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IDENTIFICATION OF SOIL CORROSION POTENTIAL FOR PLANNING IN THE GAS PIPELINE CATHODIC PROTECTION SYSTEM

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ABSTRACT

Research has been carried out to map and identify the potential for soil corrosion for the planning of cathodic gas pipeline protection systems. The research location is located in Cimanggis - Bitung, West Java, which is located at coordinates 6°19'00 "- 6°28'00" South Latitude and 106°43'00 "- 106° 55'30" East Longitude. Measurement of soil resistivity using the Wenner method that refers to ASTM G37, with variations in the distance of 0,75m, 1,50m, 2,50m and 6,00m with the number of measuring points as many as 185 points. Based on the results of data processing and soil resistivity interpretation seen that there are several locations that have low to extreme corrosion levels. Therefore, for these locations, technical planning and calculation for the protection of the pipeline to be installed is necessary.

Keywords: corrosion, resistivity, soil, protection, cathodic

INTRODUCTION

In the world of oil and gas industry, the use of pipelines is one of the elements that plays an important role, namely as a production chain. The pipeline is used as a distribution tool for various industrial needs, one of which is liquefied petroleum gas (LPG) to meet the needs of factories and housing complexes. The pipeline is usually planted in the ground. Common failures in steel pipes that are planted in the ground usually occur due to corrosion attacks. Structures such as natural gas pipelines and crude oil that have been submerged in the ground have been affected by soil corrosion. Failure of natural gas pipelines and crude oil pipelines, usually accompanied by the level of environmental corrosivity [1]-[2]. That is what will be a problem if you are going to install a pipeline that is submerged in the ground.

One effort in preparing to install a pipeline network that is submerged is to measure the soil resistivity value according to ASTM standards [3]. This is because the structure of steel pipes buried in the soil with low soil resistivity values tends to attack corrosion [4]. Soil corrosivity is almost inversely proportional to its resistivity. So if the resistivity is low, it means that the possibility of corrosion is high [5]. Resistivity is a function of soil moisture and the concentration of salts that dissolve ions, hence it is considered to be an indicator of soil corrosivity. Many factors correlate with soil resistivity such as salinity and nutrition [6], water content and preferential water flow direction [7], properties related to textures such as sand, clay, depth of clay layer or sand layer [8], soil density [9], and soil properties measured such as organic matter [10]. Understanding the resistivity of the soil structure is the key to monitoring the level of soil corrosion [11].

Research on the relationship between soil resistivity and corrosivity has been done before. Ekine, A. S. and Eemujakporue, G. O. in 2010 have investigated buried oil pipelines in the ground using the geoelectric method, and the survey results show that areas of high corrosivity are indicated by their low electrical resistivity values so that the soil is very corrosive [12]. Then, Adeoti, L. *et al*., in 2018, the results of his research suggested that the pipe structure was planted at a depth of between 1.50 and 4.50m below the surface [13]. Another research has been carried out to map the potential for corrosion in underground pipelines using the Kriging interpolation method [14]. The results show the distribution of resistivity values vary with contours that vary based on the depth of measurement. Overall the study site has the potential to be mild corrosion, medium corrosion and severe corrosion.

The purpose of this study is to identify the potential for soil corrosion in underground pipelines for planning the cathodic protection system. This corrosion potential is obtained from soil resistivity values at different depths, namely 0.75m, 1.50m, 2.50m and 6.00m. Although resistivity is not the only factor that can affect the dynamics of corrosion in the soil, the results of this study are expected to be able to identify the potential corrosion around the measurement area at different depth levels so that it can be used to design cathodic protection.

METHOD

The method of measuring soil resistivity is the 4-Point Wenner method. The Wenner method is used to determine soil resistivity in accordance with ASTM G57-06 [3]. The instrument used is the Soil Resistivity Meters (SRM) measuring instrument using 4 digital poles, namely the ND-112P Naniura Mini Logger brand, 4 electrodes, and connecting cables as shown in Figure 1. Alternating current from SRM will cause current flow on the ground between pins C1 and C2. Potential is measured between pins P1 and P2. In the Wenner configuration (Figure 1), the distance between the four electrodes is equal to A with a dipole potential P1 and P2 in the middle between C1 and C2. Soil resistivity will be obtained by entering the value read by SRM into EQUATION 1:

$$\rho = 2\pi AR \qquad (1)$$

where:

