AC Interference Risk Ranking: Case Study

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Agenda

1. Introduction and Background
2. Safety and AC Corrosion Criteria
3. Approach
4. Summary of Results
5. Summary and Recommendations
1 Introduction and Background

AC interference risk ranking of existing gas transmission infrastructure for one of the largest combination gas and electric utilities in the USA.
Project Description

Utility
- Natural gas and electric service to 15 million people
- Covers 70,000 mi² in north and central California

Gas Pipelines
- 6,700 miles transmission
- Age: 1 to 72 years
- Coatings - Bare, asphalt, bitumen, coal tar, mastic, PE tapes, FBE.
- Varying diameters, operating conditions, etc.

Electric Transmission
- 18,600 miles transmission
- 60 kV, 115 kV, 230 kV, 500 kV
- Foreign transmission lines
AC Interference

Steady state operation

- Electromagnetic induction
- V peaks typically occur at discontinuities
- Magnitude dependent on:
  - Load current
  - Parallel
  - Separation
  - Phasing
  - Coating type/condition
  - Other factors
- Integrity and safety risks
- 15V limit (NACE SP0177)
- AC Corrosion
AC Corrosion

- Mechanism not well understood
- Omellose tested coupons in simulated soil
- Corrosion increases with $i_{AC}$
- No CP – accelerated
- Overprotection ($i_{DC} > 1\text{A/m}^2$) – accelerated corrosion in some soils
- Calcareous deposits formed in most soils (containing carbonates and bicarbonates)
- AC current density primary indicator:

$$i_{AC} = \frac{8 \times V_{AC}}{\pi \times \rho \times d}$$

Residual Corrosion Rate of Carbon Steel Specimens as a Function of AC and CP Current Density (Omellose, Lazari, et al, Corrosion 2010)
2 Criteria and Risk Rating

AC Voltage Limit (Safety)

AC Current Density Limit (AC Corrosion)
Criteria

Steady State AC Voltage (Safety)
• Maximum 15 V for safety as per NACE SP0177

AC Corrosion
• No NACE stipulated or universally accepted “safe limit” for AC corrosion.
• Research in Europe has identified the following:
  • For $i_{AC} < 20 \text{ A/m}^2$, AC corrosion is negligible
  • For $20 \text{ A/m}^2 < i_{AC} < 100 \text{ A/m}^2$, AC corrosion is possible
  • For $i_{AC} > 100 \text{ A/m}^2$, AC corrosion is probable
• The European and Draft NACE standard propose 30 A/m$^2$
• Von Baeckmann “only current densities above 50 A/m$^2$ are serious” – consistent with experience in most soil conditions.
• 1 cm$^2$ holiday is worst case and standard size used
### Risk Ratings Used

<table>
<thead>
<tr>
<th>Risk Rating</th>
<th>AC Voltage Limits</th>
<th>AC Current Density Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>$V_{AC} &lt; 5V$</td>
<td>$i_{AC} &lt; 20 \text{ A/m}^2$</td>
</tr>
<tr>
<td>Moderate</td>
<td>$5V &lt; V_{AC} &lt; 15V$</td>
<td>$20 \text{ A/m}^2 &lt; i_{AC} &lt; 50 \text{ A/m}^2$</td>
</tr>
<tr>
<td>High</td>
<td>$15V &lt; V_{AC} &lt; 20V$</td>
<td>$50 \text{ A/m}^2 &lt; i_{AC} &lt; 100 \text{ A/m}^2$</td>
</tr>
<tr>
<td>Highest</td>
<td>$V_{AC} &gt; 20V$</td>
<td>$i_{AC} &gt; 100 \text{ A/m}^2$</td>
</tr>
</tbody>
</table>
3 Approach

Phase A: Data Consolidation
Phase B: Normalization
Phase C: Final Risk Ranking
Approach Phase A

Data Consolidation

- Review of all background data
- \( V_{\text{AC}} \): 1574 TP’s <100 ft powerlines (GIS – 2011-2012)
- Additional studies: \( V_{\text{AC}} \) at 209 TP’s
- Soil resistivity all locations >2V (253 sites)
- Processing of soil data (layering) and calculation of AC current density
- After verification & consolidation – 106 locations
- Safety and AC corrosion risk rating for each location based on as-measured (i.e. one off) data
Powerline Circuit Load Data Sample for 2014

Graph showing load current (A) from 0 to 500 across the months of January to December.
Approach Phase B

Data Normalization

- Measured $V_{AC}$ normalized – for peak and average load
- One powerline – linear with change in load
- Multiple powerlines – more complicated
  - Model common scenarios (worst case) to determine weighting factors ($w_a$) for each powerline circuit ($k$)
  - Calculate scaling factor ($SF$) and $V_{max}$ ($SF_{max} \times V_{meas}$)

$$SF_{max} = \frac{\sum_{k=1}^{n} w_a_k w_b_k L_{max_k}}{\sum_{k=1}^{n} w_a_k w_b_k L_{meas_k}}$$

Where:
- $L_{max_k}$: maximum load for powerline circuit $k$
- $L_{meas_k}$: load at the time of the $V_{AC}$ measurement
- $w_a_k$: weight factor for proximity to the pipeline (modelled)
- $w_b_k$: weight factor for additional considerations (experience)
- $k$: powerline circuit with 1 being closest to the pipeline
- $n$: number of influencing powerlines
## Modeled Scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Powerline Distance from Pipe (m)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P1</td>
<td>P2</td>
</tr>
<tr>
<td>A</td>
<td>20</td>
<td>-</td>
</tr>
<tr>
<td>B</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>C</td>
<td>20</td>
<td>120</td>
</tr>
<tr>
<td>D</td>
<td>20</td>
<td>220</td>
</tr>
<tr>
<td>E</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>F</td>
<td>20</td>
<td>120</td>
</tr>
<tr>
<td>G</td>
<td>20</td>
<td>220</td>
</tr>
<tr>
<td>H</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>I</td>
<td>510</td>
<td>920</td>
</tr>
</tbody>
</table>

