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Managing AC corrosion risks

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Abstract

AC and DC interference threats are a severe concern for many pipeline operators as coating performance and complexity of energy corridors increases. This results in considerable investments in mitigation equipment, survey activities and monitoring devices. Capital and operational costs are under control when proper corrosion and safety risk assessment is performed, especially within co-locations where variations in the operational load of the power lines are unpredictable.

This paper discusses a pipeline integrity management approach for a buried pipeline subjected to AC corrosion. An existing mitigation system and monitoring program was reviewed through computational modeling predicting the AC corrosion likelihood of the entire parallelism according to ISO18086 and simulating real-time AC corrosion rates based on the contineous monitoring of AC current loads of the powerlines.

Introduction

According NACE21414 and ISO18086 standards AC corrosion risks on pipelines requires knowledge on the AC and CP current density on a coating defect or coupon. The induced voltage is mainly a result of the pipeline coating properties, connections to grounded structures (anode beds, other pipelines, AC grounding systems, etc.) and the powerline characteristics (AC load, phase arrangement, tower configuration, etc.). A proper mitigation design engineering study should include all these variables. Just installing AC grounding at highest measured AC voltage on the pipe often results in trial and errors and cost-inefficient designs. Small surface areas of e.g. 1 cm^2 exhibit a higher risk than larger ones but these small coating holidays are difficult to detect during surveys. Variations in power line load may be significant during a day period or yearly season. These variations are captured by remote monitoring devices, but their installation should be carefully chosen to capture the worst case events.

Pipeline case

A 27 miles long 8” pipeline is in collocation with seven high-voltage AC powerlines. A pipeline stretch of 2 miles is paralleling a 345 kV powerline in the west and a 1-mile stretch is paralleling with a 69kV power line in the east. The length of parallelisms are relatively short. The remaining powerlines are mainly crossing the pipeline at different locations.

Computational modeling performed in Elsyca V-PIMS software to validate:

- the effectiveness of the existing AC mitigation system;
- the effectiveness of the CP system;
- the overall AC corrosion risk which is combination of CP and AC.

The pipeline was installed in 2010. In year 2016 several AC corrosion anomalies were detected during an ILI MFL inspection run. An AC mitigation system was then installed in year 2017 for controlling the induced AC voltage and current in the pipeline. The AC corrosion risk is monitored by eleven electrical resistance (ER) probes connected to the pipeline and eight electromagnetic field/longitudinal electrical field devices (EMF/LEF) next to the power lines. The former measures the corrosion rate and electrical parameters (AC voltage, AC current density, DC current density and pipe-to-soil potential) of a 1 cm^2 coupon, while the latter measures indirectly the power line load and phasing. The devices were installed as depicted in Figure 1. Three insulation joints exist at respectively the launcher(west)/receiver(east) and in the middle of the pipeline trajectory.

