American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-7, Issue-10, pp-21-27
www.ajer.org
Research Paper Open Access

# Improved Pipeline Protection Using Electrical Technique For Ekulama 1 Flow Station.

Idoniboyeobu, D. C.[1], Braide, S. L.[2]and Orogun, G. I.[3]
[1,2&3]*Department of Electrical Engineering, Rivers State University, Port Harcourt, Nigeria*
*Corresponding Author: Orogun, G. I.*

***ABSTRACT****: This research work used Ekulama 1 Flow Station as a case study to study the effectiveness of the existing cathodic protection system and design an improved Electrical technique for protecting the Flow Station Pipeline network of flow lines and delivering line used for oil and gas transportation, the research work focused on critical and detailed approach of cathodic protection of pipeline using the impressed current cathodic protection as the methodology used for the design calculation for Ekulama 1 Flow Station. Eleven (11) Active flow lines of 4inch (0.1016m) diameter each with a total length of 28,210m and one (1) delivery line of 10inch (0.254m) diameter with a length of 2000m.The impressed current cathodic protection design calculation showed that for these network of pipelines to be cathodically protected it requires a total DC current of 211.97Amp and 70mm anodes for an effective pipeline protection. Again, design calculation showed that it is either the existing cathodic protection transformer rectifier size is increase to a bigger rating and anode configuration increase in the ground bed to achieve an effective protection. The result of this design calculation indicated that Ekulama 1 Flow Station pipelines network are not adequately protected cathodically.*

***KEYWORDS****: Cathodic protection, Corrosion, Hydrocarbon, Pipeline,*

---

Date of Submission:02-10-2018 Date of acceptance: 13-10-2018

---

## I. INTRODUCTION

Electrical Technique for the protection of oil and gas pipe lines using Cathodic protection (CP) system is one of the several methods used in protection of pipe line and other metallic structures buried in soil and submerged in water against corrosion effects in the oil and gas industry. This method, cathodic protection is used in combination with pipe line coating technique as mandatory government regulation in many countries. Cathodic Protection is an Electrical method employed to provide excellent corrosion protection and control system. Cathodic protection is a technique or method use in mitigating against corrosion. It is a means of preventing corrosion of metal and can be applied to any metallic structures buried or submerged. It is usually use together with coatings and can be considered as a secondary corrosion control technique [1].Corrosion can be defined as the destruction or deterioration of a metal which happens because of its reaction with the environment, and that is usually called rust. This is a great challenge we have to endure helplessly. Corrosion is an electrochemical process whereby a current leaves a structure at the anode region and passes through an electrolyte and re-enters the structure at the cathode region. However, there is no need to replace complete pieces of pipe if corrosion can be controlled at these selective locations [2].

All over the world, pipelines are being used generally as means of transporting hydrocarbon from wellheads to production facilities, storage tanks and distribution of refined products to towns and cities. Steel pipeline is widely used for transportation of hydrocarbon and other derivatives products simply because it is most cost effective and safest means. However, one of the challenges being faced in the oil and gas industry is corrosion attack on process facilities. Several pipelines failure occurred due to external corrosion, and is on the rise as a result of exposure to corrosive environment once coating failures takes place in Nigeria Oil and Gas Industry, the networks of pipelines are huge and are installed throughout the Niger Delta areas and some other parts of the country. Pipelines may be offshore or onshore and are subject to corrosion as the case may be. It will be very dangerous and more expensive if corrosion prevention actions are not initiated. Applying electrical techniques in protection of pipelines using cathodic protection system offers an optimum of safety, efficiency and reliability of pipelines network regulations by the Department of Petroleum Resources (DPR) have established Guidelines and procedures for the construction, operation and maintenance of oil and gas pipelines and their auxiliary facilities in order to establish minimum levels of safety in the Oil & Gas Industry. These regulations require that pipelines should be protected electrically by the application of cathodic protection system combined with other means of corrosion control such as protective coatings and electrical insulations. These regulations provide excellent guidelines for the application of cathodic protection to buried and submerged pipelines [3].

