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Corrosion protection by sacrificial anode method on underground solar pipe installation: a case study in the Lombok Gas Engine Combine Cycle Power plant (Peaker) 130-150 MW

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Abstract

This study aims to determine cathodic and design corrosion protection by sacrifice anode method in underground solar pipe installations. The material used is a steel pipe. The length of pipes in the ground 35,384 m and a diameter of 150 mm. The type of anode used is high magnesium. The result shows that the large area that must be protected 16.67 m^2. The pipe protection current requirement is 0.81 A. The total number of anodes is 208.69 kg. Anode installation distance 2.36 m. Requirement of protection current based on the distance between the anode is 12.06 A. To protect the pipe along 35,384 m, the ideal amount of magnesium anode used is 208.69 kg. The results of the verification of the cathodic protection system design of the anode victim of the lower solar pipe show that the total number of anodes to supply a current of 0.81 A to protect the pipe is 15 pcs.

***Keywords**: Underground pipe, Cathodic protection, Sacraficial anode, Solar Pipe.*

1. INTRODUCTION

A problem that is often experienced by piping systems is corrosion. Corrosion is the damage/degradation of metal material caused by electrochemical reactions between metals and the surrounding environment [1]. Corrosion can cause metal thinning, the occurrence of holes and cracks, changes in mechanical properties; sudden structural failure), changes in physical properties; decreased heat transfer efficiency, bad appearance [2,3]. The corrosion process can be found in all pipe installations, both in the ground and offshore. Pipes that are planted in the soil experience corrosion on the surface due to the reaction of various minerals with metal pipes contained in the soil, and the fluid being flowed is corrosive [4].

Various methods of corrosion prevention have been developed to overcome the losses caused, such as the addition of corrosion inhibitors. As for pipes that are embedded in the ground, the method of protection with Sacrificial Anode Cathodic Protection (SACP) is more appropriate to be applied to prevent or reduce the rate of corrosion. Sacrificial Anode is protection by galvanic coupling where the metal to be protected is coupled with a more anodic metal. This anode is called a sacrificial anode which will be corroded first. In this case, the metal that is tempered must have a lower potential than the main metal so that what is corroded is an additional metal and the main metal will be hampered by the corrosion process.

Ameh et al. [5] states that corrosion attacks on pipes can be controlled with proper piping system design, material selection, pipe coating as the main protector and installation of secondary protection systems such as cathodic protection. In addition to a controlled strategy, effective pipeline integrity plans that include flow monitoring parameters, dissolved gas in bulk water, performance evaluation of cathodic protection systems and in-line inspections that provide information on corrosion profiles and remaining wall thickness are needed to protect and extend wear from the pipe. Pipeline integrity management includes documentation of pipeline data, corrosion prevention strategies used and owner of pipeline inspection guide data to determine inspection frequency, remaining life and prediction of failure without risk in service. Furthermore, Ameh & Ikpeseni, [6] revealed that the calculation of the cathodic protection methodology design that adopts a step-by-step approach will provide valuable insights and guidance for engineer corrosion in designing cathodic protection systems for pipelines.

Therefore, this study aims to design cathodic protection of metal material (pipes) using the Sacrificial Anode Cathodic Protection (SACP) method in Underground Solar Pipe Installation: Case Study at Lombok Gas Engine Project Combine Cycle Powerplant 130-150 MW.

2. Methods

In this study, a 6-inch diameter solar pipe and GA MG 32 HP high-magnesium anode embedded on the ground is located on the island of Lombok. The solar pipe and anode data are shown in table 1 and table 2.

