separation Distance. Although soil potentials and therefore touch voltages obviously decrease with increasing distance away from the faulted structure, the rate of decrease varies considerably from site to site, depending upon the soil structure, as described below.

iii) Size of Structure Grounding System. Soil potentials decrease much more sharply with increasing distance away from a small grounding system than that from a large grounding system. Conductive interference can be minimized by limiting the use of counterpoise conductors and ground rods by the power company, at sites where pipelines are in proximity to the electric transmission system structures.

iv) Soil Structure. When the soil in which the structure grounding system is buried has a significantly higher resistivity than the deeper soil layers (particularly if the lower resistivity layers are not far below the structure grounding system), earth surface potentials decay relatively sharply with increasing distance away from the structure. When the inverse is true, i.e., when the structure grounding system is in low resistivity soil, which is under laid by higher resistivity layers, earth surface potentials may decay very slowly.

v) Pipeline Coating Resistance. When a pipeline has low ground resistance (e.g., due to coating deterioration over time), the pipeline collects a significant amount of current from the surrounding soil and rises in potential. At the same time, earth surface potentials near the pipeline decrease due to the influence of the pipeline. As a result, the potential difference between the pipeline and the earth's surface can be significantly reduced.

When a conductive interference problem is present, touch voltages can be reduced by either reducing earth surface potentials near the pipeline, raising the pipeline potentials near the faulted structure, or a combination of these two (2) actions. The most effective mitigation systems perform both actions.

A.2 A Brief Perspective on AC Corrosion Mechanisms

A.2.1 AC Corrosion Mechanism

AC corrosion is the metal loss that occurs from AC current leaving a metallic pipeline at a coating holiday. The mechanism of AC corrosion occurs when AC current leaves the pipeline through a small holiday in low resistance soil conditions.

A.2.2 Mitigation of AC Corrosion

The main factors that influence the AC corrosion phenomena are:

- Induced AC pipeline voltage.
- DC polarization of the pipeline.
- Size of coating faults (holidays).
- Local soil resistivity at pipe depth.

The induced AC pipeline voltage is considered the most important parameter when evaluating the likelihood of AC corrosion on a buried pipeline.

The likelihood of AC corrosion can be reduced through mitigation of the induced AC pipeline voltage. The European Standard BS EN 15280:2013 "Evaluation of AC Corrosion Likelihood of Buried Pipelines - Application to Cathodically Protected Pipelines" recommends that AC pipeline voltages should not exceed the following:

- Ten (10) Volts where the local soil resistivity is greater than 25 ohmmeters.
- Four (4) Volts where the local soil resistivity is less than 25 ohmmeters.

These AC pipeline voltage limits are derived in part by calculating AC density at pipeline coating holidays. Since the AC current is mainly discharged to earth through the exposed steel at pipeline coating holidays, the AC corrosion rate can vary proportionately with increasing AC density at a coating holiday.

European Standard CEN/TS 15280 offers the following guidelines:

The pipeline is considered protected from AC corrosion if the root mean square (RMS) AC density is lower than 30 A/m^2. In practice, the evaluation of AC corrosion likelihood is done on a broader basis:

- Current density lower than 30 A/m^2: no or low likelihood of AC Corrosion effects
- Current density between 30 and 100 A/m^2: medium likelihood of AC Corrosion
- Current density higher than 100 A/m^2: very high likelihood of AC Corrosion

If the soil resistivity and the pipeline AC voltage are known, the risk of AC corrosion can be determined using the following formula in Equation 1 to calculate the current density at a holiday location.

$$I = (8 * V_{AC}) / (\rho * \pi * d) \quad \text{(Equation 1)}$$

<u>Where</u>:

i = Current Density (A/m^2)

V_{AC} = Pipe-to-Soil Voltage (Volts)

ρ = Soil Resistivity (ohmmeters)

d = Holiday diameter (meters)

A.2.3 Determining Steady State Pipeline AC Voltage Limits

The primary factor in calculating AC density at coating holidays is induced AC voltage on the pipeline at these coating holidays. Since the local soil does not significantly change, lowering the induced AC pipeline voltage (by adding mitigation) also lowers the local AC density.

To analyze the possible AC corrosion effects on this pipeline, calculations were completed to determine the AC density exiting the pipeline, assuming a one (1) cm^2 circular coating holiday at each soil resistivity location.

A.3 Definitions

AC Electrical Interference (Electromagnetic Interference): A coupling of energy from an electrical source (such as an electrical power line) to a metallic conductor (such as a pipeline) which at low frequencies (in the range of power system frequencies) occurs in the form of three different mechanisms; capacitive, conductive, and inductive coupling. Electrical interference can produce induced voltages and currents in the metallic conductors that may result in safety hazards and/or damage to equipment.

Coating Stress Voltage: This is the potential difference between the outer surface of a conductor (e.g., pipelines, cables, etc.) coating and the metal surface of the conductor, and results from inductive and conductive potentials.

