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Cathodic Protection of Onshore Buried Pipelines Considering Economic Feasibility and Maintenance

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Abstract

During the installation of crude oil or gas pipelines, which pass through onshore buried pipelines or onshore pipeline from subsea pipeline to onshore plant, countermeasures need to be implemented so as to ensure a sufficient design life by protecting the steel pipes against corrosion. This can be achieved through impressed current cathodic protection method for onshore pipelines and through galvanic sacrificial anode corrosion protection method for offshore pipelines. In particular, in the case of impressed current cathodic protection, isolation joint flanges should be used. However, this makes maintenance control difficult with its installation having a negative impact on price. Therefore, in this study, the most suitable methodology for onshore pipeline protection between galvanic sacrificial anode corrosion protection and impressed current cathodic protection method will be introduced.

In oil and gas transportation facilities, the media can be carried to the end users via onshore buried and/or offshore pipeline. It is imperative for the field operators, pipeline engineers, and designers to be corrosion conscious as the pipelines would undergo material degradations due to corrosion. The mitigation can be achieved with the introduction of an impressed current cathodic protection method for onshore buried pipelines and a galvanic sacrificial anode corrosion protection method for offshore pipelines. In the case of impressed current cathodic protection, isolation joint flanges should be used to discontinuity. However, this makes maintenance control to be difficult when its installation has a negative impact on the price. In this study, the most suitable corrosion protection technique between galvanic sacrificial anode corrosion protection and impressed current cathodic protection is introduced for (economic life of) onshore buried pipeline.

Keywords: Onshore buried pipeline, Galvanic sacrificial anode corrosion protection method, Impressed current cathodic protection method, Resistivity, Demand current, Corrosion

1. Introduction

Crude oil and natural gas can carry various high-impurity products which are inherently corrosive. When the media is transferred through the pipelines, it is important to protect the assets for a prolonged period of time, to extend the lifespan of the pipeline network and to minimize any repair works.

For offshore pipelines, galvanic sacrificial anode cathodic protection (SACP) method has primarily been used, whereas in the past, impressed current cathodic protection (ICCP) method has been used for onshore

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buried pipelines. However, the galvanic sacrificial anode corrosion protection method is currently being used in protection of onshore buried pipelines as well as in offshore pipelines due to the cost effectiveness and its constant current distribution.

As such, the present study aims to provide a practical and an economical design of galvanic SACP and ICCP.

2. Characteristics of SACP and ICCP

In this section, galvanic sacrificial anode corrosion protection and impressed current protection methods are introduced as a construction method to prevent corrosion in onshore buried pipelines.

2.1 SACP

SACP is a method to prevent steel pipes from generating corrosion currents by producing a protective current generated due to a potential difference, which is a result of forming a metal secondary battery through electrical connection of steel pipes with metals whose ionization tendency is high, such as magnesium (Mg) and zinc (Zn). It lets targets that need protection to come into electrical contact with metals such as Al, Zn, or Mn, which have low electric potentials, thereby supplying electrons generated during dissolution of the sacrificial anode to targets requiring protection. Zn or Al is mainly used in underwater steel structures cooling water, or ships, while Mg is mainly used in buried pipes or tanks onshore whose resistivity is high.

After the metal atoms at the anode site release electrons, there are four common cathode reactions:

1) In aerated wet soil: $O_2 + 2H_2O + 4e^- \Rightarrow 4OH^-$
2) In aerated wet acidic soil: $O_2 + 4H^+ + 4e^- \Rightarrow 2H_2O$
3) In neutral seawater: $O_2 + 2H_2O + 4e^- \Rightarrow 4OH^-$
4) In de-aerated soil or water: $2H_2O + 2e^- \Rightarrow 2OH^- + H_2$

The anodic reaction as per anode type can be represented as follows:
$Fe \Rightarrow Fe^{2+} + 2e^-$, $Mg \Rightarrow Mg^2 + 2e^-$, $Zn \Rightarrow Zn^{2+} + 2e^-$, $Al \Rightarrow Al^3 + 3e^-$

In soft soil, the reference electrode ~~used~~ is $Cu / CuSO_4$. The corresponding reaction is $CuSO_4 + 2e^- \Leftrightarrow Cu + SO_4^{2-}$, whereas in sea water, $AgCl$ is used with the corresponding reaction : $AgCl + e^- \Leftrightarrow Ag + Cl^-$.

