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Offshore Platform Leg Integrity Assessment in the Gulf of Guinea

Orji Charles Ugochukwu[1], Nitonye Samson[2*], Ahaneku Gerald[3]

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Abstract— **Offshore platforms are large structures designed to accommodate personnel and equipment required for drilling wells in the seabed, extracting oil and/or natural gas, processing the resultant fluids, and transporting them to land by shipping or pipelines. Jacket platforms are fixed structures anchored to the seabed with piles to ensure stability against wind, wave, and current forces in the marine environment. The gradual deterioration of the fixed platform over time during operations becomes a subject of concern. The study aims to carry out a structural safety assessment (SSA) of an existing offshore platform in the Gulf of Guinea (GOG) by analyzing the reliability, risk index, safety margins, and structural integrity of the platform. A detailed investigation of design specifications, material characteristics, and environmental loads assessed the structural reliability and risk margins. A risk matrix prioritizes major structural concerns, resulting in specific recommendations for mitigation, repair, and maintenance. The platform's reserve strength ratio (RSR) was examined to build long-term structural integrity, safety, reliability, and environmental resilience strategies. The platform's safety and structural integrity were assessed using Ultimate Strength Assessment (USA) and Reliability–Risk Assessment (RRA) methods. According to the findings, corrosion, fatigue, seabed scour, subsidence, overload from environmental forces (wind, waves, currents, and earthquakes), collisions, crane accidents, explosions, falling objects, fires, leaks, accidental discharges, towing incidents, and well-related damage are the main threats to the jacket platform. The extent of corrosion and the associated probabilities of failure (POF) and reliability of the platform's four jacket legs were calculated. The corrosion losses for Legs 1, 2, 3, and 4 were found to be 4.577%, 3.462%, 3.346%, and 4.039%, respectively. Leg 1 exhibited the highest POF (0.04577) and the lowest reliability (0.95423), whereas Leg 3 showed the lowest POF (0.03346) and the highest reliability (0.96654). The overall reliability factor of the platform was determined to be 1.0401, which, although lower than the safety load factor of 1.25, still indicates a level of structural safety. According to the risk matrix, all four jacket legs (L1–L4) fall within the "Medium" risk category for structural failure, suggesting the risk is within acceptable limits. To address corrosion-related risks specifically, cathodic protection is recommended as an effective mitigation and maintenance strategy. The Ultimate strength analysis produced an Ultimate strength of 3000 kN for a design capacity of 1250 kN, resulting in an RSR of 2.4, which is more than the minimum safety criterion of 1.50 for a manned structure, indicating that the jacket platform structure is SAFE and Fit-for-Purpose.**

Keywords— *Offshore* Platform, Jacket leg, Reliability, Risk Assessment, Failure, Corrosion

*Corresponding Author:nitonye.samson@ust.edu.ng

I. INTRODUCTION

An offshore platform is a substantial structure—either fixed or floating—designed to accommodate personnel and equipment for drilling into the seabed, extracting oil and/or natural\\ gas, processing the output, and transporting it to shore via pipelines or ships [1]. These platforms are generally categorized by the depth of water in which they operate, with two primary types being shallow-water and deep-water platforms. Additionally, they can be grouped based on function, including drilling platforms, storage platforms, and those that combine drilling, storage, and offloading capabilities [22]. Shallow-water platforms may be either fixed or floating. Traditionally, most offshore platforms were constructed on the continental shelf in shallower waters due to favorable economic conditions. However, resource depletion in these areas, advancements in technology, and rising oil prices have made exploration and production in deeper waters both practical and financially sustainable [1] [3] [4].

Offshore jacket platforms (OJP) are among the most widely used structures for oil and gas extraction, with over 5,000 distinct types installed in various marine locations globally [5]. In Nigeria, these platforms are particularly prevalent in shallow to intermediate waters (less than 300 meters deep) for oil and gas production [6] [7]. A typical OJP comprises a deck superstructure that houses drilling and production systems, living quarters, and a steel supporting framework known as the jacket [8]. The jacket itself is a welded steel frame formed as a three-dimensional truss structure, made up of large-diameter pipe piles (chords), smaller pipes, and various profiles that support the upper deck. The structure is secured to the seabed by piles that are driven through or around the jacket's legs. These platforms are subject to a variety of oceanic loads, including permanent (dead) loads, operational (live) loads, environmental loads, deformation loads, construction loads, and accidental loads [9] [10] [11].

Cylindrical steel components are utilized in the construction of the jacket due to their benefits, including low hydrodynamic drag, higher buoyancy, a strong strength-to-weight ratio, and consistent resistance to all

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Charles Ugochukwu Orji, Department of Marine and Offshore Engineering, Rivers State University, Port Harcourt, Rivers State, Nigeria. orji.charles@ust.edu.ng

Samson Nitonye, Department of Marine and Offshore Engineering, Rivers State University, Port Harcourt, Rivers State, Nigeria. nitonye.samson@ust.edu.ng

Gerald Ahaneku, Department of Marine and Offshore Engineering, Rivers State University, Port Harcourt, Rivers State, Nigeria. gerald.ahaneku@ust.edu.ng

directional bending. The welded connections at the termini of these members often exhibit intricate behavior and are regarded as crucial sites within the structure. Fatigue and corrosion are prevalent problems resulting from welding flaws, residual strains, and recurrent exposure to severe environmental conditions. Supplementary threats—including vessel collisions, detonations, conflagrations, fallen apparatus, and extreme meteorological conditions—present dangers that may cause failure in the structure of the platform [12]. Structural failure denotes the deterioration of structural integrity or the reduction of load-bearing capability of a structural component. Structural integrity refers to a design engineering feature of a structure's capacity to withstand its intended load (weight, force, etc.) without compromising its components. Structural Integrity Management (SIM) for offshore structures is a continuous cyclical process that ensures the safety of offshore structures and facilities for operational use, providing a framework for guaranteeing structural reliability and ongoing fitness-for-purpose. It is a systematic process applied to proactively monitor, evaluate, and assess the structural integrity of a facility, while controlling uncertainties related to structural degradation, damage, load variations, unintentional overloading, and changes in usage. A crucial element of the SIM process for offshore structures is the SSA [13] [14] [15] [16].

