https://doi.org/10.1051/itmconf/20246101022

Analysis of external corrosion protection performance on buried gas pipeline using CIPS and DCVG methods

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Abstract. The present work investigates the effectiveness of external corrosion protection using Close Interval Potential Survey (CIPS) and Direct Current Voltage Gradient (DCVG) on a buried gas pipeline. These surveys were performed on 12” gas pipeline in East Kalimantan. Coating and cathodic protection were the primary corrosion protection on these pipelines. Soil resistivity measurement was conducted every km along the pipeline to obtain the resistivity profile combined with the pH profile. CIPS showed that the Cathodic Protection system protects 79.21 % of the pipeline area. There is no sign of telluric or stray current effect from the result of CIPS. DCVG showed 159 defects that can be divided into three different clusters. There is 6-point coating defects that should be repaired immediately due to the characteristics and category of the defect. The integrated data analysis of CIPS and DCVG showed a correlation which dips pattern on CIPS graph indicating coating defect on DCVG surveyed. Soil resistivity measurement showed that the soil resistivity profile is negligible from KP 0 – 5, while KP 5 – 14 is mildly corrosive. pH measurement showed the acidity level or the soil along the pipeline were neutral. Cathodic protection level could be improved with the increase of cathodic protection current and coating repair along the area with low-level protection.

Keywords. Cathodic protection, coating defect, CIPS, DCVG

1 Introduction

In Indonesia, more than 25 % of energy consumption comes from natural gas [1], which makes natural gas the second vital energy source. In terms of the natural gas distribution, pipelines has been used for decades to link between gas operator to gas power plant [2] to generate the electricity. The reliability of the system will be critical to support the supply and demand of the natural gas distribution. Corrosion is one of failure mode that usually occurs in pipeline, and it costs nearly $2 billion economic loss [3]. External coating and cathodic protection (CP) have been widely used in the oil and gas industry as the primary corrosion protection for a buried facilities [4]. NACE (National Association of Corrosion Engineers)

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international has introduced NACE SP0169 – 2013 as a guidance to control external corrosion in underground [5], and NACE SP0502-2010 for methodology of pipeline external corrosion direct assessment [6]. External corrosion direct assessment (ECDA) has been proven to assess and locate several locations that have poorly CP protection and also locate a poorly coated area [7].

The close interval potential survey measures pipeline potential protection profile continuously for every km. In order to minimize the effect of IR, the measurement was performed by interrupting the cycle of transformer rectifier, so the true potential of the pipeline can be determined [8]. DCVG surveys locate and characterize coating defects on buried pipelines by measuring voltage gradients on the soil surface above the pipeline. These voltage gradients occur due to current pickup/discharge, which occurs at the defect when a DC is applied to the pipeline [9]. The CP currents were interrupted using 1s on and 4s off in a periodic cycle. It allows the voltage gradients on the soil surface related to the coating defects to be distinguished from gradients from other sources. Soil resistivity and pH play an important part in corrosion assessment. Soil Resistivity can define which area has a tendency to rust because of the environment, and pH is complementary data to support the condition of the soil, either acidic or alkaline.

This work investigates the performance of external corrosion protection on a 14 km buried gas pipeline in East Kalimantan. This pipeline is protected by cold tape wrap coating and impress current cathodic protection. The primary purpose is to evaluate the CP system and external coating performance after 43 years of service for the coating and five years for cathodic protection. The external corrosion protection was studied by performing CIPS and DCVG completed with soil resistivity and pH [10].

