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RISK COST-BENEFIT ANALYSIS OF 3 GI ANGKE TRANSFORMERS TO ACHIEVE OPTIMAL MITIGATION

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Abstract

The power transformer is one of the leading electrical instruments used to transmit electrical power between generators to adjust the voltage without changing its frequency. Like any other machine, the power transformer will experience degradation over time. High electrical resistance, external factors and environmental temperature could lead to faster degradation. This degradation usually affects transformer isolation material. Degradation of this component furthermore will decrease power transformer efficiency. In 2022, power transformer 3 GI Angke has been used for 28 years, while PT PLN (Persero) has decided that power transformers operating for over 25 years fall into the category of the old machine and need to be replaced. The last asset wellness maintenance data showed that ethane was found in the oil insulation in the second level inspection. The third level inspection also showed degradation of bushing insulation, with the tan delta test result showing the value of 1.28. Asset wellness management is needed in this situation to ensure stability. There are two mitigation options available, to replace some of the components or replace the power transformer altogether. Risk, cost and benefit analysis using a multicriteria approach is used in choosing the best mitigation approach for PT PLN (Persero).

Keywords: asset management, power transformer, multi-criteria analysis

Introduction

PT PLN (Persero) is responsible for supplying electricity for all customers. Electricity is generated from the generator through transmission and distribution lines so that customers can use the electricity. One of the vital components of the electricity distribution system is the power transformer. To maintain stable service, power transformers with an operating age of over 25 years are included in the old category according to PLN's SK DIR 149.

One of the transformers managed by PLN is transformer three at GI Angke. This transformer is 28 years old. Based on the last test results, an assessment of the Health Index of the transformer was carried out.

Determination of equipment health index using logic OR

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Table 1. Classification Of 1,6, 9 For Each Inspection Item.

No	Sub System	Item Inspection	Test Result	Score Item Inspection	Score Subsystem	Score Health Index
1	Dielectric	DGA	548.21 (4)	1	1	
2	Current Carrying unit	Tan Delta	1.63 %	1	1	1
3	Bushing	Tan Delta	1.38 %	1	1	

Based on table 1, the health index of the 3 GI Angke transformer is 1. Moreover, the susceptibility of the 3 GI Angke transformer is determined using the data below.

Table 2
Susceptibility Simulation Scoring Results.

No	Parameter Susceptibility	Score	Index	Average	Susceptibility
1	Average loading (1 year)	79.6 %	6		
2	TFC	270100	6		
3	Neutral	12 ohms	6	28/5 =5.5	6
4	Life	>25	1		
5	load type	Linear	9		

Based on table 2, the susceptibility of the transformer 3 GI Angke = 6

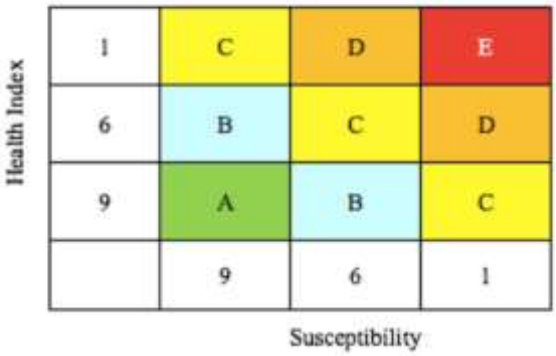

Figure 1. The Risk Assessment Matrix

Following the health index score = 1 and the susceptibility score = 6, using the matrix above, the *probability of failure* 3 GI transformer Angke = DIn order to determine the priority of work, the probability of failure is combined with the GI criticality. Transformer #3 GI Angke has a criticality level of 4, so based on the matrix below, the priority of work on transformer #3 GI Angke is priority 1 (red).