Cathodic protection is the most important of all approaches to corrosion control techniques. There are two methods in the application of cathodic protection system namely; Sacrificial anode or galvanic cathodic protection and the Impressed current cathodic protection (ICCP).Anytime the pipeline comes in contact with salty media, corrosion will occur due to the loss of metal ions at the anode area of the pipeline to the electrolyte (salty water).Considering the negative economic implication and environmental degradation as a result of corroded pipelines there is a serious need to put in place an effective and improved electrical method of mitigating corrosion in oil and gas pipelines that will serve as a secondary corrosion control technique.

## II. RELATED WORKS

Cathodic Protection System Application first success story was accredited to Sir Humphrey Davy in 1824 when it was applied to the HMS Samarag in 1824. The sacrificial anodes made from iron attached to the copper sheath of Ship Hull below water line dramatically reduced corrosion rate of the copper, though 100% breakthrough was not achieved [1]. The most rapid development of Cathodic Protection System was recorded in the USA in order to meet the ever increasing demand for expansion of Oil and Gas Industry which wanted to benefit from the advantages of using thin-walled steel pipes for underground transmission. Thus for this purpose to be fully achieved, this method was well established in USA in 1945. Over the years, several improvements have been made making it the best method to mitigate corrosion in the oil and gas industry presently [4].

Corrosion is the destructive attack of material by reaction with its environment. Corrosion is an Oxidation reduction reaction.The field of thermodynamics gives answers to why metals corrode, rate of corrosion and how long will a pipeline last**.** Reduction reaction is known as cathodic reaction while oxidation reaction is called anodic reaction. These electrochemical reactions are necessary for corrosion to take place. To maintain neutrality of charge, reduction reaction must be present to consume the actual metal loss caused by oxidation reaction; otherwise a large negative charge would develop rapidly between the metal and the electrolyte which will ease corrosion process [5].

The fundamental Mechanism of corrosion involves creation or existence of corrosion cells. There are several types or forms of corrosion that can take place in any structure. However, it should be borne in mind that for corrosion to occur, there is no need for discrete physically independent anodes and cathodes. Immersed micro level anodic and cathodic areas are be generated at the same (single) surface on which anodic (corrosion) and cathodic (reduction) reactions occurs [6].

Cathodic Protection exactly forced direct current onto all surfaces of the pipeline. This direct current will shift the potential of the pipeline in the active (negative) direction thereby causing reduction in the corrosion rate of pipeline. If the amount of current flowing is properly adjusted, this will overpower the corrosion current discharging from the anodic area on the pipeline and there will be current flow onto the pipe surface at these points and will then make the entire pipe surface to be cathodic thereby reducing rate of corrosion. However, one major activity to born in mind when designing cathodic protection system is to determine the actual level of cathodic protection required to reduce corrosion rate to an acceptable level which is a function of monitoring in conjunction with the application of cathodic protection criteria. Several considerations are used in selecting ground bed site. Again, is the proposed site on or off the pipeline right of way [7].

## III. MATERIALS AND METHOD

### 3.1 Materials - Case Study of Ekulama 1 Flow Station

Ekulama 1 Flow Station is one of the flow stations within OML 24 oil field. OML (oil mining license) 24 is located 30 kilometers Southwest of Port Harcourt, Rivers State, and is part of the NNPC/NewcrossEP Joint Venture (JV).The block lies within the near shore swamp of the Niger Delta. OML 24 is made up of three producing fields; Awoba, Awoba Northwest and Ekulama. Ekulama 1 Flow Station has a total of 25 wells, 14 of these wells are not producing presently and are regarded as inactive wells, while 11 other wells are active and producing both oil and gas which are being transported from the well heads to the flow station. However, the 11 flowing active wells shall be covered by this research work. For this research work, data from the following materials were used, carbon steel pipelines of 10 inch diameter, carbon steel pipelines of 4 inch diameter, Nilson soil resistance meter (model 400), Fluke series 87V high impedance, Digital multi-meter,Silver-silver chloride (Ag/AgCl) reference electrode and Fluke series 376 Digital clamp-on meter.

