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Design of Cathodic Protection for Underground Crude-Oil Pipeline by Applied impressed current system

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Abstract
Cathodic protection of underground petroleum pipelines by impressed current is very important in the oil field, especially when the soil resistance to current is high. the impressed Current is direct current supplied by a cathodic protection system utilizing an external power source .With this method, the structure is placed in an electric circuit with a direct-power supply and an anode groundbed. Current is forced to flow from the electrolyte to the structure The object of this study is to design of cathodic protection for underground crude-Oil Pipeline by impressed current cathodic protection to be used in the protection of the underground petroleum pipelines for X oil field of Waha Oil Company ,
Keywords: Cathodic protection , corrosion , impressed current

تصميم الحماية الكاثودية لخط انابيب نفط تحت أرضي بأستخدام نظام التيار المسلط

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الملخص
إن الحماية الكاثودية لخطوط أنابيب البترول تحت الأرض بواسطة التيار الكهربائي المطبق مهمة جدًا في مجال النفط، وخاصة عندما تكون مقاومة التربة للتيار الكهربائي عالية. التيار الكهربائي المطبق هو تيار مستمر يتم توفيره بواسطة نظام حماية كاثودية يستخدم مصدر طاقة خارجي. وبهذه الطريقة، يتم وضع الهيكل في دائرة كهربائية بمصدر طاقة مباشر وأرضية أنود. يتم إجبار التيار على التدفق من الإلكترو ليت إلى الهيكل. والغرض من هذه الدراسة هو تصميم الحماية الكاثودية لخطوط أنابيب النفط الخام تحت الأرض بواسطة التيار الكهربائي المسلط لاستخدامها في حماية خطوط أنابيب البترول تحت الأرض لحقل النفط X التابع لشركة الواحة للنفط . تم حساب متطلبات الحماية الكاثودية للتيار المسلط لخط أنابيب النفط المصنوع من الفولاذ الكربوني تحت الأرض بقطر 20 سم وطول 20 كم وفقًا للمعادلات. تم حساب متطلبات التيار المستمر للتيار المطبق على أنها 126 أمبير بناءً على نقص الطلاء ومساحات السطح الخارجية, تم تقدير

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كمية ألانودات (MMO) اللازمة لتوصيل التيار المباشر المطلوب البالغ 126 أمبير على أنه مطلوب 38 أنودًا لتلبية لعمر التصميم لخط الأنابيب النفطي تحت الأرض لمدة 20 عامًا. سيكون حجم مقوم المحول: 136.8 أمبير و 115.3 فولت. السعة المقترحة (150 فولت / 200 أمبير) لمقوم المحول تلبي وتلبي متطلبات التيار والتيارات الإضافية المحتملة في المستقبل.

Introduction

Impressed-current systems employ inert (zero or low dissolution) anodes and use an external source of DC power (rectified AC) to impress a current from an external anode onto the cathode surface .Cathodic Protection (CP) is an electrochemical (half electrical and half chemical) method used to control corrosion of buried or submerged metallic structures. It prevents corrosion by making the protected structure a cathode by installing a more anodic metal (sacrificial or galvanic) anode or a metallic (Impressed Current) anode connected to a Direct Current (DC) power source. When the proper amount of current is applied to the structure, it becomes a cathode. the goal of cathodic protection is to make a cathode of the steel. This is done by impressing a direct electric current on the pipe and providing an anode which will corrode instead. This will not only reduce corrosion, it will stop it. (1)

Cathodic protection (CP) is a technique used to control the corrosion of a metal surface by making it the cathode of an electrochemical cell. CP can, in principle, be applied to any metallic structure or plant that is in contact with a mass of soil or water. In the simple impressed current CP (ICCP) system, a source of DC electric current is used to help drive the protective electrochemical reaction . (2)

2-impressed current cathodic protection system design:

In addition to the structure to be protected and the electrolyte (soil), impressed current cathodic protection systems consist of the following essential components:

1. The current source, such as transformer/rectifiers, solar generators, etc.
2. The impressed current anodes, buried in soil or immersed in water.
3. The interconnecting cables (3)

2.1 Design consideration

Steps design of cathodic protection by impressed current system for underground crude-oil pipeline 20 km long for the X oil field (Al Waha Company)

- Carbon steel pipe
- Pipe diameter 20 cm
- Underground crude-oil pipeline. Its length 20 Km

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- Current density of 5 mA/m2 to 10 mA/m2 (Based on the Very Poor Coating Quality).
- Capacity of Rectifiers shall be 50 percent greater than design requirements to compensate for coating deterioration and future expansions.
- Design Life for a minimum of 20 years
- The groundbed output will be limited to a maximum of 100 amperes and 200 amperes respectively. The anodes material and quantity will be sufficient to sustain a minimum design life of 20 years
- Groundbeds will be constructed using Mixed Metal Oxide anodes surrounded by calcined petroleum backfill. The standard MMO anode (S.T 2.5/100) is designed for 20 years life with a current output of 8 amperes based from the manufacturer data sheets.