Capacitive Coupling: Capacitive coupling occurs because of an energized electrical source (e.g., power line) that produces a power line voltage between a conductor (such as a pipeline) and earth where the conductor is electrically insulated from the earth. An electric field gradient from the electrical source induces a voltage onto the conductor insulated from earth, which varies primarily according to the distance between the source and the conductor, the voltage of the source and the length of parallelism.

Conductive Coupling: When a fault current flows from the power line conductor to ground, a potential rise is produced in the soil about remote earth. A conductor located in the influence area of the ground for the power line structure, is subject to a potential difference between the local earth and the conductor's potential. Conductive coupling is a localized phenomenon that acts upon the earth near the flow of current to ground.

Conductive Earth Potential: This is the potential that is induced onto a conductor due to the energization of the surrounding earth by the current leaking from the power line structure.

Dielectric Breakdown: The potential gradient at which electric failure or breakdown occurs. In this case, it is pertinent to the coating of the pipeline and the potential at which damage to the coating will occur.

Earth Surface Potential: When a single-phase-to-ground fault occurs at a power line structure, the structure injects a large magnitude current into the earth and therefore raises soil potential near the structure. These potentials are referred to as earth surface potentials.

Fault Condition: A fault condition is a physical condition that causes a device, a component, or an element to fail to perform such as a short circuit or a broken wire. As a result, an abnormally high current flows from one conductor to ground or to another conductor.

Inductive Coupling: Inductive coupling is an association of two (2) or more circuits with one another by means of inductance mutual to the circuits. The coupling results from alternating current in an energized conductor (e.g., power line) which is parallel with a passive (non-energized) conductor. Inductive coupling acts upon the entire length of a conductor.

Inductive Pipeline Potential: The potential induced onto a pipeline during steady state or fault conditions that result from the mutual coupling between the energized conductor (power line) and the pipeline.

Load Condition: A load condition for a circuit is the amount of rated operating electrical power that is transmitted in that circuit under normal operating conditions for a specific period.

Local Earth: Local earth is the earth near a conductor, which is raised to a potential, typically, as a result of the flow of fault current to ground. In the case of a pipeline, which has a good coating and does not have grounding conductors connected to the pipeline where the earth potential rise occurs, the "local" earth will be the same as the "remote" earth.

Permeability: Permeability is a term used to express various relationships between magnetic induction and magnetizing force.

Potential Difference: The relative voltage at a point in an electric circuit or field with respect to a reference point in the same circuit or field.

Remote Earth: Remote earth is a location of the earth away from where the origin of the earth's potential rise occurs that represents a potential of zero Volts.

Steady State Condition: A steady state condition for a power system is a normal operating condition where there is negligible change in the electrical power transmitted in a circuit over a long period of time.

Step Voltage: The difference in surface potential experienced by a person bridging a 1-meter distance with his feet without contacting any other grounded conducting object.

Touch Voltage: The potential difference between the Ground Potential Rise and the surface potential at a point where a person is standing with his hand in contact with a grounded structure.

A.4 Mitigation System Design Objectives

An AC mitigation system designed to protect a pipeline subject to AC interference effects must achieve the following four (4) objectives:

i) During worst-case steady state load conditions for the electric circuits, reduce AC pipeline potentials with respect to local earth to acceptable levels for the safety of operating personnel and the public.

ii) During fault conditions on the electric circuits, ensure that pipeline coating stress voltages remain within acceptable limits to prevent damage to the coating or even to the pipeline steel.

Damage to the coating can result in accelerated corrosion of the pipeline itself. Coating damage can occur at voltages on the order of one thousand (1,000) to two thousand (2,000) Volts for bitumen coated pipelines, whereas damage to polyethylene or fusion bonded epoxy coated pipelines occurs at higher voltages, i.e., greater than five thousand (5,000) Volts.

iii) During fault conditions on the electric circuits, ensure the safety of the public and of operating personnel at exposed pipeline appurtenances.

ANSI/IEEE Standard 80 specifies safety criteria for determining maximum acceptable touch and step voltages during fault conditions. Special precautions must be taken by maintenance personnel when excavating inaccessible portions of the pipeline system to ensure safety in case of a fault condition.

iv) During worst-case steady state load conditions on the electric circuits, reduce AC densities through coating holidays to prevent possible AC corrosion mechanisms on the pipeline.