### 3.2 Methods of Improving Pipeline Protection of Ekulama 1 Flow Station

Considering the above materials stated, the present network of pipelines (flow line network of active wells) of Ekulama 1 Flow Station will be used to design an improved pipeline protection by using electrical techniques known as impressed current cathodic protection method (ICCP) in this research work. The impressed current cathodic protection method which is an electrical method was used in this design to improve the electrical protection of pipelines in Ekulama 1 Flow Station Cathodically to achieve the recommended criteria of NACE (National Association Corrosion Engineer) Standard NO. RP-01.

**Table 3.1 Ekulama 1 Flow Station Active Wells Flow Lines Data**

| S/No. | Well Tag Name | Distances (m) | Diameter of Pipe (m) | Status of Line |
|---|---|---|---|---|
| 1 | Well 1L | 4700 | 0.1016 | Active |
| 2 | Well 1S | 4700 | 0.1016 | Active |
| 3 | Well 3L | 1190 | 0.1016 | Active |
| 4 | Well 5L | 3120 | 0.1016 | Active |
| 5 | Well 5S | 3120 | 0.1016 | Active |
| 6 | Well 17S | 490 | 0.1016 | Active |
| 7 | Well 27S | 2200 | 0.1016 | Active |
| 8 | Well 30T | 740 | 0.1016 | Active |
| 9 | Well 35L | 3320 | 0.1016 | Active |
| 10 | Well 35S | 1730 | 0.1016 | Active |
| 11 | Well 40T | 2900 | 0.1016 | Active |

**Table 3.2 Ekulama 1 Flow Station Delivery Line Data**

| S/No | Tag. Name | Distance (m) | Diameter (m) | Status |
|---|---|---|---|---|
| 1 | Ekulama1 - San Barth Delivery Line. | 2000 | 0.254 | Active |

### 3.3 Soil Resistivity Test

Soil resistivity test is one very important factor to determine the best location for an effective ground bed site. This will help in the design work because, the average soil resistivity value calculated from the test will be used in calculation to determine the number of anodes and rectifier outputs. Soil resistivity test will also help to know the following information;

Low resistance = Low output voltage

Low resistance = Smaller rectifier

**Table 3.3 Soil Resistivity Measurement Report**

| Test Location | Nominal Pin Spacing (m) | Resistance (ohms) | Factor | Apparent Resistivity (ohms/m) |
|---|---|---|---|---|
| Anode 1 Bed | 55 | 0.5 | 0.01 | 1.0371 |
| Anode 2 Bed | 60 | 0.5 | 0.01 | 1.131 |
| Anode 3 Bed | 65 | 0.3 | 0.01 | 0.735 |
| Anode 4 Bed | 70 | 0.2 | 0.01 | 0.528 |
| Anode 5 Bed | 75 | 0.2 | 0.01 | 0.665 |
| Anode 6 Bed | 80 | 0.2 | 0.01 | 0.603 |
| Anode 7 Bed | 85 | 0.2 | 0.01 | 0.64 |
| Anode 8 Bed | 90 | 0.2 | 0.01 | 0.678 |
| Anode 9 Bed | 95 | 0.2 | 0.01 | 0.716 |
| Anode 10 Bed | 100 | 0.2 | 0.01 | 0.754 |

Source: NewcrossEP Ltd. PHC /Ben SegbaTechnical Services Ltd, Warri.

**Table 3.4 Summary of Total Length of Ekulama 1 Flow Station Pipeline to be protected**

| S/No | Pipeline Tag Name | Total Distances Covered (m) | Diameter of Pipe ($m^2$) | Status of Line |
|---|---|---|---|---|
| 1 | Ekulama 1 Flow Station Flow Lines | 28,210 | 0.1016 | Active |
| 2 | Ekulama 1 Flow Station Delivery Line | 2,000 | 0.254 | Active |

### 3.4 Design Initial Requirement Data

Before designing the impressed current cathodic protection system various initial required data or information must be obtained which will serve as the basis for this research work.

### 3.4.1 Physical Dimension of Structure to be protected

The structure physical dimension is one very important requirement in designing the ICCP system. The physical dimensions give the details of structure such as: The length of structure, width, height and diameter. These data are used to calculate the total surface area of structure to be protected. [8].

### 3.4.2 Drawing of Structure to be protected

The structure drawing must include the sizes, shapes, material type and also locations of the parts of the structure to be protected.

