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OPTIMIZING MAINTENANCE FREQUENCY ON INSTRUMENTATION WITH THE RELIABILITY CENTERED MAINTENANCE METHOD AT PT X

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Abstract

In facing maintenance challenges in offshore oil and gas operational platforms, determining instrumentation components based on Safety and Environment Critical Element (SECE) with the Reliability Centered Maintenance (RCM) method requires component repair data in the 2019-2023 time interval. So far, maintenance intervals have been carried out conventionally without considering historical reliability data, which has led to over-maintenance and under-maintenance. This study aims to optimize the maintenance frequency of SECE instrumentation with the RCM approach to improve technical, operational, and economic efficiency, as well as ensure compliance with safety and environmental standards. The methodology used includes data collection, technical document analysis, reliability calculations, and the development and re-implementation of maintenance work in the system. The calculation results show that several instruments have a high level of reliability, such as the pressure transmitter at 99.86%, while the shutdown valve recorded the lowest reliability of 97.86%, which based on a significance test can be extended to a 12-month maintenance interval. Optimizing the maintenance interval resulted in a significant reduction in man-hour requirements, up to 27% on the entire platform while maintaining system reliability. Technical recommendations were also proposed, including the use of statistical approaches such as the Weibull distribution for further analysis. This research shows that a data-driven RCM approach not only improves system reliability but also resource efficiency and overall occupational safety.

Keywords: Reliability, Maintenance Frequency, Instrumentation

INTRODUCTION

Instrumentation safety on oil and gas platforms is a critical aspect that ensures operational integrity and protects personnel and the environment. An effective safety instrumentation system (SIS) is crucial for detecting and mitigating risks associated with hazardous operations in these environments. The safety of elements in critical environments (SECE), particularly on oil and gas platforms, is heavily influenced by the IEC 61511 standard. This standard plays a crucial role in establishing a framework for the design, implementation, and maintenance of SIS. These systems are vital for mitigating risks associated with hazardous events, thereby ensuring the safety of personnel and the environment. A key aspect of the IEC 61511 standard is its risk-based approach, which facilitates the selection of appropriate SILs for the various SIFs involved in process safety. Souza et al. advocate a hierarchical organization of control systems that includes robust risk analysis, promoting a structured methodology for achieving safety through design (Souza et al., 2014).

Reliability maintenance in the oil and gas industry is crucial due to the unique environmental challenges and high operational costs associated with equipment maintenance and asset management. Given the complexity of maintaining machinery and infrastructure in remote locations, strategies focused on improving reliability are essential to minimize operational disruptions and ensure safety (Zhang et al., 2019). Reliability-centered maintenance (RCM) is a strategic approach aimed at ensuring the reliability and functionality of mechanical systems across various industries. RCM is defined as a systematic method that prioritizes maintenance tasks based on the criticality of equipment failure modes, ultimately focusing on cost-effectiveness while minimizing downtime (Rizkya et al., 2019; Ramos et al., 2018). Optimizing maintenance frequency through the lens of RCM is a crucial aspect of modern engineering management that enables organizations to minimize downtime, improve system performance, and optimize operational costs. The essence of RCM lies in its guided approach in identifying critical components and their optimal maintenance schedules based on reliability indices and operational demands (Li & Brown, 2004). The maintenance frequency rules established by API 754 and IEC 61511 provide a critical framework that guides the management and maintenance of systems and processes in the oil and gas industry, ensuring that potential hazards are effectively mitigated. These standards complement each other by integrating safety and risk management concepts that support high operational reliability.API 754 outlines a framework for Safety Performance Indicators (SPIs) designed to monitor the effectiveness of safety systems and maintenance practices. This standard highlights the importance of documenting maintenance activities, which should include the frequency of inspections and preventive maintenance that directly impact performance (Stauffer & Chastain-Knight, 2020). API 754 encourages organizations to shift from a reactive to a proactive maintenance strategy. In this context, maintenance frequency should be based on evidence derived from historical system performance data, risk assessments, and specific operational conditions to prevent failures and ensure the system remains within safe operating limits (Forest, 2018).

IEC 61511 encourages facilities to reduce maintenance frequency based on the specific operational and safety requirements of existing equipment and processes, thus facilitating customized maintenance plans (Squillante et al., 2013). The risk assessment outlined in both standards guides the decision-making process regarding maintenance frequency; higher risks require tighter maintenance schedules to prevent failure (Baybutt, 2013; Squillante et al., 2013). The minimum reliability value for Instrumentation components as recommended by the IEC 61511 standard is 98% based on safety and security considerations. Another critical element in both standards is the continuous improvement of maintenance strategies. Mugarza et al. advocate the role of data analytics directly in optimizing maintenance activities, stating that data-driven insights can significantly improve decision-making and enhance overall safety performance (Mugarza et al., 2020). A maintenance strategy that effectively combines condition monitoring with traditional preventative measures can lead to improved safety outcomes while minimizing downtime and maintenance costs (Souza et al., 2014). This study aims to optimize the maintenance frequency of SECE instrumentation by analyzing component reliability and optimizing maintenance intervals based on RCM to improve the effectiveness and efficiency of maintenance systems in offshore oil and gas production facilities.