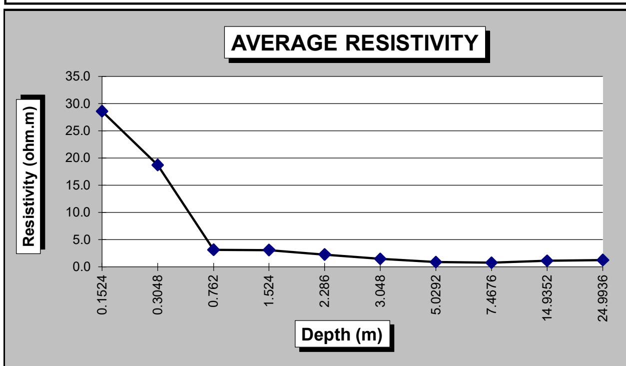
APPENDIX B –
SOIL RESISTIVITY DATA

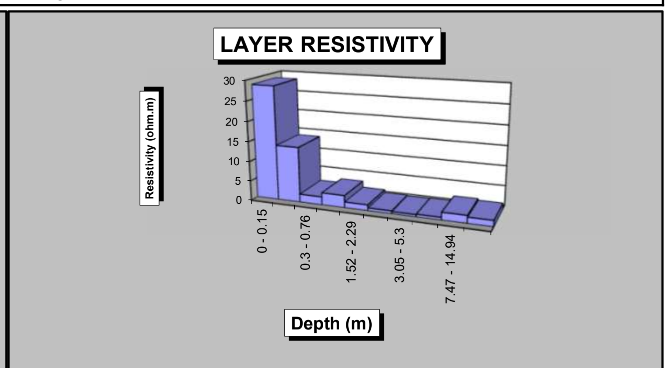
Project Name:	24-024-E-AC Collinsville
Soil Number:	#01
Date:	04/18/2024, 6:32 PM PCT
Location:	Off Stratton Ln
GPS Location:	38.081170°, -121.833897°
Testers:	Church, Conroy
Methodology:	$\rho = 2\pi dR$, per ASTM G 57 & Barnes Method
Instrumentation:	Megger
Weather:	75° Fahrenheit Clear & Sunny
Soil Description:	Clay, Loam

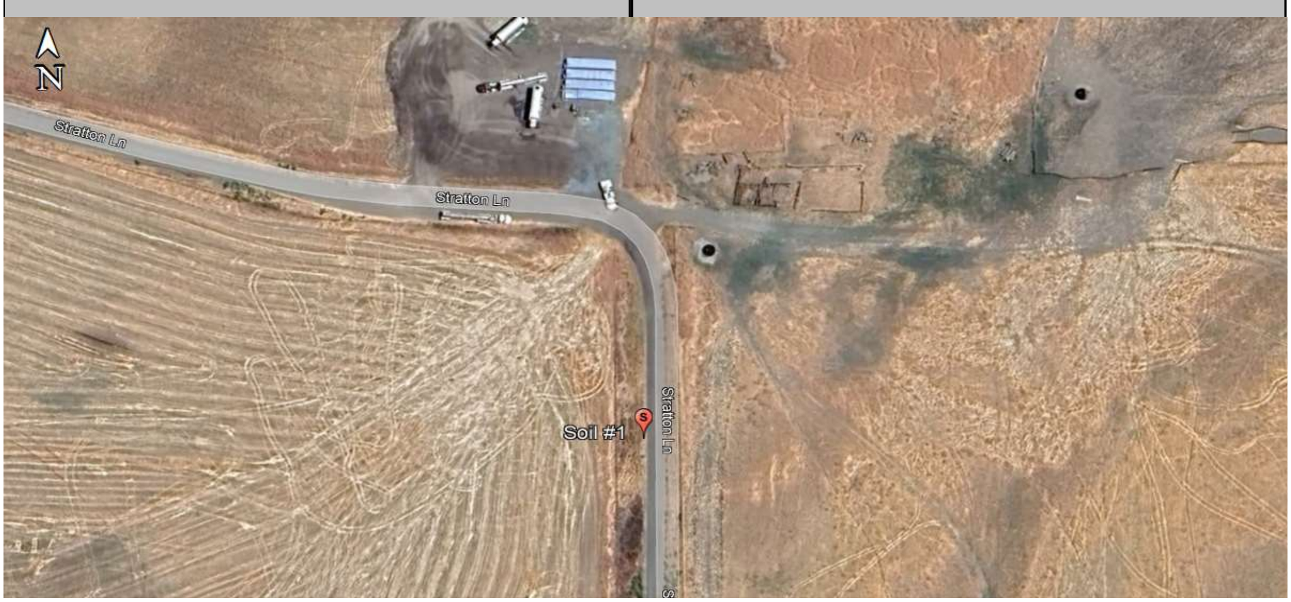
ARK® ENGINEERING & TECHNICAL SERVICES, INC.

4 Pin Wenner Data					Barnes Layer Analysis					
Depth (d) ft	Depth (d) m	R ohms	Spacing Factor	Resistivity ohm.m	1/R mhos	Δ 1/R mhos	ohms	Spacing Factor	Layer Resistivity* Layer (m)	Layer Resistivity* ohm.m
0.50	0.15	29.87	1	28.6	0.0335	n/a	n/a	n/a	0 - 0.15	29
1.00	0.30	9.77	2	18.7	0.1024	0.06888	14.519	1	0.15 - 0.3	13.90
2.50	0.76	0.66	5	3.2	1.5175	1.41510	0.707	3	0.3 - 0.76	2.03
5.00	1.52	0.33	10	3.1	3.0769	1.55947	0.641	5	0.76 - 1.52	3.07
7.50	2.29	0.16	14	2.3	6.3694	3.29250	0.304	5	1.52 - 2.29	1.45
10.00	3.05	0.08	19	1.5	13.1579	6.78847	0.147	5	2.29 - 3.05	0.71
16.50	5.03	0.03	32	0.9	35.7143	22.55639	0.044	12	3.05 - 5.3	0.55
24.50	7.47	0.02	47	0.8	58.8235	23.10924	0.043	15	5.03 - 7.47	0.66
49.00	14.94	0.01	94	1.1	83.3333	24.50980	0.041	47	7.47 - 14.94	1.91
82.00	24.99	0.01	157	1.3	125.0000	41.66667	0.024	63	14.94 - 25.0	1.52