SSA yields insights into the performance of the existing structure under current operating conditions and the reserve capacity available for future operations. This evaluation ascertains the suitability of the facility and the critical aspects to contemplate when deciding to prolong the facility's lifespan [13]. Offshore SSA entails performing two key analyses: Structural Reliability Analysis (SRA) and Quantitative Risk Analysis (QRA) [9]. Structural reliability analysis on one end of the scale is applied to identify the members that are truly critical and establish if additional members can improve structural system reliability [17]. Reliability is the probability that a system will operate for a specified period without failure. Jacket structural system reliability is established using series and parallel reliability systems. The 'series or chain reliability system applies to the platform legs that secure the jacket structure to the seabed. When any leg fails, the load shed by the failed leg renders the whole platform unsuitable for operation [6] [18]. QRA also quantifies the risk of failure in the OJP structure by analyzing the probability and consequences of OJP failure and identifies critical areas of concern in the platform structure by classifying the quantified risk using a risk matrix. It qualifies the risk level of the jacket platform structure and proves whether the risk of structural failure for the jacket platform is acceptable [19]. High reliability of all the jacket legs as well as a low-risk index of the legs improves the integrity of the jacket platform and vice versa. The SSA evaluates the ultimate strength of the OJP by determining the RSR to establish its potential to withstand random environmental loads.

Given the above concerns, this study conducted an SSA of an existing platform. The current condition of an existing offshore platform, including its structural components and systems design data, was evaluated, and the potential risks and hazards acting against the integrity of the OJP structure were identified. The reliability performance and risk index safety margins of the offshore platform were analyzed, with critical areas of concern for the platform identified, assessed, and prioritized using the risk matrix. Ultimately, the RSR of the offshore platform was assessed to develop a long-term structural integrity management plan aimed at enhancing the reliability and safety of the platform in GOG.

Recent research demonstrates that much focus has been placed on performing an engineering analysis of the SSA of an existing offshore platform. A wide range of authors are professionally engaged in the safety of fixed structures, failure paths and barriers, SIM of offshore facilities, and safety assessment approaches for aging offshore platforms exhibiting damage. [20] [21] [19]. Tawekal *et al.* (2018) [22], examined risk-reliability-based underwater inspections for offshore platforms in Indonesia, Ersdal (2005) [20] assessed existing offshore structures for life extension, and Kurian *et al.* (2015) [23] conducted a component reliability evaluation of OJP. Wang *et al.* (2010) [24] conducted a lifecycle structural performance assessment of offshore fixed platforms. Stacey *et al.* (2002) [25] analyzed reassessment challenges in the life cycle SIM of fixed steel facilities, whereas Guédé (2019) [2] explored risk-based SIM for OJP. Ersdal (2005), [20] evaluated current offshore structures for life extension, whereas Potty and Akram (2009), [26] examined SIM for fixed offshore platforms in Malaysia. [27] performed a study on offshore structural engineering, reliability, and risk evaluation. Srinivasan (2016), [9] performed a reliability-based design and assessment for the lifespan extension of aging offshore structures, whereas Nava-Viveros and Heredia-Zavoni (2016), [28] investigated statistical parameter uncertainty in the reliability analysis of jacket platforms.

These studies, however, examined the issue of conducting an engineering analysis on the structural safety evaluation of an existing offshore platform, albeit in a limited capacity. Cheok *et al.* (2022), [29] examined the vulnerability and risk assessment of a four-legged offshore structure construction. They claimed that offshore constructions are frequently employed in the oil and gas extraction sector, which is a significant economic sector in Malaysia. They asserted that recent distant earthquakes from neighboring nations (Indonesia and the Philippines) have inflicted considerable structural damage, necessitating a thorough examination of the seismic performance levels of offshore constructions. Consequently, their research examined vulnerability and assessed the risk of the four-legged fixed structure under various excitations, utilizing SAP 2000 for modeling the offshore structure in compliance with American Petroleum Institute (API) standards. The behavior of the offshore structure was assessed by analyzing its natural frequencies and periods.

The results of the integrated displacement, velocity, and acceleration demonstrated the dynamic characteristics of the structure. The four-legged fixed offshore structure is categorized as Immediate Occupancy (IO) based on FEMA 356 criteria. The results demonstrated that the existing four-legged offshore structures in Malaysia are capable of withstanding seismic loads and maintaining stability. Mat Soom *et al.* (2021), [30] performed a comparative analysis of structural reliability evaluation methodologies for fixed offshore structures. The oil and gas sector has acknowledged that the structural integrity assessment of aging platforms for potential life extension is an increasing concern, especially in relation to the unpredictability of severe maritime environments. This circumstance results in ambiguity in wave-in-deck load estimations and imposes significant stress on offshore constructions. This underscores the imperative for improved reliability, as failure could lead to inaccessibility due to uncertainties associated with long-distance services, including the precision of load and response estimates. Ezanizam *et al.* (2019), [31] contend that a reliable approach for evaluating the failure probability of fixed offshore structures involves a combination of statistical and engineering design uncertainties, which can remain flexible provided the structure adequately addresses the applied loads.

