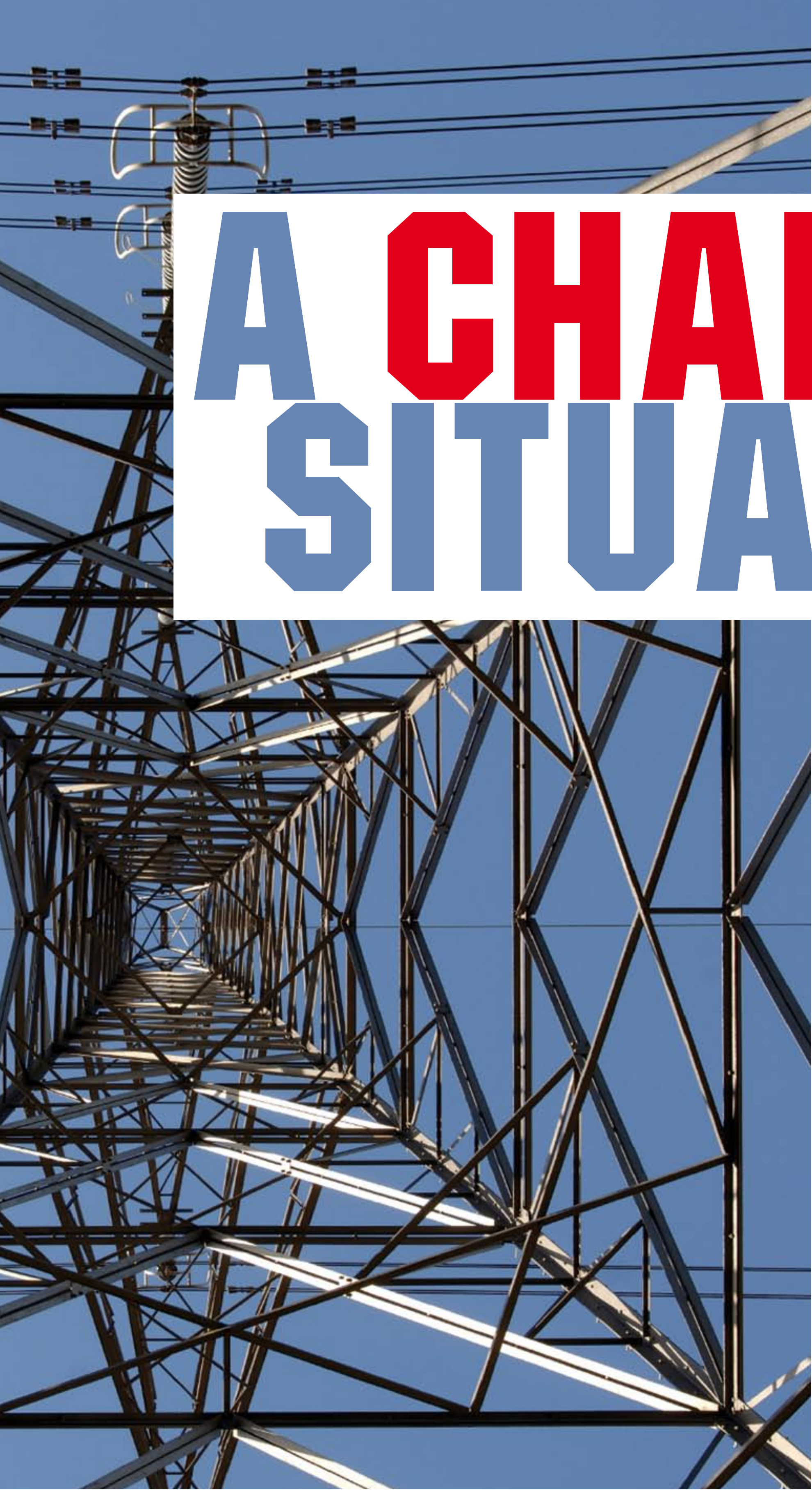

A CHARGED SITUATION

Ted Huck, MATCOR, USA, discusses the investigation and mitigation of AC induced corrosion.

Pipeline operators must be aware that AC induced corrosion is threatening newer pipelines. This is the finding from numerous pipeline integrity studies, whether it be smart pig indications or direct assessment evaluations. Pipelines with outstanding coating and cathodic protection systems are showing evidence of AC corrosion. In some cases, this is quite severe.

