Reducing Corrosion of Carbon Steel Pipes using Cathodic Protection with Anode Separation: A Case Study of Nembe Creek Flow Station

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DOI: 10.56201/ijemt.v8.no4.2022.pg100.107

ABSTRACT
This research seeks to reduce corrosion using cathodic protection with anode separation for the pipeline structures in Nembe Creek Flow Station. . Sacrificial anode and impressed current cathodic protection current demands of offshore X42 steel pipeline with 1.5m diameter and 100km length, and the onshore X65 steel pipeline with 1.0m diameter and 80km length, located in Niger Delta region spanning from Delta to Bayelsa State in Nigeria was determined using the data of the design parameters for the pipeline, anode and environment collected from NNPC/PPMC and by employing relevant Sacrificial Anode Cathodic Protection and Impressed Current Cathodic Protection methods respectively 4147440mA was estimated as 8381 anodes while 4839 anodes separated at a distance of 16.5m proportionally along the entire onshore pipeline length, are required to meet 35 years intended design life of the onshore pipeline.

Keywords: *corrosion, sacrificial, anode, cathodic and onshore.*

1. INTRODUCTION

In the oil and gas industry, carbon steel pipelines are used for shipping hydrocarbon from the oil well head through flow stations to capacity tanks are viewed as the most secure and cost effective methods for moving hydrocarbon in huge volume over significant distance notwithstanding high powerlessness to corrosion attack (Ameh & Ikpeseni, 2017). Unrefined petroleum and gas pipelines could be onshore, offshore or in swamp.

The transportation activities has stayed a high intricate and testing exertion against forces of nature. For each new field found, the pipelines are additionally presented to the test in the harshest conditions. Independent of the field area with all the climate hostility, the plain carbon steel pipes stays the best methods for item move from the openings to the oil well head because of its great thermo-mechanical properties (Onyekpe, 2002).

Ameh & Ikpeseni (2017) considered pipelines cathodic protection plan approaches for impressed current and sacrificial anode system and Unueroh *et al.*, (2016) examined pipeline corrosion control in oil and gas industry. Guyer (2009) introduced a prologue to cathodic protection while El-Alem *et al.* (2013) considered the plan of a cathodic protection system to forestall corrosion of metallic construction using cross breed sustainable power sources.

Lilly *et al.* (2007) introduced drawing out the existences of covered raw petroleum and flammable gas pipelines by cathodic protection. They expressed that in Nigeria, a significant issue is the consumption of the external surfaces of such pipelines, which are not typically satisfactorily protected during construction.
Emmanuel *et al.* (2012) examined cathodic protection of buried steel oil pipelines in Niger Delta. They attested that consumption of metals has been known to be shocking in modern arrangement and surprisingly more so in the oil business and transportation of raw petroleum, gas and handled oil-based commodities happens in pipes, frequently steel pipes.

Iseru *et al.* (2014) dissected relieving external corrosion failure in buried oil pipelines in Nigeria. They expressed that most transmission pipelines are buried underground to limit their contact with external influence and the soil ordinarily contain malicious synthetics and microorganisms that speed up the crumbling of the line steel through corrosion. Consequently, making corrosion is one of the main in-administration absconds bringing about pipeline failure.

The impressed current system (Figure 2.3) which requires external power source uses inert anodes that are associated with rectifier positive terminal while the rectifier power source positive terminal is associated with proposed structure to be protected. The impressed inert anodes stayed non-drained and undissolved all through the plan life of the impressed system (Bushman, 2012; Mohammed *et al.*, 2014).

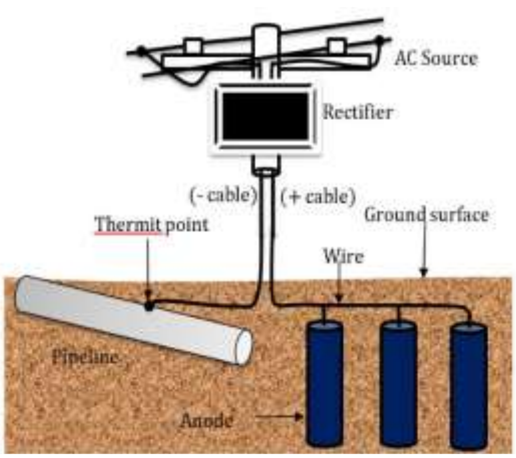

Figure 1.1: The Impressed Current Cathodic Protection System (Bushman, 2012).

