IIETA International Information and Engineering Technology Association
Advancing the World of Information and Engineering

Mathematical Modelling of Engineering Problems
Vol. 11, No. 5, May, 2024, pp. 1171-1178
Journal homepage: http://iieta.org/journals/mmep

Simulation Analysis of Protection Oil Pipe in Platform to Reduced Corrosion and Erosion Defect with Sustainability Technique

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https://doi.org/10.18280/mmep.110505

Received: 5 January 2024
Revised: 12 March 2024
Accepted: 25 March 2024
Available online: 30 May 2024

Keywords:
oil pipe, sustainability, corrosion, management of cathodic protection, capabilities and protection system design

ABSTRACT

In Iraq, an extensive network of pipelines is of vital importance for the transportation of hydrocarbon products, drinking water, and crude oil through the pipelines. The underground infrastructures experience corrosion processes, which therefore requires keeping up with the application of protective measures. This is a simulation survey that takes into account the cathodic protection optimization to reduce such hazards. Employing the Wenner four-terminal method enabled assessment of elements that affect cathodic protection such as environmental factors and soil resistivity across selected sites for the surveys. Soil pH ranges within the range of 7-8, together with anode voltage and current readings were the basis of the simulation models. These models played a crucial role in predicting the best anode locations, operating voltages and currents for various conditions and by comparing the results with empirical data from field experiments it is easy to evaluate the results. The analysis of rectifier voltage, the number of anodes, the anode resistance, and the pipeline current led to the production of the most cost-efficient designs for pipeline protection. Thus, as a result, a segment at station number 2 requires 2.5A current for its protection over the same length and a segment at station number 4 needs 12A current for its protection. Through the integration of simulation outcomes with the field observation the study highlights the accuracy and efficiency of the modeled cathodic protection systems that substantiate their fundamental role in the sustainable management of the pipeline. The results reached in this study add a great deal to this body of knowledge on the subject of subterranean structure preservation, showing this paradigm for the design and optimization of cathodic protection systems against corrosion and erosion which ensures the durability and reliability of pipeline networks.

1. INTRODUCTION

By reducing the difference between the cathode and the anode, cathodic protection can prevent corrosion [1]. It differs from all other corrosion control techniques in that it can totally stop corrosion if necessary, yet the operator can also choose to accept a lower yet quantifiable protection level [2]. This study examines the optimization and design of cathodic protection systems used for protecting underground pipelines. It provides a general approach for estimating the cathodic protection system's performance as well as identifying the ideal cathodic protection system design. In such a system, a transformer-rectifier is used to turn power taken from the national grid into direct current.

According to fundamental electrochemical theory, when the structure is polarized to the reversible electrode potential of anodic reactions, absolute protection (zero corrosion rates) is attained. Aerated soils provide complete protection for mild steel at potentials of -850mV vs. $Cu/CuSO_4$ (-800mV vs. Ag/AgCl/gulfwater, +250mV vs. Zn/gulfwater, and -780mV vs. SCE), according to field experience. It is significant to remember that the protection potential values given relate to a potential difference between the structure and reference electrode, excluding any unrelated impacts like field interference or IR drop. Seasonal variations in soil moisture content might lead to seasonal variations in potentials. Certain pipeline firms conduct annual surveys at the same time every year in order to accurately assess patterns in a pipeline's activity [3].

1.1 Sustainability in construction

According to the study of Our Common Future, sustainable development is defined as addressing the environment as well as current requirements without sacrificing the capability of future generations to address their own needs. According to the UK Charity Forum of Future, sustainable development is defined as "a process enabling all individuals to realize their potential and enhance their life quality while enhancing and protecting the life support system of the earth" [4]. Thant et al. [5] proposed that sustainable development ensured a higher quality of life for everyone, both at present and in the future.

The authors also proposed pursuing the following goals to achieve this:

(i) effective environmental protection;
(ii) social development;
(iii) high-rate economic growth;
(iv) practical use of natural resources.

The three pillars or principles of sustainable development, namely, social, environmental, and economic accountability, are acknowledged in all literature in this field [6]. Sustainable building is a subcategory of sustainable development, encompassing issues like site planning, material selection, recycling, waste minimization, and tendering, according to the Building Efficiency Energy Research Project [7]. The definition of "the responsible management and creation of a healthily built environment depending upon resource-efficient as well as ecological concepts" can be applied to sustainable construction. Nashee [8] emphasized the negative effects on the environment, including using non-renewable resources, water and air pollution, noise pollution from construction sites, excessive energy and water use, and waste production. Before constructing a sustainable facility, it is crucial to consider all the materials during the material specification pre-design stage. Thus, it is the most crucial step towards sustainable development to take into account all of the dimensions of sustainability (environmental, social, and economic effects) during the pre-design stage.