2 Materials and method

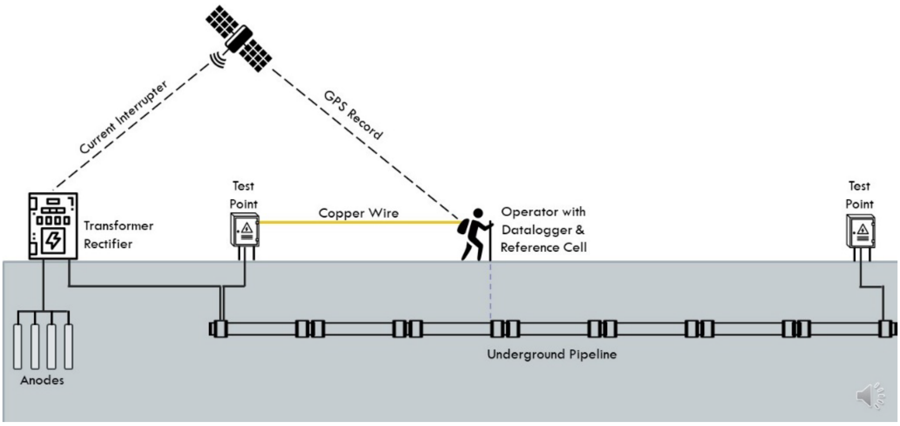
This study was conducted by using CIPS (Close Interval Potential Survey) and DCVG (Direct Current Voltage Gradient) as a primary data analysis on 14 km 12" buried gas pipeline. Soil resistivity and pH measurement were used to assess the corrosiveness of the soil along the pipeline RoW (Right of Way).

A close interval potential survey is one of the ECDA methods to assess the underground pipeline CP protection level [7]. To achieve the true potential of the pipeline, measurements were performed under an interrupted cycle transformer rectifier. These surveys were performed with 1s ON and 4s OFF periodic cycles. ON potentials are protected potentials with an IR factor caused by the current flow and soil resistivity, to exclude the IR factor, OFF potentials are recorded as IR-free potential, as we know as the true potential of the pipeline [11]. Figure 1a shows us a details setup for CIPS.

DCVG can determine the direction of CP current flow in the ground. The current flow of CP can be used to assess the electrochemical activity of the exposed metal since corrosion tends to generate currents that will flow outward from the coating defects [12]. The location of the coating defect can be determined by the current flowing out of the coating defect. DCVG was performed on a cyclic interrupt CP system. There are 4 categories to assess the state of corrosion on coating defect: cathodic/cathodic, cathodic / neutral, cathodic/anodic, and anodic/anodic. %IR can be divided into four categories, i.e., 1 – 15 % IR is category 1, 16 to 35 % IR is category 2, 36 – 60 % is category 3, and 61 to 100 % is category 4 [6]. Figure 1b shows us the details set up for DCVG.

Soil resistivity measurement methods were developed by the American National Bureau of Standards. The aim of this method is to determine the resistivity value for each soil layer. This procedure uses 4 pins to generate the alternating current. The pins space is indicated as the soil layer depth, 2 pins work for delivering the current while 2 other pins work for measuring the potential drop due to the soil path resistance [10].

The resistance can be measured and the resistivity can be calculated with formula. The calculated resistivity is the average of depth layer soil resistivity which equal to the pin spacing distances [13]. Figure 1c shows us the details set up for the soil resistivity test. pH measurement will show us the soil acidity condition either it is acidic or alkaline.



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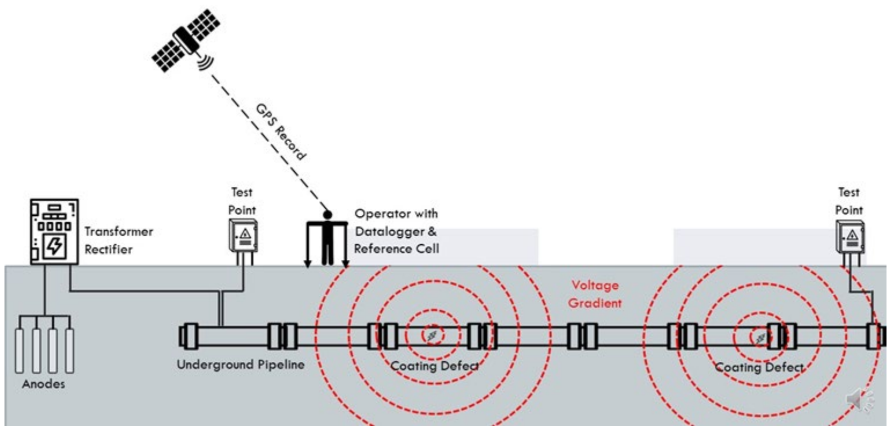