* Layer Resistivity may not correlate with Average Resistivity because of soil characteristic variations with depth

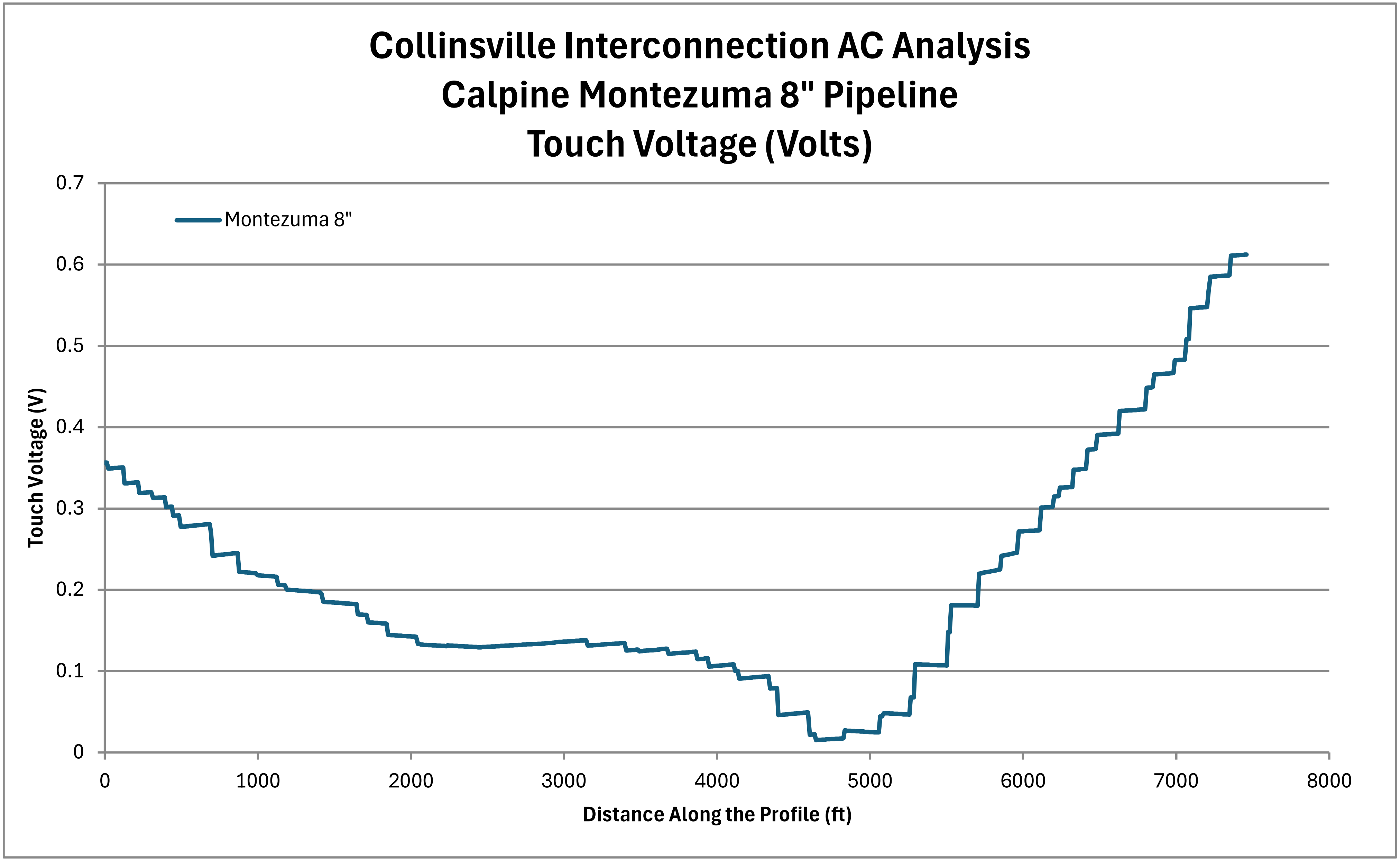