2.2 ICCP

It is a method to prevent corrosion by allowing an appropriate direct current (DC) to flow continuously through metal bodies in contact with wet soil or a corrosive aqueous solution. It employs a direct current generator (rectifier) that has the onshore pipe connected to the negative terminal of the rectifier, whereas the selected anode is connected to its positive terminal, thereby making the current flow from the selected anode to the onshore pipe forcibly and thus preventing corrosion currents in the onshore pipe. This is also called forced current method. Typical anodes are high silicon cast iron (HSCI), polymer (AnodeFlex) graphite, and iron.

The reduction reactions at the cathode are:

1) In aerated wet soil: $O_2 + 2H_2O + 4e^- \Rightarrow 4OH^-$
2) In aerated wet acidic soil: $O_2 + 4H^+ + 4e^- \Rightarrow 2H_2O$
3) In neutral seawater: $O_2 + 2H_2O + 4e^- \Rightarrow 4OH^-$
4) In de-aerated soil or water: $2H_2O + 2e^- \Rightarrow 2OH^- + H_2$

The oxidation reactions at the anode are:

1) In water or in wet soil: $2H_2O \Rightarrow O_2 + 4H^+ + 4e^-$
2) In salt or brackish water: $2Cl^- \Rightarrow Cl_2 + 2e^-$
3) In graphite anodes: $C + 2H_2O \Rightarrow CO_2 + 4H^+ + 4e^-$

3. Theory of SACP in buried pipes

In this section, the theory of SACP is discussed. The initial current required for onshore buried pipes shall be calculated accordingly using Eq. (3-1).

$$I_{initial} = A(1-\alpha)C_C + A\alpha C_B \quad \text{(mA)} \qquad (3\text{-}1)$$

where A is the surface area of the buried pipes, $(\pi \times OD \times L)m^2$
α is the rate of damage of the anticorrosion coating after the pipes are buried(1%).
C_c is the current density of buried pipeline at design temperature (below $30°C$ is $0.025mA/m^2$ and above 30℃, the current density will be increased 2.5% for every 1℃ increase in temperature)
C_B is the current density of buried pipeline $(10mA/m^2)$

The maximum electrode potential that can be generated by an anode is calculated using Eq. (3-2).

$$E_D = E_{anode} - E_p + E_{polar} \quad \text{(Volt)} \qquad (3\text{-}2)$$

where E_{anode} the standard electrode potential (copper/copper sulfate reference electrode) in volts, E_p the protective potential of buried piping (NACE standard RP0169-83) in volts, and E_{polar} potential change of anode during current flow in volts. The equations below explain the anode and anode ground resistances with relation to anode installation.

Ground resistance of anode using the Dwight formula (Dwight, 1936) for single anode is expressed as in Eq. (3-3):

$$R_{a1} = \frac{\rho_s}{2\pi L_A}\left[Ln\left(\frac{8L_A}{OD_A}\right) - 1\right](\Omega) \qquad (3\text{-}3)$$

where ρ_s is the resistivity of soil $(\Omega - m)$, L_A is the anode length (m), and, OD_A is the anode diameter (m)

If a vertically connected array of anodes is used, the ground resistance of the anode is expressed by Sunde (1949) equation as shown in Eq. (3-4):

$$R_{a1} = \frac{\rho_s}{2\pi L_A N}\left[Ln\left(\frac{8L_A}{OD_A}\right) - 1 + \frac{2L_A}{S}Ln(0.656N)\right](\Omega) \qquad (3\text{-}4)$$

where N is the number of anodes (EA) and S is the vertical spacing of the anode (m)

