

Planning Optimization Technology Study Cathodic Protection As Anti Corrosion On Subsea Pipelines

Abstract

Subsea pipes are a tool for flowing water, oil and gas fluids. By using this underwater pipe installation, fluids can be transferred from one place to another, from a production unit to another production unit, from a storage unit to a processing unit, and from a process transferred to a storage unit. During the production process, safety must be guaranteed to avoid fatal damage such as anchor drag, sinking ships, nets or trawls and other factors such as pipe corrosion. To prevent corrosion in pipes, we need appropriate and practical solutions. We can prevent this from happening by conducting a literature study regarding the application of optimization planning for cathodic protection in pipes. The design and analysis process discusses cathodic protection analysis, which refers to the DNV GL-RP-F103 standard criteria. Additional discussion is carried out as an optimization step, namely analyzing the type of paint used based on DNVGL-RP-B401.

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1. Introduction

Oil and natural gas are two resources that play a vital role in human life. Oil and natural gas are energy sources that are often used. In Indonesia, oil and natural gas consumption reached 53%, while coal and other renewable energy reached 47%. Because Indonesia has an ocean area wider than land, much oil and gas exploitation is carried out in the ocean area. Energy needs in Indonesia are spread evenly across the Indonesian islands, so an effective and efficient oil and gas distribution process is needed.[1] A subsea marine pipeline is a piping installation generally used to convey water, oil and gas fluids through piping installations placed on the sea bed (seabed). Using this underwater pipe installation, fluid can be transferred from one place to another, from a production unit to another, from a storage unit to a processing unit, and from a processing unit transferred to a storage unit.[2] Subsea pipelines are an effective and efficient distribution method because the underwater pipeline will remain under the sea with a specific route that connects the oil rig with the oil storage area, so there is no need for fuel costs like on tankers, and distribution time will be faster. Moreover, distribution can be carried out continuously without waiting for tankers to arrive.[1]

In oil and gas production, pipe design is given great attention because it ensures safety during the distribution process so that there are no leaks, which will cause impacts to the company, ranging from environmental damage to losses. During the oil and gas distribution process, pipes that stretch from one point to another have many consequences and risks of damage that can occur. For example, when the pipe is in a marine traffic and fairway area. Many possibilities can cause fatal damage to pipes, such as anchor drag, sinking ships, nets or trawls and other factors, such as corrosion of pipes.[3]

Shaw and Kelly (2006) define corrosion as the degradation of material properties due to interaction with its environment, and corrosion of most metals (and many other materials) cannot be avoided even though it is primarily related to metallic materials; all types of materials are susceptible to degradation. Bardal (2004) also describes corrosion as an attack on metallic materials that causes material degradation due to the electrochemical reaction of the material with its environment.[4]

In some cases, especially in the case of corrosion, methods to improve coordination in the marine environment are being developed. In this case, the relationship is with sea transportation facilities. One is the sacrificial method approach, which works based on the principle of cathodic protection. Initially, the surface of the metal structure in the water is converted to cathodic by providing a current received from the sacrificial anode.[5]

The natural process of corrosion is complex to prevent. However, with currently developed technology, corrosion can be controlled by inhibiting the corrosion rate so that losses resulting from corrosion can be reduced. One of the causes of damage to gas distribution pipe facilities is corrosion. To ensure the smooth operation of gas distribution pipeline facilities, it is necessary to control corrosion of all gas distribution pipeline facilities. Therefore, it is the process of preventing corrosion in pipe facilities using a cathodic protection system. Using this protection system to protect pipe facilities from corrosion is very important because the impacts caused by corrosion are very detrimental. So, this cathodic protection system is very suitable for inhibiting the rate of corrosion to protect pipe facilities from corrosion and reduce the losses that occur. Due to corrosion.[6] Therefore, this study will discuss cathodic protection planning as an anti-corrosion solution for underwater pipes.

