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The Management of Power System Reliability in the Offshore Oil and Gas Field

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ABSTRACT

The reliability of electric power systems is needed in offshore oil and gas field operations because disruptions can have a direct impact on oil production, costs, and company profits.
***Objectives**: to determine the evaluation of reliability performance and propose a model for managing the power system reliability of the PHE OSES offshore oil and gas field.*
***Methodology**: A case study with data collected through observation, interviews, and analysis of relevant documents.*
***Finding**: Reliability in 2015-2016 has not reached the target but from 2017-2021 has reached the target of 97.5%, as well as availability in 2015, 2018, 2019 & 2020 has not reached the target but in 2016, 2017 & 2021 has reached the target of 95%. This resulted in the highest production losses in 2015 at 266,965 and the lowest in 2021 at 21,388 barrels of oil. The model is proposed by combining elements in risk-based asset management method, RCM method, and redesign.*
***Conclusion**: In recent years, reliability has been on target but availability is volatile. The model is proposed to maintain reliability & availability on target so that production losses can be minimized.*

***Keywords**: Electric Power System; reliability; offshore oil and gas field.*

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INTRODUCTION

An oil and gas field or commonly referred to as an oil and gas working area (WK) is a WK that has been approved by the Ministry of Energy and Mineral Resources (ESDM) to be operated by a Cooperation Contract Contractor (PSC Contractor). The main activities in the upstream oil and gas business are exploration and exploitation. Exploration can be referred to as an activity to obtain information regarding geological conditions to find and obtain estimates of oil and gas reserves while exploitation is an activity to produce oil and gas from the working area. (de Sanctis et al., 2016) state that some of the problems or challenges in offshore oil and gas field production operations are high operating costs, guaranteeing high facility availability, safety, and environmental protection. (Kurniawan et al., 2017) state that safety and environmental issue are strategic issues and a top priority in the upstream oil and gas industry. (Munirah et al., 2019) state that accidents in offshore oil and gas fields are unavoidable and can lead to more severity for workers.

Pertamina Hulu Energi Offshore South East Sumatra (PHE OSES) is a PSC Contractor with its operating area located in the Java Sea or more precisely in the southeast area of Sumatra Island (OSES = Offshore Southeast Sumatra). WK OSES has been operating since 1968 with a total of 109 platforms. WK OSES, like other oil fields that are generally quite old, experienced a decline in petroleum production. Data in 2015 showed the average daily production reached 33,091 barrels of oil per day while in 2021, it became 24,338 barrels of oil per day.

Various incidents of disturbances in the PHE OSES electric power system that resulted in the loss of production (LOP) indicated the need for improvements in the PHE OSES electric power system. Data shows that LOP due to disturbances in the electric power system from 2015 to 2021 was 554,920 barrels with the largest in 2015 at 266,965 barrels and the smallest in 2021 at 21,388 barrels. With an average Indonesia Crude Price (ICP) in December 2021 of $73.36 per barrel, the LOP in 2021 is equivalent to $1,569,023.68. Furthermore, in operation, PHE OSES experiences several challenges such as an average equipment life of more than 30 years, generally high operating costs, and safety concerns for workers & environment. This encourages the author to explore the reliability management of the PHE OSES electric power system through asset integrity management with a risk approach that will result in recommendations regarding the determination of assets for maintenance and redesign. In the context of oil and gas companies, unplanned shutdowns caused by unexpected failures usually require expensive costs and a long time than planned shutdowns due to their complexity and difficulty (de Sanctis et al., 2016), therefore system availability is fundamental (Hussin et al., 2013; Rajpal et al., 2006). Planned maintenance programs affect equipment availability (Iftari & Nugroho, 2016) & Supply chain/availability of spare parts can affect job performance (Sutawijaya & Marlapa, 2016; Apriyani et al., 2018; Firdaus & Zakaria, 2018). Based on the previous research above, maintenance with the RCM method is appropriate because RCM focuses on the functioning of the system (Rausand, 1998) and brings maintenance to assets where reliability is critical (Garg & Deshmukh, 2006). When maintenance is not enough to reduce risk to a tolerable level and or resources (assets) are currently unable to solve the existing problem, it is necessary to redesign.