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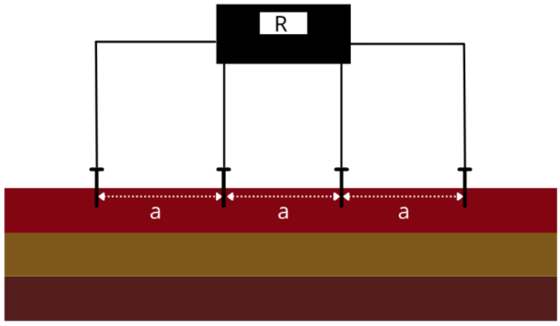


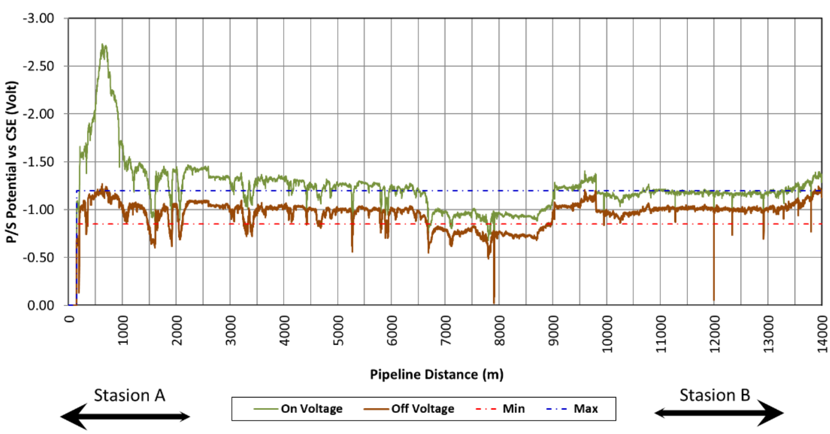
(c)

Fig. 1. Survey methods, (a) CIPS, (b) DCVG, and (c) Soil resistivity.

3 Results and discussion

Figure 2a shows that areas with potential below the minimum protection are KP 6+700 – KP 9+000. The lack of CP protection level in this section is generally caused by the lack of CP current provided by the cathodic protection system. The result showed us that the cathodic protection system protects 79.21 % of the pipeline, with the detailed distribution in Table 1. A potential drop is caused by coating defects and variations in soil structure at some points [9]. There is not any sign of stray or telluric effect on this section because telluric and stray currents could change the potential rapidly [14].

Figure 2b shows there was 159 coating defects on the pipeline. As mentioned in the methods section, NACE SP052 – 2010 has given a specific ranking for each cluster [6]. This matrix will help us define the corrective action that will lead us to improve the integrity of the coating system. The first region in the white box is where it should be repaired immediately due to the tendency of active corrosion characteristics [6, 12]. The second region in the blue box is the area that needs further judgment from in – line inspection (ILI) data to support evidence that there is an active corrosion region. The third region in the yellow box is the area that has coating defects that do not tend to corrode because of the CP system.