Pipeline operators and regulators are well aware of the DC corrosion risks associated with buried steel piping systems. For decades, pipeline companies have employed both coatings and cathodic protection to minimise the damaging and relentless effect of corrosion. Despite these efforts, the US Department of Transportation's Office of Pipeline Safety continues to cite external corrosion as the leading cause of failures to hazardous liquid and gas pipelines.

Historically, the focus of corrosion mitigation efforts has been to eliminate galvanic or DC corrosion. Increasingly however, pipeline operators are becoming aware of additional corrosion threats from a surprising source – conventional high voltage AC power transmission lines. The corrosion risk from AC induced current is a relatively new phenomenon. AC induced currents were only addressed as a safety issue with no concern over the potential corrosion risk.

Conventional pipeline experience says that AC induced current does not cause corrosion and should instead be addressed as a personnel safety hazard. Indeed, John Morgan's well respected NACE textbook, titled Cathodic Protection (2nd edition, 1987), states "In general, AC corrosion is not a hazard and there is little evidence…that alternating current causes corrosion." However, this conventional thinking has been turned upside down. Two principal factors have united to make AC induced corrosion a growing problem.

Congested right of ways

As areas become increasingly developed, land availability for utility right of ways are becoming scarce. The advantages of common utility right of ways are compelling. The area has been cleared of trees where power lines run above ground, creating a cleared highway perfectly suited for installing pipelines and other buried utilities. Telephone wires, fibre optic cables, water lines, natural gas and oil pipelines and electrical transmission lines are often forced to co-exist to supply required services to large industrialised areas supplying internet connections, sewer systems, cable television and fuel to homes, businesses and industry. From a land use perspective, this makes good engineering and economic sense, as the government can secure a single utility right of way.

Exceptionally advanced coatings

Figure 1. AC induced corrosion.

Figure 2. Congested right of way.

The use of high end fusion bonded epoxy (FBE) and three layer polyethylene (3LPE) coatings have proven quite effective in protecting pipelines from conventional galvanic corrosion. These coating systems represent significant improvement over the conventional coating systems that they have replaced. Installed coating efficiencies exceeding 99.9% are common.

Surprisingly, however, a newly constructed pipeline boasting an outstanding coating system is much more prone to AC induced corrosion. Induced or stray AC current picked up along a buried pipeline with a high quality coating holiday has only a limited number of small coating defects from which they can dissipate to ground. Thus, the localised AC current density at the discharge location can be quite high. In contrast, older pipelines with larger and more frequent coating defects offer numerous sites for AC current to discharge back to ground.

AC induced current

The pickup of AC current on buried pipelines has long been recognised and understood as a safety issue. Basic electro-magnetic field theory provides a detailed explanation of how high voltage power lines provide a gradient field around a pipeline. The pipeline acts as a large conductor and induced AC current flow can easily be anticipated. The amount of current induced will vary depending on the electrical transmission load at any given time. Lightening and fault conditions, while less common, are often much more severe.

The safety impact is well documented. Anyone touching a valve or above ground appurtance might be subject to shock. NACE International standards provide for a maximum acceptable AC voltage limit of 15 VAC for personnel protection purposes. It is quite common for pipeline companies to use grounding mats under any above ground appurtenance to protect personnel from electrical shock. The grounding mats are typically zinc ribbon or mesh buried below the appurtenance to provide a low resistance ground path for AC current to dissipate.

The corrosion affect of induced AC corrosion, however, is often not given sufficient attention. AC corrosion rates can range from 2 to 500 mpy with a typical value in the range of 60 mpy. AC induced corrosion can occur even when the AC voltage levels are well below the 15 VAC safety threshold cited by NACE. AC current density, soil conditions and holiday size all affect the corrosion rate.

Evaluating AC corrosion risk

For existing pipelines located in electrical utility corridors shared by high voltage transmission lines, it is possible to use existing techniques to evaluate corrosion risk. The chart below provides classification criteria for evaluating AC corrosion indications.

Evaluating corrosion risk requires a thorough knowledge of the soil conditions along the pipeline right of way. Areas where there is a wide swing in soil resistivity within the influence of high voltage transmission lines are of special concern. Transitions from dry well aerated ground conditions to wet swampy areas and then back again invite both DC and AC corrosion.