If anodes are installed horizontally, the ground resistance of the anode is expressed by Sunde (1949) equation as shown in Eq. (3-5):

$$R_{a1}=\frac{\rho_s}{2\pi L_A}\left[Ln\left(\frac{4L_A^2+4L_A\sqrt{S^2+L_A^2}}{OD_AS}\right)+\frac{S}{L_A}-\frac{\sqrt{S^2+L_A^2}}{L_A}-1\right](\Omega) \qquad (3\text{-}5)$$

where S is two times the depth at which the anode is buried (m)

Nevertheless, eq.3-3, 3-4 and 3-5 can be used to obtain only ground resistance of filling materials, ρ_s, OD_A, and L_A, for grounding electrode. However, to obtain an electrical resistance of buried pipeline, ρ_b, OD_B, and L_B will be represented as filling materials in eq. 3-6. instead of above parameters

$$R_{metal}=\rho_{metal}\frac{L_P}{A_P}(\Omega) \qquad (3\text{-}6)$$

where ρ_{metal} is the resistivity of steel pipe, $\left(=2.2\times10^{-7}\Omega-m\right)$

L_p is the distance between the anode and buried pipe (m), and A_p is the Ccross-sectional area of the buried pipe. $\left(=\pi\frac{\left(OD^2-\left(OD-2t_\omega\right)^2\right)}{4}m^2\right)$

The electrical resistances of anode, junction box, and cathode wires of buried pipes can be expressed using Eq. (3-7).

$$R_{cable}=\rho_{cable}\left(\frac{L_{c1}}{A_{c1}}+\frac{L_{c2}}{A_{c2}}\right)(\Omega) \qquad (3\text{-}7)$$

where ρ_{cable} is the resistivity of cable($=1.68\times10^{-8}\,\Omega\text{-}m$), L_{c1}, L_{c2} is the wire length between the anode and junction box and between the buried pipe and junction box (m), and A_{c1}, A_{c2} is the cross- sectional area of the wire between the anode and junction box, and between the buried pipe and junction box. $\left(=\pi\frac{d^2}{4}m^2\right)$

Thus, the total electrical resistance of anode and ground can be expressed using Eq. (3-8):

$$R_{total}=R_{a1}-R_b+R+R_{metal}+R_{cable}(\Omega) \qquad (3\text{-}8)$$

Thus, the maximum generating current of anode, I, can be expressed ~~as~~ in Eq. (3-9).

$$I = E_D/R_{total}\ (mA) \qquad (3\text{-}9)$$

Based on the above maximum generating current, the quantity and the spacing of the anode can be calculated from the required current and relationships of buried pipe using Eqs. (3-10) and (3-11).

$$N_{req'd} = I_{Iinitial}/I\ (Nos) \qquad (3\text{-}10)$$

$$S_{span\,req'd} = L/N_{req'd}\ (m) \qquad (3\text{-}11)$$

where L refers to the entire length (m) of onshore buried pipes. Note that when an arrangement of anodes is connected vertically, some adjustment may be needed with regard to anode distance $S_{req'd}$, if in some cases, anodes are installed horizontally.

However, the life of an anode shall be examined separately depending on type of anode or value of electrical resistance in the ground. The calculation/value can be obtained from Eq. (3-12).

$$Y_{req'd} = \frac{P_{ac}}{I_{initial}} U_f \ (\hbar our) \qquad (3\text{-}12)$$

where P_{ac} is is the capacity of the anode $(\mathrm{A.hr/kg})$, U_f is the utilization factor of the anode (=85%).

For the calculation of driving voltage and lifetime of the anode, equations (3-13) and (3-14) are used. Eq. (3-13) is employed when a single vertical anode is used and Eq. (3-14) is employed when multiple vertical or horizontal anodes are used.

$$V_d = \frac{0.106922398589065 W_a N_{req'd} R_b}{L_f} \ (Volt) \qquad (3\text{-}13)$$

$$\mathrm{V_d} = \frac{0.016979026455 \mathrm{W_a} \rho_a}{\mathrm{L_f L_A}} \left[\mathrm{Ln}\left(\frac{8\mathrm{L_A}}{\mathrm{OD_A}}\right) - 1 + \left(\frac{2\mathrm{L_A}}{\mathrm{S_{req'd}}}\right) \mathrm{Ln}\left(0.656 \mathrm{N_{req'd}}\right) \right] \ (\mathrm{Volt}) \qquad (3\text{-}14)$$

where $\mathrm{W_A}$ is the net anode mass per piece, $\mathrm{M}_A/N_{req'd}(kg)$