1.2 Sustainable design

Implementation in pre-design as well as design stages could be characterized as an essential component of the overall design integration regarding all engineering disciplines, in addition to taking sustainability factors into account when choosing materials and equipment. The following hierarchy (Figure 1) can be obtained from the literature mentioned above. The following sections emphasize the importance of offshore and eco-friendly materials, as well as green design.

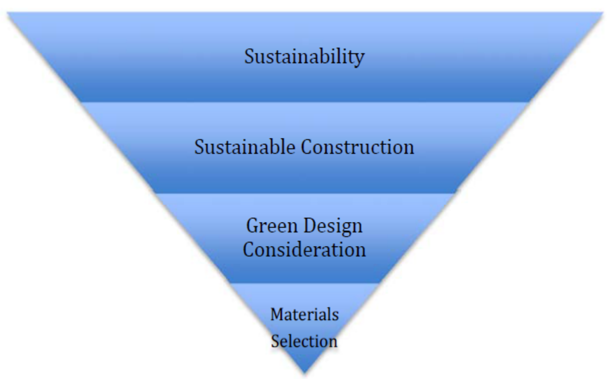

Figure 1. Hierarchy towards sustainable design

Because of the effects of topside facilities on human health and the environment, water and air pollution represent a serious concern. For the purpose of eliminating the negative effects rather than just mitigating them, research into the social and environmental effects of offshore topside facilities needs to be increased by both agency regulators and offshore operators. This might lead to more investigation into the development of air monitoring systems and water treatment. Onshore facilities for gas and oil create the same effects as topside facilities on platforms. Thus, a framework such as this might be created for onshore gas and oil facilities, and it might be enhanced to incorporate downstream industries like petrochemical projects and refinery projects. Research into alternative uses for the related gas must be done, as gas flaring from onshore as well as offshore facilities is a waste of energy resources. Lastly, future studies on environmental management systems and sustainable design for the gas and oil industry's downstream and upstream sectors may build on the suggested framework.

The study presents an approach called Preliminary Sustainability Analysis of the Enterprise (PSAE) for conducting sustainability assessments on oil production facilities. The strategy is based on participatory action research methodology, where sequential case studies are implemented against real-life projects in some of the key oil companies in Iraq through this method. The PSAE approach proposes sustainability actions and makes an inventory of their influence on the three pillars of sustainability. It requires the materiality test and monetary aggregation to determine the importance of sustainability actions for sustainability indicators.

The PSAE method aims at enhancing both the efficiency of sustainability assessments and their objectiveness; it also links these assessments to the sustainable reporting of the company. It is a fundamental tool for the engineering managers who have to make referential decisions on the corporate sustainability policy of the organization.

The investigation details a model of an early PSAE, making it possible to perform such assessments at oil production companies. The PSAE model uses participatory action research methodology for sooner or later projects implemented by a large oil firm in Iraq. It draws out and appraises the sustainability of actions by considering the three pillars of sustainability. The PSAE method increases the evaluation of indicators by bringing materiality testing and monetary aggregation into play while also controlling subjectivity. The PSAE technique links projects with the company's sustainability report and offers important information to help the decision-making process of engineering managers regarding the company's sustainability policy.

1.3 Statement of the problem

Numerous studies have shown that fixed-platform facilities have a major detrimental social and environmental effect. In the future, oil and gas producers will have no choice but to increase the scope of their exploratory efforts. However, improper management of such activities could have serious negative social and environmental effects. There is a critical role that governments of oil-producing regions have in safeguarding the environment and making sure that the current and future populations of those regions can reap the long-term advantages of gas and oil development. Those results confirm what they believe to be the optimal economic stance in the gas and oil industries, which is to reach production as soon as possible. Thus, sustainability is not taken into consideration throughout the design process. In the future, all of these variables will undoubtedly lead to budget overruns and detrimental social and environmental effects. Additionally, they stated that the operation and installation of projects require billions of dollars in profit and investment; nevertheless, significant losses may result from careless investment selections. Optimizing the choices made regarding operations and investments is necessary. Hence, the development of gas and oil encounters numerous social, environmental, and economic challenges. Because of these factors, the platform's design is extremely complex, and there are risks to people's safety, the environment, and the economy (in terms of maintenance and operating costs).