(S.T. 2.5/100):

- Diameter cm/in (2.5/1.00).
- Length cm/in (100/39.4).
- Current Output Amp (8.00).

The following table lists the MMO anodes available and their characteristics:

Designation	Diameter cm/in	Length cm/in	Current Output Amp
Soil			
S.T. 2.5/50	2.5/1.00	50/19.7	4.00
S.T. 2.5/100	2.5/1.00	100/39.4	**8.00**
S.T. 1.6/50	1.6/0.63	50/19.7	2.50
S.T. 1.6/100	1.6/0.63	100/39.4	5.00
Fresh - Brackish Water			
FW.T. 2.5/50	2.5/1.00	50/19.7	4.00
FW.T. 2.5/100	2.5/1.00	100/39.4	8.00
FW.T. 1.6/50	1.6/0.63	50/19.7	2.50
FW.T. 1.6/100	1.6/0.63	100/39.4	5.00
Sea Water			
SW.T. 2.5/50	2.5/1.00	50/19.7	25
SW.T. 2.5/100	2.5/1.00	100/39.4	50
SW.T. 1.6/50	1.6/0.63	50/19.7	15
SW.T. 1.6/100	1.6/0.63	100/39.4	30

2.2 Design Calculations:

Total Surface Area, (Sa) = π x D x L

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Sa = 3.1416 x 0.2 x 20000

The Total Surface Area, (Sa) = 12,566 m^2

Current Requirements (It)

Formula: It = Cd x Sa

It = 10mA/m^2 x 12566 m^2

It = 125.66 Amps.

Total Required Current (It) = 126 Amps.

2.3 Calculation of Anode Quantity:

Number of MMO Anodes Na

Na= I/A¡ Ì

I : is total protection current in milliamperes

A¡ : is anode surface area in square feet per anode

Ì : is recommended maximum current density output in milliampers

Na= 126000mA/0.423 ft^2 × 8000 mA

Na =37.23

Na =38 anodes

Because the soil resistance is high on the surface, ρ is the average soil resistivity as 58 ohm- m. therefore we use the vertical anode at a depth of 60 meters according to the soil resistance records. Deep anode beds are generally employed where top soil strata have a high resistivity . active length of Anode Deepwell Groundbed = 60 meters

2.4 Calculation of Anode Resistance:

Using (H.B. Dwight) equation for vertical anode

$$R_v = 0.00512\ \rho \frac{\textbf{Ln 8(Al/Ad) -1}}{Al}$$

$$R_v = 0.00512 \times 58 \left[\ln \frac{8(1+ 0.5/0.025+0.2)}{1+0.5} - 1\right]$$

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R_v = 0.598 Ohms

Where:

R_v = Anode Groundbed Resistance (ohms)

ρ = Resistivity of soil : 58 ohm- m (approx.)

Ad = Diameter of coke backfill column 0.2m

Al = is the anode length plus backfill,1+0.5

Experience has shown that the resistance of the backfill column to earth is approximately 85% of the total circuit resistance.

Therefore . the total circuit resistance is:

Rt = 1.15 x 0.598

Rt = 0.688 ohms

2.5 Rectifier Sizing:

A rectifier is a device that converts alternating current (AC) electricity from the power grid to direct current (DC) electricity for impressed current cathodic protection.

The proposed two (2) transformer rectifiers to be used with the following ratings conform and meet the requirements as shown in the calculations below:

Knowing the estimated total circuit resistance and groundbed current requirements, the corrected rectifier voltage can be determined by ohm's law:

Volts, DC = current (amps) x resistance (ohms) plus 2.0 volts

(The 2.0 volts are added to overcome back voltage of the anode and cathode.)

The calculated current requirement is 126 amperes and a circuit resistance of 0.0.688 ohm, the voltage would be:

Vtotal = 126 A x 0.688 ohm + 2V

Vtotal = 86.688 + 2

Vtotal = 88.688 V

It is advisable to obtain a rectifier with 30 % excess capacity to handle changing soil conditions, pipe coating conditions or future expansion.

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The calculated transformer rectifier size would be: 136.8 Amperes and 115.3 volts Therefore, the proposed **(150 V / 200 A)** capacity of Transformer Rectifier satisfy and meet the current requirements and for possible additional currents in the future.

3. Conclusion

The cathodic protection of the underground oil pipeline is designed by the applied current method because the soil resistivity is high .Impressed current cathodic protection demands of the underground carbon steel oil pipeline with 20Ccm diameter and 20 km length have been computed according to equations . The impressed current direct current demands were calculated as 126 Amps based on coating deficiency and external surface areas. the quantity of MMO Anodes needed to deliver the direct current demand output of 126 Amps was estimated as 38 anodes are required to meet 20 years intended design life of the underground pipeline. transformer rectifier size would be: 136.8 Amperes and 115.3 volts . the proposed (150 V / 200 A) capacity of Transformer Rectifier satisfy and meet the current requirements and for possible additional currents in the future .

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