II. METHOD

The materials used for this research work are the geometric data of the jacket platform structure, data on the properties of the structure, and the environmental loads (wave, current, and wind) acting on the jacket platform. Similarly, data on the hazards and vulnerabilities associated with the jacket platform failure risk were used. The offshore platform structure was modelled and subjected to the environmental conditions in which it operates using Structural Analysis and Computer Software (SACS). Then the safety and integrity of the offshore structures were assessed. Table 1 shows the design data of the principal dimension of the jacket platform.

The jacket construction stands 48 meters high and operates at a water depth of 19.5 meters. The production platform consists of two components: the metering platform and the well group platform, linked by a trestle bridge. The metering platform is anchored to the seabed with four piles, while the well group platform is secured with six piles. The diameter of the pipes ranges from 1.3m to 0.4m with depth, while the thickness varies between 26mm and 14mm.

Two methods were adopted to assess the safety and integrity of the offshore structures, viz: the USA and RRA. The current condition of an existing offshore platform, including its structural components and systems design data, was evaluated, and the potential risks and hazards acting against the integrity of the OJP structure were identified. The reliability performance and risk index safety margins of the offshore platform were analyzed, with critical areas of concern for the platform identified, assessed, and prioritized using the risk matrix.

TABLE 1.
DESIGN DATA OF THE OJP LEGS PRINCIPAL DIMENSION [6]

Structure	Dimensions	Elevation (z) above MSL
Production Deck	17.06 x 17.06m	9.47m
Jacket legs	Outer diameter (D_o) = 76.15cm Thickness (t) = 2.6cm	-9.01m ≤ z ≤ +5.04m
	Outer diameter (D_o) =76.15cm Thickness (t) = 1.82m	-19.5m ≤ z ≤ +6.01m
Piles	Outer diameter (D_o) = 76.2cm Thickness (t) = 2.98cm	20m penetration depth

The acceptance standards for the ultimate strength level are defined by the ratio of the platform's ultimate capacity to the design loading, often the 100-year wave loading, referred to as the Reserve Strength Ratio (RSR) [32]. The RSR is given as equation (1) :

$$\mathrm{RSR} = \frac{\text{Jacket Platform Ultimate Strength Capacity}}{\text{Design Strength Capacity}} \tag{1}$$

The POF is defined as the probability of exceeding a limit state within a defined reference period after combining all possible loading patterns [33]. It is the measure of the likelihood of failure occurring. Using the total probability theorem, equation (2) estimates the probability of failure [POF] (P_f) [17]:

$$P_f = \sum\nolimits_{all\,h} P[L - R > 0 \mid H_{max} = h] \,.\, P[H_{max} = h] \tag{2}$$

where:

$P[H_{\max} = h]$ = the likelihood of a loading pattern which is a function of wave height, h.

$P[L - R > 0 \mid H_{\max} = h]$ = the probability of the loading effect being greater than the structural resistance given $H_{\max} = h$.

Equation (2) can be rewritten as follows [17]:

$$P_f \quad = \quad P[L - R > 0\,] \tag{3}$$

$$P_f = \int_{all\,h} P[L - R > 0 \mid H_{max} = h] \,.\, f[H_{max}].\, d_{H\,max} \tag{4}$$

where:

$f[H_{\max}]$ = the probability density function of maximum wave height, $H_{\max}$ as the indicator of the selected wave loading pattern.

The lateral force pattern is constructed using relevant wave theory to approximate the shear patterns anticipated after an intense event. The load profile employed is the one that produces the maximum base shear in the most essential direction. Equation (2) is rewritten in the following format according to equations (5-8) to express the annual rate of failure (λ_f) [17]. Figures 1 and 2 show the Jacket structure supporting legs and the reliability schematic diagram

$$\lambda_f = v.P[L - R > 0] \tag{5}$$

$$\lambda_f = \int_{all\ h} P[L - R > 0 \mid H_{\max}].v.f[H_{\max}].d_{H\max} \tag{6}$$

$$\lambda_f = \int_{all\ h} P[L - R > 0 \mid H_{\max}].v.\left|\frac{dF[H_{\max}]}{dH_{\max}}\right| d_{H\max} \tag{7}$$

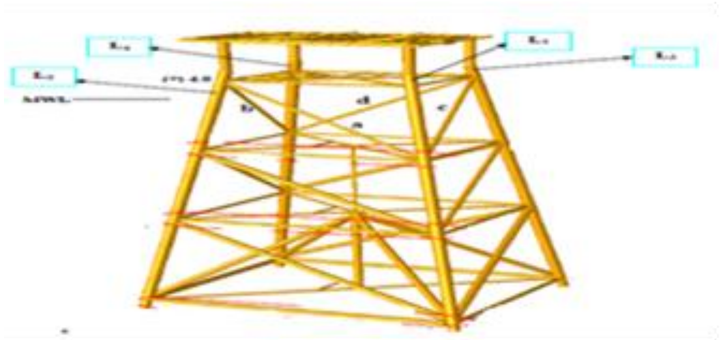

Figure. 1. Jacket Structure Diagram showing Support Legs (Elsayada *et al*., 2014)