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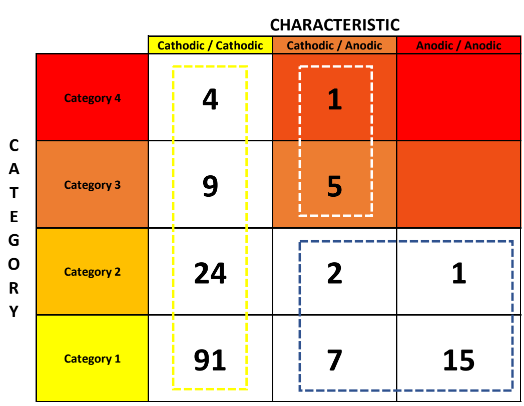
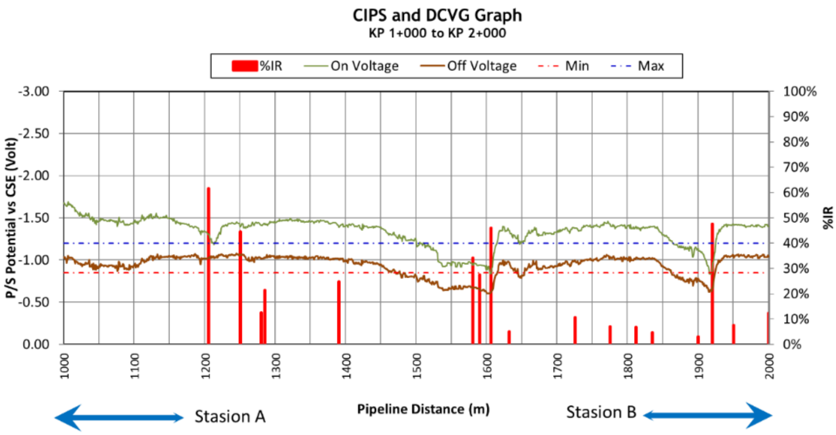


(b)

Fig. 2. Survey results of (a) CIPS graphic, (b) DCVG matrix, (c) Integrated graphic of CIPS, and DCVG, (d) Soil resistivity and pH measurement.



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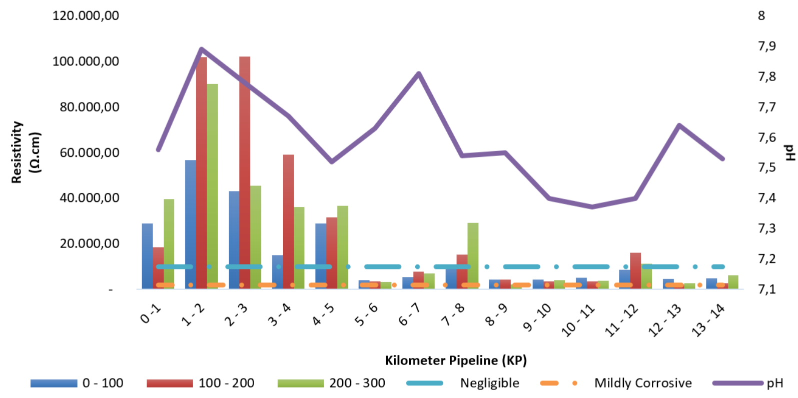

(d)

Fig. 2 (continued). Survey results of (a) CIPS graphic, (b) DCVG matrix, (c) Integrated graphic of CIPS, and DCVG, (d) Soil resistivity and pH measurement.

Figure 2c shows us the integrated graph of CIPS and DCVG inspection. The advantage of using integrated data is that we can see the correlation between pipe to soil potentials to the coating defect on the pipeline [7]. As we can see in Fig. 2c, the dips pattern of the pipe to soil potential leads us to the coating defect area [15]. For example, defect on KP 1+920 on the pipe to soil potential is decreasing from – 1300 mV vs. $Cu/CuSO_4$ to – 870 mV vs $Cu/CuSO_4$ on the defect location, off pipe to soil potential is decreasing from – 1000 mV vs $Cu/CuSO_4$ to – 670 mV vs $Cu/CuSO_4$. The potential increases after the defect location forms a dips pattern on the CIPS graph.

From Fig. 2d, we have three different depths of measurement to cover the soil resistivity of the pipeline. The result shows us that soil resistivity is negligible from KP 0 – KP 5 because the soil resistivity is above 10,000 ohm-cm. KP 5 to 14, the soil resistivity is mildly corrosive in the 2,000 – 10,000 ohm-cm range [10]. The pH measurement ranges between 7.3 to 7.9. It is neutral to alkaline. From Fig. 2d, we can conclude that KP 5 – to KP 14 tend to corrode more than KP 0 to KP 5. KP 0 to KP 5 is rocky ground and sandy soil, whereas KP 5 to 14 has a swamp area and backfilling soil.