METHOD

This research is based on damage data processing including Preventive Maintenance and Corrective Maintenance activities for each instrumentation component. The SECE category on the instrument includes Pressure Transmitter (PIT), Level Transmitter (LIT), Temperature Transmitter (TIT), Level Switch (LSH), Pressure Switch (PSH), Blowdown Valve (BDV), Shutdown Valve (SDV), Actuated Deluge Valve (ADV), and Pressure Safety Valve (PSV) in the period 2019 – 2023. The analysis process in optimization in this research is shown in the flow diagram of Figure 1.

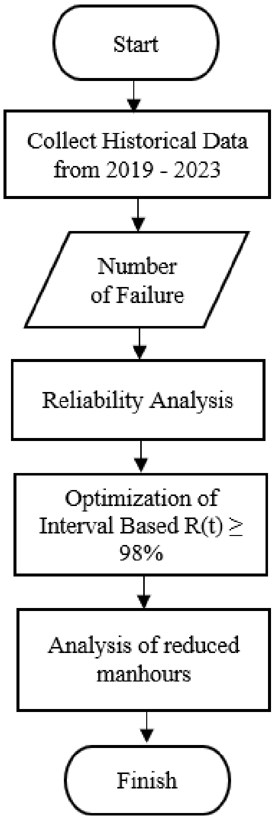

Figure 1. Research Flowchart

Information document related to the number of components, repair time, and repair category based on data for each job used for reliability analysis. with the number of damages in Table 1.

Table 1. Number of Component Failures for Each Platform

Platform (Location)	Number of Instrumentation Component Failures								
	TIT	PIT	LIT	LSH	PSH	BDV	SDV	ADV	PSV
1	0	4	0	3	10	0	33	0	1
2	0	0	0	4	1	1	6	0	0
3	5	1	30	0	0	14	44	0	5
4	7	15	14	0	1	14	57	5	11
5	0	0	0	0	0	0	3	0	0
6	0	0	0	0	0	0	7	0	0
7	0	0	4	7	5	2	6	0	1
Total per component	12	20	48	14	17	31	156	5	18

Reliability is the probability that a component will be able to perform a specific function under certain operating conditions and a certain time period (O'Connor, 1991). The time of failure for each piece of equipment is a random variable. Before calculating the reliability probability, it is necessary to statistically determine the distribution of equipment failures. The distribution of failures based on the failure time interval uses an exponential distribution to model a constant failure rate for a continuously operating system. The relationship between the reliability equation and the maintenance frequency interval is as follows.

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

$$t = 2\frac{\ln{(R)}}{-\lambda}$$

Information :

R(t) = Reliability function

e = Exponential (e = 2.71828)
λ = Rate of Deterioration

The failure rate is the probability that a component will fail within a given time interval, given that it was in good condition at the beginning of the interval. The failure rate equation is as follows.

$$\lambda = \frac{Number\ of\ Failure}{Total\ Operational\ Hours}$$

In preventive maintenance (PM), the maintenance frequency for each instrument component is determined based on the tool number (tag number) within a work order . To obtain the man-hours per tag, the average time to perform maintenance is calculated to determine the total annual maintenance time. Some maintenance schedules have associated tags; the best approach is to average the total man-hours across all associated tags to obtain the man-hours per tag. The analysis of the total annual man-hour calculation is calculated by summing the man-hours of all preventive maintenance tasks based on the specified frequency. For preventive maintenance, the total annual man-hour is calculated by summing the man-hours of all PM tasks based on the specified frequency. For example, a 12-month (12M) task is performed once a year. However, PMs with shorter intervals, such as 3 months (3M) and 1 month (1M) require further analysis using a job list, as some tasks may be interchangeable. For example, a 3M PM is expected to be performed four times a year, but if its job instruction coincides with a 12M PM, it may only be performed three times, with the fourth instance covered by the 12M PM. The failure proportion hypothesis test is performed on the doubtful reliability values to be extended in instrumentation components on a particular platform using the Two Proportion Z-Test . This test aims to determine statistically whether the difference in failure rates between two different maintenance intervals is truly significant or is simply caused by random sampling variation (Montgomery, 2019). The statistical hypothesis tested consists of the null hypothesis (H_0) which states there is no significant difference between the failure proportions at the compared maintenance intervals ($p_1 = p_2$), and the alternative hypothesis (H_1) which states there is a significant difference ($p_1 \neq p_2$) or that the failure proportion at the longer interval is greater ($p_1 < p_2$) for a one-way test. The statistical equation of the Two Proportion Z-Test for this case is.