$\mathrm{M}_A = N_{req'd} V_A \rho_A$ is the net anode total mass (kg)

$V_A,\ \rho_A$ is the net anode volume per piece and unit mass, and $(m^3, kg/m^3)$

$L_f = Y_{req'd}$ is the lifetime of the anode (years)

The following Figures (3.1) and (3.2) illustrate the installation plan of SACP in onshore buried pipes.

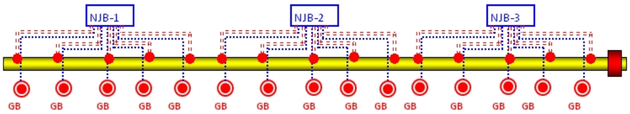

Figure 3.1 Arrangement of anodes during SACP

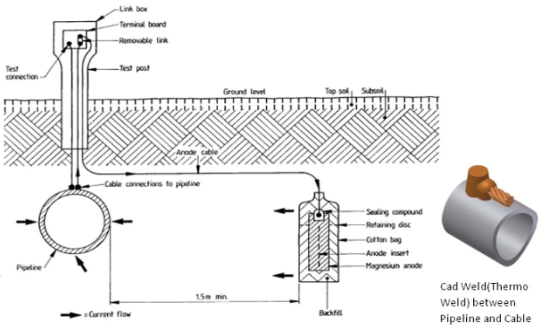

Figure 3.2 Installation diagram of anode-connection device - piping in the corrosion protection method

4. Theory Of ICCP In Buried Pipes

In this section, ICCP method is discussed for corrosion protection of onshore buried pipes. To deploy impressed current, current maximum protection distance is needed to be calculated using the following equation (4-1).

$$L_m = \frac{cosh^{-1}(\Delta E_d/\Delta E_X)}{\alpha}\ (m) \tag{4-1}$$

where $\Delta \mathrm{E_d} = \mathrm{E_d} - \mathrm{E_{nat}}$ is the (negative potential of the leaking point), $\Delta \mathrm{E_X} = \mathrm{E_{min}} - \mathrm{E_{nat}}$ is the (potential movement from the pipe end), $E_{min} = -0.85V$ (limit of positive potential) , $\alpha = \sqrt{\frac{R_L}{R_T}}$ (Damping constant) $E_d = -0.95V$ (limit of negative potential) , $E_{nat} = -0.5V$ (Nnatural potential of pipe corrosion).

Thus, the length and horizontal resistance of an onshore buried pipe can be expressed using Eqs. (4-2) and (4-3) in order to obtain the result of Eq. (4-1).

$$R_L = \frac{\rho}{\pi t_w(OD - t_w)}\ (\Omega/m) \tag{4-2}$$

$$R_T = \frac{1}{g_T}\ (\Omega/m) \tag{4-3}$$

where ρ and OD are the resistivity$(2.2 \times 10^{-7\Omega} - \mathrm{m})$, and diameter (m) of the steel pipe, respectively, $\mathrm{t_w}$ is the thickness of the steel pipe (m), $\mathrm{g_T} = \mathrm{A/R_c}\left(\mathrm{m/\Omega - m^2} = 1/\Omega - \mathrm{m} = \mho/\mathrm{m}\right)$, $\mathrm{R_c}$ is the resistance of the steel pipe ($10000\Omega - \mathrm{m}^2$ for 3LPE), and $\mathrm{A} = \pi\mathrm{ODL/L}$ is the area per unit length of the steel pipe circumference $(\mathrm{m^2/m})$.

Followings, the required current according to the piping method and current density of anode are defined in order to calculate the required quantity of anodes and the maximum current generation.