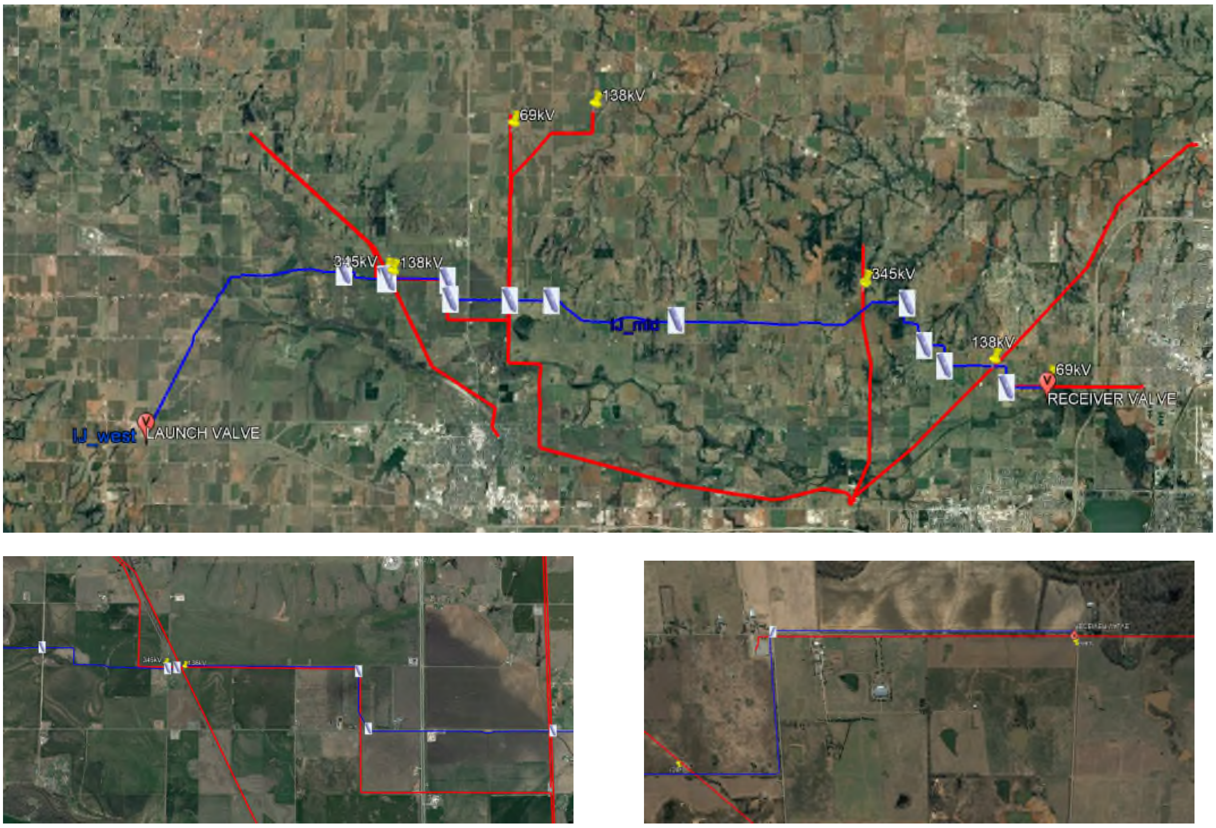

Figure 1 – pipeline routing (blue) in collocation with high voltage AC power lines (red) (LEF/EMF devices with corresponding powerline rating; ER-probes)

Figure 2 – corresponding V-PIMS computational model

Power line ID	Voltage [kV]	Phase arrangement	Current load [A]		
			Min	Avg.	Max
HV01	345	ACB	25	231	621
HV02	138	ABC	13	86	337
HV03	138	ACB	20	171	471
HV04	69	CBA	5	45	544
HV05	345 345	ACB BCA	70 54	612 582	1444 1400
HV06	138	ACB	20	195	739
HV07	69 distr.	CBA ABC	34 -	292 75*	608 100*

*assumed

Table 1 – powerline operating conditions

Model calibration

Field data and pipeline properties are used to calibrate the computational model such that simulation results are aligned with real-world data. Recordings from the LEF/EMF devices allowed calibration of the power line loads and conductor phasing. The pipeline coating resistance/impedance of 23kOhm for the FBE coating was found by iterating on the pipe-to-soil ON potentials (figure 2) and AC voltage on the pipeline (figure 3). The variations in induced AC voltage (figure 4) are well aligned between measured and simulated data.

For the pipe potentials two different CP scenarios were considered since the insulation joint (IJ) halfway the pipeline route was deficient for a short time. The AC voltage readings over time were taken in the western parallelism where most of the ER-probe data and EMF/LEF data is available. The ILI anomaly size of corrosion features exceeding 10% metal loss was included in the model to refine the coating holiday size and coating resistance. Soil resistivity measurements were taken at ten selected locations and publicly available soil maps were consulted. The soil resistivity at the pipeline depth varies between 3.5 Ω-m and 253 Ω-m with the logarithmic mean value of 13 Ω-m.