Table 1. The solar pipe specifications

Parameters	Specifications
Material	*Steel pipe*, EN 10216-2, 168.3*4.5 P235GH TC1
The length of pipe	35384 mm
Diameter	6 inci
Average soil resistivity	30 Ω-m
Current density	0,100 A/m^2
Coating breakdown	0,46
Protection system	*Sacrificial Anode Cathodic Protection* (SACP)
Design age	30 years

Table 2. Specifications of anode victims

Parameters	Specifications
Anode Type	*high Magnesium* GA MG 32 HP
The mass of each anode	14,515 kg
Potential to electrolyte	-1,75 V
Desired potential	-0,95 V
Polarized potential	-0,2 V
Driving voltage	0,6 V
Utility factor	0,85
Safety factor	0,05
Capacity	1200 Ah/kg
Efficiency	0,5

The parameters measured in underground solar pipes are like equations (1), (2), (3), (4), (5), (6).
The surface area that must be protected can be calculated using equation 1 [4].

$$A = \pi.d.L \quad (1)$$

The current needed to protect the structure is measured using equation 2 [4].

$$I = Cd.A.Cb \quad (2)$$

The anode used is a high magnesium anode, 32 lb. Anode weight is calculated using equation 3 [4].

$$M = \frac{I_{total} \times t \times 8760}{u \times c} \tag{3}$$

The total number of anodes can be calculated by equation 4 [4].

$$N = \frac{M_{total}}{M_{anoda}} \tag{4}$$

Anode installation distance can be determined by equation 5 [4].

$$S_a = \frac{L}{N} \tag{5}$$

Protection current requirements based on the distance between the anodes can be determined by equation 6 [4].

$$Is = \pi . L . S_a . I_c . C_b \tag{6}$$

A description of the parameters measured is shown in table 3.

Table 3. A description of the parameters used in this study.

Codes	Specifications
A	Area to be protected (m^2)
L	pipe length (m)
I_{total}	Pipeline protection current requirements (A)
C_d	current density
C_b	coating breakdown
M	Anode weight requirement (kg)
T	anode design life (years)
U	anode utilization factor
C	Anode's electrical capacity (Ah/kg)
N	Total number of anodes (Pcs)

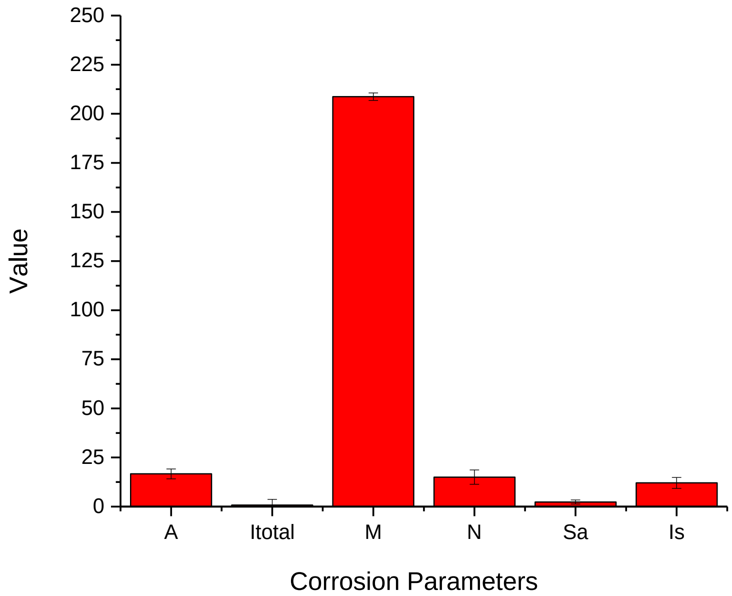
3. Result and Discussion

Based on the calculation of several SACP parameters using equations 1, 2, 3, 4, 5 and 6 are presented in Table 4. In this figure 1. To protect the pipe along 35,384 m, the number of magnesium anodes used is 208.69 kg. The verification results of design calculations sacrificial anode cathodic protection system solar underground pipes indicates that the total amount of the anode needs (I_{total}) to be able to supply a current of 0.81 A in order to protect the pipe is 15 pieces.

Table 4. The result of the calculation of the parameters of corrosion.