The required current for corrosion protection is obtained using Eq. (4-4).

$$I_t = A_s \frac{C_D(1-C_B)+C_{Db}C_B}{1000}(1 + SF_1)\ (Amp) \tag{4-4}$$

where $\mathrm{A_s} = \pi\mathrm{ODL}$ is the area of the steel pipe circumference ($\mathrm{m^2}$), C_D is the required current density of the buried pipe at the design temperature ($0.025mA/\mathrm{m}^2 + 2.5\%$ for every 1°C increase in temperature), C_{Db} is the required current density of the steel pipe (10 mA/m2), C_B is the damage rate of pipe coating (1%), and SF_1 is the safety margin for protection current (25%).

The current density in the anode can be expressed from Eq. (4-5).

$$log\,Y = 3.3 - log\ I_d \rightarrow I_d = 10^{(3.3-log\,Y)}\ (A/m^2) \tag{4-5}$$

The maximum generation current of anode is expressed using Eq. (4-6).

$$I_O = A_s\,I_d\ (Ampare) \tag{4-6}$$

Thus, the minimum quantity of anode can be expressed from Eq. (4-7).

$$\mathrm{Q}_{min} = I_t/I_o \tag{4-7}$$

In order to re-verify the quantity of anode, it can be validated using Eq. (4-8).

$$Q_{min} = Y\,I_t C/W_A \tag{4-8}$$

where Y is the design life (*years*), C is the anode consumption (*kg/Ayr*), and W_A is the mass of each anode (*kg*).

Thus, the minimum quantity of anode, after considering the safety margin, can be calculated using the Eq. (4-9)

$$Q = Q_{min}(1 + SF_2),\ where\ SF_2\ is\ 15\% \qquad (4\text{-}9)$$

In order to re-verify the quantity of anode, Eq. (4-10) is used to verify the current area of the anode.

$$J = I_t/I_d\ (Amp/Anode)\ \text{is the anode current.} \qquad (4\text{-}10)$$

Thus, the minimum required surface area of the anode can be expressed from Eq. (4-11).

$$A_s = J/I_d(m^2) \qquad (4\text{-}11)$$

The surface area of the anode is calculated using the formula $A_s = \pi L_A\, OD_A$, which should be greater than J/I_d.

Next, the resistance of the direct current circuit shall be examined and the capacity of the transformer rectifier needs to be determined.

In order to examine interactive resistance between the filling material and the anode, the Dwight equation is employed, leading to Eq. (4-12).

$$R_a = \frac{\rho_b}{2\pi L_A}\left[ln\left(\frac{8L_A}{OD_A}\right) - 1\right]\ (\Omega) \qquad (4\text{-}12)$$

where ρ_b is the resistivity of filling material $(\Omega - m)$, L_A is the anode length (m), OD_A is the anode diameter (m).

Since an interactive effect of vertical distance to anode occurs, an interference coefficient taking into consideration the interactive effect can be calculated using Eq. (4-13).

$$f_A = 1 + \frac{2L_A}{S_A}\,\frac{ln(0.656N_A)}{ln[(8L_A/OD_A - 1]} \qquad (4\text{-}13)$$

where $N_A = Q/N_{gb}$ is the number of anodes in the filling material, and S_A is the distance between the tips of the anode in the filling material (m).

Next, the resistance of the filling material (groundbed) and ground can be expressed using Eq. (4-14), the Dwight equation.

$$R_b = \frac{\rho_s}{2\pi L_{gb}}\left[ln\left(\frac{8L_{gb}}{OD_{gb}}\right) - 1\right]\ (\Omega) \qquad (4\text{-}14)$$

where ρ_s is the resistivity of the soil $(\Omega - m)$, L_{gb} is the is the length of the groundbed (m), and OD_{gb} is the diameter of the groundbed (m).

The resistance of deep groundbed can be expressed as shown in Eq. (4-15).

$$R_{gb} = \frac{R_A}{N_A}\, f_A + R_b(\Omega) \qquad (4\text{-}15)$$

An interference coefficient of the filling material can be expressed as shown in Eq. (4-16).

$$f_{gb} = 1 + \frac{2L_{gb}}{S_{gb}} \frac{ln(0.656N_{gb})}{ln[(8L_{gb}/OD_{gb}-1]} \tag{4-16}$$

where L_{gb} is the active length of the groundbed (m). S_{gb} is the distance between the groundbeds (m), and N_{gb} is the number of groundbeds.