2. Theory And Methodology

Corrosion is an electrochemical process involving electric current flow on a micro and macro scale. Corrosion occurs at the anode and not at the cathode (unless a base attacks the metal at the cathode). The anode and cathode in the corrosion process can be two different metals connected, or as occurs in rusting steel, they are close together on the surface of the same metal. The initial causes of corrosion are 1) natural potential differences between two different metals, 2) variations in metallurgical conditions on the metal surface, 3) differences in local environmental conditions, such as variations in oxygen on the surface where oxygen-rich areas become cathodes and oxygen-poor areas become anodes [7]. Based on the pattern and form of distribution, corrosion is divided into five types: galvanic, erosion, stress, crevice, and pitting.[8]

Internal corrosion prevention is essential to protect pipes and not interfere with pipe operations. Internal corrosion prevention includes 1) using chemicals with corrosion inhibitors to slow down the corrosion rate and 2) pigging, which is a method of preventing corrosion from inside the pipe by cleaning the remaining water or condensate in the pipe. Meanwhile, external corrosion prevention can be done by doing several things, namely 1) Painting (coating) with paint containing lead and zinc, 2) Wrapping, which protects the iron from direct contact with water or oxygen, 3) This cathodic protection is a commonly used method to protect metal structures from corrosion.[6]

Protection is the protection of an object so that the object can continue to work optimally without interference. Various types of protection are carried out by companies and industries, one of which is cathodic protection. Cathodic protection is a system where a structure is protected using an oxidation reaction method that occurs in 2 metals. Many types of structures can be

protected by cathodic protection, including underground pipes, storage tanks, and even upstream parts of ships.[9]

The principle of CP is to convert all areas on the metal surface into cathodes by connecting the anode from the outside to the protected metal and passing a DC electric current. The external anode can be a galvanic anode, where the current flows from the potential difference between the two metals, or an impressed current anode, where the current flows from an external DC power source. CP can be achieved in two ways, namely 1) With a galvanic (carbon) anode, "Sacrificial Anode Cathodic Protection" (SACP) and 2) With a counter-current "Impressed Current Cathodic Cathodic Protection (ICCP).[7]

There are four influencing factors in determining how many total anodes are needed.

a. Based on anode mass

1. Determination of total anode

$$N_{mcd} = \frac{M_{tot}}{M_{ad}} \quad (1)$$

2. Determination of anode mass

$$SP_m = \frac{\frac{(L_{end}-L_{start})}{L_j}}{N_{mcd}} \quad (2)$$

Based on equation (1), N_{mcd} is the required number of anodes (pieces), M_{until} is the total mass of the anode required (kg) and M_{ad} is Mass per Anode (kg). Based on equation (2), SP_m is the average distance requirement between anodes (m), L_{end} is the final length of the pipe (m), L_{start} is the initial length of the pipe (m), and L_j is the length of the pipe connection (m).

b. Based on current density

1. Determination of total anode

$$N_{fcd} = \frac{I_{cf}}{I_{af}} \quad (3)$$

2. Determination of anode mass

$$SP_f = \frac{\frac{(L_{end}-L_{start})}{L_j}}{N_{fcd}} \quad (4)$$

c. Based on the anode weakening factor

1. Determination of total anode

$$N_m = \frac{L_{end}-L_{start}}{\text{jarak antar 2 sambungan}} \quad (5)$$

2. Determination of anode mass

$$SP_m = \frac{\frac{(L_{end}-L_{start})}{L_j}}{N_{mar}} \quad (6)$$

Based on equation (1), N_{mcd} is the required number of anodes (pieces), M_{until} is the total mass of the anode required (kg) and M_{ad} is Mass per Anode (kg). Based on equation (2), SP_m is the average distance requirement between anodes (m), L_{end} is the final length of the pipe (m), L_{start} is the initial length of the pipe (m), and L_j is the length of the pipe connection (m).

d. Based on the maximum distance between anodes

1. Determination of total anode

$$N_{mar} = \frac{L_{end} - L_{start}}{M_{AS}} \quad (7)$$

2. Determination of anode mass

$$SP_{mas} = \frac{\frac{(L_{end} - L_{start})}{L_j}}{N_{mar}} \quad (8)$$

Based on equation (5), N_{mar} is the number of anodes required (pieces). Based on equation (6), SP_{but} is the average distance requirement between anodes (m), L_{end} is the final length of the pipe (m), L_{start} is the initial length of the pipe (m), and L_j is the length of the pipe connection (m). Based on the factors above, it is known that the factor used in determining the number and installation distance between anodes is the maximum distance between anodes (usually used in long pipe circuits). To find out whether the resulting calculations are in accordance with what is needed in the field, it is necessary to use the crack tendency ratio equation, namely:

$$CPR = \frac{\pi \times L_{at} \times ID_a}{5 \times t_a^3} \quad (9)$$

Where :

CPR is Crack propensity ratio, π value: 3.14159265358979323846, ID_a is the inner diameter of the anode (mm), the value of t_a is the thickness of the anode (mm). In determining this crack ratio, the CPR value must be less than 5mm^{-1} .