Table 1. AC corrosion classification criteria

Tool	Classification Severe indications.	Classification Moderate indications.	Classification Minor indications
Coupon (AC current desnity) CIS.	> 100 A/M^2.	Between 20 and 100 A/m^2.	< 20 A/m^2.
DCVG (surface area).	< 2 %. 1 - 2 cm^2.	Between 3 and 5 %. 3 - 5 cm^2.	> 5 %. 6 - 10 cm^2.
AC potentials versus resistivity.	1 VAC <500 ohm cm. 3 VAC 600 - 1000 ohm cm. 10 VAC 1000 - 5000 ohm cm. 15 VAC > 5000 ohm cm.	2 VAC < 500 ohm cm. 4 VAC 600 - 1000 ohm cm 20 VAC 1000 - 5000 ohm cm. 30 VAC > 5000 ohm cm.	4 VAC < 500 ohm cm. 6 VAC 600 to 1000 ohm cm. 30 VAC 1000 to 5000 ohm cm. 40 VAC > 5000 ohm cm.

The next step is to determine the location and size of any coating defects. Unlike conventional DC corrosion studies where the larger coating holidays are of greatest concern, it is the smaller holidays that are at the greatest risk for AC corrosion. DCVG (Direct Current Voltage Gradient) surveys performed by an experienced operator can locate and classify even very small defects in high quality coatings. Combining the DCVG data with the soil resistivity information helps to identify those areas of highest concern. Custom corrosion coupons can then be used to evaluate AC current density. These coupons are manufactured to simulate the pipeline geometry, coating and metallurgy. They have a calibrated defect to facilitate measuring the AC current discharge over a given area.

Figure 3. PCR installation.

Predictive modelling for new pipelines

Several predictive models exist, including a software package available from PRCI, to predict areas of high AC voltage pickup. These models use a variety of inputs including peak load factors and usage patterns supplied by the electric transmission service provider, information on tower grounding, the physical attributes of the pipeline, soil data and other information. The quality of the predicted AC induced voltage is a function of the software modeling and the accuracy of the data being provided.

These models have been developed and are used to mitigate AC voltages below the 15 VAC safety threshold that is accepted within the industry. As pipeline, the industry has largely discounted the risk of AC induced current, as these models were not developed to predict areas of concern for AC corrosion. While mitigation of AC voltages to below 15 VAC will address personnel safety risks, AC corrosion can occur at voltages as low as 1 VAC under the right circumstances.

As there are many site-specific variables as to whether AC interference will be a problem in a specific electrical transmission corridor, finding the warning signs can be complicated. Specialised corrosion engineering consultants experienced in AC corrosion can identify where the pipelines are most at risk for AC effects and design an investigative program for those areas.

Mitigation

While conventional AC current mitigation has focused almost exclusively on reducing AC voltage below the threshold for personnel safety risk, the technology employed is also appropriate for mitigating AC induced corrosion. AC mitigation involves providing a low resistivity drain to allow AC current to be dissipated. This can be achieved through a variety of strategies. Common approaches include running a gradient control wire parallel to the pipeline in selected locations. This can be either bare copper wire, zinc ribbon anode or even a bare casing or sleeve. Copper offers a longer service life and lower impedance than zinc or steel. Another approach that is more suitable for higher resistivity environments is the use of deep well beds as AC current drains.

Whatever approach is taken to dissipate the AC current, the effect on conventional DC cathodic protection systems is the same – they don't work well together. Placing a large current drain in the same DC circuit as the pipeline would render the cathodic protection system ineffective. Thus, the AC and DC systems must be 'de-coupled.' Fortunately, the technology exists in the form of the PCR. These remarkable devices are installed in series with the AC current drain and allow AC current to flow while providing DC isolation of the current drain from the pipeline. Thus, effectively isolating the cathodic protection system from the AC current drain and allowing both the DC cathodic protection and the AC mitigation to work independently.

Post mitigation assessment

Once a mitigation system has been designed and installed, post assessment testing is required to assure that the corrosion has indeed been mitigated. The elements of a successful post assessment are similar to those used during the initial assessment and may involve the installation of calibrated test coupons, monitoring of AC voltages using data loggers over a period of time, and resurveying the pipeline.

Summary

Pipeline operators must be aware of the heightened risks of AC corrosion resulting from the installation of pipeline in electrical transmission utility right of ways using advanced coatings with high coating efficiencies. Monies need to be allocated to thoroughly investigate and if necessary, mitigate AC risk, not just from the perspective of personnel safety, but with an understanding that corrosion may also be a significant threat.