ρ = soil resistivity (Ohm-cm), A = distance between probes and R = instrument readings (Ohm)

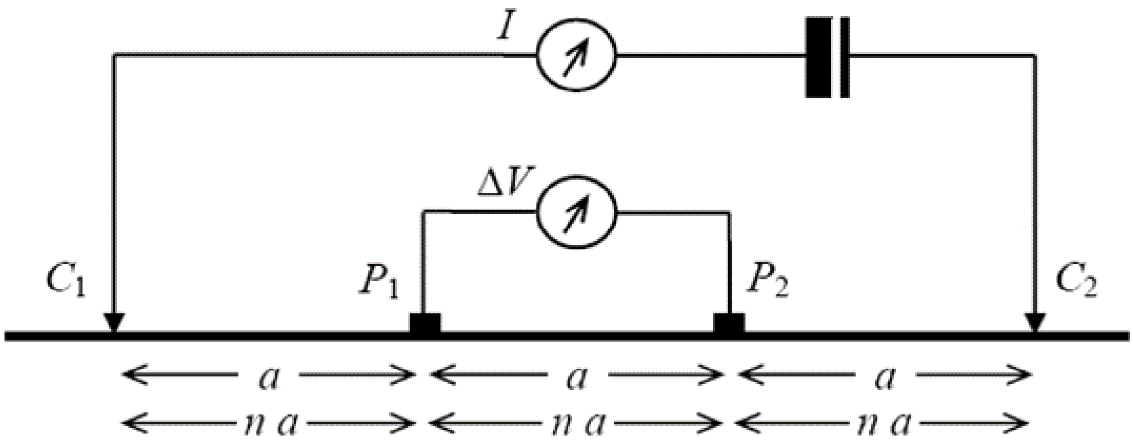

FIGURE 1. Electrode configuration of the Wenner method

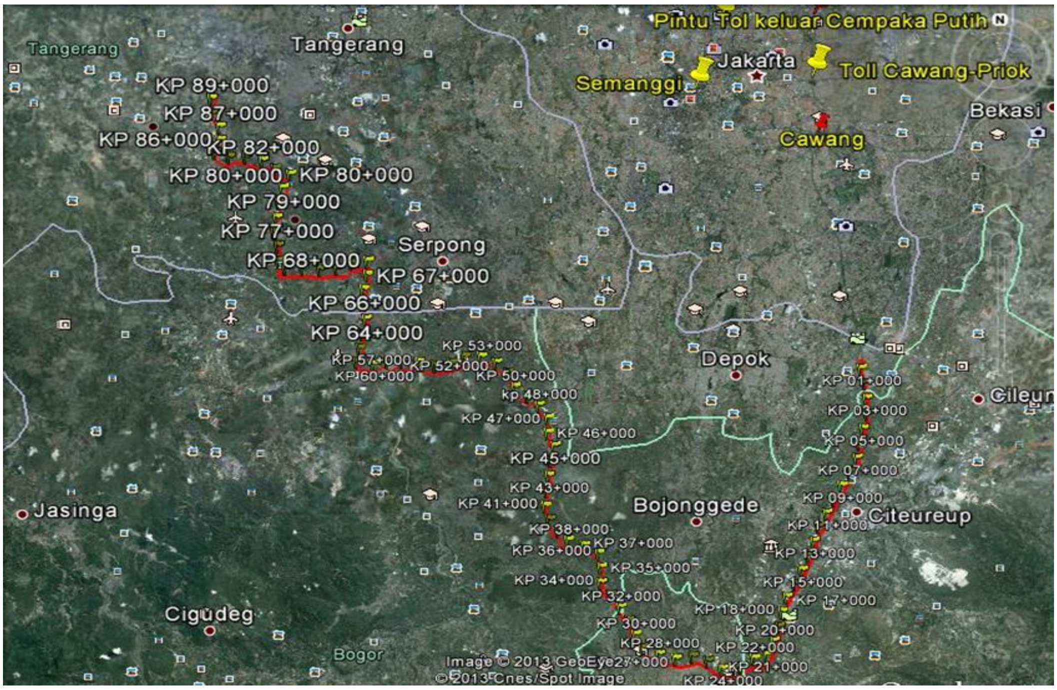

FIGURE 2. Location of Soil Resistivity Measurement

The study sites are located in Cimanggis to Bitung, West Java, which is located at coordinates 6°19'00"- 6°28'00" South Latitude and 106°43'00"- 106° 55'30" East Longitude (FIGURE 2). Measuring points for soil resistivity surveys have been determined every 500 m, starting from SR-01 (OTS Cimanggis) to SR-185 (OTS Bitung) totaling 185 points. Each survey point was measured three times for depths of 0.75 m, 1.50 m, 2.50 m and 6.00 m.