3. Results And Discussion

Based on research conducted by Arief et al. (2020)[12], namely carrying out cathodic protection analysis based on DNVGL-RP-F103. The dimensions of the sacrificial anode are shown in Table 1.

Table 1. Anode Dimensions

Parameter	Symbol	Mark	Unit
Anode length	L_o	255	mm
Anode thickness	T_a	40	mm
Gap antar anoda (half shell gap)	G_a	75	mm
Anode density	r_a	2730	kg/m ³
Anode type		Bracelet Love	

The following shows an example of the calculation results by obtaining the current requirement value, the total mass of the anode, and the final output current per anode in Table 2.

Table 2. Calculation of cathodic protection

Parameter	Symbol	Mark	Unit
Average current demand (mean current demand)	I_{cm}	288.938	A
Final current demand	I_{cf}	393.536	A
Total net anode mass	m_a	23729.04	Kg
Anode resistance	R_{of}	0.182	Oh
Total output current for one anode	I_{of}	1.373	A

Based on this value, the number of anodes needed and the distance between anodes can be calculated to meet the total and final current requirements shown in Table 3.

Table 3. Calculation of the number and distance between anodes

Parameter	Symbol	Mark	Unit
The number of anodes to meet the total net anode mass requirements	N_m	756	Unit
The number of anodes required to meet the final current requirements	N_{of}	287	Unit
Distance between anodes to achieve the total net anode mass requirement	L_m	30	Pipe joint length
Distance between anodes to meet final current requirements	L_{of}	82	Pipe joint length
Distance between selected anodes	L_s	30	Pipe joint length
Check: ($L_s < 300$ m)		$L_s = 366$ m	> 300 m
Results of the distance between anodes due to attenuation calculations	L_{to}	490.82	m
Czech ($L_s < 300$ m)		$L_{to} = 490.82$ m	> 300 m

The calculated distance exceeds the maximum permitted limit, namely 300 m, so the distance taken is 300 m. Next, the final results of the distance between anodes in pipe joint length, number of anodes required, and total mass required are shown in Table 4.

Table 4. Final results of cathodic protection analysis

Parameter	Symbol	Mark	Unit
Design results of distance between anodes in pipe joint length	And	24	Pipe joint length
		292.8	m
Total design resultsthat's it required	In	970	Unit
Total anode mass required	Mrec	30475.201	kg

The final results of the cathodic protection analysis calculations are shown in Table 4, namely that the number of anodes required for the cathodic protection system along the submarine pipeline route is 1038 anodes with a total anode weight of 32.6 tons.

Next, we can optimize the cathodic protection design by comparing the types of paint used for cathodic protection by referring to research by Wiryawan and Iswanto (2020)[13] to create a calculation application on an offshore platform using Microsoft Excel and Matlab with the total number of variables required, namely 19 parameter variables with the calculation scheme shown in figure 1.

To optimize this anode protection design, one of the offshore platforms is looking for the optimum economic value with a cathodic protection design, namely the type of paint that will be used based on DNV, namely Type-1: one layer of epoxy paint, total min. DFT 20 μ m, Type-2: one or more coats of marine paint (epoxy, polyurethane or vinyl-based), total min. DFT 250 μ m, Type-3: two or more coats of marine paint (epoxy, polyurethane or vinyl-based), total min. DFT 350 μ m. Surface area. The use of paint is divided into three types: Full-coat, where the entire surface of the structure is painted; splash zone, namely, only the area in the splash zone is painted; and uncoated, namely, not using paint. Service life is divided into 3 types: five years, ten years and 15 years.

