

Case Study of AC-Induced Corrosion on Buried Pipeline: Field Test and Mitigation Design

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Abstract

In this paper, a case study on AC interference measurement and mitigation was introduced. A buried pipeline was running in parallel with 500 kV high-voltage alternating current (HVAC) transmission line for about 10 km. The distance between them was about 25~600 m. Field test showed that the maximum AC voltage was 44.3 V and AC current density was 1248 A/m² at cathodic protection (CP) polarized potential of $-0.90 V_{CSE} \sim -0.95 V_{CSE}$. Overall, these results indicated that the buried pipeline suffered serious AC interference. Therefore, corrosion coupons were buried and electrically connected with the pipeline to investigate AC corrosion, which was analyzed according to weight loss test results and corrosion morphology analyses. Based on the collected information, numerical simulation model was established and adjusted to meet field test results. And then, mitigation schemes were designed and optimized with the help of the numerical simulation. The final mitigation scheme was got to reach the mitigation target.

Introduction

In the recent thirty years, more and more AC related failures of cathodically protected pipelines were reported in succession, and thus AC corrosion attracted extensive attention in the international corrosion field.¹⁻³ In 1991, a high-pressure gas pipeline was parallel to high voltage transmission line (HVTL) for 4000 m. The maximum AC voltage on the pipeline reached 28 V.⁴ Its corrosion rate at the pipeline coating defects reached 1.4 mm/y even though the CP potential was $-1.45 V_{CSE}$. In 2002, a natural gas pipeline from America was parallel to HVTLs. Corrosion perforation occurred even though the CP potential of the pipeline was $-1.3 V_{CSE}$.⁵ Subsequently, corrosion leakage of a buried metal pipeline occurred under AC current density of 144 A/m² and CP polarized potential of $-1.23 V_{CSE}$.⁶ Similarly, crude oil leaking caused by AC corrosion

at northern Alaska resulted in great economic losses.⁷ In 2018, Andreas Junker has found that AC corrosion rate of a buried pipeline was ~ 0.2 mm/y as CP potential of $-1.3 V_{CSE}$.⁸ Taken together, these cases suggested that in the case of AC interference, buried pipelines still encountered corrosion even under good CP level. These AC corrosion cases have been reported in Canada, America and Europe. In China, more and more pipelines were buried in parallel to HVAC transmission lines with rapid development of electricity, petroleum and transportation industry. Therefore, buried pipelines suffered from serious AC interference in these conditions.⁹⁻¹⁰ However, few AC corrosion was measured in field currently. In this work, a buried pipeline running parallel with HVAC transmission line was investigated.

Figure 1 was a map of the area showing the pipeline and HVAC transmission line. The buried pipeline was parallel to an HVAC transmission line rated at 500 kV for approximately 10 km. The distance between pipeline and HVAC transmission line was about 25~600 m. It was constructed using L415 which has diameter of 762 mm and wall thickness of 11.1 mm. In addition, the external coating of the pipeline was reinforced epoxy powder. To evaluate AC corrosion likelihood of pipeline, field test was carried out. We used the corrosion coupons with working area of 1 cm^2 to investigate corrosion behavior. Furthermore, mitigation scheme was designed to ensure the operational safety of the pipeline.



Figure 1: Pipeline and HVAC transmission line route

Methods of Investigation

From Figure 1, there were 10 test posts (1#~10#) on the pipeline. Field tests were conducted at the test posts. According to NACE SP21424-2018, AC voltage (U_{ac}), AC current density (J_{ac}), on-potential (E_{on}), off-potential (E_{off}) and DC current density (J_{dc}) measurements were often performed using coupons.¹¹ The reference electrodes

(copper/copper sulfate) were placed on remote earth. A data logging device was programmed to measure these parameters for 24 h. Then one terminal of the data logging device was connected to the reference electrode. Another terminal was connected to the coupons and the third one was connected to the pipeline through the test post. Besides, soil resistivity was measured by the Wenner Four-Pin Method.

Based on the detection results, corrosion coupons were buried at the chosen test post to study corrosion behavior. The corrosion coupons were buried 2 m in depth, and then electrically connected to pipeline to simulate coating defect. The corrosion coupons and pipeline were at the same CP level and AC interference. There were two parallel samples at every test post to analyze corrosion behavior. AC corrosion behavior was investigated by weight loss test, morphology analyses, Energy-dispersive X-ray (EDS) and X-ray diffraction (XRD).

After collecting required basic information, the AC interference calculation model could be established and adjusted to meet field test results with the help of computer simulation. Based on the final AC interference model, the mitigation was designed and optimized to reach the mitigation target.