### 3.4.3 Electrical Isolation

Once a structure is to be protected by a cathodic system, that structure must be electrically connected to the anode. Sometimes, parts of a structure or system are electrically isolated from each other by insulators. For example an electrical insulator may be used at a valve along the pipeline to electrically isolate one section of the system from another. The location of these insulators must be known.

### 3.4.4 Short Circuit

When one pipeline system contact another, a short circuit can occur causing interference with the cathodic protection system. All short circuit must be identify and eliminated from existing and new cathodic protection system.

### 3.4.5 Corrosion History of Structure in the Area

Corrosion history of the area where structure is located is very helpful in designing cathodic protection system. This will assist in establishing valid predictions for corrosivity of a given structure and its environment. Facilities personnel are very reliable source of information of corrosion history.

### 3.4.6Electrolyte Resistivity Survey

Resistivity of the Electrolyte can be measured either in a laboratory or at the site where the system anode will be located. Resistivity data will be used to carry out design calculations. Again, a structure corrosion rate is proportion to the electrolyte resistivity.

### 3.4.7 Current Requirement

One vital and critical part of design calculations for cathodic protection system on existing structure is the amount of current required for square meter called current density to change the structure to electrolyte potential to – 0.85 volt.

## 3.5 Design Calculation Procedures

The following information about the pipelines and anode type were used for the design calculations.
That is flow lines and delivery line data from tables 3.1 and 3.2 were used.
The anode type is the MMO LIDA Tubular Anode

### 3.5.1 The Total Surface Area of the Pipeline that is to be protected

Total surface area, Sa ($m^2$) of pipeline was calculated using equation (3.1):

$Sa = \pi DLfc$-(3.1)

Where;

$\pi = 3.142$

D=diameter of pipeline

L=length of pipeline

Fc=coating efficiency

Surface area of flow lines were equally calculated from (3.1):

$Sa = \pi DLFc$

$\pi = 3.142$

D=0.1016m

L=28,210m (Total length of 11 flow lines)

Fc=0.8 (aging pipeline i.e 80%)

$Sa = 3.142 \times 0.1016 \times 28{,}200 \times 0.8$

$= 7{,}201.77 m^2$

Surface area of delivery line also applied equation (3.1) as:

$Sa = \pi DLFc$

$\pi$ = 3.142
D = 0.254m
L = 2000m (length of delivery line)
fc = 0.8 (aging pipeline i.e 80%)
Then; Sa= 3.142 x 0.254 x 2000 x 0.8
= 1,276.91$m^2$

Therefore;
Total surface area of all pipelines becomes:
$Sa_{(Total)}$ = $Sa_{(Flow\ lines)} + Sa_{(Delivery\ line)}$
= 7,201.77 + 1,276.91
= 8,478.68$m^2$

### 3.5.2 Current Requirement (Ireq)

The total current required to protect the pipelines is calculated by using equation (3.2) as seen:
Ireq = Sa x $1_d$ (3.2)
Sa = Total surface = 8,478.68$m^2$
$I_d$ = Current density = 25mA/$m^2$
$I_{req}$ = 8,478.68 x 25 = 211,967mA
Or
$I_{req} = \frac{211967}{1000} = 211.967$amps
Total dc current required to protect the entire pipeline is 211,967mA or 211.967amps

### 3.5.3 Anode Quantity Required for Protection

To calculate the total no of anode required by design to protect the entire pipeline, this equation is applied.
$Na = \frac{TXCX\ I_{Req}}{UXW}$ (3.3)
Where;

| | | | | |
|---|---|---|---|---|
| T | = | Design Life | = | 20yrs |
| C | = | Consumption rate | = | 0.00271kg/A/year |
| Ireq | = | Current Required | = | 211.967A |
| U | = | Utilization factor | = | 50% (0.5) |
| W | = | Weight of anode | = | 0.36kg |

Now;
$$N_a = \frac{20 X 0.0027 X 211.967}{0.5 X 0.36}$$
$N_a = \frac{11.4462}{0.18} = 63.59$ anodes
Approx. 64 anodes
Approximately, 64 anodes of MMO LIDA Tubular anodes are needed by design to protect the total pipeline lengths. However 70 anodes were used to compensate for future lost or reduction in ground bed resistance.