No.	Parameters	Symbol	Unit	Values
1.	Area that must be protected	*A*	m^2	16.67
2.	Pipeline protection current requirements	I_{total}	*Ampere*	0.81
3.	Anode weight requirements	*M*	*Kg*	208.69
4.	Total number of anodes	*N*	*pieces*	15
5.	Anode installation distance	S_a	*Meters*	2.36
6.	Protection current requirements are based on the distance between the anodes	*Is*	*Ampere*	12.06

From the whole series of achievements in the case studies that have been carried out it is shown that based on the use of the Sacrificial Anode Cathodic Protection method for the Lombok GECC Powerplant 130-150 MW-Mataram underground solar pipeline along 35,384 m, it was designed with 1 part. The total anode needed is 15 pcs and the type of anode used is high Magnesium GA MG 32 HP anode, with a mass of each anode of 14,515 kg. While the surface area that must be protected is 16.67 m2. The current requirement to be added with a safety factor of 5% of the required current, so that the total current requirement is used to protect the pipe along 35,384 m is 0.81 A. Based on the pipe length of 35,384 m, the ideal amount of magnesium anode used is 208, 69 kg. Based on the time for 30 years, the anode needed is 14.38 high Magnesium anode or 15 Pcs. The mounting distance between the anodes was 2.26 m. The current requirement for each distance between the anodes is 12.06 A.



Graphic 1. Corrosions parameters used in this study.

The corrosion in metals is an electrochemical reaction where most corrosion events occur due to electrochemical reactions because metals have free electrons that are capable of generating electrochemical cells on a small scale within the metal itself. Some metals will be corroded in water and open atmosphere so that all environments can be said to be corrosive on a certain scale [7]. An electrochemical reaction is a reaction that involves displacement which includes an oxidation reaction and a reduction reaction. The oxidation reaction and the reduction reaction are as follows:

$$Z_n \rightarrow {Zn_2}^+ + 2e^- \ (Oxidation\ reaction)$$

$$2H^+ + 2e^- \rightarrow H_2\ (reduction\ reaction)$$

The process of corrosion in iron is influenced by the environment, especially temperature; an increase in temperature causes an increase in the speed of corrosion. This is because the higher the temperature the kinetic energy of the reacting particles will increase and exceed the magnitude of the activation price and consequently the rate of reaction (corrosion) will also be faster, and vice versa [8]. Fluid Flow Velocity where the rate of corrosion will increase if the rate or velocity of fluid flow increases. This is because the contact between reagents and metals is greater so that more metal ions are released and the metal will experience corrosion [9]. Furthermore, acidic solutions are very corrosive to metals; in other words, metals in acidic media will corrode more quickly because it is an anode reaction. While alkaline solutions can cause corrosion in the cathode reaction because the cathode reaction is always simultaneous with the anode reaction. Oxygen in the air can come in contact with a moist metal surface. So the possibility of corrosion is greater. In an open environment, the presence of oxygen also causes corrosion [10].

The DC current generated from the sacrificial anode system is also the result of the application of a protected galvanic pipe pair and magnesium as the anode itself. Anode material usually has a more negative potential value. The procedure and installation of the Sacrificial Anode Cathodic Protection (SACP) method especially the sacrificial anode are shown in Figure 2.

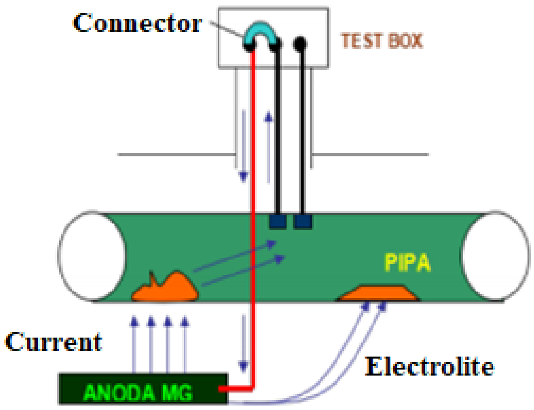


Figure 1. The procedure sacrificial anode system [3]

Based on the results of calculations that have been done, cathodic protection with the Sacraficial Anode Cathodic Protection (SACP) method does not require additional currents from the outside, because the protection current originates from the anode itself, installation in the field is relatively simpler, easy maintenance, cheaper than the counter current system, it might have a small interference effect, the design is very simple, and does not require external power.