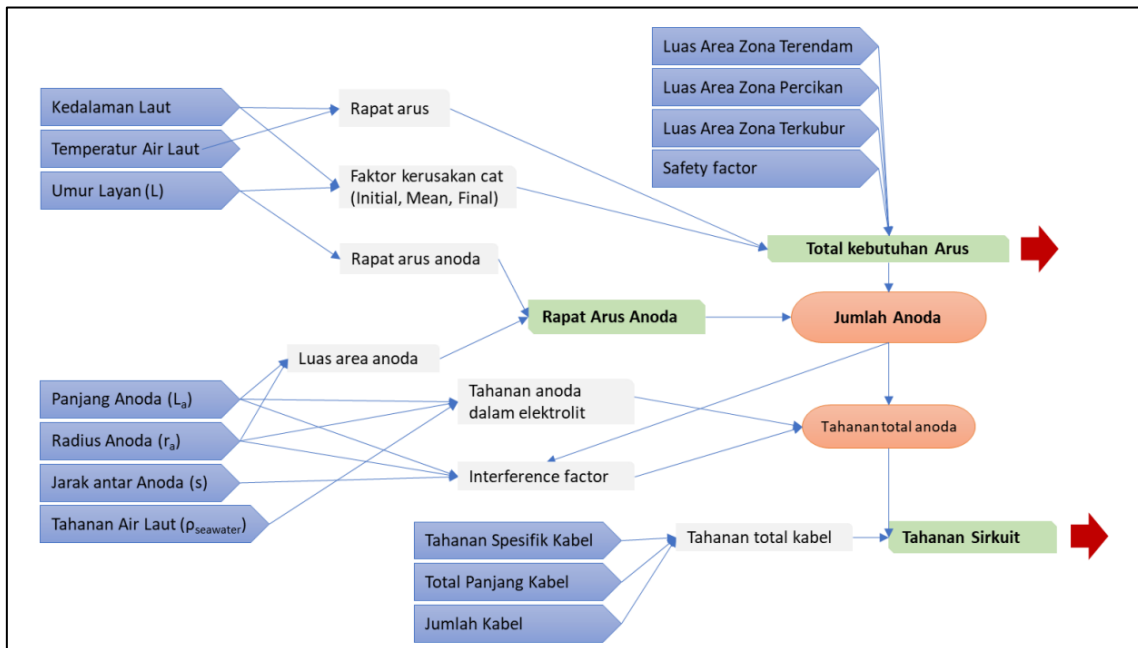


Figure 1. Calculation Scheme for Forced Current Cathodic Protection System Design Application for Offshore Platform Structures (1 of 2)

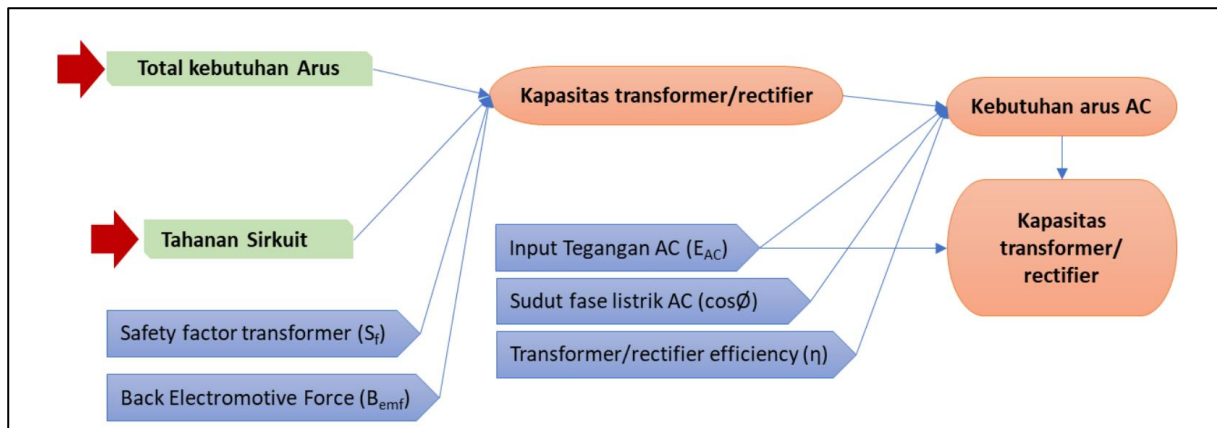


Figure 2. Calculation Scheme for Forced Current Cathodic Protection System Design Application for Offshore Platform Structures (2 of 2)

Based on the results of calculating current requirements and the number of anodes it is shown in Figures 2 and 3. If we look at the current requirements in the initial, mean and final periods from Figure 2, it can be seen that the current requirements change in each period. Initial, mean, and final values are created to assume changes in current requirements that change over time due to the accumulation of calcium deposits, marine biota, and polarization processes. In structures without protective paint, current requirements in the early period are more significant than in the middle period because of scale deposits that will form during the protection period. Meanwhile, in the final period, the current requirement is higher because it is predicted that scale deposits and marine growth have been damaged and need to be re-polarized to restore the layer. In Figure 5 and Figure 6, it can be seen that the value of the current requirement and the number of anodes increases with increasing service life. This is caused by the paint damage factor, which is influenced by a function of time, illustrating that the paint will be damaged as the structure ages.