The method of collecting data in the field is carried out with the following steps: (1) Arranging the resistivity meter series using the Wenner method, (2) Determining the distance A, (3) Calculating the K value, (4) Embedding a current and potential electrode with a depth of about 50 cm and flush water, (5) Inject current and look at the ampermeter, record the electric current (I) and potential difference (V) between the 2 electrode points on the paper, (6) Read the value of R and (7) Calculate the value of soil resistivity, (8) Repeats for other places along the measurement location. Field data analysis is processed using software, then the results are analyzed and interpreted on the level of corrosion of soil conditions in the field by referring to the standards in TABLE 1 [15].

TABLE 1. Corrosion Levels based on Soil Resistivity Value

Value of Soil Resistivity (ohm.m)	Corrosion Levels
>200	Essentially non-corrosive
100 – 200	Mildly corrosive
50 – 100	Moderately corrosive
30 – 50	Corrosive
10 – 30	Highly corrosive
<10	Extremely corrosive

RESULT AND DISCUSSION

Processing of soil resistivity data is grouped based on field results data consisting of locations: (1) Two stations namely in Cimanggis and in Bitung namely SR-01 and SR-185; (2) Jasamarga Toll Road consists of 44 points, namely SR-02 to SR-45; (3) Jabar Sarana Toll Road consists of 8 points, namely SR-46 to SR-53; (4) The Bogor Outer Ring to Parung National Road consists of 60 points, namely SR-54 to SR-113; (5) West Java, Parung to Rumpin Roads consist of 17 points, namely SR-113 to SR130; and (6) Tangerang District Road to Banten Province Road consisting of 54 points, namely SR-131 to SR-184. The type of surface at all locations is the type of soil and gravel. The analysis was carried out at a depth of 2.5m and 6.0m because the pipe would be planted at a depth of between 2.5 to 6.0m. Table 2 shows the soil resistivity values at the most critical locations. Based on these values, it can be used for analysis of cathodic protection design at these location points. This is because soil resistivity greatly influences the technical and economic needs of the sacrificial anode cathodic protection (SACP) method [16].

TABLE 2. The soil resistivity values in various location groups at the most critical 2.50 to 6.00 m depth.

Location of survey	Value of soil resistivity (ohm.m)	Corrosion Levels	Environment conditions
Station of Cimanggis SR-01	28.92	Highly corrosive	Roadside and parallel to the road
High way of Jasamarga at point SR-19 to SR-24	24.00	Highly corrosive	Roadside and parallel to the road
High way of Marga Sarana Jabar at point SR-52 to SR-53	44.64	Corrosive	Roadside and parallel to the road
Road of Lingkar Luar Bogor to Parung at point SR-54 to SR-113	2543	Highly corrosive	Roadside and parallel to the road
Road of Propinsi Jabar, Parung to Rumpin at point SR-125 to SR-130	26.90	Highly corrosive	Roadside and parallel to the road
Road of Kabupaten Tangerang to road of Propinsi Banten at point SR-182	15.70	Highly corrosive	There are pipelines along the highway
Station of Bitung SR-185	4.52	Extremely corrosive	There are pipelines along the highway