2. MATERIALS AND METHODS

2.1 Materials

The materials used for this study were obtained from the Petroleum& Product Marketing Company (PPMC), a subsidiary of the Nigerian National Petroleum Corporation (NNPC) Rivers Area Office, covering both Rivers State and Bayelsa State by the case study company with one of its trunk line situated at Nembe Creek in Bayelsa State. The data collected from NNPC/PPMC were analysed using the cathodic protection plan methods and presented in tables and graphs to show the cathodic protection plan criteria, current demands, coating resistivity, the anode selection, number of anode, anode weight, resistance to earth and electrochemical capacity of the anode for the plan of the pipeline's cathodic protection. Impressed current and sacrificial anode cathodic protection current demands of the Nembe Flow Station pipelines were computed according to the plan methods. The impressed current and sacrificial anode direct current demands were calculated respectively based on coating deficiency and external surface areas. On the other hand, the quantity of platinum clad anodes needed to deliver the direct current demand output was estimated and the number and weight of the selected anodes required to meet the intended plan life of the onshore pipeline was evaluated.

2.1.1 General Procedure

In this research work, the plan of cathodic protection mechanism for the case study was conducted on Nembe Creek Flow Station, Bayelsa State. This study identified the forms and cause of corrosion in the case study pipelines. The data of the material structure, types, dimension, coatings and the environmental condition of the pipeline for the analysis of this study were collected from the NNPC/PPMC Industry which was used to evaluate the cathodic protection plan criteria, current demands, coating resistivity, the anode selection, number of anode, anode weight, resistance to earth and electrochemical capacity of the anode for the plan of the pipeline cathodic protection. The data for the plan was analysed using MATLAB which is a powerful tool for CP plan data analysis.

2.2 Method of Corrosion Reduction- Cathodic Protection with Anode Separation

The impressed current cathodic protection system uses a direct current (rectifier unit, battery bank etc) to supply electrons from a non-consumable (inert) anode such as iron silicon-chromium (Fe SiCr), platinum (Pt) etc).

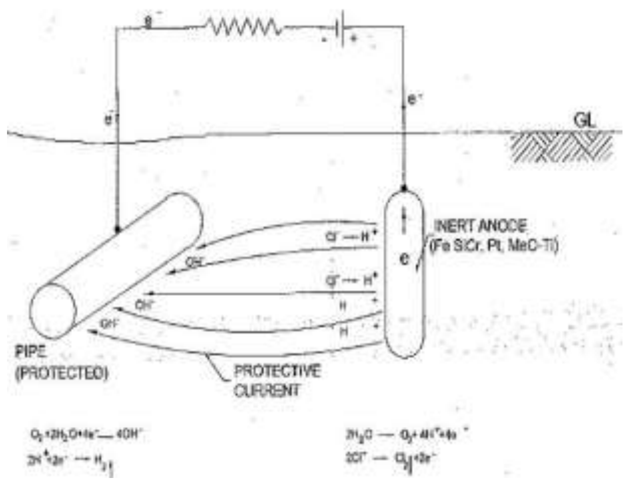

Figure 2.1: Impressed Current Cathodic Protection System (Ameh & Ikpeseni, 2017)

At the cathode:

$$O_2 \quad + \quad H_2 \quad + \quad 4e \quad \rightarrow \quad 4OH^- \tag{2.1}$$

$$2H_2O_2 + \quad 2e^- \quad \rightarrow \quad H_2 \uparrow \quad + \quad 2OH^- \quad \text{(High potential)} \tag{2.2}$$

At Anode:

$$2H_2O \quad \rightarrow \quad O_2 \uparrow \quad + \quad 4H^+ \quad + \quad 4e \tag{2.3}$$

$$2Cl^- \quad \rightarrow \quad Cl_2 \uparrow \quad + \quad 2e \tag{2.4}$$

Carbon steel pipelines were laid in an onshore location at Nembe Creek in Niger Delta region spanning from Bayelsa to Rivers State in Nigeria. Impressed current cathodic protection system will be planed for installation.