$$Z = \frac{p_6 - p_{12}}{\sqrt{P(1-P)\left(\frac{1}{n_6} + \frac{1}{n_{12}}\right)}}$$

Information :

p_6 = Proportion of failures at 6-month intervals
p_{12} = Proportion of failures at 12-month intervals
n_{12} = Total operational time in 5 years (hours)
n_6 = Half the total operating time in 5 years (hours)

The value of the variable P(Pooled Proportion) is stated in the following equation.

$$P = \frac{(p_6.n_6) + (p_{12}.n_{12})}{n_6 + n_{12}}$$

The resulting Z-value is then compared with the critical value of the standard normal distribution at a significance level of $\alpha = 0.05$. If the p-value < α, then H_0 is rejected, indicating that the difference in the proportion of failures between the two intervals is statistically significant (Devore, 2015). This approach provides statistical validation of the proposed maintenance interval change recommendations. planned working hours will be reduced by the proposed future working hours , and the percentage savings can be calculated by dividing the reduced working hours by the planned working hours. The following is the working hour savings equation.

$$Saving = \frac{Planned - Future}{Planned} \times 100\%$$

RESULTS AND DISCUSSION

This study covers seven operational locations (platforms) with 10 instrumentation components whose reliability will be analyzed. The total number of working hours for all components analyzed over a five-year period, or 7,200 working hours, is shown in Table 2. The reliability values for each maintenance interval for each component are shown in Table 2.

Table 2. Reliability Values Based on Maintenance Time Intervals

Component	**Maintenance Time Interval**	
	6 Months (6M)	**12 Months (12M)**
P IT	99.86%	99.72%
L IT	99.67%	99.34%
TIT	99.92%	99.83%
LSH	99.90%	99.81%
PSH	99.88%	99.76%
BDV	99.80%	99.60%
SDV	98.92%	97.86%
ADV	99.97%	99.93%
PSV	99.88%	99.75%

Based on Table 2, concerning component reliability values based on maintenance intervals, it can be analyzed that, in general, all components experience a decrease in reliability as the maintenance interval increases. This indicates that the longer a component is operated without maintenance, the greater the likelihood of performance degradation. The Actuated Deluge Valve (ADV) component demonstrated the best performance with the highest reliability values at all intervals, ranging from 99.97% for the 6-month maintenance to 99.93% for the 12-month interval. Similarly, the Temperature Indicator Transmitter (TIT) and Level Switch High (LSH) demonstrated excellent reliability characteristics with a relatively gentle decline. Conversely, the Shutdown Valve (SDV) was the component with the lowest reliability and the most significant decline, from 98.92% at the 6-month interval to only 97.86% at the 12-month interval.

Therefore, extending the interval is not recommended. Other components, such as the Level Indicator Transmitter (LIT) and Blowdown Valve (BDV), also show a significant decline as the maintenance interval is extended. The decline in component reliability as maintenance intervals increase occurs due to accumulated wear and material aging, as well as continued operational exposure without intervention, such as regular inspections or maintenance. This phenomenon is more pronounced in components with demanding workloads and operating environments (API, 2016). Based on the results of the reliability level by considering technical and non-technical factors, the maintenance interval for each component can be proposed to be extended as in Table 3.

Table 3. Proposal to Extend Instrumentation Component Intervals

Component	**Platform**						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Pressure Transmitter	12M	12M	12M	12M	12M	-	-
Level Transmitter	6M	6M	-	-	-	-	6M
Pressure Switch	12M	-	12M	-	-	12M	12M
Level Switch	12M	12M	12M	-	-	12M	12M
Temperature Switch	-	12M	-	-	-	-	12M
Blowdown Valve	12M	12M	12M	-	-	12M	12M
Shutdown Valve	12M	12M	12M	12M	12M	12M	12M
Actuated Deluge Valve	12M	12M	-	-	-	-	-
Pressure Safety Valve	12M	12M	12M	-	-	12M	12M

Notes :

6M : Maintenance Interval Period Every 6 Months
12M : Maintenance Interval Period Every 12 Months

