A careful balance of AC and CP

Lars Vendelbo Nielsen and Andreas Junker (MetriCorr, USA), with Casey Heinrich (Dominion Energy, USA), offer a detailed look at an AC corrosion remote monitoring concept.

Alternating current (AC) corrosion can be defined as corrosion initiated and propagating under the influence of alternating current. Buried pipelines sharing the right-of-way (ROW) with high voltage power lines systems are particularly prone to AC induction and subsequent risk of AC corrosion. This corrosion risk has been subject to a substantial amount of research and incorporated into the broader pipeline integrity perspective. Standards on criteria, mitigation and monitoring have been developed. The AC corrosion risk is highest at smaller coating defects (around 1 cm²) and the level of AC induction increases with increasing quality of the coating.

AC corrosion mitigation

Traditionally, mitigation of AC is performed for safety reasons, to protect maintenance personnel working on the pipeline. Left unmitigated, pipelines paralleled with high voltage power lines may easily induce voltages in excess of 15 V (sometimes 50 - 100 V) thereby constituting a severe hazard. Mitigation measures imply the establishment

Figure 1. High voltage power line sharing the ROW with a buried pipeline – introducing the risk of inducing AC on the pipeline.
Figure 2. A test station remote monitor in a so-called Big Fink test station. The monitor measures corrosion rate and pipeline electrical fingerprints and remotely transmits to a webservice.

of earth electrodes, which drain AC from the pipeline to the adjacent soil and into ‘far earth’. The earth electrodes are typically copper rods, zinc ribbon mitigation wires etc. connected through AC discharge devices (DC decoupling devices, polarisation cells, polarisation cell replacements etc.). These devices essentially block DC while creating a low resistance AC path. The installation of such grounds is associated with significant costs.

Cathodic protection (CP) of the pipeline by sacrificial anodes or by transformer rectifiers is designed to protect the pipeline from corrosion at coating defects. Research and experience shows that CP is also necessary for protection against AC corrosion. However, a moderate level must be maintained as excessive CP is a major factor in the creation of AC corrosion. Hence, a careful adjustment of the CP level can be used to effectively mitigate AC corrosion risk. Depending on the actual conditions, the adjustment of the CP can be carried out in combination with the AC mitigation, or as a standalone measure. The adjustment of the CP, which in many cases is a simple adjustment of the transformer rectifiers, is therefore a very cost-effective solution as compared with AC mitigation measures. However, all safety precautions shall of course be in comply.

Monitoring
Pipelines unaffected by AC or other interference are monitored by means of polarised potential measurements. These measurements can be performed on the pipeline itself or using coupons connected to the pipelines. A coupon of well-known area is buried next to the pipeline and in the same backfill as the pipeline itself to represent a coating defect.² Polarised potential is obtained by disconnecting the coupon and measuring the potential instantaneously after the disconnection. The polarised potential is checked for compliance with existing standards — for instance more cathodic than -850 mV CSE.³

<table>
<thead>
<tr>
<th>Period</th>
<th>$\text{V}_{\text{corr}}$ μm/y</th>
<th>$\text{Eon}$ V CSE</th>
<th>$\text{E}_{\text{ir}}$ V CSE</th>
<th>$\text{J}_{\text{dc}}$ A/m²</th>
<th>$\text{U}_{\text{ac}}$ V</th>
<th>$\text{J}_{\text{ac}}$ A/m²</th>
<th>$\text{R}_s$ Ω.m²</th>
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<tbody>
<tr>
<td>1</td>
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<td>-1.109</td>
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<td>-1.694</td>
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<td>-1.188</td>
<td>1.34</td>
<td>1.71</td>
<td>38</td>
<td>0.045</td>
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The coupon approach is necessary in the case of AC interference as well. A small 1 cm² coupon is used for the measurements. The electrical fingerprints that can be used to characterise the AC interference condition include DC potential (ON/polarised), DC current density flowing to the coupon, AC voltage between pipe and earth and coupon AC current density. Additionally, by forming the coupon as an electrical resistance (ER) probe, the corrosion rate can be obtained. AC and DC current density can be used as a normative measure of the AC corrosion risk. The AC current density shall not exceed 30 A/m² in average or the cathodic DC current density shall not exceed 1 A/m² in average. The direct corrosion rate measurement is a strong normative approach that may overrule current density criteria using a threshold corrosion rate to verify a safe condition. Figure 2 illustrates a test station with a built-in remote monitoring concept for measuring the above-mentioned data and transferring this data to a web service, through which the pipeline operator can access key values, analyse trends and establish root cause in case of critical values.

**Case study**

The AC corrosion remote monitoring concept can be illustrated by a simple case study. Test stations were installed along a pipeline that was essentially very well protected from AC corrosion. Effective grounds were in place keeping the AC voltage well below 1 V. CP potential was adequately moderate. From this initially safe starting point a controlled series of various conditions were applied to the pipeline in terms of disconnecting grounds and adjusting CP transformer rectifiers. The results are shown in Figure 3 and summarised in Table 1. Note that the corrosion rate can be deducted from the slope of the thickness curve in the upper graph in Figure 3. The reported period covers approximately five months.

**Period 1**

The starting point with safe conditions was monitored during period 1. No corrosion is observed. The DC current density is well below 1 A/m² and the AC current density well below 30 A/m².

**Period 2**

Increased CP level causing excessive DC current density well above 1 A/m² (2.32 on average). In itself this increased CP level does not cause AC corrosion, since the AC is still mitigated by grounds and the AC current density is still well below 30 A/m² (8 A/m²).

**Period 3**

Besides the increased CP level, a number of grounds were disconnected to increase the induced AC level. The AC current density is now on average 151 A/m², the DC current density 5.83 and the corrosion rate dramatically increased (almost 500 μm/y).

**Period 4**

This condition is exactly the same with regard to CP rectifier settings and grounds as throughout period 3. However, a decreased demand for power due to cooling of the weather conditions (no need for air conditioning) results in a lower level of induction and decreased corrosion rate (65 μm/y).

**Period 5**

Same condition as period 3 and 4, but the weather is now causing a high demand for air conditioning — corrosion rate increasing to 1170 μm/y.

**Period 6**

After period 5, the CP level was decreased while groundings remained in a disconnected condition. As observed, the corrosion rate continuously decreases throughout this period, and finally reaches 8 μm/y — a condition deemed to be safe. Note that the induced AC voltage level is higher than ever. Hence, adjusting the CP level is a very effective mitigation measure in itself.

**Period 7**

The high CP level has been re-established and combined with the disconnected grounds (high AC induction) the corrosion rate is again much too high.

**Period 8**

Back to the original starting point with safe conditions — grounds re-established and CP level moderated. The resulting corrosion rate is, again, low and under control.

By executing the above system test at multiple selected test sites, the operator was reassured that a full control was maintained regarding AC corrosion mitigation remedies.

**Conclusion**

AC corrosion in cathodically protected pipelines is a complex phenomenon, resulting as a combined effect of induced AC and excessive CP level. The mechanisms are continuously better understood, and the control of AC induced corrosion is possible by either mitigating the AC, by careful control of CP or a combination of both. AC mitigation is quite a costly measure, whereas control of the CP level in many cases is a simple adjustment of the transformer rectifiers involved. A cost-effective balance between AC mitigation and CP adjustments can be facilitated by a real time monitoring of corrosion rate and involved electrical fingerprints.

**References**