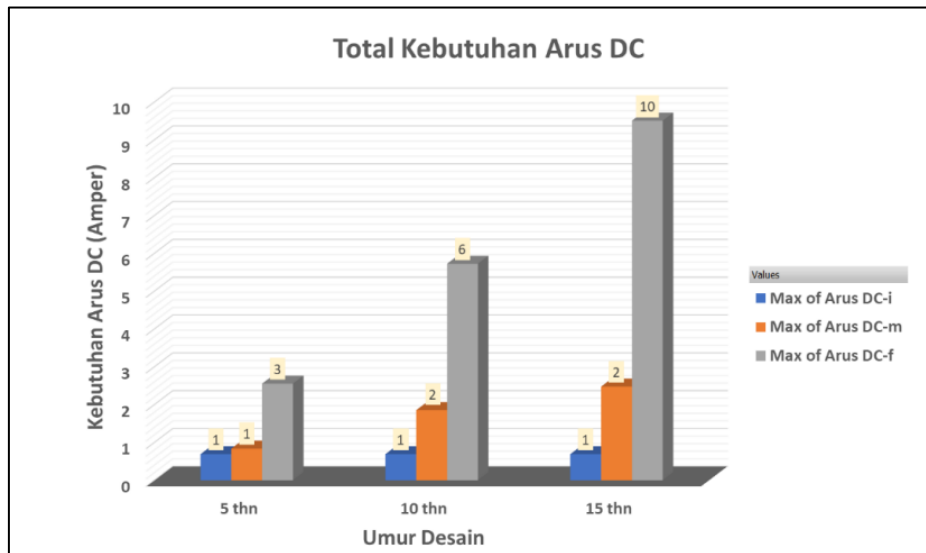


Figure 3. Graph of Calculation Results of DC Current Requirements with Several Design Age Variations

Some requirements must be met to ensure that cathodic protection is applied more economically and reliably[7] and is

- Electrical continuity. The resistance of the conductor and structure must minimize the potential drop (IR drop) of the protective current returning to the structure.
- Coating. A protective/insulating layer on the structure will significantly reduce the need for CP current from the protected metal surface. Using appropriate and suitable layers increases the effectiveness of CP's current distribution. The combination of coating and CP will generally produce the most practical and economical protection system. The ideal coating has high electrical resistance, continuity, and a solid bond to the metal surface. Other desirable characteristics are stability in the environment, abrasion resistance and suitability to the alkaline environment created or enhanced by CP.
- Isolation of structures. Often, the CP's current spread needs to be limited. This can be achieved for pipes by inserting monolithic electrical insulating connections in the structure or insulating flange devices. To isolate the earthing system (grounding), polarization cells, which can withstand low voltage DC CP but pass high voltage AC, are sometimes used.
- Test facility. It is essential to consider the location of test facilities, test stations, corrosion monitoring coupons, permanent reference electrodes and how data can be collected or viewed routinely.
- Carry out supervision and maintenance. The CP system can be monitored effectively by measuring the potential between the structure and the electrolyte using a high input impedance voltmeter and appropriate standard electrodes. Practical standard electrodes are CSE, Ag-AgCl or Ag-KCl and Zn. The survey results will determine how far the CP current output must be adjusted to ensure the protection potential is maintained at a harmful level consistent with project specifications. The level of protection for steel in soil or water is potentially more negative than -850 mV (CSE) or -800 mV (Ag-AgCl seawater). Maintenance includes mechanical maintenance of power source equipment and surface maintenance (paint). It is good practice to notify all owners of CP systems and infrastructure in affected areas of any new CP systems or significant changes to existing systems so that the impact of these facilities can be assessed.

4. Conclusion

Subsea pipes, as a medium for oil and gas production operations, require anti-corrosion protection to protect from direct interaction of the pipe with seawater. When designing cathodic

protection placement plans, you need to pay attention to the DNVGL-RP-F103 standard and support performance by optimizing the design, namely planning cathodic protection using paint recommended according to the DNVGL-RP-B401 standard. In cathodic protection analysis, variations in anode dimensions require different sizes to find effective and efficient results.

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