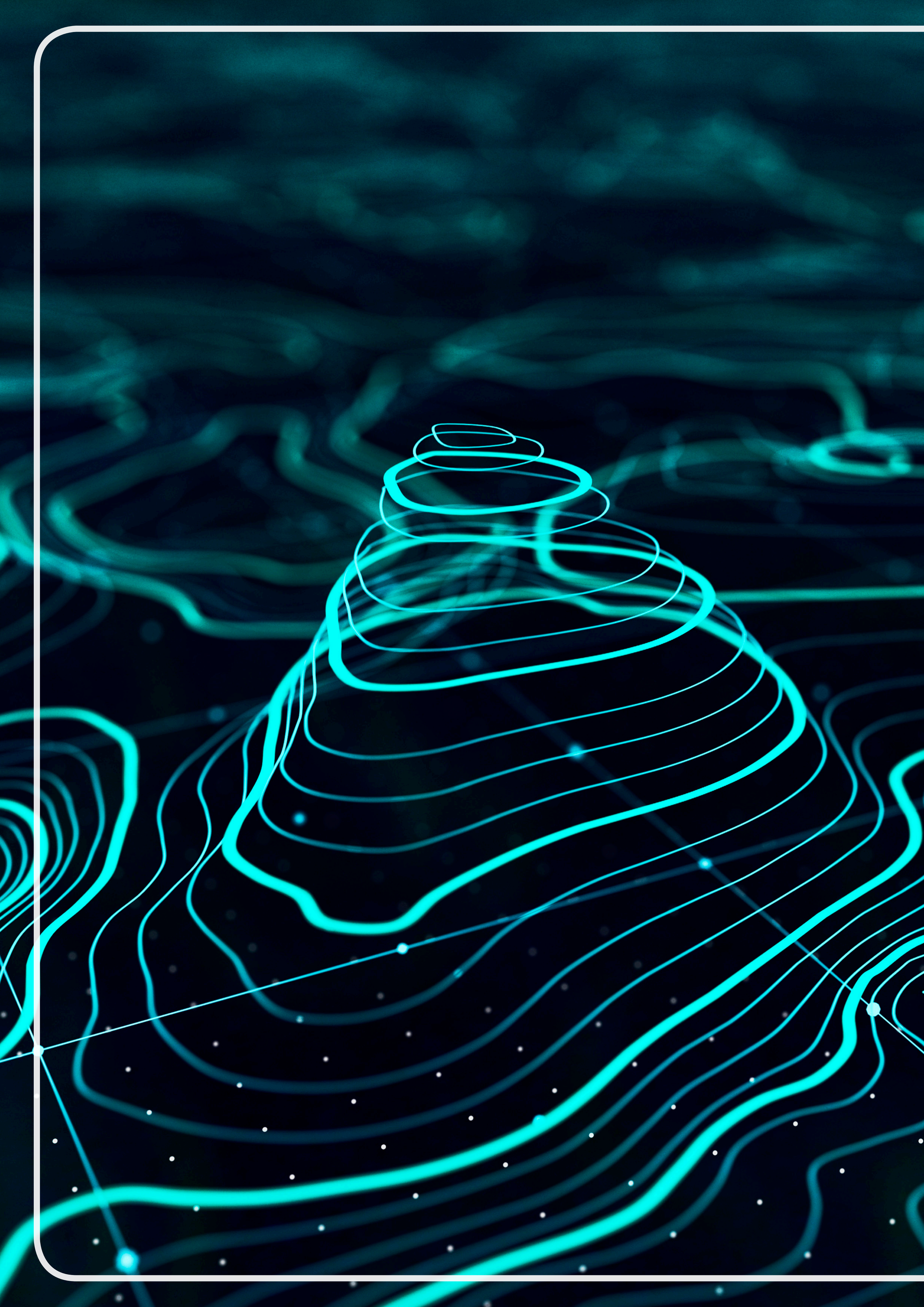

TECHNOLOGY IN UNCHARTED TERRITORY

Len Krissa, Enbridge Inc., Canada and Christophe Baete, Elsyca nv, Belgium, discuss cathodic protection technology for inspecting damaged coatings on HDD installed pipelines.