LITERATURE REVIEW

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Research on the reliability management of offshore oil and gas field power systems using risk-based asset integrity management is still very rare. Most of the research on reliability in the oil and gas field is regarding the reliability analysis of pipelines (Ahmad et al., 2018; Omoya et al., 2019), processing facilities (Naseri & Barabady, 2014, 2016), safety instrument systems (Lundteigen & Rausand, 2009), humans (Ramos et al., 2020), power electronic equipment (Tripathi & Srivastava, 2018) & high-pressure compressors (Izzaidah, 2016).

In the electric power business that strongly maintains outages (disturbances), some research regarding the reliability of electric power systems has been made such as plant reliability (Martinek et al., 2017; Palakodeti et al., 2020), transformers (Chafai et al., 2016), switchgears (Chen et al., 2018; Ruan et al., 2020), protection (Zhang, 2012), power grids both transmission and distribution (Boateng et al., 2003; Khudyakov, 2011; Tien et al., 2018), & systems (Pinchukov & Makasheva, 2018).

The reliability of the electric power system is a major concern because it exerts tremendous pressure on transmission and distribution assets which is the greatest risk of power supply disruptions. Therefore, risk analysis is an important part of asset management (Khuntia et al., 2016). This is in line with the oil and gas business infrastructure or assets in oil and gas fields that are rapidly aging which would increase the risk of failure. For operators, this increases the challenge of maintaining asset reliability (Akashraj & Maleith, 2020). The risk-based methodology presents a cost-effective way to minimize lifecycle costs in asset management while maintaining reliability or availability and operating within the safety and environmental regulations (Bharadwaj et al., 2012).

Asset integrity management with a risk-based approach when compared to other approaches. This approach provides flexibility in asset management to meet the same goals. Flexibility is the result of performing actions not on a fixed schedule or rule but on some identified risk measure. The risk-based approach uses risk-based criteria to prioritize efforts and make optimal use of this flexibility (Bharadwaj et al., 2012).

Below is an example of a risk matrix, it can be seen that assets A and B have greater risk than assets C so the maintenance of assets A and B is tighter than assets C. (Gulati, 2021)

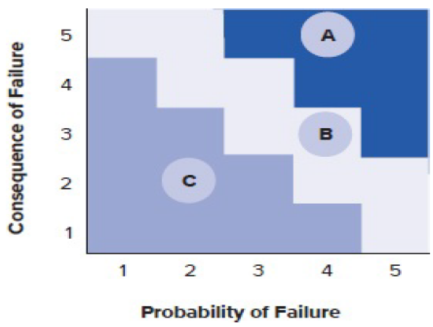

Figure 1: Risk Matrix

Source: (Gulati, 2021)

Reliability-Centered Maintenance (RCM) is a process used to determine what must be done so that the physical assets owned can continue to be used following their design and function

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(Moubray, 1997). RCM's philosophy considers preventive, predictive, condition-based, reactive, and proactive maintenance in an integrated manner to increase the probability that an asset will function as required throughout its design life with minimum maintenance. The goal is to establish the required functions of a piece of equipment/system by meeting the availability and reliability needed at a low cost. The essence of RCM is to manage the consequences of failure (Geisbush & Ariaratnam, 2022).

A redesign is an option when maintenance is not enough to reduce risk to a tolerable level and or resources (assets) are currently unable to solve existing problems so additional resources are needed. Redesign generally consists of several stages such as feasibility study, preliminary engineering, detailed engineering, execution, and commissioning.

This research is different from previous research at least in two points:

1. Research regarding the reliability management of offshore oil and gas field power systems is still very rare
2. Model proposal by combining asset integrity management based on risk, maintenance methods in this case RCM, and redesign methods

Therefore, this research has a contribution to the reliability management of offshore oil and gas field power systems.