Furthermore, most oil corporations overlook future costs, sustainability, and environmental considerations during the early design process because of the explosive increase in offshore gas and oil exploration. With regard to semi-structured interviews, it was discovered that about 70.7% of participants had heard of the life cycle costing idea but were unsure about how to carry out the analysis. This is where the significance of the conceptual phase in the project's early stages for determining the evaluation criteria begins to emerge. Following the completion of the exploratory phase, the construction and engineering phase begins with the conceptual phase, which typically entails concept analysis, pre-engineering, and alternative selection. Because of the absence of information, there are a number of uncertainties in this phase. One of the main uncertainties is the operating expenses caused by equipment and materials. Existing practices, particularly in the nations of the Arabian Gulf, prioritize engineering and technical feasibility over the sustainability or life cycle costs of alternatives. Because engineering criteria are the only ones used to make decisions, life cycle costs and other sustainability-related factors still lack a solid foundation in the present methodology. A few of the main reasons for the high operational costs for topside facilities on platforms are those restrictions and the poor choices made throughout this stage. In order for the decision-maker to choose the best substitute to go to the subsequent phase at this point, a modified method for capturing such gaps in the conceptual phase is necessary. Thus, choosing the right materials with a focus on sustainability can reduce life cycle costs and provide major benefits for social, environmental and safety issues.

2. SYSTEM DESCRIPTION

2.1 Pipelines

The research examined two pipelines with a coating of coal tar in carbon steel (manganese 0.5027 wt%, carbon 0.1649 wt%, sulfur 0.0068 wt%, phosphor 0.002 wt%, iron rest). One of the pipes is 28 km in diameter and the other is 52 km in diameter. Every pipe has a depth of 1.20 meters.

2.2 Ground bed

Shallow ground beds are placed between 100 and 150 meters apart and horizontal to the pipeline to ensure that the current is diffused appropriately to the line given the environmental conditions. High-silicon cast iron was chosen as the anode type. In order to facilitate the transmission of low current density over long distances with a moderate voltage of soil to the pipe at the line, ground beds were constructed in areas distant from the cathode. Data derived from practices indicates that the optimal distance for the anode's distance to the pipe is 100 to 250m. The resistance regarding the first pipe varies between 1.6 and 0.464 ohm, whereas the second pipe varies between 0.929 and 0.48 ohm. The depth of the ground bed ranges from 2.5m to 3m. With regard to the 52 km pipeline, 50 anodes were utilized; and for the 28 km pipeline, 25 anodes. Anode beds were installed well below the surface in certain installations to solve interference issues. As a result, there is less interference between structures that are shifted horizontally and the current flow becomes more vertical. When the resistivity of the soil is high close to the surface, deep anodes are utilized. The following properties are considered ideal for an impressed current anode material [4]:

• Low rate of consumption, independent of reaction products and environment.
• High reliability.
• Low resistance at the anode-electrolyte interface, excellent electrical conductivity, and low polarization levels regardless of the various anode processes. Designing for the lowest feasible grounding resistance helps reduce electric power consumption and, consequently, operating expenses [5].
• Highly resistant to erosion and abrasion.
• High mechanical integrity for reducing mechanical damage when doing maintenance, service use and installation.
• Simplicity of fabrication in various forms.
• Low cost in comparison with the entire scheme of corrosion protection.

2.3 Soil

The lack of homogeneity in such desert soils is one of their defining characteristics. A high-resistivity ground matrix is interspersed with a multitude of low-resistivity salty patches. Insufficient yearly rainfall in desert soils prevents soluble salts from penetrating deep into the ground. In desert regions, there are often a lot of salty patches where the soil is clayey and has some ability to retain water. Conversely, the surface comprises loose sand particles with limited water retention capacity. Because of the search for water-bearing formations, such desert soils prevent winter rainfalls from penetrating deeply into the ground [6]. When designing cathodic protection, it is important to consider the following main environmental or soil elements:

- Soil resistivity, or resistivity, majorly denotes electrical resistance that is related to a material’s standardized cube [4].
- PH of soil.