Table 3 explains that almost all components can have their maintenance intervals extended to 1 year. LIT components at platform locations 1 and 7 have a 6-month maintenance interval that allows cleaning to be carried out before the coating reaches a critical point. Plugging problems on impulse lines are prone to occur when the maintenance interval is extended to 12 months (Shah, MH, & Agashe, SD 2016). The different conditions of each platform make the workload factor vary by ensuring the integrity of the measurement data. SDV components have a 12-month maintenance interval that approaches the minimum acceptable reliability value of 98% according to the IEC 61511 standard. A significance test was performed on the SDV component to validate the extension of the maintenance interval using the Two-Proportion Z-Test with the null hypothesis (H_0) stating that there is no significant difference between the failure rates at 6-month (p_6) and 12-month (p_{12}) intervals. The test result for the critical SDV component showed a Z value = -1.212 with a p-value = 0.113. With a significance level of $\alpha = 0.05$, p-value > α indicates that there is insufficient statistical evidence to reject H_0. In other words, the difference in failure rates between 6-month (0.32%) and 12-month (0.38%) intervals is not statistically significant and can be considered as random variation. This finding strengthens the recommendation to extend the SDV maintenance interval to 12 months, as the risk of increased failures was not statistically evident. However, close monitoring is still needed considering that the absolute reliability of the SDV at the 12-month interval (97.86%) has approached the minimum acceptable limit of 98%. This statistical approach provides a more objective basis for making maintenance decisions than relying on absolute reliability values alone. Optimizing the frequency of maintenance intervals was done by optimizing employee working hours due to the extension of maintenance intervals. The results of optimizing working hours for each platform are shown in Figure 2.

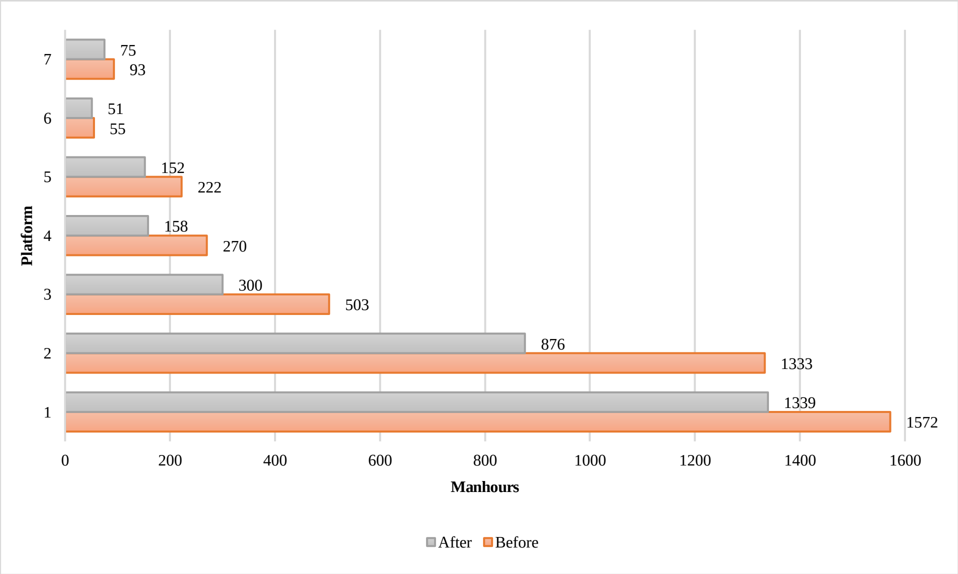

Figure 2. Results of Optimizing Working Hour Reduction

The results of optimizing the frequency of maintenance for instrumentation on each platform resulted in significant efficiency with a total saving of 27% of working hours, equivalent to 1097 hours, from the previous 4048 hours to 2951 hours, where the variation in the level of savings is different in each platform, the highest on Platform 3 and 4 respectively 40% and 42%, while the lowest on Platform 6 at 8%. This proves the implementation of a maintenance strategy based on conditions and risks specifically, shifting the paradigm from the conventional scheduled approach to a smarter model through the implementation of condition-based and predictive maintenance, which not only optimizes resource allocation and reduces operational costs, but also increases asset reliability, availability of production facilities, and overall operational safety.

CONCLUSION

Based on the analysis and discussion conducted, this study successfully achieved its objective of optimizing the maintenance frequency of SECE instrumentation. The implementation results show that the data-driven RCM approach allows for a significant extension of maintenance intervals for most components, such as the Shutdown Valve (SDV) which can be extended up to 12 months, without sacrificing system reliability. This application is not only theoretical, but has been implemented into the working system by producing specific schedule recommendations for each platform, as seen in platforms 3 and 4 which achieved the highest working hour efficiency of 40% and 42%. This success demonstrates an effective paradigm shift from conventional scheduled maintenance to a dynamic and risk-based strategy. For future development, this study recommends the integration of advanced statistical approaches, such as the Weibull distribution, and the application of predictive maintenance to further sharpen the accuracy of failure predictions and further optimize resource allocation.

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