The final resistance of the filling material considering the interference coefficients of each filling material can be expressed in Eq. (4-17) for a filling material with two layers.

$$R_{gbt} = \frac{R_{gb}}{N_{gb}} f_{gb}(\Omega) \tag{4-17}$$

The ICCP method requires electric wires divided into cathode and anode, which requires the resistance of each wire to be examined separately. Hence, the electric wire resistance of anode cables between anode and the connecting device can be calculated using Eq. (4-18).

$$R_{A-cable} = \Sigma_1^{N_{c1}} \frac{L_{c1}R_{e1}}{N_{c1}C_1} \ (\Omega) \tag{4-18}$$

where L_{c1} is the cable length (m) and R_{e1} is the resistance per unit length of the cable (Ω/m), N_{c1} is the number of cable connections=N_A is the number of anodes, and C_1 is the number of cable cores.

The resistance of the anode cable length between the connecting device and the transformer rectifier can be calculated using Eq. (4-19).

$$R_{PJB-TR} = \Sigma_1^{N_{c2}} \frac{L_{c2}R_{e2}}{N_{c2}C_2} \ (\Omega) \tag{4-19}$$

where L_{c2} is the cable length, R_{e2} is the resistance per unit length of the cable (Ω/m), N_{c2} is the number of cable connections, and C_2 is the number of cable cores.

Hence, the sum of resistances of the anode cable from the anode to connecting device and transformer rectifier can be calculated using Eq. (4-20).

$$R_{Positve-cable} = (R_{A-cable} + R_{PJB-TR})/N_{gb} \ (\Omega) \tag{4-20}$$

where N_{gb} is the number of groundbeds.

Thus, the total anode resistance from the anode and groundbed to the transformer rectifier can be expressed using Eq. (4-21).

$$R_{t-Positve} = R_{gbt} + R_{Positive-cable} \ (\Omega) \tag{4-21}$$

The resistance of the cathode cable between the connecting device and the pipe can be expressed using Eq. (4-18) and the notation of resistance can be expressed in Eq. (4-22).

$$R_{P-cable} = \Sigma_1^{N_{c1}} \frac{L_{c1}R_{e1}}{N_{c1}C_1} \ (\Omega) \tag{4-22}$$

where $L_{c1}$is the cable length (m), R_{e1} is the resistance per unit length of cable (Ω/m), N_{c1} is the number of connections between the pipe and cable, and C_1 is the number of cable cores.

The resistance of the wires connecting the cathode cable between the connecting device and the transformer rectifier can be expressed using Eq. (4-23).

$$R_{NJB-TR} = \Sigma_1^{N_{c2}} \frac{L_{c2}R_{e2}}{N_{c2}C_2} \ (\Omega) \tag{4-23}$$

where L_{c2} is the cable length (m), R_{e2} is the resistance per unit length of cable (Ω/m), N_{c2} is the number of cable connections, and C_2 is the number of cable cores.

Hence, the sum of resistances of the cathode cable from the pipe to the connecting device and the transformer rectifier can be calculated using Eq. (4-24).

$$R_{N-cable} = \left(R_{P-cable} + R_{NJB-TR}\right)/N_{cp} \ (\Omega) \qquad 4\text{-}24)$$

where N_{cp} is the number of Cadwelds with the pipe.

Thus, the total circuit DC resistivity in cathode and anode circuits can be expressed in Eq. (4-25).

$$R_T = R_{t-positive} + R_{N-cable} \ (\Omega) \qquad (4\text{-}25)$$

Hence, the capacity of the DC transformer rectifier can be expressed in Eq. (4-26).

$$V_{DC} = R_T\, I_t(1 + SF_3) + B_{emf} \ (V) \qquad (4\text{-}26)$$

where I_t is the current required for corrosion protection (AMP), SF_3 is the allowable safety factor of the transformer rectifier (20%), and B_{emf} is the backflow voltage of the transformer rectifier (2 Volt).