3. SIMULATION

For the purpose of designing a cathodic protection system, several tasks need to be completed, such as setting up test programs, analyzing data from various sources, building corrosion problem profiles, recommending maintenance or operating schemes, creating test programs for changing operating conditions or choosing new materials, and creating corrosion problem remedial plans. The number of anodes in a pipeline is a critical design component that plays a significant role in cathodic protection. As such, the factor has been tuned to monitor the impact on the electric power that is required to keep metal surfaces protected. Soil cathodic protection systems were the main target of computer program optimization and design. The simulation conducted with COMSOL Multiphysics software version 6.5, 2022, is displayed in Figure 1. Metal pipes were in use for a very long time. Since cast iron pipe initially supplanted wooden pipe in the 1800s, it was utilized through the pipeline as well as gas utility industries [8]. Over time, improvements in metallurgy have led to a consistent increase in the variety and quality of metal available for pipe networks [9]. Nowadays, there is a lot of metallic pipes in the ground, of various kinds. Hundreds of thousands of miles of metallic pipe are still in use in America's gas and hazardous liquid distribution and transmission networks, despite the fact that a large portion of cast iron as well as other metallic distribution pipe has been replaced with plastic pipe. A large portion of it is old, and corrosion affects everything. The majority of individuals are aware that steel and iron corrode or rust if they come into contact with moisture and oxygen. The majority of individuals are unaware that there are ways to slow down or even stop this fundamental electrochemical process. However, pipelines as well as gas utilities are aware of this. For this reason, they currently commit a large amount of financial and human resources to cathodic protection.

The scope below is suggested as a general guideline for planning every dive and selecting the members and anodes to be surveyed. The quality of the observed data could cause variations in percentages, and survey locations might differ according to safe access. Before performing any underwater cleaning operations that can depolarize the structure, all cathodic protection survey dives should be completed [10]. The data is tabulated for ease of access (Table 1). The primary prerequisite is that the reference electrode be held with the open end in contact with the anode or the member that is being surveyed. The inspection diver must wear a helmet or have a cathodic protection probe mounted on a video camera so that the data recorder can detect the start and stop of a scan. Maintaining a mostly constant scan speed is crucial. The platform level refers to the subsea steel work located between the primary horizontal framing elevations [11].

Table 1. Recommended Survey extent and Location

Structural Elements	Inspection Extent	Orientation of the Scan	Notes
Risers	100% from (-)10'0" to mud line.	Orientation unimportant	Make sure the insulating device, if installed, has a ground connection on the correct side.
Main Legs	100% from (-) 10'0" to mud line.	Outboard side	Node crotch readings are not necessary for this procedure, although they can be obtained if needed. If fitted, scan each leg anode.
Conductors (If installed)	One vertical scan across the whole platform depth in the conductor area.	Orientation Unimportant	A shielded conductor inside the bundle is what should aim for.
Horizontal, Vertical, and Vertical Diagonal Framing	25% of members that carry anodes at every level of the platform.	In the case when an anode is fitted, it should be 90° from its orientation; if not, it is not significant	Scan at 3 or 9 o'clock if the anodes were inserted at 6 o'clock.
Skirt Piles and Guides (If installed)	25% of the guides all the whole to the mudline.	Outboard side	If specified, stab exposed pile above the guide with a tip contact probe.
Anode (Scans)	25% or more of the anodes on every one of the platforms.	Scan face furthest from supporting member	Point read at both ends and in the middle of the chosen anodes in the case when the scan is difficult.
Anode (Cleaning)	For each platform level, at least two anodes. On more than 200 feet of seawater, increase to 4 or 8 pile structures.	Clean (Water Blast) one end (6in) and the center (12 in of the band) full circumference	Depending upon potential studies, choose one low and one high anode for every level when cleaning.

The study aims to enhance understanding of low-voltage mineral deposition technology as an eco-friendly way to safeguard offshore platforms from corrosion and promote biodiversity. Prototype structures were placed in the Shatt al Arab to imitate submerged offshore platforms and evaluate mineral composition, growth rates, and corrosion resistance on steel substrates. Deposits protected steel from corrosion, reaching a maximum thickness of 2.4 mm after 6 months of deposition. Deposit rates varied from 20.0 to 50.3 μm/d, with a positive correlation with seawater temperature.

The work gives fresh insights for the implementation of low-voltage mineral deposition technology in temperate rivers. It also contributes to the sustainability of offshore platforms and biodiversity.