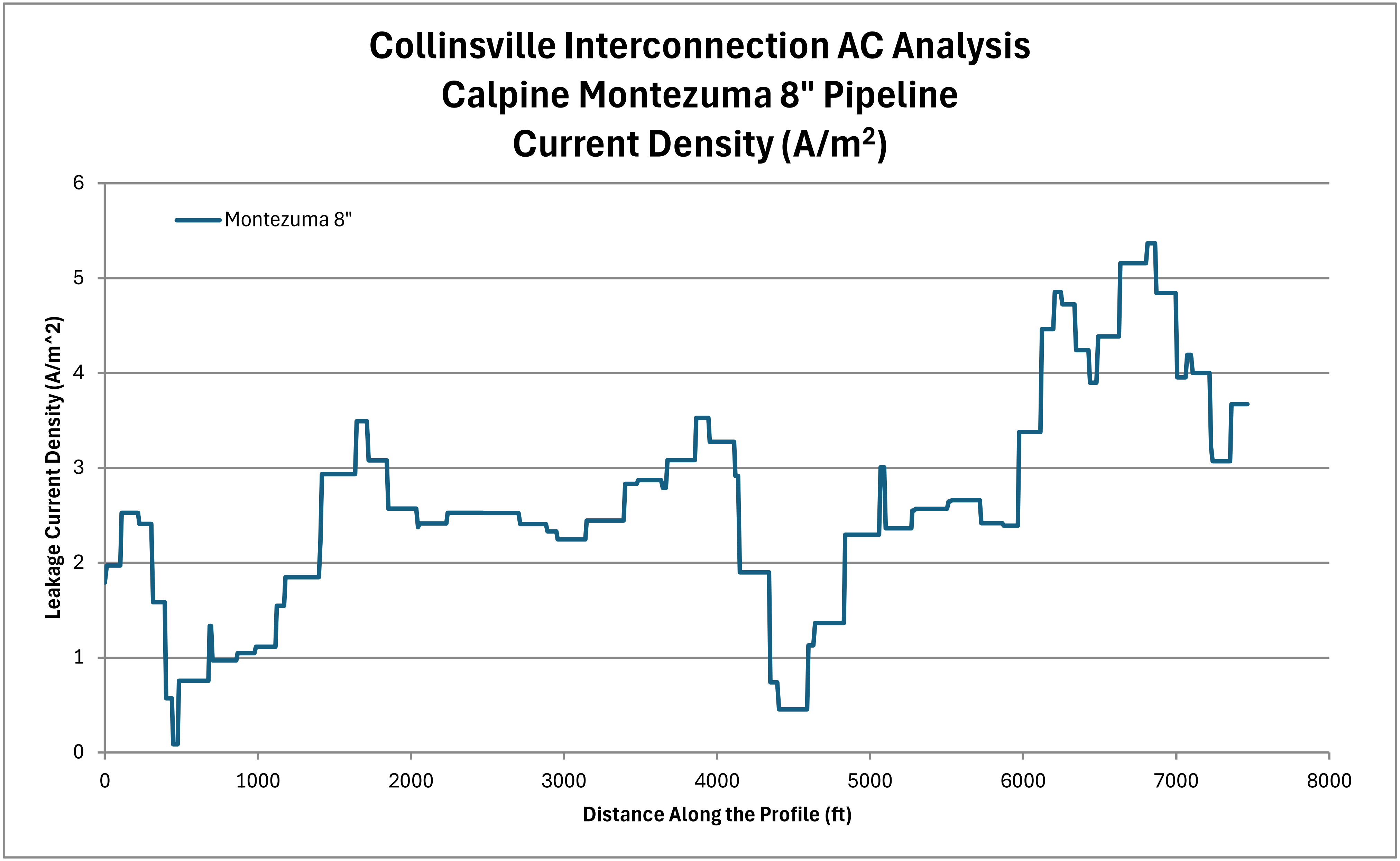
APPENDIX C –
PIPELINE STEADY STATE, AC DENSITY, FAULT PLOTS & ABOVE GRADE VOLTAGES