Tabel 1: Literature Review

		Bharadwaj et al., 2012	Martinek et al., 2017	Chafai et al., 2016	Chen et al., 2018	Zhang, 2012	de Sanctis et al., 2016	Khuntia et al., 2016	Omoya, 2019	Lundteigen & Rausand, 2009	Tripathi & Srivastava, 2018	Izzaidah, 2016	Welly (2023)
	Reliability		■	■	■	■	■	■	■	■	■	■	■
Industry	Oil & Gas						■		■	■	■	■	■
	Electric Power	■	■	■	■	■		■					
Asset	Process system						■						
	Safety Instrumented System									■			
	Power Electronic										■		
	High Pressure Compressor											■	
	Pipe								■				
	Electric Power System	■						■					■
	Power Generation		■										
	Transformer			■									
	Switchgear				■								
	Protection system					■							
Method	Asset Management							■					
	Risk-based Asset Management	■						■					■
	Maintenance	■					■				■		
	Maintenance - RCM				■		■						■
	Redesign										■		■
	Reliability Analysed using exponential distribution & Weibull distribution		■	■									
	Time-Spatial-Source dimension coordinated reliability evaluation model				■								
	Fault Tree Analysis				■	■				■			
	Reliability Block Diagram			■									■
	Reliability, Availability, Maintainability Analysis						■		■			■	■

METHOD

The data analysis method in this study uses the reliability, availability, and maintainability (RAM) & Reliability block diagram (RBD) method which will perform calculations to obtain index availability, MTBF & reliability. RAM analysis was chosen because electric power is generated, distributed, and used by PHE OSES itself. This method has been applied to other equipment in the oil and gas industry such as oil and gas production facilities (de Sanctis et al., 2016), reciprocation compressors (Corvaro et al., 2017), and high-pressure compressors (Izzaidah, 2016). RBD analysis is a way to reduce a system to a series and simple parallel series of components or assets that can be analyzed using mathematical equations. With the

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implementation in the oil and gas field, the LOP calculation will also be carried out. (Gulati, 2021)

The data sources in this study are primary data and secondary data. Primary data in the form of equipment/asset information or data such as nameplates, operating parameter data such as amperes, working time data of assets/equipment, and equipment disturbance time data such as the cause of the fault along with LOP data in the Power & Gas department of PHE OSES. Secondary data in the form of other data related to this study such as Indonesian MIGAS production data obtained from the SKK MIGAS annual report, data from previous research, and other data related to this research.

Data collection was obtained by conducting observations and interviews with the Sr Supervisor power system, Sr Operations Supervisor, and Sr Supervisor maintenance in the PGPI department as well as analyzing relevant documents. The place where the research was conducted in the offshore oil and gas field PHE OSES.

Reliability Calculation

Calculation of reliability using equations (Gulati, 2021)

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

Where λ is the failure rate (number of failures/year).

Mean Time Between Failure (MTBF) Calculation

MTBF calculation using equation(SMRP, 2017)

$$MTBF = \frac{Operating\ Time\ (hrs)}{Number\ of\ failures}$$

Availability calculation

Availability calculation using equation (SMRP, 2017)

$$Availability\ (\%) = \frac{Uptime\ (hrs)}{Total\ Available\ time - Idle\ Time}\ X\ 100$$

Loss of Production (LOP)

LOP states that the data on production loss due to disruption, the data used is data on production loss due to disruption to the electric power system.