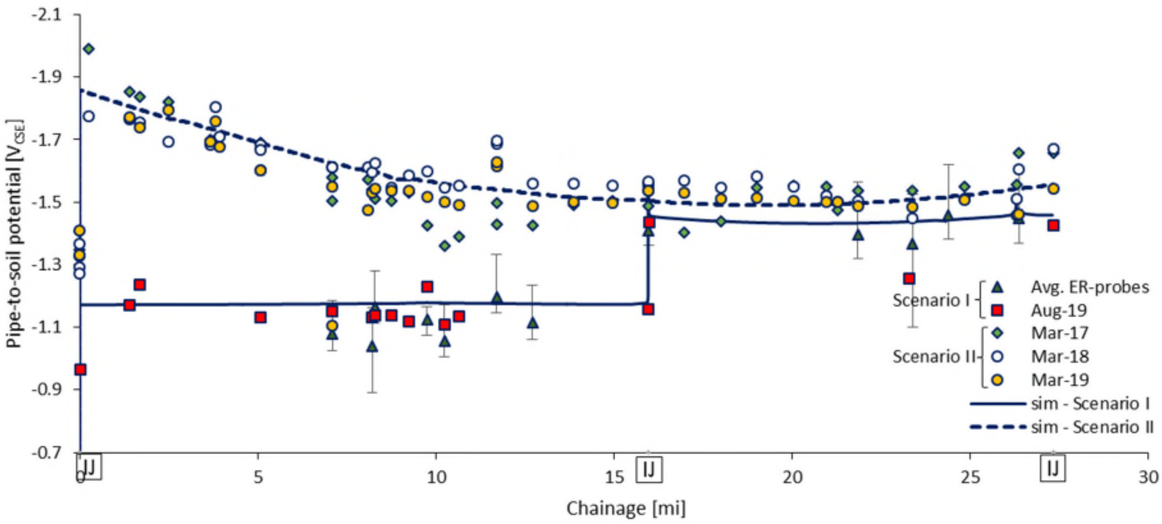

Figure 3 – pipe-to-soil ON potentials before and after repair of insulation joint (IJ)

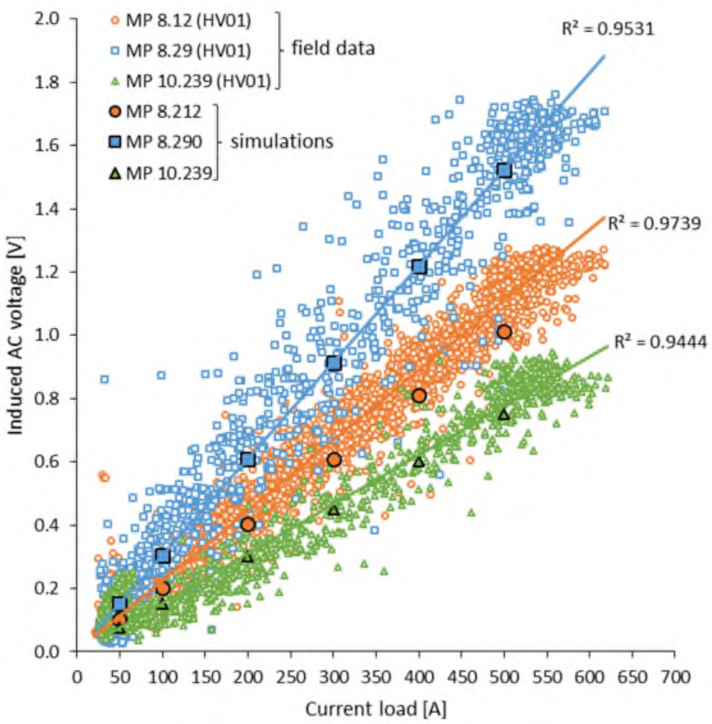

Figure 4 – AC potential fluctuations (measured and simulated) as function of power line loads