PIPELINE STEADY STATE



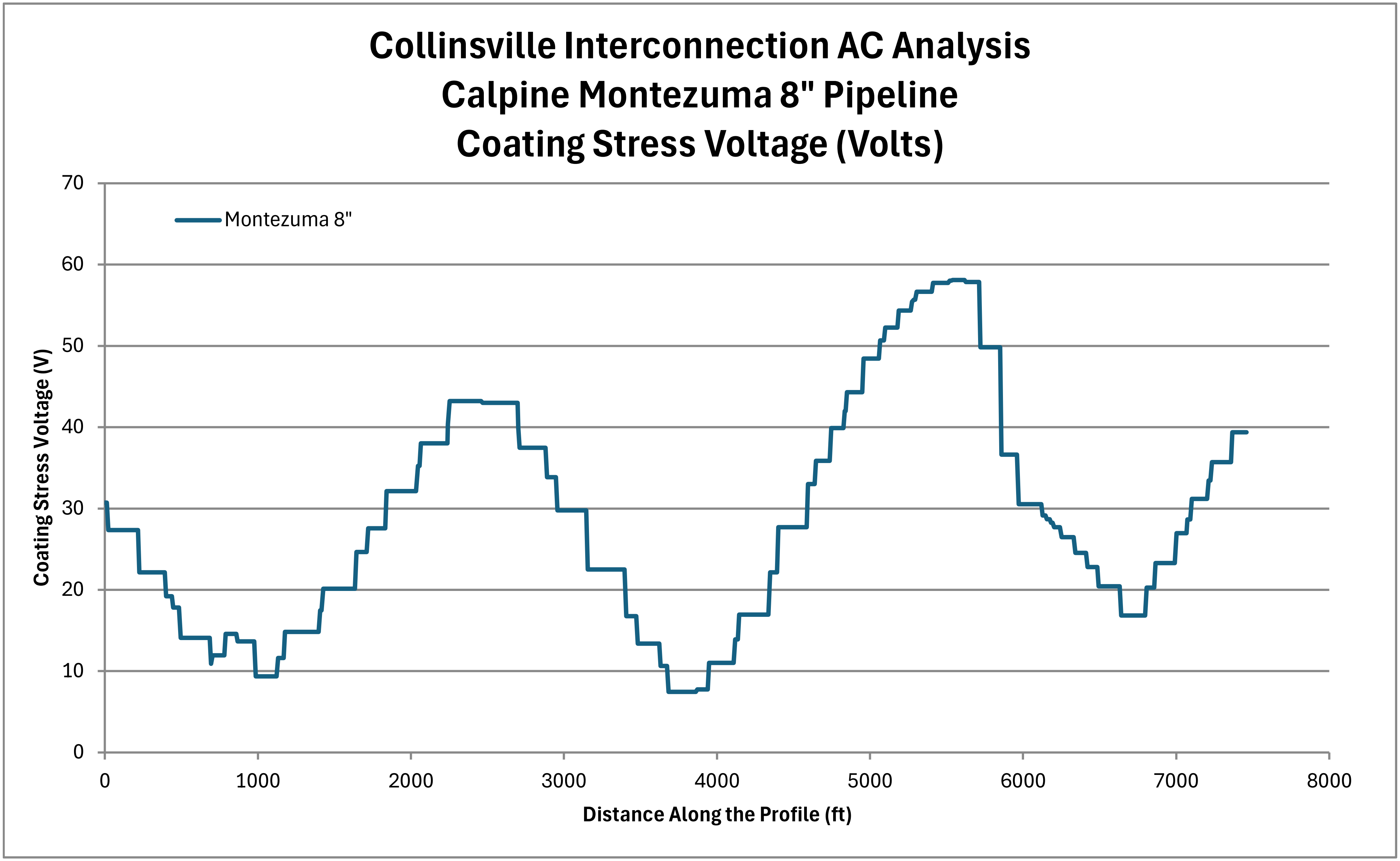
Collinsville Interconnection AC Analysis
Calpine Montezuma 8" Pipeline
Touch Voltage (Volts)
Montezuma 8"
Touch Voltage (V)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1000
2000
3000
4000
5000
6000
7000
8000
Distance Along the Profile (ft)

AC DENSITY



Collinsville Interconnection AC Analysis
Calpine Montezuma 8" Pipeline
Current Density (A/m²)
Montezuma 8"
Leakage Current Density (A/m^2)
Distance Along the Profile (ft)
0
1
2
3
4
5
6
0
1000
2000
3000
4000
5000
6000
7000
8000

FAULT – COATING STRESS VOLTAGE



Collinsville Interconnection AC Analysis
Calpine Montezuma 8" Pipeline
Coating Stress Voltage (Volts)
Montezuma 8"
Coating Stress Voltage (V)
0
10
20
30
40
50
60
70
0
1000
2000
3000
4000
5000
6000
7000
8000
Distance Along the Profile (ft)

APPENDIX D –
POWER & PIPELINE COMPANY DATA

POWER DATA

Thank you,
Michael

Michael Harmon
Engineering Manager
ARK Engineering & Technical Services, Inc.
OFFICE: 781-849-3800
EMAIL: mharmon@arkengineering.com
WEB: www.arkengineering.com

From: James Schuchard <JSchuchard@lspower.com>
Sent: Friday, October 25, 2024 9:21 AM
To: Robert Proude <rproude@arkengineering.com>; Michael Harmon <mharmon@arkengineering.com>; Kevin Almonacid <kalmonacid@arkengineering.com>; Kevin Hughes <khughes@arkengineering.com>
Cc: Margaret Bratcher <MBratcher@lspower.com>; Brian Coughlin <BCoughlin@lspower.com>; Kip Knote <KKnote@lspower.com>; Jason Niven <JNiven@lspower.com>; Lauren Kehlenbrink <LKehlenbrink@lspower.com>
Subject: RE: External: RE: LS Power Overhead Electric Transmission Line Crossing - Fresno County