Field Test Results

AC interference parameters

The AC voltages and current densities were monitored for 24 h and the results measured at 2# test post were shown in Figure 2. AC voltage and current density of the pipeline had the same trend during the monitoring. It seemed that AC voltage and current density would reach a steady value and the results were presented in Figure 3. It could be seen that AC voltage exceeded 4 V at all test points and exceeded 15 V at 6 test points. The AC current density of pipeline exceeded 100 A/m² at all test sites and exceeded 300 A/m² at 5 test sites. Moreover, the maximum AC voltage reached 44.3 V and the maximum AC current density was 1248 A/m². From the results above, some U_{ac} peaks exceeded the maximum allowable AC touch voltage of 15 V according to NACE SP 0177¹² and some J_{ac} peaks exceeded the maximum allowable AC current density

according to NACE SP21414-2018¹¹. It could be concluded that the buried pipeline suffered from serious AC interference.

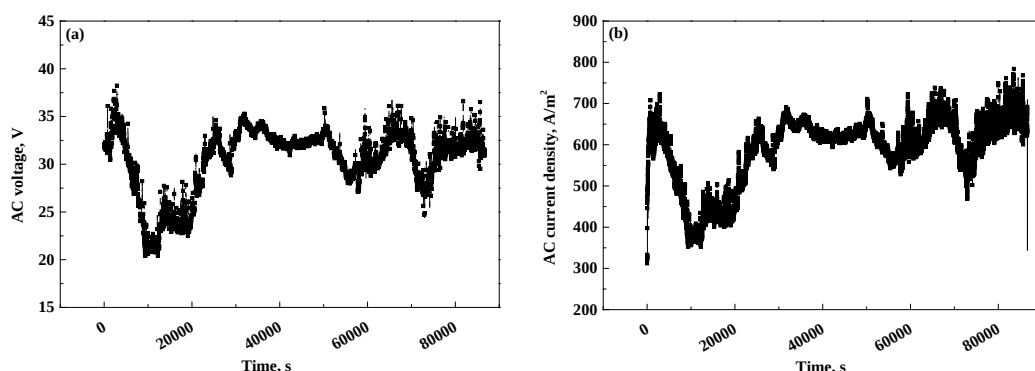


Figure 2: Detection results of AC voltage and AC current density at 2# test post: (a) AC voltage; (b) AC current density

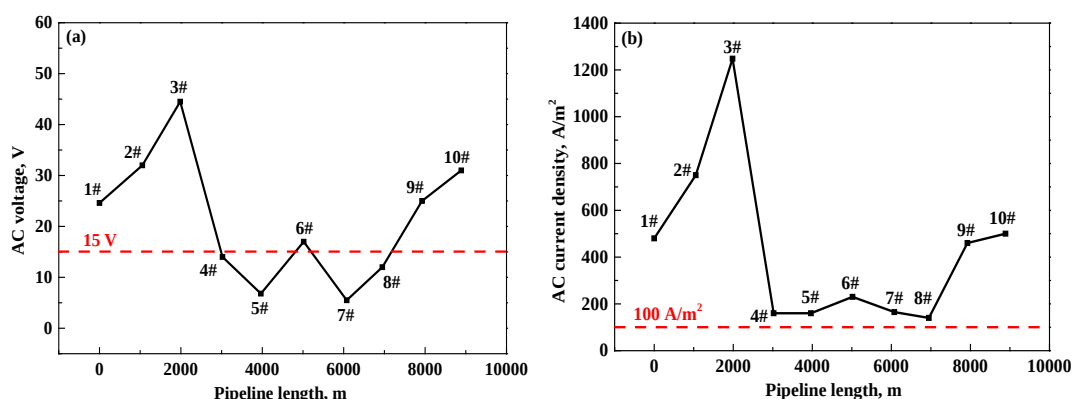


Figure 3: Detection results of AC voltage and AC current density at all test posts: (a) AC voltage; (b) AC current density

Cathodic protection parameters

Figure 4 demonstrated that the detection results of on-potential, off-potential and DC current density at the selected four posts. On-potential of pipeline ranged from $-1.0 V_{CSE}$ to $-1.05 V_{CSE}$ and off-potential ranged from $-0.90 V_{CSE}$ to $-0.95 V_{CSE}$. It meant that the cathodic protection of pipeline worked well. The DC current density of pipeline was lower than $0.2 A/m^2$ at all test points. According to SP21424-2018, the AC current density should not exceed a time-weighted average of $100 A/m^2$, on condition that DC current density was less than $1 A/m^2$.¹¹ The pipeline had suffered from serious AC interference based on AC interference and CP parameters test.