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Design of Cathodic Protection for Underground Crude-Oil Pipeline by sacrificial anodes systems

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Abstract

Cathodic protection is the most important of all approaches to corrosion control and for underground crude oil pipelines .In petroleum industry cathodic protection, is a precautionary measure used to provide complete corrosion protection to ferrous metal structures and tubes as their surfaces are exposed to soil or water, as they begin to gradually erode when in contact with soil or water under the influence of Chemical reactions accompanied by an electric current flowing. Sacrificial anode cathodic protection is one of the most widely used methods in protecting underground petroleum pipelines against the corrosion damages. The object of this study is to design of cathodic protection for underground crude-Oil Pipeline by sacrificial anodes systems to be used in the protection of the petroleum pipelines that pass through the Naseer oilfield to the EL Brega region.

Keywords: *Cathodic protection , corrosion , sacrificial anode.*

1. Introduction

Cathodic protection is an electrical method of control or preventing external corrosion of pipeline steels and other metallic structures buried in soil or submerged in water [1]. Cathodic protection is a technique used to control the corrosion of a metal surface by making it the cathode of an electrochemical cell .Cathodic protection can be applied by connecting sacrificial anodes to a structure. Basically, the principle is to create a galvanic cell, with the anode representing the less noble material that is consumed in the galvanic interaction . Ideally, the structure will be protected as a result of the galvanic current flow. In practical applications a number of anodes usually have to be attached to a structure to ensure overall protection levels.

Most transmission pipelines are buried in the ground and are made of carbon steel. External corrosion is caused by electrochemical interaction between the pipe and the surrounding environment (soil in the case of buried pipes). The process is similar to the reactions in a battery, where electrons flow between anodic (positive terminal) and cathodic (negative terminal) sites on metals. Crude oil is important and the sole source of income for the Libyan state, so we must pay attention to the petroleum pipelines to preserve and protect them from damage caused by corrosion .In my country; (Libya,) the length of the oil and gas pipelines is about 11,088 km (2). The soil environment contains oxygen and is sufficiently conductive to allow passage of electrical current; therefore, buried steel structures are subject to corrosion.

Sacrificial anode cathodic protection makes use of the corrosive potentials for different metals. Without cathodic protection, one area of the pipeline exists at a more negative potential than another, and corrosion results. If, however, a much less inert object (that is, with much more negative potential, such as a magnesium anode) is placed adjacent to the pipeline to be protected, such as a pipeline, and a metallic connection (insulated wire) is installed between the object and the structure, the object will become the anode and the entire pipeline will become the cathode. Thus, the galvanic cathode protection system is called a sacrificial anode cathodic protection system because the anode corrodes sacrificially to protect the structure. Galvanic anodes are usually made of either magnesium or zinc because of these metals' higher potential compared to steel structures.

2. Sacrificial anode (galvanic) cathodic protection system design:

The following nine steps are required when designing galvanic cathodic protection systems.

1) Review soil resistivity. The site of lowest resistivity will likely be used for anode location to minimize anode-to-electrolyte resistivity. In addition, if resistivity variations are not significant, the average resistivity will be used for design calculations.

2) Select anode. As indicated above, galvanic anodes are usually either magnesium or zinc. Zinc anodes are used in extremely corrosive soil (resistivity below 2000 ohm- centimeters). Data from commercially available anodes must be reviewed. Each anode specification will include anode

weight, anode dimensions, and package dimensions (anode plus backfill) . In addition, the anode's driving potential must be considered. The choice of anode from those available is arbitrary; design calculations will be made for several available anodes, and the most economical one will be chosen.

3) Calculate net driving potential for anodes. The open-circuit potential of standard alloy magnesium anodes is approximately -1.55 volts to a copper-copper sulfate half-cell.The open-circuit potential of high-manganese magnesium anodes is approximately -1.75 volts to a copper-copper sulfate half-cell.

a) The potential of iron in contact with soil or water usually ranges around -0.55 volt relative to copper-copper sulfate. When cathodic protection is applied using magnesium anodes, the iron potential assumes some value between -0.55 and - 1.0 volt, depending on the degree of protection provided. In highly corrosive soils or waters, the natural potential of iron may be as high as -0.82 volt relative to copper-copper sulfate. From this, it is evident that -0.55 volt should not be used to calculate the net driving potential available from magnesium anodes.

b) A more practical approach is to consider iron polarized to -0.85 volt. On this basis, standard alloy magnesium anodes have a driving potential of 0.70 volt (1.55-0.85 0.70) and high potential magnesium anodes have a driving potential of 0.90 volt (1.75- 0.85 0.90). For cathodic protection design that involves magnesium anodes, these potentials, 0.70 and 0.90 volt, should be used, depending on the alloy selected.