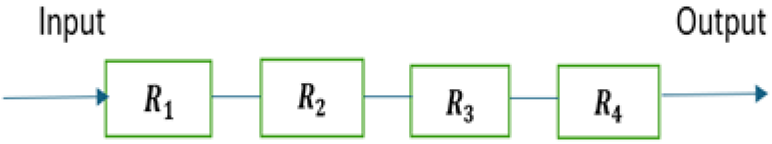

Figure. 2. Jacket Structural Reliability Schematic Diagram (Legs in Series reliability mode) (Elsayada *et al*., 2014)

$$\lambda_f = \int_{all\ h} P[L - R > 0 \mid H_{\max}].d\lambda_{H\max} \tag{8}$$

where:

$f[H_{\max}]$ = the cumulative probability density function (*CDF*) of maximum wave height.

$\lambda_{H\max}$ = the wave hazard in terms of the mean annual frequency of exceedance of specific maximum wave heights

V = is the number of sea states in one year.

$d\lambda_{H\max}$ = the differential of the mean annual frequency of exceeding a specific maximum wave height.

The POF is also given according to equation (9).

$$P_f = 1 - \Phi\beta \tag{9}$$

where: P_f = probability of failure, Φ = the CDF of the standard normal variate, β = reliability (safety) index

The cumulative distribution function (CDF) ϕ is obtained from the cumulative distribution table.

The P_f depends on β, defined as the ratio of the mean value of z to its standard deviation.

For a log-normal distribution, the safety index β is given as in equation (10)

$$\beta = \frac{In\left[\frac{\mu_R}{\mu_L}\right]}{\sqrt{\delta R^2 + \delta L^2}} \tag{10}$$

With :

$$\delta = \frac{\sigma}{\mu} \tag{11}$$

where:

μ_R = mean of the resistance, μ_L = mean of the load, δR = uncertainty in the resistance of the steel (material properties, fabrication, modeling etc.), δL = uncertainty in the load, σ = Standard Deviation, and μ = Mean

The safety margin (m) is obtained from the equation (12)

$$m = \frac{2}{(2-m)Y^{m(\sqrt{\pi a})^m}\left[\Delta a^{\frac{2-m}{m}}\right]} - C(\Delta\sigma)^m.N \tag{12}$$

The mean of the resistance μ_R is determined using equation (13)

$$\mu_R = \frac{2}{(2-m)Y^m\left[(\sqrt{\pi a})^m\left(\Delta a^{\frac{2-m}{m}}\right)\right]} \tag{13}$$

Mean of the load μ_S is expressed as equation (14)

$$\mu_S = C(\Delta\sigma)^m.N \tag{14}$$

The resistance standard deviation is obtained from equation (15)

$$\sigma_R = \mu_R\sqrt{\Delta a} \tag{15}$$

The load standard deviation is obtained from equation (16)

$$\sigma_S = \mu_S\sqrt{\Delta a} \tag{16}$$

The exponential reliability model adheres to the Weibull distribution, making it appropriate to denote the continuous random variable for failure time as t. The PDF of the Weibull distribution as given by [34] is expressed as equation (17)

$$f(t;\beta;\theta)=\frac{\beta}{\theta}.\left(\frac{t}{\theta}\right)^{\beta-1}.exp\left[-\left(\frac{t}{\theta}\right)^{\beta}\right] \quad (17)$$

where:
t = hours of operation/ up time,
θ = scale parameter of the Weibull distribution and
β=the shape parameter.

$$R(t)=e^{-\lambda t} \quad (18)$$

$$F(t)=1-e^{-\lambda t} \quad (19)$$

where: λ = Failure rate of the structure and t = time in operation of the structure.

The reliability 'R' is calculated from the POF using the formula:

$$R(t)=1-P_f(t) \quad (20)$$

where: R (t) = reliability, P_f = POF

Equation (20) is written in terms of the member's thickness and time variant corrosion wastage, as shown in Equations (21) and (22):

$$R(t)=T-P_f(\Delta t) \quad (21)$$

$$R(t)=1-\frac{\Delta t}{T} \quad (22)$$

where: T = initial thickness of member, Δt = thickness loss due to corrosion.

A. *Jacket Legs Reliability*

In a stationary offshore platform, the pile head is presumed to be situated at the mudline. The dependability of the leg system is determined by the product of the individual leg reliability, as each jacket leg is crucial for the platform's successful operation. Accordingly, for a four-legged jacket platform, the system reliability *SL R* is shown in equation (23):

$$R_{SL} = R_{1}.R_2.R_3.R_4$$

(23)

where:R_1, R_2, R_3,R_4, is the corresponding reliability for each jacket platform's four legs.

B. *Jacket System Reliability*

The jacket platform structure comprises legs distributed along its length. The reliability of the jacket system can be determined by the application of network reduction techniques. The network reduction depicted in Figure 2 is the most suitable for a four-legged jacket structure featuring six bracing groups.

To use the assessment procedure, specific fieldwork must be conducted. The recommended jacket structural member thicknesses for evaluation must include the discrepancies between the original and current thicknesses of the members.