The study covers the difficulties encountered during the late-life production of oil and gas facilities in which sand is generated alongside the production fluid. Mitigation strategies for sand erosion in offshore pipelines and risers include flow assurance, increased bend radius, and material resistance to sand erosion. The report offers a case study of sand erosion mitigation in an existing PETRONAS pipeline replacement project that employs unbonded flexible pipes. A computational fluid dynamic finite element analysis simulation was utilized to represent erosion caused by sand particle solutions in the pipeline. Experiments were done to examine erosion at different riser bend orientations. The internal carcass thickness was determined to be sufficient to withstand the erosion hazard posed by sand particles during the pipeline's entire design life. The modeling and experimental testing results can enhance the prediction model of sand erosion in offshore pipelines, particularly for flexible pipeline and riser applications.

3.1 Equations of allowable corroded pressures for interacting defects

3.1.1 Entire length [12]

$$l_{nm} = l_m + \sum_{i=n}^{i=m-1} (l_i + s_i)$$
$$= (200 + 200 + 79.05\text{mm})$$
$$= 479.05\text{mm}$$

3.1.2 Effective depth [13]

$$d_{nm} = \frac{\sum_{i=n}^{i=m} d_i l_i}{l_{nm}} = (12.50\text{mm} \times 200\text{mm}) + (12.50\text{mm} \times 200mm) / 479.05\text{mm} = 10.4373\text{mm}$$

3.1.3 Factor of length correction [14]

$$Q_{nm} = \sqrt{1 + 0.31\left(\frac{l_{nm}}{\sqrt{Dt}}\right)^2}$$

$$\sqrt{1 + 0.31\left(\frac{479.05mm}{\sqrt{500mm \times 50mm}}\right)^2} = 1.96$$

3.1.4 Adjusted depth ratio [15]

$$(d_{nm}/t) *= (d_{nm}/t)_{meas} + \varepsilon dStD(d_{nm}/t) = \left(\frac{10.44}{50.00}\right) + 1(0.08)$$

$$p_{nm} = \gamma_m \frac{2tf_u(1 - \gamma_d(d_{nm}/t) *)}{(D - t)\left(1 - \frac{\gamma_d(d_{nm}/t) *}{Q_{nm}}\right)} = 0.2888$$

3.1.5 Allowable corroded pressure [16]

$$\frac{0.77 \times 2 \times 50.00 \times 530.9 \times (1 - 1.16(0.2888))}{(500 - 50)\left(\frac{1 - 1.16(0.2888)}{1.96}\right)} = 72.86 \text{ Mpa}$$

3.1.6 Maximum allowable corroded pressure [17]

$$p = min\ (p1, p_{nm}) = 72.86 \text{ MPa}$$

3.2 Result summary

Two graph types were plotted. The allowable corroded pressure versus normalized depth parameter was considered for the first graph type, whereas the allowable corroded pressure versus the normalized space parameter [18] was considered for the second one [19].

The study does not specify a method for safeguarding oil pipes on offshore sites from corrosion and erosion. The research focuses on component characterisation and modifications to the remaining usable life equation [20].

The study examines erosion and corrosion at offshore platform valves. However, it does not offer particular methods for safeguarding oil pipelines from corrosion and erosion. The report does not provide a particular method for preventing corrosion and erosion in oil pipelines on a platform [21]. The presented study does not specify any specific approach for preventing corrosion and erosion in oil pipelines on platforms.

4. RESULT

The proposed survey approach could be conducted offshore with little to no additional expense over a standard potential survey. It is possible to more precisely plan retrofits with the new information. The surveys emphasize the conservative nature of the early Gulf of Arabia design criteria (as well as the unpredictability of early anode quality [20]) for cathodic protection designers. More data collection and the application of novel cathodic protection design techniques highlight the value of such kinds of surveys and encourage further technological advancements.

Through cathodic protection, steel structures immersed in gulfwater can be shielded from corrosion. Sacrificial anodes or an impressed external current could be used to provide this protection. Because it's so easy to utilize, sacrificial anode technology is frequently used. The principle behind cathodic protection with sacrificial anodes is very straightforward: in the case when the electrodes are immersed in gulfwater, the sacrificial anode becomes cathodically polarized and the steel structure becomes anodically polarized because the steel structure is connected (electronically) to a less noble metal like aluminum. Anodic dissolution of metal dissolves the anodes, and oxygen reduction occurs at the steel structure's surface. The current density regarding oxygen reduction is frequently limited by the oxygen supply, resulting in a limiting current at the steel structure's surface that is nearly constant throughout a few hundred millivolts of potential. The blue curve's shape depends on the type and number of anodes in the system. The system designer must ensure that all of the steel structure's components are well within the red cathodic curve's "flat" part, which protects against corrosion, or else the structure won't be completely protected and could begin to corrode.