Good morning Robert,

I'm not sure what experience you have reading those short circuit models. The below images have the relevant portions highlighted. The fault current is 39,896A for the 2028 Case and 40,673A for the 2035 Case.

```
The largest mutual group has 52 lines

Summary of fault being displayed:
Prefault voltage: From a linear network solution
Generator impedance: Subtransient
MOV iteration:                   [ On]
Enforce generator current limit [  A]
Voltage controlled current source simulated [No]
Type-3 wind plant simulated [No]
Converter-interfaced resource simulated [No]
ANSI x/r ratio calculation       [ On]
   In X-only network when X=0 use X=0.0001 p.u.
   In R-only network when R=0 compute R using method 2
      with Rc=0.0001 p.u.
   Assume Z2 to be same as Z1 for generators and phase shifters.
Ignore loads:                    [Yes]

==================================================================================================================================
  2. Bus Fault on:          0 COLLINSVI        230. kV 1LG Type=A
                                                         FAULT CURRENT (A @ DEG)
                  + SEQ             - SEQ            0 SEQ            A PHASE            B PHASE            C PHASE
              13298.7@ -85.2    13298.7@ -85.2    13298.7@ -85.2    39896.0@ -85.2       0.0@   0.0        0.0@   0.0
                                                         THEVENIN IMPEDANCE (OHM)
            0.18539+j3.45706   0.18719+j3.47516   0.24447+j3.29481

                  SHORT CIRCUIT MVA= 16728.5        X/R RATIO= 16.5743      R0/X1= 0.07072     X0/X1= 0.95307
                                                 ANSI X/R RATIO= 28.3917
----------------------------------------------------------------------------------------------------------------------------------
BUS       0 COLLINSVI        230.KV  AREA   1  ZONE 500   TIER   0       (PREFAULT V=1.053@  -0.0 PU)
                                 + SEQ            - SEQ            0 SEQ          A PHASE          B PHASE          C PHASE
VOLTAGE (KV, L-G)          >   92.327@  -0.1    47.683@-179.8    44.645@ 179.5    0.000@   0.0   138.048@-119.0   138.982@ 118.8
BRANCH CURRENT (A) TO      >
     0 Series React  230.  1L    1413.6@  91.3    1590.1@  91.3    1491.3@  93.4    4494.3@  92.0    207.4@-175.4      99.3@  -5.2
     0 SeriesReacto  230.  1L    1416.7@  91.3    1589.7@  91.3    1491.3@  93.4    4497.1@  92.0    205.2@-174.6      95.6@  -5.4
     0 COLLINSVILLE  525.  2X    5237.5@  95.7    5063.1@  95.8    5158.5@  95.1   15459.0@  95.5    206.3@   5.0      97.5@ 174.7
     0 BUS45          13.8  2X
                  AUTO NEUTRAL CURRENT =    11087.5 @    94.5 A
     0 COLLINSVILLE  525.  1X    5237.5@  95.7    5063.1@  95.8    5158.5@  95.1   15459.0@  95.5    206.3@   5.0      97.5@ 174.7
     0 BUS44          13.8  1X
                  AUTO NEUTRAL CURRENT =    11087.5 @    94.5 A

CURRENT TO FAULT (A)       >   13298.7@ -85.2   13298.7@ -85.2   13298.7@ -85.2   39896.0@ -85.2      0.0@   0.0       0.0@   0.0
THEVENIN IMPEDANCE (OHM)   >   3.46203@  86.9    3.48020@  86.9   3.30387@  85.8
----------------------------------------------------------------------------------------------------------------------------------
EQUIVALENT IMPEDANCE OF MOV-PROTECTED SERIES CAPACITORS THAT FIRED (OHM):             PHASE A          PHASE B          PHASE C
         VD DE2 525.0kV -      VD SC2_1 525.0kV                                  1.0 + j  -8.7    0.0 + j  -9.1    0.0 + j  -9.1
       VD SC2_1 525.0kV -        VD SC2 525.0kV                                  2.6 + j -16.8    0.0 + j -17.9    0.0 + j -17.9
----------------------------------------------------------------------------------------------------------------------------------

Summary of fault being displayed:
Prefault voltage: From a linear network solution
```