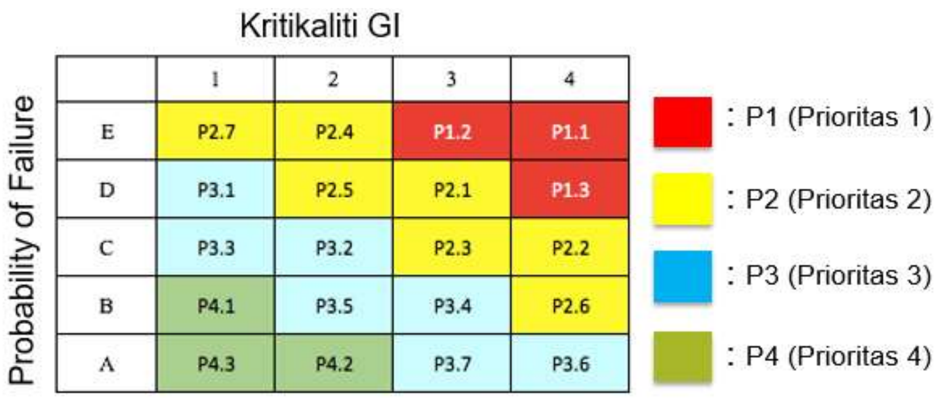

Figure 2. Matrix For Determining The Priority

An old Power Transformer is very susceptible to failure due to a decrease in the quality of insulation or damage to its components. To minimize interference, the old transformer can be taken corrective action. Actions that can be taken care in the form of replacing a new transformer or repairing damaged components. Each mitigation action has its advantages and disadvantages. For this reason, it is necessary to analyze the costs/benefits and risks of the two mitigation action options. Limited resources and time owned by PT PLN (Persero) are essential considerations in determining mitigation actions with the most optimal benefits.

Cost analysis is related to the investment costs required in mitigation actions. Risk analysis includes the calculation of machine usability and customer satisfaction. In comparison, the benefit analysis calculates the efficiency of the machine and the company's profits. These three factors are summarized into the following 5 criteria, which are used as considerations in selecting mitigation actions, including:

1. **% Transformer Readiness**

   % transformer readiness is the percentage of transformer readiness in delivering electrical power to its nameplate capacity. A decrease in % transformer readiness occurs if the results of the transformer assessment show deterioration. The assessment parameters used in the loading reference are DGA test assessments, oil characteristics and electrical tests. In this journal, % transformer readiness is divided into 3 with the distribution of values:

   2: declaration of % transformer readiness >90%

   1: 80 % < declaration of % readiness transformer < 90%

   0: declaration % transformer readiness < 80%

2. **Power Transformer Life**

   Transformer life is when the transformer can operate since it is first energized. The longer the transformer can operate, the better for PT PLN (Persero) due to the large investment costs for new transformer installations starting from the

procurement of transformers until the transformer can finally be energized. Transformer life is grouped into 3 value categories:
2: lifetime >15 years
1: lifetime 5-15 years
0: lifetime <5 years

3. **Investment cost**

   The number of investment costs causes stakeholders to consider the available options in dealing with the case of a transformer that has deteriorated. This is important because PT PLN (Persero) manages GIs throughout Indonesia, where each GI has its transformer problem. Investment costs are also categorized into 3 value groups:
   2: investment costs<1M
   1: investment costs 1-10M
   0: investment costs >10M

4. **Rupiah ENS (Energy Not Served)**

   The reliability of a transformer can be seen from the frequency and duration of the transformer experiencing disturbances. One of the indicators used is the ENS transformer. This ENS is used to determine the number of losses experienced by PT PLN (Persero) due to the transformer not operating due to interference. The amount of ENS rupiah is categorized into 3 values:
   2: ENS Rupiah = IDR 0, -
   1: ENS Rupiah = IDR 0, - to IDR 86, 820, 000, -
   0: ENS Rupiah > 86, 820, 000, -

5. **Level of customer satisfaction**

   Apart from pursuing profit, PT PLN (Persero) as a BUMN must also pay attention to customer satisfaction. The level of customer satisfaction can be seen through the level of voltage and frequency that reaches the customer's house line, the number of power outages and customer complaint reports. The level of customer satisfaction is grouped into 3 values:
   2: nominal voltage
   1: voltage drop
   0: complaints occur

Each value of the 5 criteria above is used to compare the two available mitigation actions.

Table 3
Criteria for comparing mitigation options

	Value		
Criterion	2	1	0
Efficiency	>85 %	60 - 85 %	<60 %

Lifespan	>15 years	5 - 15 years	<5 years
Investment Cost	<1 M	1 - 10 M	>10 M
Rupiah ENS	Rp 0	Rp 0,- up to Rp 86.820.000,-	> Rp 86.82 million,-
Customer Satisfaction Level	Nominal	Voltage Drop Voltage	Complaints

Research Methods

The process of selecting mitigation options using risk and cost-benefit analysis. The research started with collecting test data, conducting a risk analysis, and analyzing economic feasibility, and then a multi-criteria analysis was carried out.