The preferred method of new pipeline construction for most major liquid products transmission companies at significant watercourse and roadway crossings is horizontal directional drilling (HDD). Pipelines installed by HDD have an increased likelihood of experiencing coating damage as opposed to those constructed through conventional open trench techniques. Currently available methods for identifying damaged coating regions within pipe installed by HDD cannot always provide absolute or accurate information on the location, size and geometry of the holidays. Although cathodic protection (CP) monitoring at HDD locations

can be validated at the entry/exit extremities, the region between is either assumed or speculated. Additionally, soil resistivity variations and drilling mud characteristics may adversely affect CP current distribution, leaving some coating defects unprotected and susceptible to corrosion. The approach of combining monitoring techniques and field surveys with computational modelling technology ascertains the external corrosion threat on pipelines within HDD locations.

Corrosion risks

Typical HDD begins with a pilot hole followed by reaming and then the pipe section is pulled through. Most HDD trajectories follow a curvature with considerable forces applied on the HDD wall during pulling with risk for coating damage. Friction reduction and stability is provided by a bentonite based drilling mud, often mixed using a local water source. Usually the current demand is relatively low (10 - 20 mA/m^2) because of the low oxygen concentration

Figure 1. Scratch-like coating defects are likely to occur at HDDs.

Figure 2. Testing and monitoring is limited at the entry/exit location.

and relative high pH of the drilling mud. The drilling mud becomes permanently part of the installation, filling the annular space, and knowledge on how it may affect long term corrosion susceptibility is uncertain. However, there is work being completed to evaluate and control drilling mud corrosivity through water quality procedures and use of additives.

There are situations where CP on a HDD pipeline may not be accomplished. For instance, it is reasonable to assume the pipeline will have the most coating damage in vicinity of the pilot entry and be adequately protected by using the majority of available CP current to this point. However, if there is coincidental damage situated in the mid-region of the HDD, in a high resistivity rock stratum the resistance to earth may be too high for adequate current to reach and protect defects at such locations. Under these circumstances, this location will not be protected and may corrode. CP will also be ineffective within regions of the HDD section where coating defects exist but are not in immediate electrolyte contact within the annular space. Unfortunately, there is no international mill coating standard for trenchless applications due to lack of consensus in abrasion, impact, shear strength and scratch resistance requirements. In practice, abrasive resistant overcoats (AROs) are used. A coating damage representing a maximum of 0.01% bare steel is typical acceptance criteria.

Testing and monitoring

Comprehensive evaluation of CP performance and monitoring techniques at HDD locations is imperative. Two separate field test methods are usually conducted at the entry and the exit side of the HDD for determining its coating condition. The methods are applied when the HDD is not yet tied-in into the network. First, a coating conductance test is executed based on the potential method (NACE TM0102) by applying a limited amount of DC current which polarises the HDD to approximately 200 mV more electronegative than native potential. Once the polarisation level is reached, the current is switched off to eliminate further polarisation. Based on the potential difference measured from two reference cells, on the entry or exit side, the coating conductance is calculated. Secondly, a current requirement test is performed to determine the degree of polarisation achieved after a fixed applied CP current of the same order of magnitude after a set duration. The test current must be imposed from a remote (2× HDD length) anode bed for uniform current distribution. However, errors in the conductance calculations can be expected due to:

- Reference electrodes are more influenced by the coating condition of the entry and exit extremities.
- Depending on the type, undamaged coating may consume 10 - 20% of the test current, especially for longer and large diameter HDDs.
- Drill fluid properties/soil strata (and thus resistivity profile) is not symmetric around the HDD.