### 3.5.4 Ground bed Design & Configuration

The type of Ground bed to be used for this design is the single vertical anodes system. The soil resistivity test carried out was based on 100m distance translating to 100m deep well to be dug and use for the vertical anode system. The soil resistivity test was done over a distance of 100m length. The vertical depth of the ground bed will be 100m depth based on soil resistivity test carried out.
The active length of the ground bed is give as
La = (S + 1) n (3.4)
Where;
La = active length
S = anodes spacing
n = no of anodes
Ground bed borehole active length and inactive length calculation will be based on the 100meter depth anode spacing of 4 meter and 10 unit anodes first.
Now La = (S + 1) n
= (4 + 1) 10
= (5) 10
= 55m

The total length of ground bed borehole is 100m depth. Therefore, inactive length becomes:

$L_b$= La + Lin - (3.5)

Where;

| | | | | |
|---|---|---|---|---|
| | $L_b$ | = | total length of ground bed borehole = | 100m |
| | La | = | active length of ground bed borehole = | 55m |
| | Lin | = | inactive length = | ? |
| Now; | 100 | = | 55 + Lin | |
| | Lin | = | 100 – 55 | |
| | | = | 45m | |

From the surface of the soil, the following were established.

| | | |
|---|---|---|
| Total length of grounded borehole | = | 100m |
| Active Length of grounded borehole | = | 55m |
| Inactive length of grounded borehole | = | 45 |

From the calculation above, the total no of ground bed required to produce needed current to protect entire pipeline is calculated thus:

$$G_T = \frac{N_a}{N_a/_G} \quad (3.6)$$

Where

| | | |
|---|---|---|
| $G_T$ | = | Total no of ground bed required |
| Na | = | Total no of Anodes |
| $Na/_G$ | = | No of anodes per ground bed borehole |

$G_T = \frac{70}{10} = 7$

## IV. RESULTS AND DISCUSSION

### 4.1 Results from Design Calculations

Electrical technique known as impressed current cathodic protection system was used as the method to carried out this research work, to improve on the existing pipeline protection management system of Ekulama 1 Flow Station network of pipelines made up of eleven (11) active flow lines of 4 inch diameter pipe each and one (1) delivery line of 10 inch diameter pipe. Results obtained from the impressed current cathodic protection calculation are presented in tables 4.1 – 4.3.

**Table 4.1 Ekulama 1 Flow Station Pipelines Impressed Current Protection design calculated data**

| S/No. | Well Name/Tag | Length of Pipeline (m) | Diameter of Pipeline (m) | Current Density (mA/m$^2$) | Surface Area of Pipeline (m$^2$) | Current Requirement (mA) | Current Requirement (Amps) |
|---|---|---|---|---|---|---|---|
| 1 | Well 1L | 4,700 | 0.1016 | 25 | 1,200.29 | 30,007.36 | 30.0074 |
| 2 | Well 1S | 4,700 | 0.1016 | 25 | 1,200.29 | 30,007.36 | 30.0074 |
| 3 | Well 3L | 1,190 | 0.1016 | 25 | 303.91 | 7,597.61 | 7.5976 |
| 4 | Well 5L | 3,120 | 0.1016 | 25 | 796.79 | 19,919.78 | 19.9198 |
| 5 | Well 5S | 3,120 | 0.1016 | 25 | 796.79 | 19,919.78 | 19.9198 |
| 6 | Well 17S | 490 | 0.1016 | 25 | 125.14 | 3,128.43 | 3.1284 |
| 7 | Well 27S | 2,200 | 0.1016 | 25 | 561.84 | 14,045.99 | 14.0460 |
| 8 | Well 30T | 740 | 0.1016 | 25 | 188.98 | 4,724.56 | 47.2456 |
| 9 | Well 35L | 3,320 | 0.1016 | 25 | 847.87 | 21,196.69 | 21.1967 |
| 10 | Well 35S | 1,730 | 0.1016 | 25 | 441.81 | 11,045.26 | 11.0453 |
| 11 | Well 40T | 2,900 | 0.1016 | 25 | 740.67 | 18,515.18 | 18.5152 |
| 12 | Ekulama 1 Delivery Line | 2,000 | 0.254 | 25 | 11,276.91 | 31,922.75 | 31.9220 |