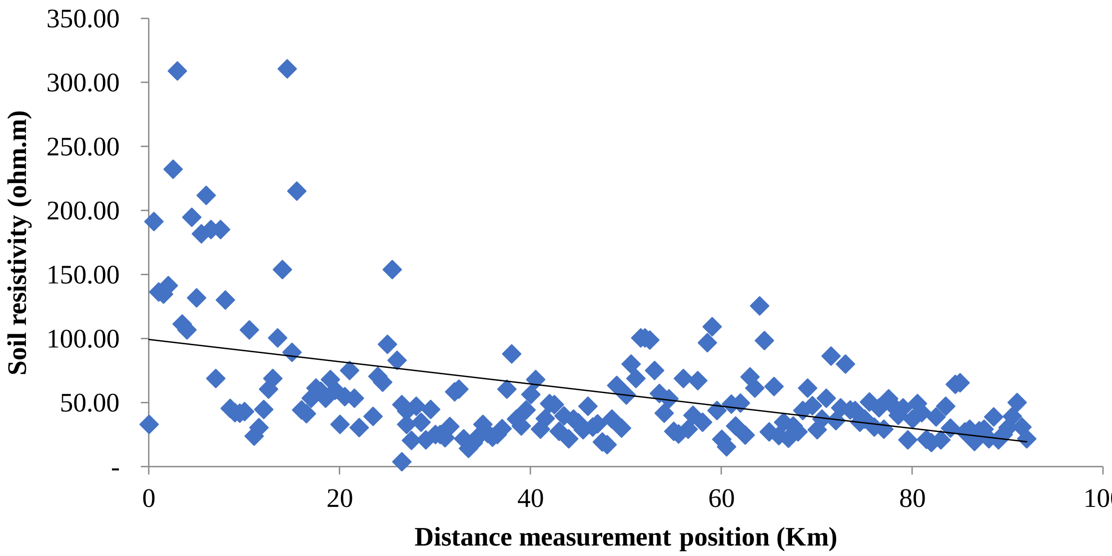

FIGURE 3. Curve value of soil resistivity to the position of measurement at a depth of 2.50 m

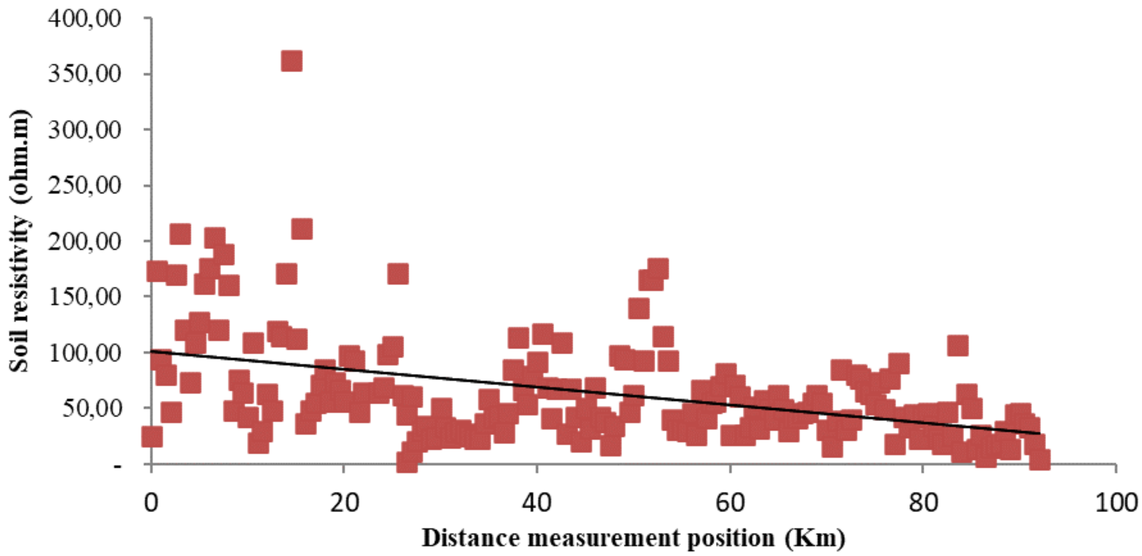

FIGURE 4. Curve value of soil resistivity to the position of measurement at a depth of 6.00 m

Based on the results of data processing using the linearity method in FIGURES 3 and 4, it is obtained: (1) at a depth of 2.50 m to 6.00 m from the OTS-Cibitung point to 30 km, the soil resistivity value obtained is 89.49 ohms.m 84.78 ohm.m. This soil condition is categorized as corrosive moderate, meaning that the soil condition is less corrosive. (2) at a depth of 2.5 m to 6 m from the point of 30 km to 60 km, the value of soil resistivity obtained is 56.05 ohms.m to 68.95 ohms.m. This soil condition includes moderate corrosive category, meaning that the soil condition is less corrosive. (3) at a depth of 2.5 m to 6 m from the point of 60 km to 90 km, the value of soil resistivity obtained is 30.93 ohms.m to 34.67 ohms.m. This soil condition is categorized as corrosive, meaning that the soil condition is corrosive.