AC corrosion threats

The profile of the simulated induced AC voltage along the line with the existing mitigation in place was simulated and compared with survey and monitoring data at various times. Under maximum recorded powerline load the induced voltage reaches 4V just upstream of the insulation joint halfway the pipeline route and 13V at most eastern part at the receiver valve. Note that there are no ER-probes installed where the highest peaks in the AC voltage occur. The simulated AC current density resulting from the AC voltage and local soil resistivity reaches values above 100 A/m^2 in locations where no monitoring devices were present. This is caused by a 69kV power line with a distribution powerline system (HVAC07) and the electrical discontinuity (insultation joint) of the pipeline. The peak in AC current density also occurs at remote distance from the parallelism between the pipeline and power line were mitigation systems were installed. In Figure 6 it is clearly seen that the AC grounding should be foreseen upstream of the insulation joint of the receiver in the east and the existing mitigation system in between MP6 to MP11 is not adequate for reducing high AC current density values further downstream of the collocation.

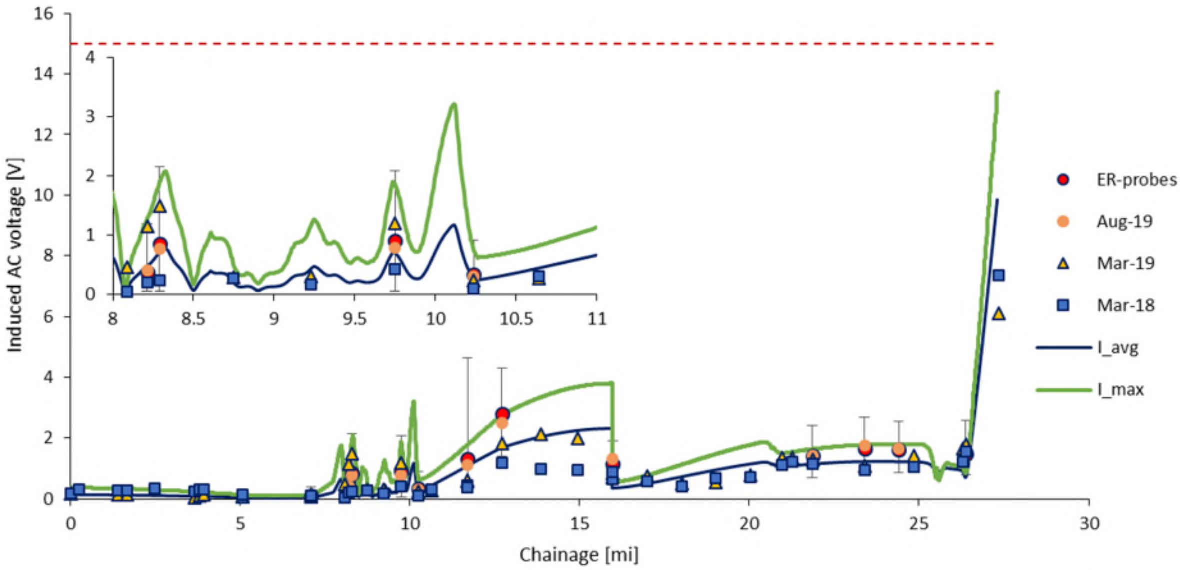

Figure 5 – simulated (full line) versus measured (markers) induced AC voltage

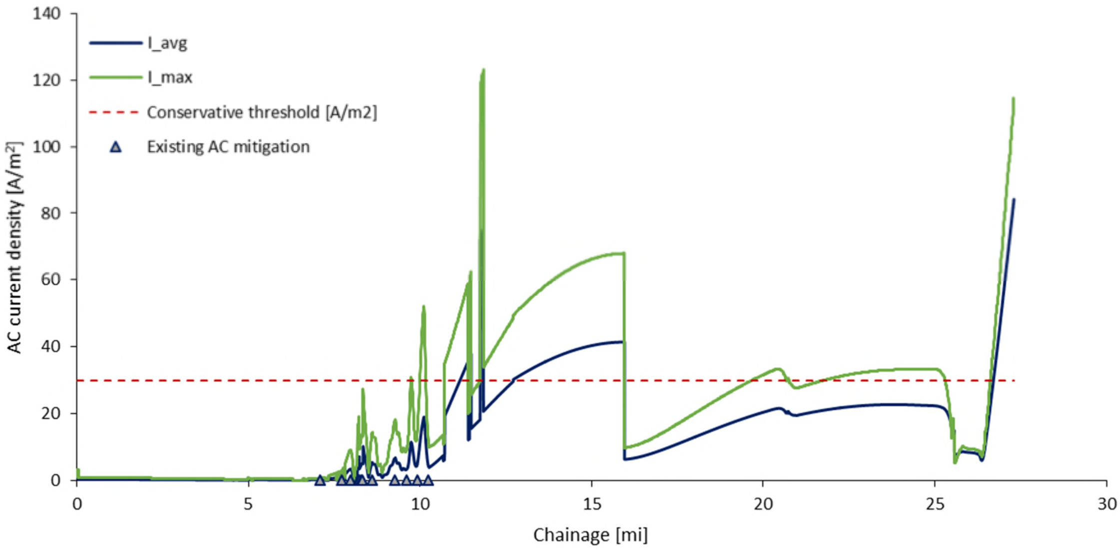

Figure 6 – simulated AC current density profile along the pipeline route

The simulated AC and DC current density at a coating defect along the pipeline for a specific powerline load condition are shown in Figure 7. The high-resolution simulations are at level of the pipe joint/spool and consider the anomaly size from the ILI and CIPS surveys. The current densities under the average and peak load are plotted (Figure 8) in the AC corrosion risk diagram of ISO18086 standard for those locations where ER-probes were installed, metal loss features were detected, and maximum AC corrosion activity is expected from simulations (peaks in Figure 6 and 7). Figure 8 demonstrates that the computational model predicts AC corrosion risks at most vulnerable pipeline locations (Jac max, metal loss features), at ER-probe locations or in any pipe section of interest.