4) Calculate number of anodes needed to meet groundbed resistance limitations.

3. Design consideration

3-1 Steps in design of cathodic protection installation sacrificial for underground crude-oil pipeline:-

Table 1: Some characteristics of the pipeline:-

Underground crude-oil pipeline. Its length 100 Km from Naseer oil-field to Albraga port region in Libya.
- Flow of petroleum is naturally due to different level.
-carbon steel pipeline.
- Tube diameter 40 cm

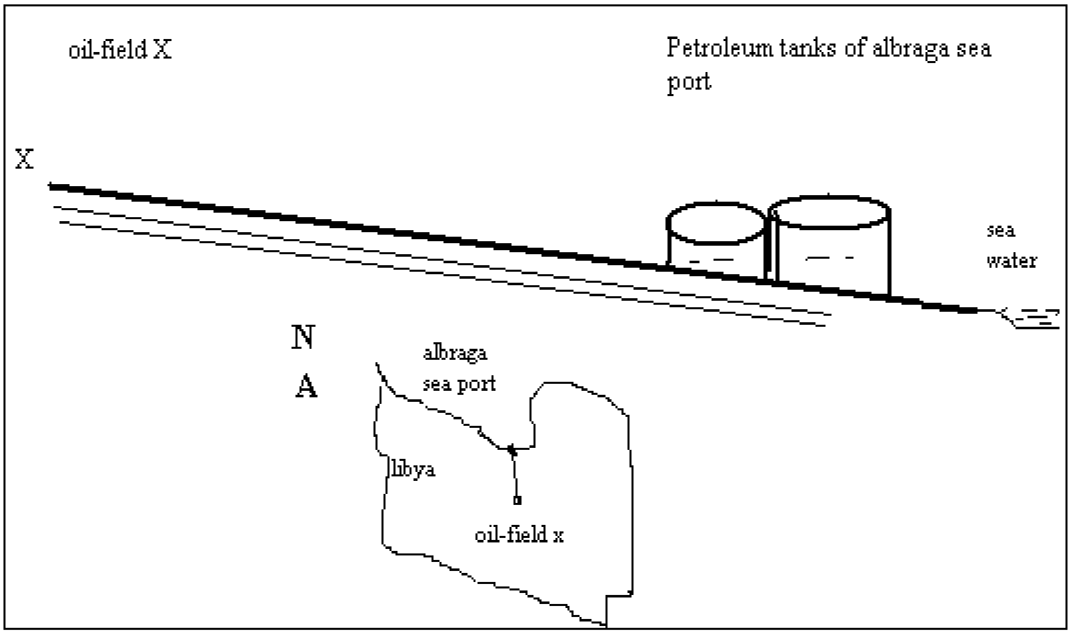

Fig:(1) Diagram showing the location of the pipeline.

3-2 Applying sacrificing anode protection pattern:

Soil resistivity is considered as the first criteria taken into consideration as basis for design of cathodic protection. If the soil resistance is high, so we will need to apply high voltage to drive the electric current into the metal, and if the resistance is small, so we will need to apply high current density.

Determination of the value of current density, number of sacrificing anodes and distance between the tube to be protected and anodes, all these depend on the resistance of the surroundings, the earth with high conductivity need to low number of anodes and vice versa, also it depends on the kind of metal to be protected.

From the international experience we find that table (2) demonstrates the current density for normal steel as the following:

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Table (2)

Current density (mA/m^2)	**Soil resistivity (Ωcm)**
	In the earth
10-20	50-500
5-10	500-1500
1-5	1500-5000
>1	>5000
100	In seawater 20-40
25	In the Libyan Salina that contains bacteria(50-200)

For new structures not yet installed, the amount of current needed to provide protection as defined in National Association of Corrosion Engineers (NACE) RP-0l-69 (reference 3) will be dependent on a number of variables . The efficiency of the coating system, both when new and at the end of design life, is a determining factor in the range of current that will be required over the lifetime of the system.