TABLE 2.
OFFSHORE PLATFORM LEGS RELIABILITY (SERIES SYSTEMS)

Group	ID	Corrosion Loss = tp (%)	Progressive Collapse Failure Probability (P = tp/100)	Reliability (1 – P)
Support	L1, (P_{L1})	4.577	0.04577	0.95423
	L2, (P_{L2})	3.462	0.03462	0.96538
	L3, (P_{L3})	3.346	0.03346	0.96654
	L4, (P_{L4})	4.039	0.04039	0.95961
	Reliability (R_{SL}) = R_{L1}. R_{L2}. R_{L3}. R_{L4}			0.96144

C. *Reliability Factor*

The reliability of a newly installed jacket is absolute, at 100%, due to the absence of corrosion in the structural components. A reliability factor (RF) is produced to assess the rate of decline in structural system dependability, comparing intact and corroded jacket systems. The proposed factor can be represented mathematically as equation (24) [35]: Table 2 is the platform leg reliability.

$$RF=\frac{1}{R_n} \quad (24)$$

where, R_n = Jacket structural system reliability

Offshore constructions are influenced by environmental stresses, including operational and storm conditions, which affect their fatigue behavior. Fatigue can result in the failure of structural components, potentially leading to the complete failure of the system. The development of fractures under random loadings may be approximated by equation (25):

$$\frac{da'}{dt}=C(\Delta K_{mr})m_v \quad (25)$$

$$\Delta K_{mr}=YS_{mr}\sqrt{\pi a'} \quad (26)$$

where: C and m are parameters for the material properties, ΔKmr = the interval of the mean stress intensity,
v′ = the rate of positive crosses by zero,
Y = the geometric correction factor,
Smr = the mean stress interval of the response of the elements,
a′ = the crack size. In this equation,

The stochastic load is replaced with an analogous cyclic load, characterized by amplitude and frequency determined by the average attributes of the random process. For the fatigue crack growth model, the Paris-Erdogan equation below can be applied:

$$\frac{da}{dN} = C.(\Delta k)^m$$

(27)

$$K = Y.\sigma\sqrt{\pi a} \quad (28)$$

where: $\frac{da}{dN}$ = fatigue crack growth rate (mm/cycle),
N = number of cycles,
Δk = range of stress intensity factor (SIF),
a = crack length, C and m = material's constants,
Σ = applied uniform stress (tensile) acting perpendicular to the crack plane,
Y = a dimensionless parameter which depends on the geometry of the specimen.

Figure 3 shows the SACS Computer Interface of the modelled Jacket Platform frame

2.1 Wave, Wind and Current

To generate the stochastic wave loading and determine the current/wave load, Morrison equation is used for slender structures:

$$F = \frac{1}{2}\rho C_D D\left|\dot{U}\right|\dot{U} + \rho C_M A_P \ddot{U} \tag{29}$$

where: F = Wave Force per unit length acting on the platform at elevation Z from the sea level,
ρ = Density of water,
C_D = Drag coefficient,
C_M = Inertia,
A_P = Projected Area per unit length
D = Diameter of member (marine growth inclusive),
$\dot{U}$ = Horizontal component of water particle velocity at elevation z from the sea level,
$\left|\dot{U}\right|$ = Absolute value of $\dot{U}$,
$\ddot{U}$ = horizontal component of water particle acceleration at elevation z from the sea level

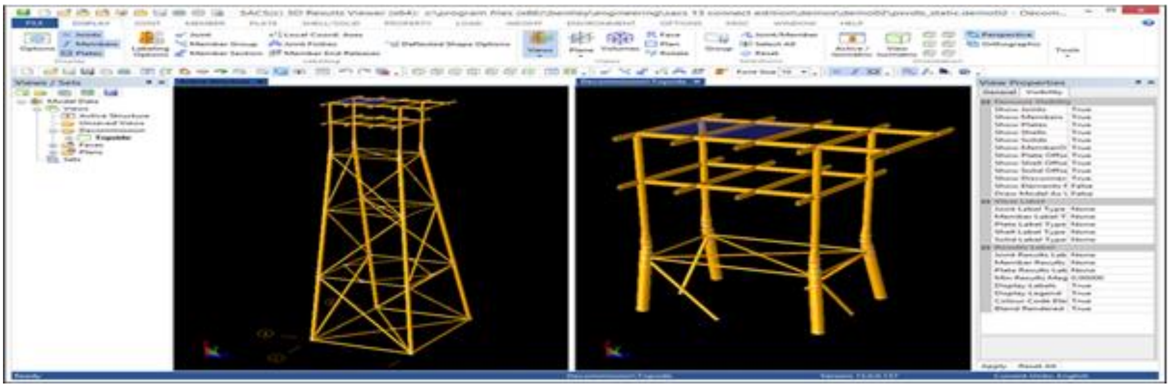

Figure. 3. SACS Computer Interface of the modelled Jacket Platform frame.