2.2.1 Single Vertical Anode Resistance to Earth Requirement for ICCP System

Furthermore, anode to electrolyte resistance known as resistance to earth remains a critical parameter in cathodic protection system plan evaluation in predicting anode current output. The other resistances include structure to electrolyte and cabling resistance and are often neglected in plan for offshore location. The resistance to earth of a single vertical anode is computed using the mathematical expression (Dwight, 1936):

$$R_V \quad = \quad 0.00512\rho \frac{\left[In \left(\frac{8A_l}{A_d} \right) - 1 \right]}{A_l} \tag{2.5}$$

where R_V = the resistance to earth of vertical anode

A_l = the anode length plus backfill

A_d = the anode diameter plus backfill

ρ = the average soil resistivity

3. RESULTS AND DISCUSSION

3.1 Result of the Sorts of Cathodic Protection System Used to Reduce Pipeline Corrosion.

The data of the material structure, types, dimension, coatings and the environmental condition of the pipeline for the analysis of this study was collected from the NNPC/PPMC Industry which was used to evaluate the cathodic protection plan criteria, current demands, coating resistivity, the anode selection, number of anode, anode weight, resistance to earth and electrochemical capacity of the anode for the plan of the pipeline cathodic protection

Table 3.1: Pipeline Data

Anode Parameter	Specification
Anode material	Mg alloy

Current density	25mA/m^2
Dimension	0.67x 0.67 x 3.5
Mg alloy consumption rate	4kg/amp-yr
Potential with ref to CuSO4	-1.55 volts
Electrochemical capacity of anode	1230 Amp-hr/kg
Weight of anode	25kg
Utilization	0.85

Source: (NNPC/PPMC, 2020)

Plan of the sacrificial anode cathodic protection system is carried out based on the preliminary field information collected from the company.

The vertical anode resistance to earth and the soil resistivity at different distances from the 0^{th} km to the 80^{th} km as calculated are presented in Table 3.2.

Table 3.2: Soil Resistivity and Distance of Pipeline Length

Distance of Pipeline Length (m)	Resistivity (ohm.m)	Resistance to earth (ohms)
0	50	0.124
10000	45	0.111
20000	50	0.124
30000	52	0.128
40000	60	0.148
50000	65	0.161
60000	70	0.173
70000	75	0.186
80000	74	0.183

The relationship between the resistivity of the soil and the distance of the soil environment around the pipeline length is shown in Figure 3.1. The graphical illustration shows that the soil resistivity increases with increasing distance of the pipeline length for the impressed current cathodic protection plan of the pipeline.

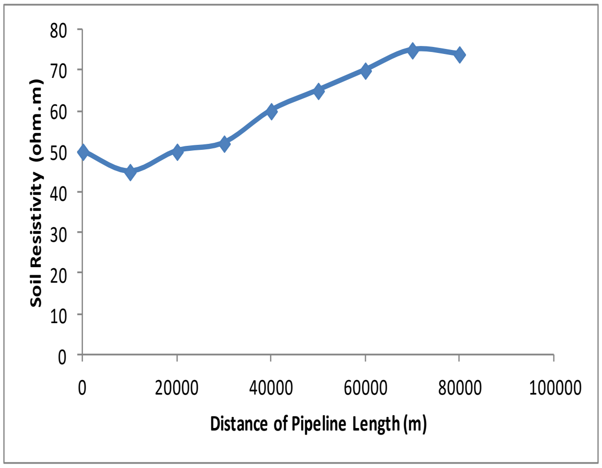

Figure 3.1: Soil Resistivity against Distance of Pipeline

The relationship between the anode resistance to earth and the distance of the soil environment around the pipeline length is shown in Figure 3.2. The graphical illustration shows that the anode resistance to earth increases just as the distance of the pipeline length for the impressed current cathodic protection plan of the pipeline.

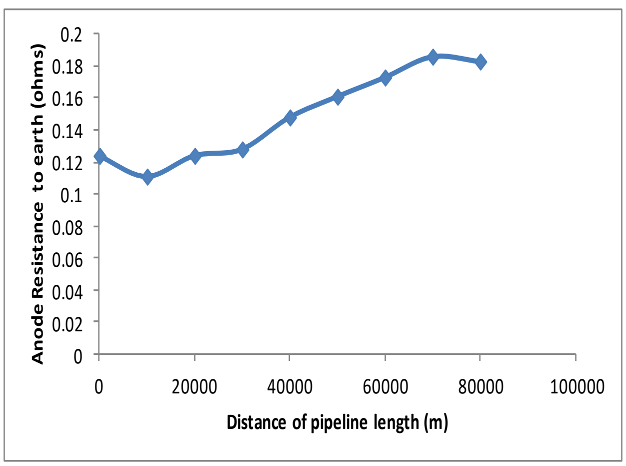

Figure 3.2: Anode Resistance to Earth against Distance of Pipeline

The relationship between the anode resistance to earth and the resistivity of the soil is shown in Figure 3.3. The graphical illustration shows that the anode resistance to earth increases with increasing soil resistivity for the pipeline impressed current cathodic protection plan.