Table 1. Details CIPS result in percentage per km.

Area	Protected (%)	Not protected (%)
KP 0 – 1	93.06	6.94
KP 1 – 2	78.60	21.40
KP 2 – 3	94.00	6.00
KP 3 – 4	86.90	13.10
KP 4 – 5	96.40	3.60
KP 5 – 6	90.90	9.10
KP 6 – 7	66.10	33.90
KP 7 – 8	0.00	100.00
KP 8 – 9	5.60	94.40
KP 9 – 10	99.70	0.30
KP 10 – 11	100.00	0.00
KP 11 – 12	99.60	0.40
KP 12 – 13	99.30	0.70
KP 13 – 14	99.80	0.20
KP 14 – 14+050	100.00	0.00

4 Conclusion

This study revealed the effectiveness of external corrosion protection using the analysis of integrated CIPS and DCVG data with soil resistivity and pH measurement as complementary. Table 1 shows us that the protection level of this pipeline is 79.21 %, the area with low protection level is KP 6+700 – KP 9+000. The protection level can be improved by increasing the CP current and repairing the coating defect along with those areas. Fig. 2b shows us that 159 coating defect is on the pipelines with three different cluster. Cluster 1 has six defects that should be repaired immediately, cluster 2 has 25 coating defects that need further judgment from ILI data to repair, and cluster 3 has 128 coating defects that do not need to be repaired because of the CP system. The soil resistivity shown from KP 0 – 5 is negligible while KP 5 – 14 are mildly corrosive, pH measurement, all area is neutral to alkaline. Corrosion could be a significant threat to the integrity of the pipeline. This study helps us understand how to manage and maintain the condition of corrosion protection that is applied for external corrosion to improve the integrity program.

Acknowledgements

We would like to thank PT Wilson Walton Indonesia who has granted the permission for the usage of CIPS and DCVG data for the publication purpose.

References

1. Secretary General of the National Energy Council, Indonesia Energy Outlook 2019, [National Energy Council, Jakarta, 2020), ISSN 2527-3000.

2. M. Hamedi, R. Z. Farahani, M. M. Husseini and G. R. Esmaeilian, Energy Policy **37**, 799-812 (2009).
3. M. G. Fontana and N. D. Greene, *Corrosion Engineering* (McGraw-Hill, New York, 1978).
4. S. Papavinasam, *Corrosion Control in the Oil and Gas Industry* (Elsevier, 2013).
5. NACE SP0169. *Control of External Corrosion on Underground or Submerged Metallic Piping Systems* (NACE International (NACE), 2013).
6. NACE SP0502, *Pipeline External Corrosion Direct Assessment Methodology* (NACE International (NACE), 2010).
7. S. M. Segall, R. A. Gummow and R. G. Reid, Corrosion, NACE-06193, 2006.
8. J. P. Nicholson, Corrosion, NACE-2015-5796, 2015.
9. C. Onuoha, S. McDonnell, E. Pozniak, M. Krywko and V. Shankar, Corrosion, NACE-2016-7091, 2016.
10. A. W. Peabody, *Peabody's Control of Pipeline Corrosion*, 2nd Ed. (NACE International, Houston, 2001).
11. M. C. Miller Co. I., *CIS Training Manual – Gx Version* (M. C. Miller Co., Inc., Florida, 2013).
12. M. C. Miller Co. I., *DCVG Training Manual – Gx Version* (M. C. Miller Co., Inc., Florida, 2013.
13. IEEE Standards Association in *IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Grounding System* (The Institute of Electrical and Electronics Engineers, Inc., New York, 2012).
14. P. Nicholson, Corrosion, NACE–07182, 2007.
15. E. Nicholson, Corrosion, NACE-2018-11518, 2018.