Next, the maximum allowable resistance can be expressed using the relationship between the above DC voltage and DC current as shown in Eq. (4-27).

$$R_{rated} = V_{DC}/I_{DC} \ (\Omega) \qquad (4\text{-}27)$$

where V_{DC} is the allowable voltage of the rectifier (V), which should be $\geq$ $(4-26), V_{DV}$ the value yielded by the circuit calculation resistance equation. I_{DC} is the allowable current in the rectifier $(A) \geq I_t$

The maximum allowable resistance $R_{rated}(\Omega)$ in Eq. (4-27) is greater than the DC resistance $R_T(\Omega)$ according to the calculations in Eq. (4-25). Since alternating current (AC) is supplied to the transformer rectifier instead of a DC supply, DC has to be converted into AC, which can be executed using Eq. (4-28).

$$I_{AC} = \frac{I_{DC}V_{DC}}{V_{AC}\cdot eff \cdot \sqrt{3}} \ (Amp) \qquad (4\text{-}28)$$

where I_{DC} is the allowable current of the rectifier (AMP), V_{DC} is the allowable voltage of the rectifier (V), V_{AC} is the supply AC voltage (generally 110.0 V but varies by area). eff is the efficiency of the rectifier (80%).

Hence, the capacity of the transformer rectifier can be expressed in Eq. (4-29).

$$V_{AC-cp} = I_{AC}\ V_{AC}\ \sqrt{3} \ (Volt) \qquad (4\text{-}29)$$

Although the design life of anode is mentioned in the design standards, it can be determined according to the type of anode used. The life of an anode should be larger than its design life at least as far as its consumption is concerned. Eq. (4-30) depicts the life of an anode.

$$Life = \frac{W_a}{C\cdot I_{DC}} \ (Years) \qquad (4\text{-}30)$$

where W_a is the total mass of the anodes, C is the annual consumption by anode type $(0.08 \sim 0.737kg/A\,Yr.)$, I_{DC} is the allowable current of the rectifier (AMP).

The arrangement of the anode, onshore buried pipes, and rectifier is shown in Figure (4.1).

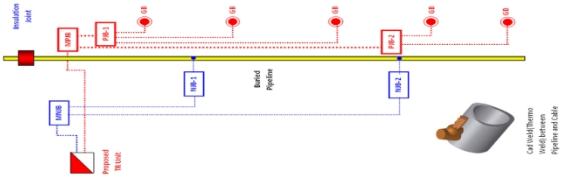

Figure 4.1: Diagram of arrangement in the ICCP method

5. Conclusion

In the present study, the SACP and ICCP methods were examined as means of corrosion protection to be used for onshore buried pipelines. The study showed that the ICCP method has advantages of higher current and power outputs as well as providing adjustable protection levels. It is also suited for large areas of protection and requires a lower number of anodes. It can also be used to protect poorly coated structures.

However, the ICCP method also has the following disadvantages: it requires complex equipment and has higher installation as well as maintenance costs. There are also possible interference problems with foreign structures and the risk of incorrect polarity connections. Furthermore, it requires installation of isolation joint flanges in the connecting section between offshore and onshore regions to prevent current deviation and distinguish the SACP in offshore pipelines and ICCP in onshore pipelines.

For the SACP method, the following advantages can be mentioned: no requirement of an external power source, ease of installation, and low maintenance costs. In addition, it can provide a uniform distribution of current and no special isolation joint flanges are required to be installed in the connecting section between offshore and onshore pipelines for current deviation prevention. However, it has the following disadvantages: it produces limited current and power output, a large number of anodes are required in high resistivity environments or for large structures, and it requires periodic replacement of anodes owing to the depletion of anodes after a certain period of time. Therefore, the SACP method is advantageous and economical for onshore pipelines when the condition of the ground is relatively good, no acidifying materials are found, and the electric resistance of the ground is low. On the other hand, when the ground condition is relatively poor, no acidifying materials are found, and electric resistance of ground is large; the ICCP method is found to be more advantageous than the SACP method, even though isolation joint flanges are required to be installed at the intersection of offshore and onshore areas.

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