Reliability Blok Diagram (RBD)

The reliability of a system consisting of several components in a series array is (Gulati, 2021)

$$Rsys = R1x\ R2\ x\ R3\ X \dots X\ Rn$$

The reliability of a system consisting of several components in a parallel arrangement is (Gulati, 2021)

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$$Rsys\ xy = 1 - ((1 - Rx)\ (1 - Ry))$$

RESULTS AND DISCUSSION

PHE OSES in operations is divided into several departments, namely South (which operates the south region), Central (which operates the central region), North which operates the north region), and PGPI (which operates power plants, gas plants, water treatment and maintenance facility on Pabelokan Island). The Power & gas department operates a power plant with an installed capacity of 120 MW, the transmission of electric power using submarine cables with an average equipment life of more than 30 years. Here is a one-line diagram of the PHE OSES electric power system consisting of electric power generation, transmission & distribution.

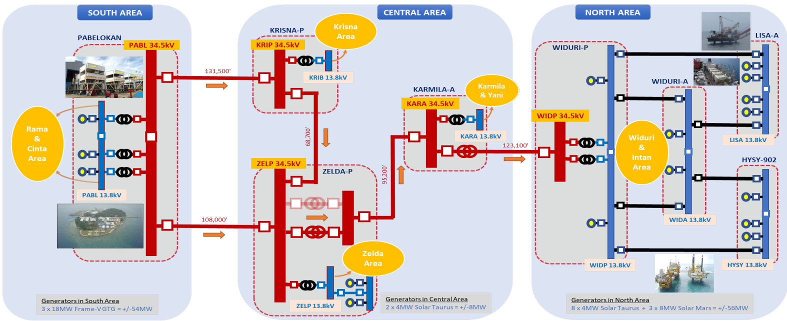


Figure 2: PHE OSES Electric Power System

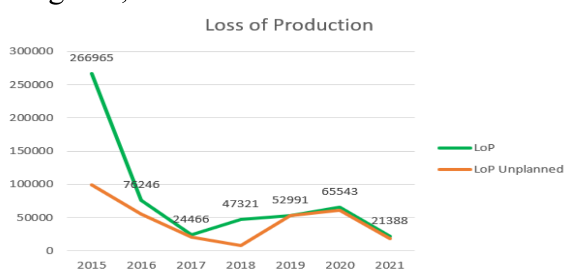
Source: Powersys PHE OSES

PGPI is responsible for the operation, maintenance, and engineering of the electric power system facilities so that the electricity produced is reliable and of high quality which can ultimately be used by the South / Central / North in producing oil and gas.

Here are some philosophies of operating the PHE OSES electric power system:

1. Normal conditions:
   i. Generation in Pabelokan operates in isochronous mode as a spinning reserve.
   ii. The electric power system operates interconnected with the flow of power from south to north
2. Interference conditions:
   i. Protection systems are intended to isolate interference effectively and efficiently.
3. Abnormal conditions:
   i. In islanding operations, the load on the North will be supplied only by generation in the North. South Central will be separate from North.

The LOP in the Power & Gas department from 2015 to 2021 was 554,920 barrels of oil (bo) with the largest in 2015 being 266,965 bo and the smallest in 2021 at 21,388 bo.



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Gambar 3: LOP PGPI FACTION OSES

Source: PGPI PHE OSES

LOP in Power & Gas departments can be caused by various things such as disruptions to plants or disruptions to distribution. Data in 2015-2021 shows that the largest contribution of LOP, namely 43% is due to unplanned shutdowns in power distribution.

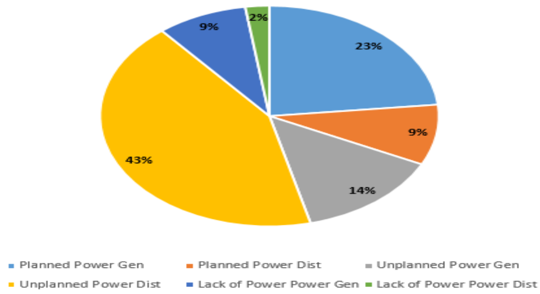

Figure 4: Causes of LOP PGPI PHE OSES

Source: PGPI PHE OSES

The trend of reliability of the PHE OSES electric power system can be seen in Figure 5. As shown in Figure 5, reliability is above the target of 97.5% since 2017.