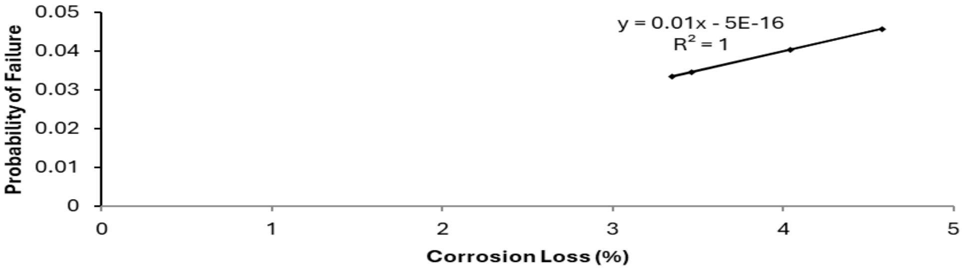

Figure. 4. Offshore Platform Leg Corrosion Loss against Progressive Collapse Failure Probability

According to (OCIMF,1994), the wind load on the structure above sea level with a standard elevation of 10m above the MWL and an average time of one hour is given by the equation (30)

$$F_w = \frac{1}{2}\rho_a C_w A\, U_w^2 \tag{30}$$

And the current load is estimated using equations (31);

$$F_c = \frac{1}{2}\rho_w C_c A\, U_c^2 \tag{31}$$

where: ρ_a , ρ_w = Density of Air (1.226kg/m^3) and density of sea water (1025 kg/m^3 for Standard Temperature and Pressure), C_w = wind Shape coefficient (1.0 for the overall projected area of the platform), A = Projected Area of Structure, U_w = Sustained Wind Velocity, U_c = Current Velocity.

2.2 Dynamic Structural Response

The discrete EOM that obeys Newton's second law of motion is used to obtain the platform's dynamic response (lateral deflection). The term on the right-hand is the Action force, while that on the left is the resistive forces ( ):

$$M\ddot{x} + C\dot{x} + kx = F(t)$$

where; M = Mass or Inertia term, C = Damping (to reduce the effect of the external excitation), K = Stiffness (restoring force - opposes displacement), F(t) = Total loads/external excitation

$x, \dot{x}, \ddot{x}$ and (i.e. responses) = displacement, velocity, and acceleration, respectively.

The jacket platform under examination is modeled in local wind sea waves for both 1-year and 100-year return periods (normal and extreme conditions) utilizing the

JONSWAP wave spectrum, in accordance with environmental conditions in the GOG at a water depth of 100m and the established guidelines for jacket platform construction. It is given as a function of frequency *f* in Hz expressed by equation (33)

$$S(f) = \alpha \frac{g^2}{(2\pi)^4}\frac{1}{f^5}exp\left\{-1.25\left(\frac{f_m}{f}\right)^4\right\}x\gamma^{exp\left\{\frac{-(f-f_m)^2}{2(\sigma f_m)^2}\right\}} \quad (33)$$

where: γ = peak shape parameter, 3.30 as an average, $\alpha = 0.076\left(\bar{x}\right)^{-0.22}$, $\sigma = 0.07$ for $f \leq f_m$, and 0.09 for $f \succ f_m$,

$$f_m = 3.5\left(\frac{g}{\bar{U}}\right)\left(\bar{x}\right)^{-0.33} \quad (34)$$

$\bar{x}$ = dimensionless fetch = $\frac{gx}{\bar{U}^2}$,

x = fetch length (km),

$\bar{U}$ = mean wind speed (m/sec)

$$\bar{U} = kx^{-0.615} \cdot H_S^{1.08} \quad (35)$$

where: $k = 83.7$ for $\gamma = 3.30$,

Hs = significant wave height (meters)

2.3 Risk Assesment

Each identified risk was evaluated according to its likelihood of occurrence and the severity of its repercussions, based on the classification of probability and frequency. The significance of this risk is defined as the product of its likelihood and the outcome of the risk occurrence [36[

$$Risk(t) = POF(t) * COF \quad (36)$$

where: POF = Probability of Failure and is a function of time, t, and COF = Consequence of Failure

2.4 The SACS Computer Software

Figure 3 shows the jacket structure modelled using Structural In-place Analysis and Computer Modeling Software (SACS), a numerical tool for dynamic analysis to determine the ultimate strength and stress analysis of space frame structures.

III. RESULTS AND DISCUSSION

The SSA of an existing platform in the GOG was done using the geometric data of the platform design, the environmental loads acting on the jacket platform, corrosion, loads, and the current condition of the existing offshore platform. The potential risks and hazards to the OJP operation and environmental conditions acting on the jacket platform were modelled using Structural Analysis Computer Software (SACS), and then the probability of failure, reliability index, reliability factor, and risk index safety margins of the OJP were analyzed using MATLAB. The critical risk areas of concern for the platform were identified and prioritized with specific recommendations and strategies for risk mitigation, repair, and maintenance. Ultimately, the RSR of the OJP was assessed to develop a long-term SIM plan aimed at enhancing its safety, reliability, and environmental resilience.

3.1 Reliability Analysis of the Offshore Jacket Platform (OJP)

i. Offshore Platform Legs Reliability (Series Systems)

The values for the corrosion loss, probability of failure and reliability (Series Systems) for the jacket platform legs are presented in Table 2. The results showed that the corrosion loss of the jacket leg-1 is 4.577%, the corrosion loss of the jacket leg-2 is 3.462%, the corrosion loss of the jacket leg-3 is 3.346% and the corrosion loss of the jacket leg-4 is 4.039%. The analysis revealed that within the period of consideration (about twenty-two years), less than 5% of all platform legs have been lost to environmental corrosion, with Leg-3 having the list corrosion loss of about 3.3% followed by Leg-2 with 3.5% loss. Leg-4 and Leg-1 are the highest in corrosion losses, with about 4% and 4.6% respectively. This assessment implies that if the corrosion rate continues at the same rate, with time, Leg-1 will fail before Leg-4, while the last to fail will be Leg-3. The result also revealed that jacket leg-1 had the highest POF of 0.04577, while jacket leg-3 had the least POF of 0.03346. The results also showed that jacket leg-3 had the highest reliability of 0.96654, while jacket leg-1 had the least reliability of 0.95423. The jacket reliability prediction is presented in Table 3.