Collinsville 230kV Faultduty_PGE23-24TPP-2035case - Notepad
File Edit Format View Help

```
Summary of fault being displayed:
Prefault voltage: From a linear network solution
Generator impedance: Subtransient
MOV iteration:                  [ On]
Enforce generator current limit [  A]
Voltage controlled current source simulated [No]
Type-3 wind plant simulated [Yes]
Converter-interfaced resource simulated [Yes]
ANSI x/r ratio calculation      [ On]
   In X-only network when X=0 use X=0.0001 p.u.
   In R-only network when R=0 compute R using method 2
      with Rc=0.0001 p.u.
   Assume Z2 to be same as Z1 for generators and phase shifters.
Ignore loads:                   [Yes]

=====================================================================================================================================
  2. Bus Fault on:           0 Collinsville     230. kV 1LG Type=A
                                                         FAULT CURRENT (A @ DEG)
                  + SEQ                - SEQ               0 SEQ              A PHASE             B PHASE             C PHASE
              13557.6@ -84.8       13557.6@ -84.8      13557.6@ -84.8      40672.9@ -84.8         0.0@   0.0          0.0@   0.0
                                                         THEVENIN IMPEDANCE (OHM)
            0.17494+j3.27521    0.17569+j3.28826    0.24183+j3.25567

                  SHORT CIRCUIT MVA= 16848.3         X/R RATIO= 16.5735     R0/X1= 0.07384    X0/X1= 0.99403
                                                ANSI X/R RATIO= 29.3321
-------------------------------------------------------------------------------------------------------------------------------------
BUS      0 Collinsville   230.KV  AREA   1  ZONE   1   TIER   0       (PREFAULT V=1.040@   0.3 PU)
                                  + SEQ            - SEQ            0 SEQ            A PHASE          B PHASE          C PHASE
VOLTAGE (KV, L-G)          >    91.944@   0.1   46.701@-179.7   45.244@ 179.8    0.000@   0.0   137.580@-119.4   138.262@ 119.5
BRANCH CURRENT (A) TO      >
     0 Series React  230.  1L    1445.0@  91.1    1599.4@  91.5    1512.7@  93.7    4556.2@  92.1     197.8@-172.9      70.6@  -0.1
     0 SeriesReacto  230.  1L    1445.0@  91.1    1599.4@  91.5    1512.7@  93.7    4556.2@  92.1     197.8@-172.9      70.6@  -0.1
     0 Collinsville  525.  2X    5338.4@  96.3    5183.7@  96.3    5266.7@  95.6   15788.7@  96.1     197.8@   7.1      70.6@ 179.9
     0 COLL BK2      13.8  2X
                  AUTO NEUTRAL CURRENT =    11309.9 @   95.0 A
     0 Collinsville  525.  1X    5338.4@  96.3    5183.7@  96.3    5266.7@  95.6   15788.7@  96.1     197.8@   7.1      70.6@ 179.9
     0 COLL BK1      13.8  1X
                  AUTO NEUTRAL CURRENT =    11309.9 @   95.0 A

CURRENT TO FAULT (A)       >   13557.6@ -84.8   13557.6@ -84.8   13557.6@ -84.8   40672.9@ -84.8       0.0@   0.0       0.0@   0.0
THEVENIN IMPEDANCE (OHM)   >   3.27988@  86.9   3.29295@  86.9   3.26464@  85.8
-------------------------------------------------------------------------------------------------------------------------------------
EQUIVALENT IMPEDANCE OF MOV-PROTECTED SERIES CAPACITORS THAT FIRED (OHM):             PHASE A         PHASE B         PHASE C
         VD DE2 525.0kV -       VD SC2_1 525.0kV                                  1.3 + j  -8.6   0.0 + j  -9.1   0.0 + j  -9.1
       VD SC2_1 525.0kV -        VD SC2 525.0kV                                   3.0 + j -16.4   0.0 + j -17.9   0.0 + j -17.9
-------------------------------------------------------------------------------------------------------------------------------------

Summary of fault being displayed:
Prefault voltage: From a linear network solution
```


James Schuchard (he/him)
Lead Project Engineer
636.231.0465

From: James Schuchard
Sent: Thursday, October 24, 2024 3:59 PM
To: 'Robert Proude' <rproude@arkengineering.com>; Michael Harmon <mharmon@arkengineering.com>; Kevin Almonacid <kalmonacid@arkengineering.com>; Kevin Hughes <khughes@arkengineering.com>
Cc: Margaret Bratcher <MBratcher@lspower.com>; Brian Coughlin <BCoughlin@lspower.com>; Kip Knote <KKnote@lspower.com>; Jason Niven <JNiven@lspower.com>; Lauren Kehlenbrink <LKehlenbrink@lspower.com>
Subject: RE: External: RE: LS Power Overhead Electric Transmission Line Crossing - Fresno County

Good afternoon Robert,

Attached are fault data ran at Collinsville 230kV bus. Note, we've included year 2035 (future topology) just in case you need it. This is based on most recent available data…i.e CAISO 23-24 TPP PGE's short circuit model.

The normal loading will be 2100 amps per circuit. Please let me know if anything else is needed.

Thank you,

James Schuchard (he/him)
Lead Project Engineer

PIPELINE DATA

ARK Data Request

Utility Name: CPN Pipeline Company

Date Requested: 06/7/2024

Requested by: ARK Engineering & Technical Services

Completed by:

Pipe Information				Depth	Age			
Pipeline Name	Future / Existing	Pipe Diameter (in)	Wall Thickness (in.)	Pipe Cover/Depth (ft)	Year of Install	Coating Type (FBE/CTE/Etc.)	Coating Thickness (mils)	Coating Quality If Known (Good/Fair/Bad/Etc.)
Montezuma 8"	**Existing**	**8.625**	**0.188**	**5**	**1973**	**FBE**	**40**	**Unknown**

Existing AC Mitigation on Pipeline?	Yes/No
Please provide locations of SSD's and AC mitigation, and mitigation type (copper, zinc, etc) If a KMZ of mitigation locations is available please send.	

Additional Comments/Notes on Pipeline

* Please Provide the all pipelines within a 1-mile radius and their location