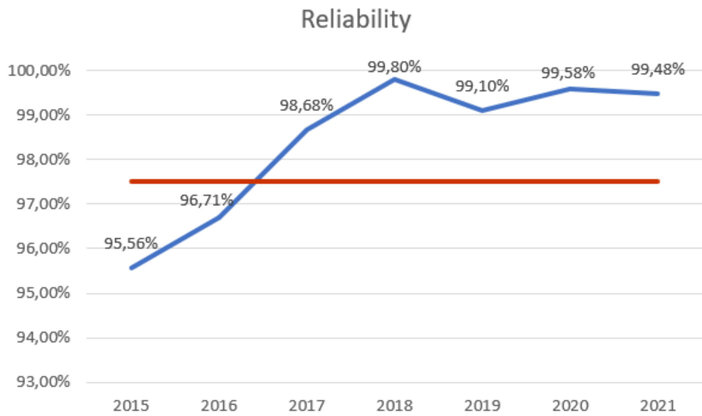

Figure 5: PHE OSES Electric Power System Reliability

Source: PGPI PHE OSES

The trend of the availability of the PHE OSES electric power system can be seen in Figure 6 below. Availability in 2015, 2018, 2019 & 2020 was below the target of 95%.

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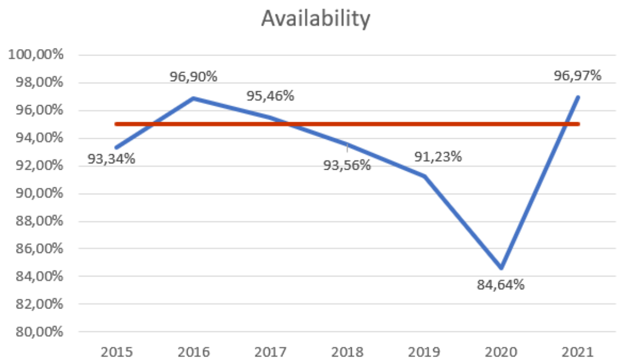

Figure 6: Availability of PHE OSES Electric Power System

Source: PGPI PHE OSES

The MTBF trend of the PHE OSES electric power system can be seen in Figure 7. The highest MTBF value was in 2018.

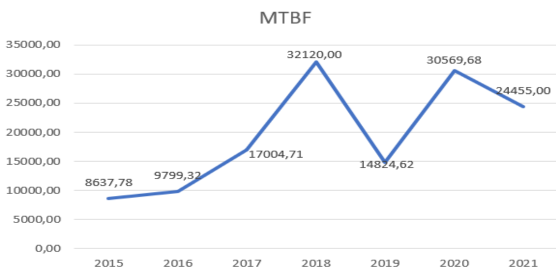

Figure 7: MTBF PHE OSES Electric Power System

Source: PGPI PHE OSES

Model Proposal

To ensure the availability of electrical energy, PHE OSES continuously strives to optimize the use of available assets while ensuring the reliability of the system is within satisfactory limits. Based on previous research, the way to manage the reliability of electric power systems in offshore oil and gas fields is to be helped by asset integrity management with a risk approach. Asset integrity management with a risk approach is carried out by focusing on high-risk assets and optimizing resources by reducing the focus on low-risk assets. (Tang et al., 2015) states that Reliability Centered Maintenance (RCM) makes maintenance methods for drilling and production equipment effective. (Zakikhani et al., 2020) states that RCM can be used for the improvement of the availability of 24" gas transmission pipelines. Based on the above, maintenance with the RCM method is appropriate because RCM focuses on the functioning of the system (Rausand, 1998) and brings maintenance to assets where reliability is critical (Garg & Deshmukh, 2006). When maintenance is not enough to lower the risk to a tolerable level and or assets are currently unable to solve the existing problem, it is necessary to redesign. A redesign can be like a project such as the improvement of protection systems. Therefore, it is generally related to asset investment and is carried out in several stages such as feasibility studies, preliminary engineering, detailed engineering, execution, and commissioning.