TABLE 3.
OFFSHORE PLATFORM RELIABILITY & RELIABILITY FACTOR ESTIMATION

S/N	Period	1975	2024
1	Duration	0 years	24 years
2	Support Legs (R_{SL})	1	0. 96144
3	Reliability (R_{JS})	1.0	(0. 0. 96144)
4	Reliability Factor (RF)	(1.0/1.0) = 1.0	(1.0/0. 96144) = 1.0401

The results showed that within the years of consideration of over 20 years, the corrosion loss of jacket leg-1 is about 4.6%, the corrosion loss of jacket leg-2 is 3.5%, the corrosion loss of jacket leg-3 is 3.3%, and the corrosion loss of jacket leg-4 is 4.0%. The result revealed that jacket leg-1 had the highest corrosion loss of 4.6% while jacket leg-3 had the least corrosion loss of 3.3%. Assessing the reliability of the jacket platform based on the legs as a system, the system reliability is $R_{JS} = 0.96144$ according to equation (23). Therefore, the structural reliability of the jacket platform system structure can be said to be 0.96144 (about 96%).

The result also revealed that jacket leg-1 had the highest POF of 0.04577 (4.6%), while jacket leg-3 had the least POF of 0.03346 (3.3%). The results for the structural reliability of the jacket platform legs showed that jacket leg-3 had the highest reliability of 0.96654, while jacket leg-1 had the least reliability of 0.95423 in 22 years.

Figure 4 reveals the results for the relationship between corrosion loss and the POF for the jacket platform legs. The results showed that the POF for the jacket platform legs is directly proportional to the corrosion loss of the jacket legs. This means that as the corrosion loss of the jacket legs increases, the POF for the jacket platform legs also increases. The results showed that a strong positive relationship exists between corrosion loss and the POF for the jacket legs. The result obtained, and the research approach correlate with the results obtained and the approach followed by previous studies, as highlighted in the works of [15] [6].

Figure 5 reveals the results for the relationship between POF and the reliability of platform legs. The results showed that the POF of the jacket platform legs is inversely proportional to the reliability of the jacket platform legs, meaning that as the POF of the jacket platform legs increases, the reliability of the jacket platform legs decreases.

The results showed that a strong positive relationship exists between the POF and the reliability of the jacket platform legs

TABLE 4.
OFFSHORE PLATFORM LEGS RELIABILITY (SERIES SYSTEMS)

ID	Design Thickness (mm) Yr-2000	UT Thickness (mm) Yr-2022	Corrosion Loss = tp (%)	Probability of Failure (P = tp/100)	Likelihood Ranking	Consequence/ Severity Ranking	Risk Value/ Level
L1, (PL1)	26.00	24.81	4.577	0.04577	3	4	12 (Medium)
L2, (PL2)	26.00	25.10	3.462	0.03462	3	4	12 (Medium)
L3, (PL3)	26.00	25.13	3.346	0.03346	3	4	12 (Medium)
L4, (PL4)	26.00	24.95	4.039	0.04039	3	4	12 (Medium)

This result and the research approach agree with the results obtained and the approach followed by previous studies [15] [6].

ii. Reliability Factor

The reliability of the newly installed jacket is 1.00 or 100%, as the structural components are free from corrosion. A reliability factor (RF) is produced to assess the rate of decline in structural system dependability, comparing intact and corroded jacket systems. The suggested factor is mathematically expressed as indicated in Equation (24). The structural reliability of the jacket platform structures is 0.96144. By substituting data into Equation (24), the reliability factor (RF) of the jacket platform is determined to be 1.0401. Accordingly, jacket reliability prediction for the year 2024 is in Table 3.

The dependability factor is crucial for assessing jacket safety over the operational lifecycle, since it indicates the rates of reliability degradation for the jacket. The reliability factor of the jacket platform structure determined is 1.0401, which is less than the load factor of safety of 1.25. Therefore, the jacket platform structure is structurally SAFE.

iii. *Offshore Platform Risk Assessment*

The critical areas of concern for the platform were identified, assessed, and prioritized using the risk matrix, and specific recommendations and strategies for risk mitigation, repair, and maintenance were developed. Each identified risk was evaluated according to its possibility of occurrence and the severity of its repercussions, using the probability and frequency rating from equation (34).

Similarly, based on the frequency categories and criteria as well as the severity/consequence categories and criteria, the risk of the jacket leg is analysed and presented in Table 4.

Table 4 presents the evaluated and recognized important areas of concern for the platform utilizing the risk matrix. The risk matrix indicated that the jacket legs L1, L2, L3, and L4 present a MEDIUM risk of structural failure, signifying that the risk is acceptable. To mitigate this risk, HSE Management must develop essential steps to avoid alterations to existing risk controls and guarantee the execution of all feasible controls. The precise advice and solutions for risk mitigation, repair, and maintenance concerning the corrosion of jacket legs are cathodic protection techniques. Corrosion Protection (CP) is an electrochemical safeguard achieved by lowering the corrosion potential to a threshold that substantially diminishes the metal's corrosion rate. The CP measurements of anodes should range from -1150 mV to -900 mV [21]. Values lower than -1150 mV are deemed excessive protection, perhaps resulting in damage to structural components. A value less negative than -900 mV is deemed insufficient for protection, leading to corrosion. In instances where the CP reading is inapplicable, a survey must still be conducted to assess the depletion of the CP; if over 75% of anodes are depleted, it should be recorded as an abnormality