- Powerline: 115 kV vertical, Phasing A-B-C, 10 km parallel
- Pipeline: 600 mm diameter; Coating: FBE, 100 kΩ/m²
Modeling Results for Scenario H

![Graph showing induced AC voltage along the pipeline distance. The graph includes lines for P1 (20m), P2 (40m), P3 (60m), P4 (80m), and ALL.]
Weighting Factors Based on Modeling

<table>
<thead>
<tr>
<th>Voltage Contribution (%)</th>
<th>Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>A</td>
</tr>
<tr>
<td>60%</td>
<td>B</td>
</tr>
<tr>
<td>80%</td>
<td>C</td>
</tr>
<tr>
<td>85%</td>
<td>D</td>
</tr>
<tr>
<td>80%</td>
<td>E</td>
</tr>
<tr>
<td>75%</td>
<td>F</td>
</tr>
<tr>
<td>65%</td>
<td>G</td>
</tr>
<tr>
<td>50%</td>
<td>H</td>
</tr>
<tr>
<td>40%</td>
<td>I</td>
</tr>
</tbody>
</table>

Legend:
- Powerline P1
- Powerline P2
- Powerline P3
- Powerline P4
- Powerline P5
Final Risk Ranking

- All test locations were risk ranked based on normalized $V_{AC}$ and $i_{AC}$
- Test locations were consolidated and tallied on a pipeline basis (52 pipelines)
- In-depth review of pipeline routes, parameters, and influencing powerlines
- Each pipeline rated in order of priority from 1 to 5 (with 1 being top priority)
4 Summary of Results

AC Interference risk rating of each measurement location.

AC risk ranking and prioritization by pipeline.
Summary of AC Voltage and Current Density Data

AC Current Density (A/m²) vs. Maximum AC Voltage (V)

- Measured Data
- Scaled Data

Legend:
- LOW
- MODERATE
- HIGH
- HIGHEST
Summary of AC Voltage Ratings

Measured AC Voltage

- Low: 104
- Moderate: 2

Maximum AC Voltage

- Low: 59
- Moderate: 14
- High: 21
- Highest: 12
Summary of Current Density Ratings

Calculated Current Density

- Low: 32
- Moderate: 52
- High: 15
- Highest: 7

Average Current Density

- Low: 22
- Moderate: 53
- High: 13
- Highest: 18
Prioritization by Pipeline

Prioritized in order of risk:

- Priority 1: one or more highest
- Priority 2: two or more high
- Priority 3: two high or several moderate
- Priority 4: one moderate
- Priority 5: All low
# Pipeline Prioritization Summary

<table>
<thead>
<tr>
<th>Pipeline Example</th>
<th>Description</th>
<th>Risk Rating Summary</th>
<th>Recommendation</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A</strong></td>
<td>7 km parallel with 2 powerlines from MP 51.5 to MP 55.8.</td>
<td>Highest AC voltage and AC corrosion risk</td>
<td>Full AC study: Site survey, modeling and mitigation</td>
<td>1</td>
</tr>
<tr>
<td><strong>B</strong></td>
<td>4 miles of parallel from MP 42 to MP 46 with 3 powerlines.</td>
<td>Highest AC voltage risk at one location. (high scale factor)</td>
<td>Further site investigation to confirm the results. Full AC study if required.</td>
<td>2</td>
</tr>
<tr>
<td><strong>C</strong></td>
<td>Multiple powerline parallels: MP 1.5 –3.8; MP 17.1– 17.9; and MP 27.5 - 34.</td>
<td>Moderate safety and AC corrosion risks at multiple locations.</td>
<td>Site investigation, and potential AC study.</td>
<td>3</td>
</tr>
<tr>
<td><strong>D</strong></td>
<td>0.5 km parallel with 1 powerline near MP 14.5.</td>
<td>Moderate risk</td>
<td>Monitor</td>
<td>4</td>
</tr>
<tr>
<td><strong>E</strong></td>
<td>2.7 km parallel with 1 powerline from MP 14.5 to MP 16.2.</td>
<td>Low risk</td>
<td>None</td>
<td>5</td>
</tr>
</tbody>
</table>
5 Summary and Recommendations
Limitations and Summary

Limitations
• Variability in powerline loading and age of data
• Variability in soil resistivity
• Only test stations within 100 feet of powerline tested
• Coating type – thickness and holiday size
• Effect of soil chemistry
• Effect of CP levels $i_{DC}$

Summary
• Method for screening AC risks implemented on a large gas transmission network.
• Risk ratings attributed to each test location
• Priority ratings for pipelines assigned with specific recommendations
Recommendations

Specific Recommendations
• Full AC Study for 20 pipelines (Priority 1, 2 and 3)
• Investigation for 13 pipelines (Priority 1, 2, 3 and 4)
• Monitoring of Priority 4 locations
• No action required for Priority 5 locations

General Recommendations
• Further prioritization: ILI/ECDA data, HCA, coating type, etc.
• Perform action items in order of priority as part of multi-year program
• Measure AC voltages (time-stamped) during annual CP survey to identify additional locations
• Adequate CP; avoid overprotection ($i_{DC} < 1 \text{A/m}^2$)
Questions?