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Based on the analysis above, a model in this study is prepared by combining asset integrity management based on risk, maintenance methods in this case RCM, and redesign methods. In asset integrity management, asset data collection will be carried out and verification related to factors that affect the Probability of Failure (PoF) and Consequence of Failure (CoF). After that, a risk matrix will be created to obtain data related to assets that can be carried out by maintenance (RCM) and redesign. In the RCM method, assets will be identified for maintenance based on the results of the risk matrix, reliability index evaluation, and LOP. After that, an FMEA analysis and decision diagram analysis will be carried out to choose alternative maintenance. In the redesign method, one of the redesign projects will be identified based on the results of the risk matrix, reliability index evaluation, and LOP. After that, preliminary design, detailed engineering, commissioning, and cost-benefit analysis will be carried out.

The combination of these methods is expected to maintain reliability & availability on target so that production losses can be minimized. The measurement plan of this model is 6 months from May to October 2022 then calculations such as reliability and availability will be carried out. The framework scheme of this study can be seen in Figure 8. In the preparation of the model, several assumptions were made such as:

1. The Number of assets is large & diverse in the electric power system
2. Operation & maintenance activities are carried out by the company (PHE OSES) and the use of electrical energy for the company itself.
3. Aspects of safety & environment are taken into account in the calculation of risks.
4. The cost of maintaining and replacing assets has not been taken into account.

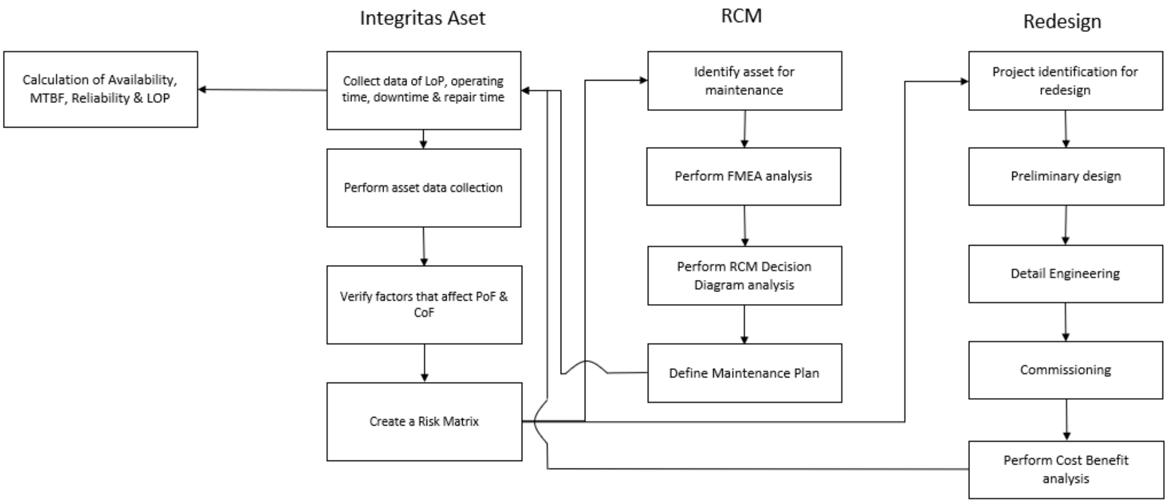

Figure 8: Model Scheme for Managing the reliability of offshore oil and gas fields

CONCLUSION

The conclusions that can be drawn from the results of the discussion are as follows:

1. In recent years, reliability has been on target of 97.5% from 2017 - 2021 but availability is still volatile.

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2. The model is proposed by combining elements in risk-based asset management method, RCM method, and redesign proposed to maintain reliability & availability on target so that production losses can be minimized.
3. As a suggestion, it is necessary to develop a model using other factors that can influence the risk to complement the probability of failure (PoF) & consequence of failure (CoF).

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