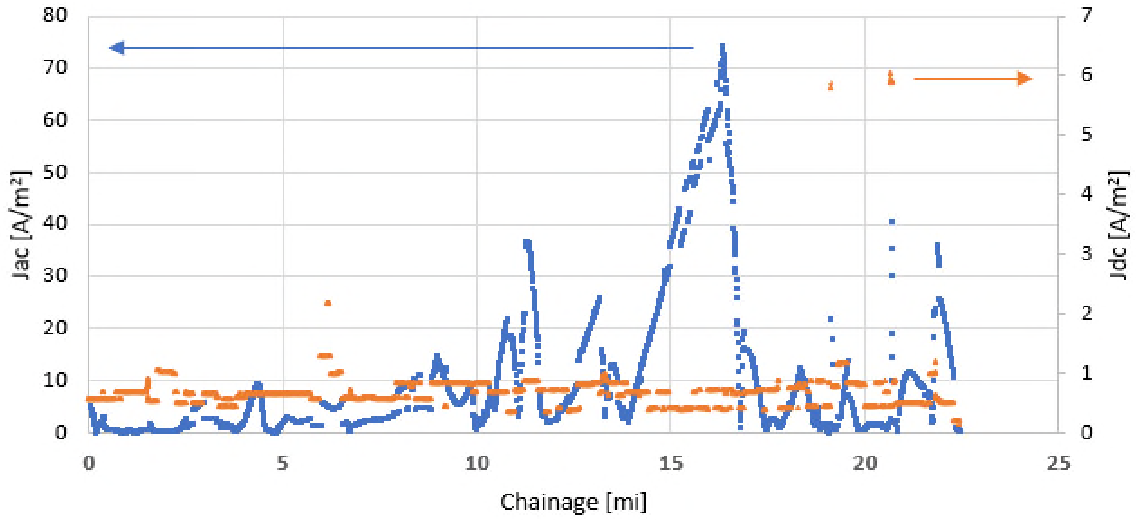

Figure 7 – instantaneous simulated AC and DC current density along the pipeline

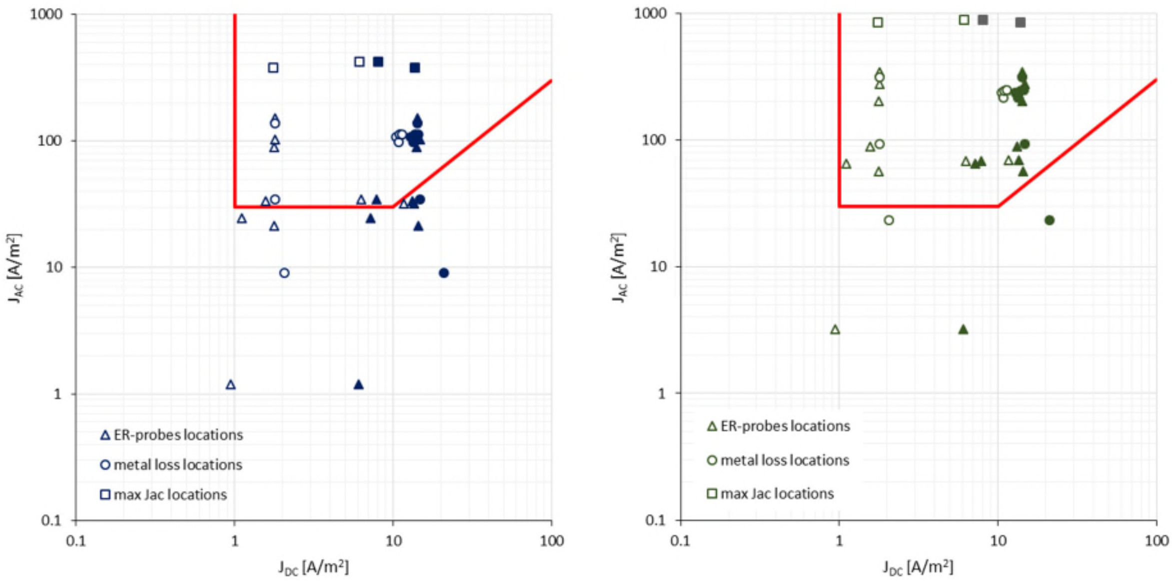

Figure 8 – simulated AC corrosion risk at locations of interest under average (left) and maximum AC powerline loads (full markers are under elevated CP)

Mitigation

Acknowledging the risks and identifying the most vulnerable locations allow further optimization of the AC mitigation system. In first instance the sensitivity of the existing mitigation design was investigated through modeling. Figure 9 shows that the AC grounding