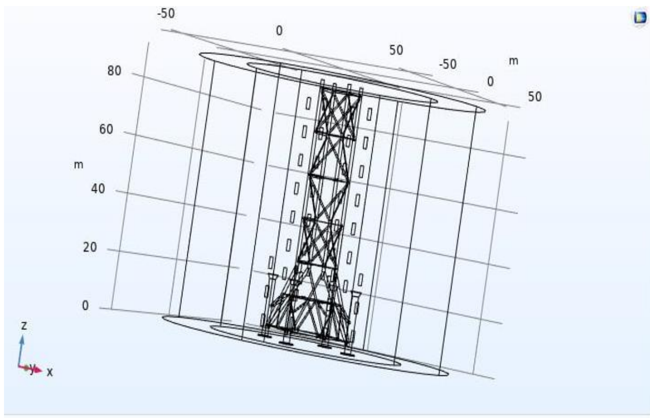

Figure 2. Model geometry

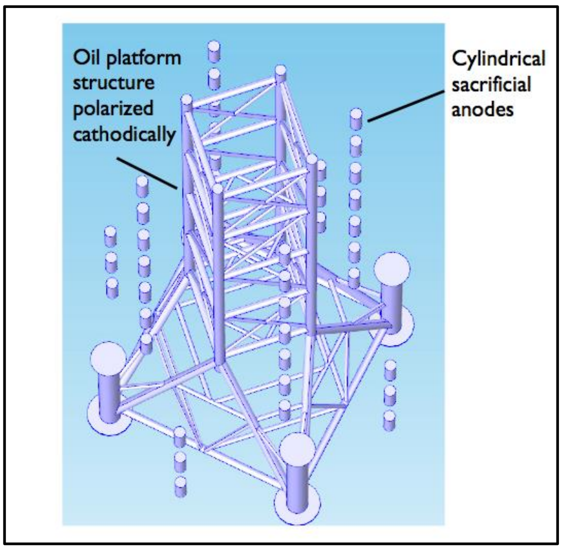

Figure 3. Close-up view of cylindrical sacrificial anodes and oil platform structure

A few hundred millivolts are the width of oxygen-decrease portion of the curve. The anodes must also be capable of supplying the necessary potential in order to maintain the current. Thus, assuming constant cathodic current (oxygen reduction), the first stage in designing a cathodic protection system is examining the steel structure's potential. The potential must be well within the necessary range to prevent hydrogen evolution, which could ultimately lead to hydrogen embrittlement, and to safeguard the structure through oxygen reduction. In the infinite element domain, equations can be rescaled to depict a cylinder that is roughly a thousand times larger. Figure 2 shows the geometry of the model. Figure 3 shows a close-up view of cylindrical sacrificial anodes and oil platform structure.

The composition of gulf water is thought to vary very little, while the contribution from current-carrying ions' migration in an electric field is far greater than the diffusion of those ions. This presumption permits the system to be subjected to a primary current density distribution analysis in which just the impact of ohmic effects in the specified geometry is considered in conjunction with boundary conditions. As for the somewhat quick kinetics, a constant potential was set at sacrificial anode surfaces. According to such presumptions, it makes sense to select a constant potential, as a highly minor change in surface overpotential results in a highly substantial current density change. To incorporate electrode reaction kinetics in a subsequent stage, the model could be readily expanded to secondary current density distribution analysis. For instance, anode film resistance effects can be referred to for cathodic corrosion protection.