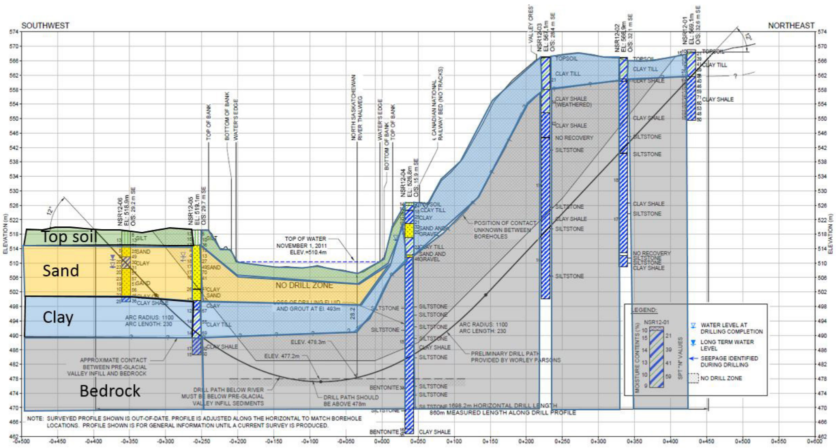

Figure 3. Example of soil strata profiling during geotechnical survey.

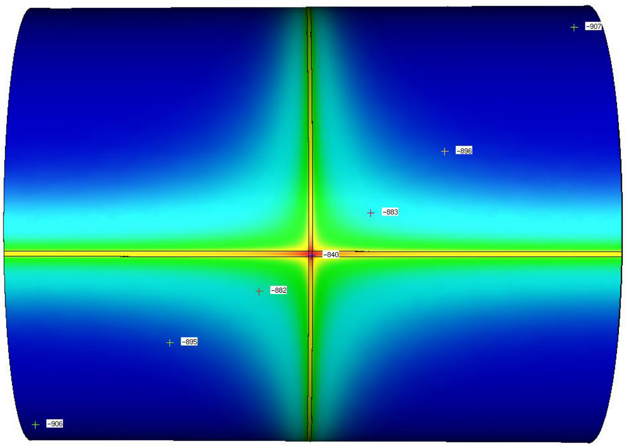

Figure 4. Zoomed out image of simulated IR-free potential on coating scratches.

Figure 5. Large scale post-construction HDD excavation and repair.

Coupons for long term monitoring are generally installed at the extremities, are not in immediate proximity to the pipeline nor backfilled in a representative environment, which may lead to discrepancies in potential readings. Drilling mud characteristics can also be considerably different than the neighbouring native soil.

Downhole modelling

Finite Element Analysis (FEA) is a feasible approach to confirm whether effective CP is being achieved throughout the entire length of an HDD crossing. Based on the geotechnical data obtained from boreholes during stability investigations, a 3D computational model is built in Elsyca CPMaster. Soil resistivity values of the different strata are obtained from ground penetrating radar measurements or derived from the soil composition sampled from the boreholes.

Results from the conductance and CP current requirement test are used to calibrate the model for the boundary conditions. The test current is applied with exact position of the remote anode bed and reference cells. The position of scratch-like coating defects around girth welds and at the bottom of the joint sections is iterated until the simulated OFF potential at the extremities is in line with the field measurements. The soil potential distribution and CP current flow from anode bed towards the HDD and coupons is obtained. As such the polarisation level of coupons and HDD coating defects can readily be compared. Zooming into the sections with coating defects, the IR-free potential and current density is simulated for compliancy validation against the CP criteria.

Conclusions

Coating conductance, CP current requirement test and geotechnical survey data are used as inputs to create a 3D computational model that simulates the polarisation level of HDD coating defects. Modelling enables the position of the scratch-like coating defects to be estimated on the girth welds and bottom of the HDD pipe. This approach provides better guidance for optimal ground bed design, configurations and current outputs to maximise cathodic protection effectiveness at HDD locations. Comparing polarisation levels of coupons against the simulated HDD model coating defects improves the overall effectiveness of the corrosion prevention monitoring programme.

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