**Table 4.2 Summary of Ekulama 1 Flow Station Impressed Current Cathodic Protection Design Requirement**

**Data**

| Description of Pipeline | Total surface area of Ekulama 1 Flow Station Pipeline Network (m$^2$) | Total current required for Ekulama 1 Flow Station Pipeline Network Protection (m/Amps) | Total current required for Ekulama 1 Flow Station Pipeline Network Protection (Amps) |
|---|---|---|---|
| All Ekulama 1 Flow Station Flow Lines and Delivery Line | 8,478.68 | 211,967 | 211.97 |

**Table 4.3 Breakdown of ICCP Design Calculation for Ekulama 1 Flow Station.**

| Description of Item | ICCP Design Calculated Value | Ekulama 1 Flow Station Existing Value |
|---|---|---|
| Total number of Anodes required for pipeline protection | 70 | 10 |
| Number of Cathodic Protection Transformer Units required with respect to design calculation | 4 | 1 |
| Number of Ground bed required with respect to design calculation | 7 | 1 |
| Total dc current required for protection of all Ekulama 1 Flow Station Pipeline with respect to existing cathodic protection transformer rectifier | 211.911 Amps | 50Amps |

### 4.2 Analysis from Impressed Current Cathodic Protection Design Calculation Result

The result obtained from the impressed current cathodic protection design calculation in order to improve on the pipeline protection from corrosion effect on Ekulama 1 Flow Station Pipeline network indicated the following:

The impressed current demand to cathodically protect entire Ekulama 1 eleven (11) active flow lines and the delivery line pipeline network was calculated to be 211, 967mA or 211.967Amps with respect to pipe coating deficiency and total pipeline external surface area.

The quantity of anodes required to deliver the current requirement for complete pipeline polarization was calculated from the design procedures to be 70 pieces of LIDA MMO anodes. The current required and the number of Anodes needed to adequately protect the pipelines as obtained from the design calculation can effectively protect the entire Ekulama 1 Flow Station pipeline network for 20 years.

## V. CONCLUSION

### 5.1 Conclusion

The impressed current cathodic protection design calculation showed that, the current required to adequately protect the flow station pipelines network is**211.97**amps dc current. Also the number of anodes required to attain 20 years of pipelines network to be cathodically protected is 70 pieces of MMO LIDA anodes.

The impressed current design calculation compared with the existing values has indicated that all flow station active flow lines and the delivery lines are not adequately protected from corrosion. If this trend continues, the entire flow station pipeline network will be badly corroded in the nearest future.

## REFERENCES


[1]Peabody, A.W., (2018). Peabody's Control of pipeline Corrosion. 2nd edition
Retrieved from: https://store.nace.org>peabody-s-control-of-pipeline-corrosion-pdfR.
[2] F.G.N., (1990). Oil and gas pipeline Act. CAP 338. Laws of the Federation of Nigeria. 1990
Retrieved from: www.nigeria-law.org>oilpipelinesact
[3] NACE international. (1943-2018) 04101 New 150 Cathodic Protection Standard for offshore Pipelines.https://store.nace.org
[4] Volkan, C. (2017). Corrosion Engineering and Cathodic Protection Handbook. Wileg – Scrivener Publisher
1st edition, February, 2018. Retrieved from: https://www.goodreads.com
[5] Abed, S.F. (2016). Cathodic Protection Design for Buried Steel Pipes. LAP, Lambert Academic Publishing.
[6] Bradford, S.A. (2001). Corrosion Control. Hand Book. 2nd edition. Casti Publication Inc. Alberta, Canada.
[7] Roberge, P.R. (2013). Handbook of corrosion engineering. 2000 pdf. Retrieved from: https://studfiles.net>preview
[8]. Francis, P.E. (2007). Cathodic Protection. National Physical Laboratory.www.npl.co.uk>upload>pdf>cathodicprotection


.

Orogun, G. I. "Improved Pipeline Protection Using Electrical Technique For Ekulama 1 Flow Station "American Journal of Engineering Research (AJER), vol. 7, no. 10, 2018, pp. 21-27