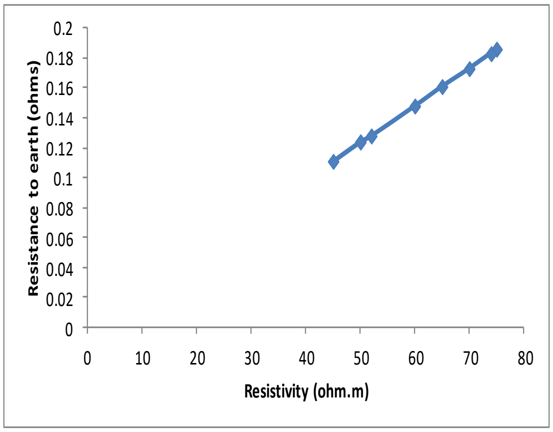

Figure 3.3: Anode Resistance to Earth against Soil Resistivity

The relationship between the distance of pipeline length and the anode spacing is investigated as an important plan parameter that is used to ensure maximum allowable voltage drop is not exceeded. The anode spacing (A_s) is estimated with equation (2.1):

4. CONCLUSION

The aim of this research was to reduce corrosion using cathodic protection with anode separation for the pipeline structures in Nembe Creek Flow Station. The objectives of this study which included: to assess the causes of corrosion associated with pipeline in the case study flow station and the types of cathodic protection systems for pipelines, which was achieved using the conceptual framework as presented in section 2.3 of this work,

5. ACKNOWLEDGEMENTS

The authors express profound gratitude to Engr. Prof. B. T. Lebele Alawa, (the HOD Mechanical Engineering Department), all departmental and faculty of engineering lecturers.

REFERENCES

Ameh, E. S. & Ikpeseni, S. C. (2017). Pipelines Cathodic Protection Plan Methodologies for Impressed Current and Sacrificial Anode System, *Nigeria Journal of Technology*, 36(4): 1072 – 1077.

Bushman, J. B. (2012). *Corrosion and Cathodic Protection Theory*, Bushman Associate Inc, Medina, Ohio.

Dwight, H. B. (1936) Calculation of Resistance to Ground, Electrical Engineering, 55(12), 1319 – 1329.

El-Alem, A. I., Azmy, A. M. & Hosam-Eldin, A. (2013). Plan of a Cathodic Protection System to Prevent Corrosion of Metallic Structure using Hybrid Renewable Energy Sources. *Engineering Research Journal* 36(12), 109-117.

Emmanuel, J. E., Emmanuel, J., Akpabio, E. J. & Ubong, I. E. (2012) Cathodic protection of buried steel oil pipelines in Niger Delta. *International Journal of Advances in Engineering, Science and Technology*, 6(4) 304-307.

Guyer, J. P. (2009). *Introduction to Cathodic Protection*. Continuing Education and Development Lecture Notes, Continuing Education and Development Inc. 22.

Iseru, E., Fagbemi, E., Awolola, K., Akpovwovwo, T. (2014) Mitigating External Corrosion Failures in Buried Petroleum Pipelines in Nigeria: A Review. *International Journal ofEcological Science and Environmental Engineering*. 1(2), 67-72

Lilly, M. T., Ihekwoabaa, S. C., Ogaji, S. O. T. & Probert, S. D. (2007) Prolonging the lives of buried crude-oil and natural-gas pipelines by cathodic protection. *Applied Energy*, 84(9), 958 – 970.

Mohammed, O. M., Omar, T., Racid, Z., Saida, B. & Cari, D. (2014) Corrosion Induced by High Voltage Powerline on Cathodically Protected Pipeline, *International Conference on Control, Engineering and Information Technology – proceeding, IPCO.*

Onyekpe, B. (2002) Corrosion in Oil and Gas Production. *Ambik Press*: Benin City.

Unueroh, U., Omonria, G., Efosa, O. & Awotunde, M. (2016). Pipeline Corrosion Control in Oil and Gas Industry: A Case Study of NNPC/PPMC System 2A Pipeline. *Nigerian Journal of Technology* 35(2): 317-320.