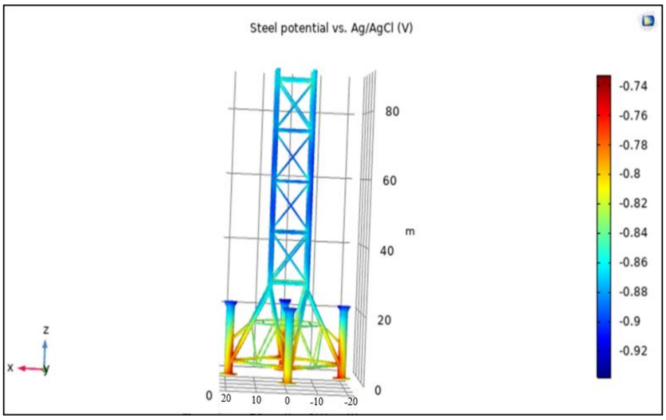

Figure 4. Steel platform potential versus an Ag/AgCl reference

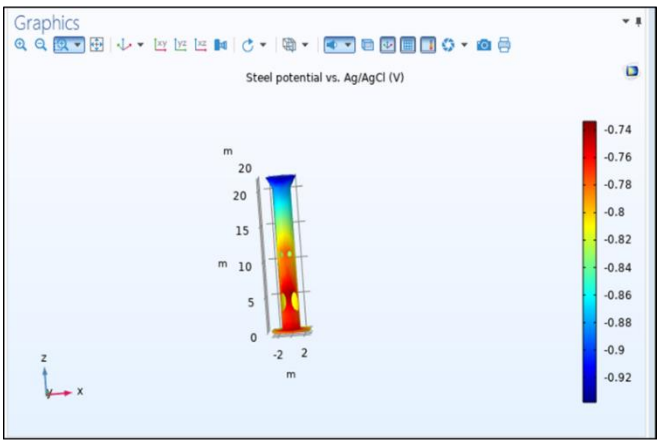

Figure 5. Potential on a platform structure leg

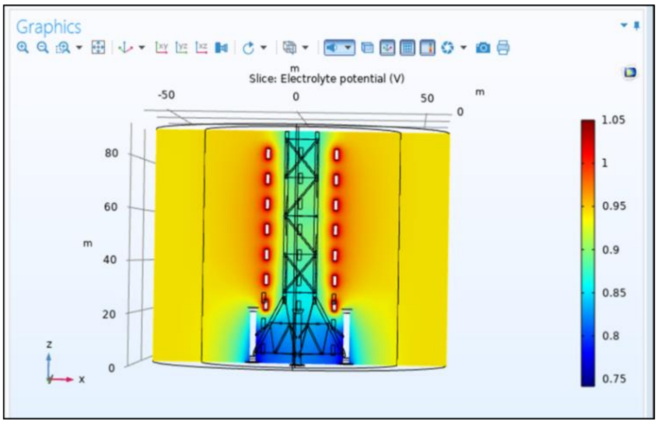

Figure 6. Slice plot of electrolyte potential

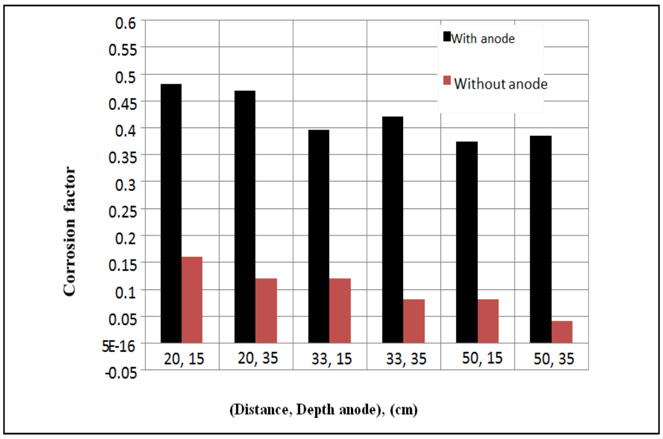

Figure 7. Power consumption of pipe in all platforms

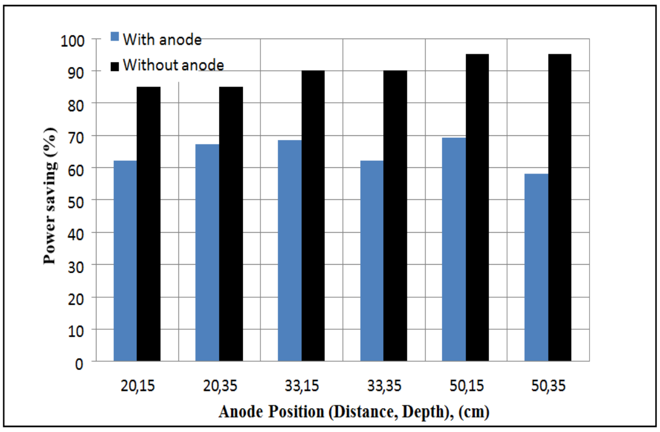

Figure 8. Power saving of bare pipe and dry (5%) soil in different anode position

The corrosion module may be used for tertiary current density distribution analysis, which takes into consideration the transport of charged species, necessitating the use of alternative physics interfaces. A slice plot of the electrolyte's potential is displayed in Figure 4. Based on the position, the potential near the steel structure surface changes by many hundreds of millivolts. Because the current in electrolyte flows from anodes to steel cathodes, the potential should decrease with increasing distance from an anode. Figure 5 shows the potential on a platform structure leg.