MIT05 is responsible for a significant increase in AC current density (increase by a factor of 5) when not functional. Permanent monitoring of drainage current through this grounding or pipeline potential was recommended.

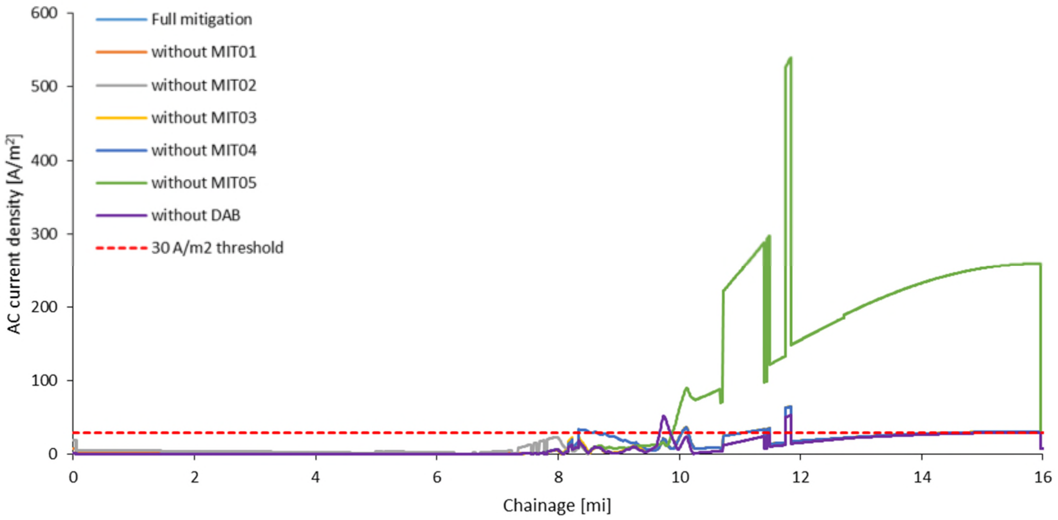

Figure 9 – effect of malfunctioning AC grounding on the AC current density (west part shown only)

Finally, three additional AC grounding systems have been designed for securing pipeline's integrity. At maximum power line load the maximum current density does not exceed the 100A/m^2 and remains below 30A/m^2 under average load.