iv. Offshore Platform Structural Load Analysis for RSR

A structural load analysis was performed using SACS software to determine the ultimate load-bearing capacity of the platform. In a stress analysis, the loadings are applied in two stages. The preliminary stage encompasses the platform's static weight and superstructure loads. In the subsequent phase, diverse environmental conditions are imposed on the platform. Figure 6 presents the findings of the platform stress analysis. The approach considers the nonlinear impacts of individual component behavior, encompassing material behavior and the deflection of structural components and systems. The analysis facilitates the shifting of loads from overburdened individuals. Concentrated stresses were exerted at the master joints at the center of gravity (COG) of the platform. The analysis was conducted with loading applied once in the global x-direction and once in the global y-direction due to the platform's asymmetry. The various load conditions of the environment are implemented. The platform's ultimate strength capacity was established at 3000 kN.

The structure achieved an RSR of 2.4, calculated using equation (1), with a design strength capacity of 1250 kN. The minimum acceptance safety criterion of RSR for a manned structure is 1.50 [23]. Since the RSR of the jacket platform structure is determined to be 2.4 which is greater than the minimum acceptance safety criterion of RSR for a manned structure of 1.50. Therefore, the jacket platform structure is SAFE.

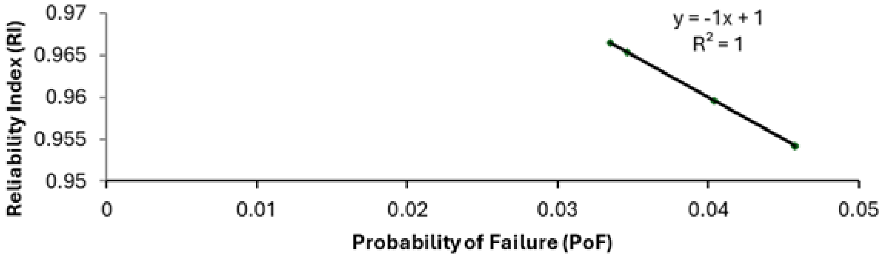

Figure. 5. Offshore Platform Leg Progressive Collapse Failure Probability against Reliability

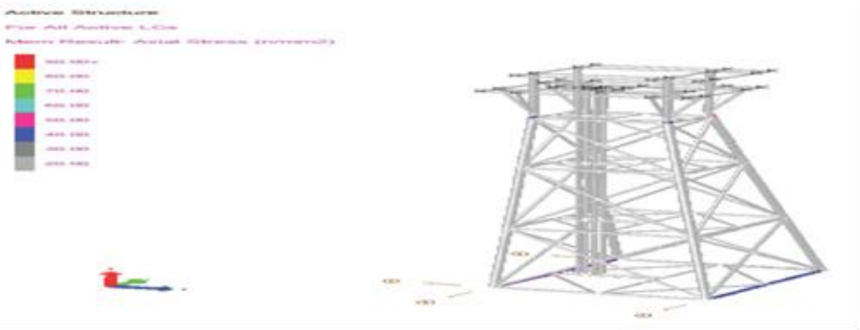

Figure. 6. Load Analysis: x-y direction on offshore platform

IV. CONCLUSION

The potential risks and hazards acting against the jacket structure's integrity were assessed. The current condition of the existing offshore platform, and the potential risks and hazards militating against the integrity of the OJP structure have been determined. The reliability performance, the reliability factor, risk index, safety margins, and RSR of the OJP structure were analyzed. The critical areas of concern for the platform have been identified and prioritized using the risk matrix to develop specific recommendations and strategies for risk mitigation, repair, and maintenance. The reliability and risk index safety margins from the legs of the existing offshore platform were also conducted, and the results also showed that. The results showed that jacket leg-3 had the highest reliability of 0.96654, while jacket leg-1 had the least reliability of 0.95423. The reliability factor of the jacket platform structure determined is 1.0401, which is less than the load factor of safety of 1.25. Therefore, the jacket platform structure is structurally SAFE. The risk and critical areas of concern in the platform were assessed using the risk matrix for risk mitigation, repair, and maintenance. The risk matrix showed that the jacket legs comprise L1. L2. L3 and L4 have a medium risk of structural failure, which defines a tolerable Risk condition**.**

To manage this risk, it is recommended that HSE Management implement critical measures to preserve existing risk controls and guarantee the deployment of all viable controls. The specific recommendations and strategies for risk mitigation, repair, and maintenance against the jacket legs corrosion was the cathodic protection technique. The POF and reliability of the offshore platform depend significantly on the percentage of corrosion loss and reduction in the thickness of the structure as such should be considered in order to predict the failure probability and reliability of the offshore platform. The SIM system framework developed for the offshore platform should be employed as a means of managing the structural risk levels for the platform to ensure that the structure's fitness for purpose (FFP) is maintained. Special attention and priority of risk-based inspection/maintenance should be given to critical risk areas of concern for the platform, especially the jacket legs as the risk matrix showed that the jacket legs comprise L1. L2. L3 and L4 have a MEDIUM risk of structural failure than the bracings. Relevant stakeholders in the industry should assist in facilitating and financing further research on SSA of existing offshore platforms in the GOG, using Digital Twin Technology, AI-driven predictive maintenance, Drone and ROV-based inspections, and Machine learning for Anomaly detection.

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