Figure 6 displays the current densities on anodes. These are significant since the anode metal consumption rate is directly correlated with their magnitudes. At their highest density, about four times as much current flows through the anodes as at their lowest.

Figure 7 shows the power consumption of pipes on all platforms. Figure 8 shows the power saving of bare pipes and dry (5%) soil in different anode positions. This study focuses on the importance of aligning social, economic, and environmental aspects within the Sustainable Development Goals in the oil industry. Current methods used for project analysis in the oil industry fail to consider these aspects in light of a company's sustainability policies. This result is most likely due to the large cathodic polarization current densities achieved throughout the experiment. Although brucite is predicted to deteriorate the physical-mechanical properties of the mineral deposits, the overall deposits were able to shield the electrified steel material from corrosion to some extent. After six months of induced mineral deposition, the layer over the steel attained a maximum thickness of roughly 2.4 mm, following a non-linear trend as a function of time. The deposition rates ranged from 20.0 to 50.3 μm d-1 in relation to the applied current densities. At the same time, a favorable link between deposit growth rates and seawater temperature has been found. Overall, the results of this study provide new elements for the application of low-voltage mineral deposition technology in temperate seas, and pave the way for defining the best operating conditions to protect steel structures from corrosion and support biodiversity, thus contributing to the sustainability of natural capital.

The study is limited to prototype trials and does not cover long-term field observations or large-scale applications of low-voltage mineral deposition technologies. The trials were carried out in the Shatt al-Arab Sea, a unique location of the Northwest Mediterranean Sea. The results may not be relevant to other maritime settings with varying circumstances. The study focuses largely on the mineral deposits' elemental and chemical composition, growth rates, and corrosion protection capabilities. Furthermore, insufficient attention is paid to the influence on marine creatures besides aquaria inhabitants, their depopulation and general ecology. Although the impact of both the natural and operational environment on deposition was considered, all other elements affecting the technology's performance were just briefly analyzed. The disadvantages include a lack of long-term field observations, limited availability of data, and a focus on certain parameters. More research ought to be made on the conquest of those constraints and the evaluation of the efficiency of the method used in low-voltage mineral deposition technology and its components in the environment.

This study depicts the apparatus and the operating procedure for corrosion prevention in the subsea electrically heated multi-pipelines. The covering of the outer pipe's outside surface with a powerful and durable coating is made in the splash zone of all sections as well as at the hot line bulkhead. An output electrode is located inside the space isolation, or a bared conductor is reasonably close to the ground. Means are indicated to assess the space allocated to the discharge tube or bare pipe.

The study describes an apparatus and technique for providing corrosion protection to submerged (river) pipe-in-pipe electrically heated pipelines. The application of a thick protective coating on the outside surface of the outer pipe, particularly in the splash zone and at the bulkhead of the heated line, aids in corrosion prevention. Placing a discharge electrode on the thick protective covering or constructing a bare pipe near it improves corrosion protection. The study also discusses ways for estimating the needed area in the discharge electrode or bare pipe, which can help with the actual use of the corrosion prevention system.

5. CONCLUSIONS AND OBJECTIVES

This study aims to create a framework for sustainable design with regard to the offshore sector that could be applied early in the topside platform project life cycle. Additionally, this framework can serve as a useful tool for decision-makers to analyze and evaluate the project's conceptual design from a sustainability standpoint. The research objectives set forth to achieve this aim are as follows:

(i) The total resistance of anodes decreases with an increase in their number.

(ii) When anodes are configured in parallel, multiple anodes draw a higher current than a single anode under identical voltage conditions supplied by the rectifier.

(iii) The area requiring protection expands as the distance between the pipeline and the anode increases.

(iv) The study aims to determine the effects of topside facilities for offshore platforms on social and environmental aspects.

(v) The identification of important criteria/factors which impact the selection of materials and the sustainable design of topside projects for fixed offshore platform projects was conducted from engineering, economic, social, and environmental sustainability perspectives.

(vi) Semi-structured interviews with offshore experts were used to verify and confirm the significance of the selected criteria, which were then ranked according to their importance.

(vii) The development of a value-based framework for material selection and sustainable design within the offshore industry was pursued.

(viii) The applicability of the framework was tested through a case study to ensure face validity.

(ix) To gauge its effectiveness, the framework was evaluated through semi-structured interviews using a scoring model method.

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