From table (2) we could find that expected current density that should be found in the protection to suppress the current at corrosion of steel in the different climates.

If we take the current density for steel in the different climates as $0.03A/m^2$ and if the expected current density to supperss is the corrosion current for tubes in the different climates, and if we assume that there is some ratio of flow out and escape at current because of the permeability at the coating “coating break down factor” f=10 %.

Then the current density we have

$i = 10\ \% \times 30 = 3\ mA/\ m^2 \rightarrow 0.003A/\ m^2$.

After calculating the total area for tubes, we calculate the value of total current required for protection tubes as follows :

Total area of tubes:

2 π d/2 =12506 cm → 1.256 m

Total area = 1.256 × 100.000 =125600 m^2

I =A × i =125600 × 0.003=376.8 A.

According to this table (3) we could determine the type of cathodic protection and the type of used anodes in protection if we have soil resistivity.

Table (3) choosing type of cathodic protection

Resistivity of soil	**Corrosion force of soil**	**Possible protection type**
Above 20000	Not corrosive	CP probably unnecessary
20000 to 5000	Barely corrosive	CP useful. Impressed current. MG for small pieces
5000 to 2000	Corrosive	Impressed current. MG anodes.
2000 to 5oo	Very corrosive	Impressed current. MG anodes.
Below 500	Extremely corrosive	ZN anodes. Impressed current.
20 to 40	Seawater .Extremely corrosive	AL or ZN anodes. Impressed current.

We select magnesium (MG) as one of the famous anodes to be used in electrolytes with high electrical resistance such as soil or graphite.

After choice of the type of required anode for protection, we provide some specification and characterizations:

Capacity “c” =1150 Ah/Kg.
Efficiency “F %” =80 %
Length “L” =1.5 m
Wight “wa” =25Kg

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So we calculate the total weight for anodes required for protection of total area of tubes for a period for 10 years.

W=I ×8766 ×y /c×f

W=376.8×8766×10/1150×0.8=35902. 5kg

So the number of anodes" =w/wa

"n" =35902.5/25=1436

We then calculate the area that is protected by only one anode

- current provided by one anode

Ia=I/n=376.8/1436=0.2623A

- area covered by one anode

Aa=Ia/ i=0.2623/0.003= 87.43 m^2

Then, an anode will cover area of 87 m^2, then, we calculate the distance between anodes on the line of the pipeline.

Every one meter of tubes with area 1.25 m^2. then, the distance between an anode =87.43/1.25=69.57m.

Then, every 69.50meter we put an anode. We place the anode vertically and at a depth if the soil resistance on the surface is high about three meters, magnesium anodes are located from 15 to 20 feet of pipelines.

Thus, we have completed the protection of the pipeline, we must monitoring the pipeline every period of time by Connect a copper sulfate half-cell to the volt meter and make contact with the ground, while connecting the meter to underground metal. Afterwards, measure the pipeline to soil voltage potential. the readings should be 0.85 or higher. Measurements lower than 0.80 is indicative of corrosion.

4. Conclusions

In this study , we designed the cathodic protection to an underground petroleum pipeline by applied the sacrificial anode method and calculated both the required current shoulder and the area of the pipeline and through it we calculated the total current required. After that , we calculated the total weight of the magnesium anodes, and through it we calculated the number of anodes needed to protect the pipeline with a length of 100 kilometers and their number was 1436 anodes , after that we calculate the area that can be protected for a single anode by dividing the total current by the total number of anodes so that we get the area that can be protected by each anode, which is 87.43 m^2 , From it we calculate the distance between each anode, where every 69.50 meter we put an anode along the pipeline. We place the anode vertically and at a depth if the soil resistance on the surface is high about three meters, magnesium anodes are generally located from 15 to 20 feet of pipelines.

Thus, we have completed the protection of the pipeline, and then the process of monitoring the pipeline is completed from one period to another.

5. References

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