Based on the results of processing the soil resistivity data and referring to TABLE 1, it can be interpreted into several corrosive environmental zones, namely very corrosive zones, moderate corrosive zones, and non-corrosive zones. This is because soil resistivity is a function of soil moisture and the concentration of dissolved ionic salt which is considered the most comprehensive indicator of the value of corrosion by the soil. Usually, the lower the soil resistivity value, the higher the corrosion as shown in FIGURES 3 and 4. The results of the data processing using the linearity method in FIGURES 3 and 4 show that the soil resistivity value decreases from the Cimanggis point to the Bitung location, thus the soil condition at depth 2.50 to 6.00 m is more corrosive from Cimanggis point to Bitung.

To design the design of the gas pipeline network, especially to provide innovation to the cathodic protection system and coating system in the Cimanggis-Bitung gas pipeline network must consider the soil resistivity value of the zone to be passed by the pipe. From the results of the interpretation of the soil resistivity values it can be seen that there are several locations that have low to extreme corrosion rates as shown in TABLE 2. Thus for these locations it is necessary to do technical planning and calculations for pipe protection to be installed. The steps in planning the design of the sacrificial anode cathodic protection system can be described in outline covering: (1) Determining the type of soil resistance; (2) Estimating the total current required which will depend on environmental aggressiveness, the nature of the protected layer, the area of the structure, and the construction material used; (3) Selection of suitable sacrificial anode; calculate the total weight of the anode for the design time needed; (4) Determine the anode size to meet the total output current and current distribution requirements; (5) Calculate the anode mounting distance based on the total pipe length; and (6) Consider facilities for the monitoring process [17].

Cathodic protection is used to control corrosion on steel pipe surfaces. The process is usually in the form of an electrochemical reaction where the surface of the steel that is protected will act as a cathode. Current flows from the anode through the electrolyte cell to the cathode. So that the protection ability of the cathode can be achieved by flowing the electric current. Steel consists mainly of iron, which has a redox potential of -0.41 volts SHE. This means that it will tend to lose electrons in environments that have less negative redox potential, such as water or moist soil around it. The presence of water in the ground will come in contact with the surface of the steel to form an electrochemical cell in which the iron is oxidized.

This cathodic protection principle seeks to prevent corrosion by providing an alternative source of electrons. In a galvanized protection system, metals with a more negative redox potential than the metal to be protected are connected to structures with insulated wires, forming anodes. For example magnesium alloys, with a redox potential of -2.38 volts SHE are often used for this protection system. To protect steel following the protection criteria required by NACE RP 0169 [18], namely: (1) making the primary structure a minimum potential of -850mV vs CSE when a cathodic protection system is applied; (2) the metal structure has a polarization potential of 850 mV vs CSE; (3) metal structures have a minimum residual polarization potential of -100mV vs CSE.

SUMMARY

There are several soil resistivity values obtained from the survey indicating that the soil in the environment around the location that will become a pipeline is in the corrosive to very corrosive (extreme). Therefore, for these locations, technical planning and calculation for the protection of the pipe to be installed is necessary.

Based on the results of data processing using the linearity method in Figures 3 and 4, we obtain:

1. The value of soil resistivity at a depth of 2.5 m to 6 m from the OTS-Cibitung point to 30 km is 89.49 ohms.m to 84.78 ohms.m, including the corrosive moderate category means that the soil condition is less corrosive.
2. The value of soil resistivity at a depth of 2.5 m to 6 m from the point of 30 km to 60 km of 56.05 ohms.m to 68.95 ohms.m, including moderate corrosive categories means that the soil conditions are less corrosive.

3. The value of soil resistivity at a depth of 2.5 m to 6 m from the point of 60 km to 90 km is 30.93 ohms.m to 34.67 ohms.m, including corrosive categories means that the soil conditions are corrosive.
4. The protection design used can use a Sacrificial Anode system, and / or use an Impressed Current system as long as the electricity grid is already available at that location.
5. Coating systems can be used for non-corrosive to low corrosive locations.
6. The results of soil resistivity testing range from 345.71 ohms.m (non-corrosive) to 4.52 ohms.m. (extremely corrosive).

From the conclusions from the analysis of the data it can be recommended that:

1. Using a Sacrificial Anode system for locations that are corrosive to highly corrosive to protect pipe structures from the risk of corrosion.
2. Can use an impressed current system to protect the pipe structure from the risk of corrosion, if an electricity source is available at the location.

For areas that cross under the highway (crossing), must get more treatment where the pipes under the highway must be ventilated to avoid corrosion due to aeration (differences in oxygen levels in the soil). The pipe must be covered by casing pipe which functions as a provider of air space for the pipe.

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