Furthermore, there are shortcomings of cathodic protection with the SACP method, namely the driving voltage of this system is relatively low because the protection current only occurs from the galvanic reaction of the material itself so that this system can only be used to protect structures with relatively small protection currents and low environmental resistivity; so it becomes less economical if used to protect relatively large structures; the ability to control variable effects of instantaneous currents on the structure to be protected is relatively small. The performance of SACP cannot be controlled, and the maintenance process of the protection system will be very complicated.

For a period of 30 years, the required anode is 14.38 high Magnesium anode or 15 Pieces with an anode mounting distance of 2.26 m and the current requirement for each anode distance of 12.06 A.

4. Conclusion

Cathodic protection design of pipes using the Sacrificial Anode Cathodic Protection (SACP) method in the Underground Solar Pipe Installation has been carried out in the Lombok GECC Powerplant underground solar pipe project. The results of calculations and analysis show that the total anode needed is 15 pcs with a high Magnesium GA MG 32 HP anode type. The surface area and total current needed are 16.67 m2 and 0.81 A respectively; to protect the pipe along 35.384 m with the weight of the magnesium anode used at 208.69 kg.

REFERENCES

1. Zhou, Q., Wu, W., Liu, D., Li, K., Qiao, Q. Estimation of corrosion failure likelihood of oil and gas pipeline based on fuzzy logic approach. Engineering Failure Analysis. 2016; 70: 48–55. http://dx.doi.org/10.1016/j.engfailanal.2016.07.014.
2. Liu, Z., Gao, X., Li, J., Du, L., Yu, C., Li, P., Bai X. Corrosion behaviour of low-alloy martensite steel exposed to vapour-saturated CO2 and CO2-saturated brine conditions. Electrochimica Acta. 2016; 213: 842–855. http://dx.doi.org/10.1016/j.electacta.2016.08.024.
3. Sari, N. H. Material Teknik. Yogyakarta: Deepublish. 2018: 93-102
4. Wahyuningsih, U., Rusjdi, H., Sulistiyo, E. Penanggulangan Korosi Pada Pipa Gas Dengan Metode Catodic Protection (Anoda Korban) PT PGN Solution Area Tangerang. Jurnal Power Plant. 2017; Vol. 5, No. 1 November Tahun 2017. ISSN : 2356-1513. https://doi.org/10.33322/powerplant.v5i1.109
5. Ameh, E. S., Ikpeseni, S. C., Lawal, L.S. A Review of Field Corrosion Control and Monitoring Techniques of the Upstream Oil and Gas Pipelines. Nigerian Journal Of Technological Development, 2018; Vol. 14, No. 2, 2017. doi: http://dx.doi.org/10.4314/njtd.v14i2.5.
6. Ameh, E. S., Ikpeseni, S. C. Pipelines Cathodic Protection Design Methodologies For Impressed Current And Sacrificial Anode Systems. Nigerian Journal of Technology (NIJOTECH). 2017; Vol. 36: 1072 – 1077. Print ISSN: 0331-8443, Electronic ISSN: 2467-8821. http://dx.doi.org/10.4314/njt.v36i4.12.
7. Syafrizal. 2016. Analisa Korosi Pipa Solar Mesin Diesel di Sebuah PT. X. Tugas Akhir. Prodi Teknik Mesin, Politeknik Enjinering Indorama, Jawa Barat.
8. Ziovany, R. Kinerja Anti Korosi dan model isotherm adsorpsi Mangan disikloheksilditifosfat dengtan teknik polarisasi potensiodinamik. S1 Skripsi. Bogor: Departemen Kimia fakultas matematika dan ilmu pengetahuan alam Institut Pertanian bogor; 2016.
9. Zakaria, K., Hamdy, A., Abbas, M. A.,Abo-Elenien, O. M. New organic compounds based on siloxane moiety as corrosion inhibitors for carbon steel in HCl solution: Weight loss, electrochemical and surface strudies. Journal of the Taiwan instituteof chemical engineers. 2016; 1-4. https://doi.org/10.1016/J.JTICE.2016.05.036
10. Yang, Y., Scenini, F., Curioni, M. A study on magnesium corrosion by real-time imaging and electrochemical methods: relationship between local processes and hydrogen evolution. Electrochimica Acta. 2016; 198: 174–184. http://dx.doi.org/10.1016/j.electacta.2016.03.043.