The results of the calculation of the condition of the 3 GI Angke power transformer after mitigation were tested with the 5 criteria listed in the previous table. To determine the weight of each criterion, a questionnaire was given to stakeholders and experts. The average of the importance of each criterion is used as a tool to obtain the most optimal mitigation action.

1. **Risk Analysis**

   Risks that may occur if no mitigation measures are selected. The operation of the 3 GI Angke transformer without any repairs will make the transformer prone to breakdown. The material risk is worth more than 6,000,000,000 rupiahs.

2. **Economic feasibility analysis**

   Economic feasibility analysis is carried out by calculating investment costs and rupiah ENS

3. **Investment Cost Calculation for Replacement and Repair of Transformer #3 GI Angke**

   The budget plan is an analysis carried out to interpret the costs that will be used to complete a project. A review of the budget plan is carried out before the project is implemented. How to calculate the costs that will be incurred to work on a project according to the following equation:

   RAB = Volume of work x Unit Price

   RAB Transformer Replacement = IDR 11,829,649,850

   RAB Transformer Repair = IDR 268,094,603

4. **Rupiah ENS (Energy Not Served)**

   ENS is the sum of MWh that has not been distributed to customers for 1 year due to power supply interruptions. ENS is calculated by:

   $$ENS = \Sigma[gangguan(MW)xdurasi(h)]$$

   While AENS is the average amount of energy that is not channelled into the distribution system in 1 year.

   $$AENS = \frac{\Sigma ENS}{n(tahun)}$$

   ENS data in this study using transformer fault data in the Duri Kosambi ULTG area from 2019 to 2022. The selected ENS is transformer fault due to equipment conditions. During the last 3 years, transformers with less than 5 years of operation have never experienced problems due to equipment conditions. Meanwhile, for transformers over 25 years old, there has been 1-time fault due to damage to the control cable, which resulted in a sudden pressure relay experiencing a short circuit.

The total ENS in the Duri Kosambi ULTG area in the last 3 years for transformers aged over 25 years can be calculated:

$$ENS = 0{,}42\ MWh$$

$$AENS = \frac{0{,}42}{3} = 0{,}14\ MWh$$

Using the electricity selling price of rupiah for over 25 years are:

Rupiah ENS = 0.14 MWh x Rp 1477,- = Rp 206.780,-

Table 4
Calculation Result of Power Transformer ENS

	Transformer age < 5 years	Transformer age > 25 years
ENS	0	0.42 MWh
AENS	0	0.14 MWh
Rupiah ENS	0	Rp 207.780,-

Results and Discussion

The value of each mitigation option is shown in the following table:

Table 5
Multi-Criteria Analysis Scoring Results

Criteria	Weight	Transformer replacement		Transformer repairment	
Declaration % Transformer readiness	23	Good (2)	0.46	Medium (1)	0.23
Lifespan	22	Long (2)	0.44	Short (0)	0
Investment Cost	17	Expensive (0)	0	Cheap(2)	0.34
Rupiah ENS	17	Rp 0 (2)	0.34	Rp 207,780(1)	0.17
Customer Satisfaction Level	21	Satisfied (2)	0.42	Satisfied (2)	0.42
Total	100		1.66		1.16

Based on the results of the multi-criteria analysis in the table above, it can be seen that the transformer replacement score is 1.66 while the transformer repair score is 1.16. Overall, power transformer replacement is worth more engine efficiency and long service life. The new power transformer will produce a higher efficiency than the repaired old power transformer. Although transformer repairs require fewer investment costs, both mitigation options have the same value in terms of Return on Investment. From the two mitigation options, PT PLN (Persero) will get the entire investment cost back in less than one year. By considering these values, the conclusion that can be drawn is that for a 3 GI Angke power transformer, the mitigation option of replacing a transformer is better and more profitable than repairing a few components.

Conclusion

Multi-criteria analysis can help select more profitable mitigation options for PT PLN (Persero). From the analysis that has been carried out in considering the best mitigation options for the 3 GI Angke Transformer, the transformer replacement option is superior, with a difference of 0.50 in value. An assessment using more complex and varied data is needed to validate the multi-criteria analysis.

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