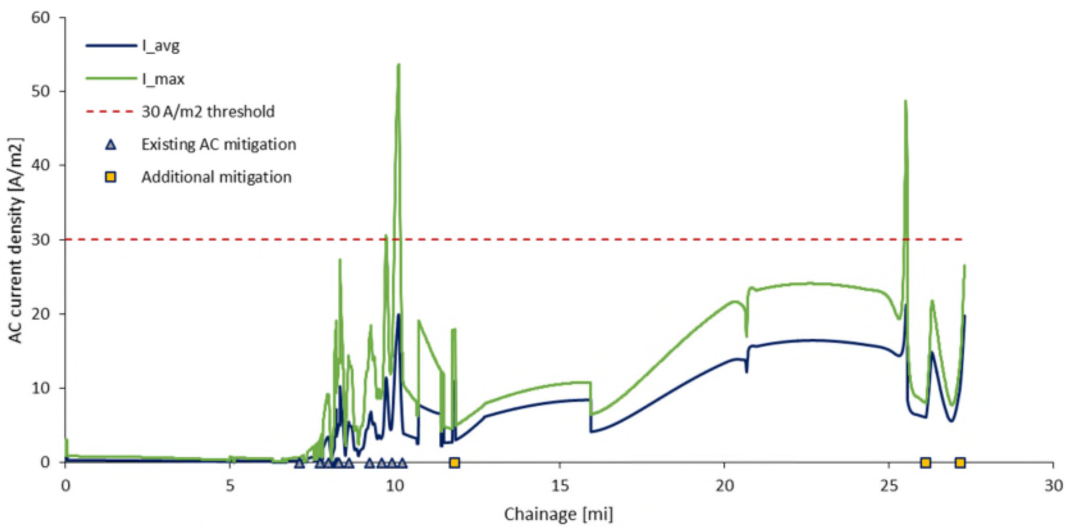

Figure 10 – AC current density with improved mitigation system (full pipe)

Mitigation system		Property		
		Amount	R [Ω]	Length [ft]
Existing	E_MIT01	1	-	400
	E_MIT02	1	-	2503
	E_MIT03	2	-	2 x 310
	E_MIT04	2	-	2 x 1536

	E_MIT05	1	-	5246
New	MIT06	1	0.50	115
	MIT07	1	0.15	610
	MIT08	1	0.25	1035

Table 2 – existing and new mitigation system

Conclusions

Pipelines are easily victim of AC corrosion risks when not properly assessed and mitigated. Risk assessments must be based on reliable data gathered in the correct locations and the mitigation system should be designed where hot-spots areas on the pipeline occurs. The cathodic protection and AC interference simulations deliver the required DC and AC current density on coating defects for AC corrosion risk assessments for the full pipeline route as required per ISO18086.

In this particular study the AC and DC current densities along the entire routing were obtained from high resolution model, CIPS, ILI and soil data. In addition, variations in the powerline loads were monitored with dedicated LEF/EMF devices. Simulations were well aligned with measured pipe-to-soil potentials, AC voltages and ER-probe readings. Despite the intensive field surveys and investment in monitoring equipment, the most vulnerable locations were not monitored, nor properly surveyed, and the mitigation system was insufficient.

Computational modeling calculates the risks and predicts AC corrosion attack for the full pipeline avoiding any missed critical locations and under designed mitigation systems. This ultimately leads to cost reduction since a considerable amount of inspection digs, pipeline repairs and monitoring devices could have been avoided.