Feasibility analysis of DMSY cubicle in Dago Pakar substation, Indonesia, using FMEA, technical age, NPV and economic age

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Abstract. Cubicle is used as dividers, breakers, connectors, controllers and safety of power delivery systems. Based on data of APN West Java APD asset maintenance in 2016 and 2017, it is known that there are 10171 asset anomaly. Of the total anomaly, about 4% of disorders were experienced by cubicles. Data of the cubicle disorder, the author's main consideration to know more about the role and function of the aspect of the feasibility value. The X brand is one of the cubicle brands that often experience interference. In this research, the authors conducted a feasibility study related to the feasibility of operating the DMSY X feeder cubicle (Desa Mekar Saluyu) at the Dago Pakar substation based on technical age through simple load forecasting and FMEA (Risk Priority Number) RPN (Failure Mode and Effect Analysis) cubicles and financial feasibility based on NPV (Net Present Value) and economic life of cubicles. From the results of this research, DMSY brand X feeder cubicles were declared feasible to operate even though the results of the DMSY cubicle economic age analysis only until 2015. This is because the cubicle load forecasting this year is still within the limits of cubicles, this cubicle has never experienced interference based on interference data, and in NPV, cubicle provides a net benefit (Net Benefit) which is greater than the investment value of Rp. 35,576,912,923.27.

1. Introduction
Cubicle of 20 kV is one of the important components to deliver electrical energy from the transmission system to the distribution system which will be channeled to consumer, either small, medium or consumer priority [1]. Cubicles act as dividers, breakers, connectors, controllers and electrical supply systems [1].

Based on data of APN West Java APD asset maintenance in 2016 and 2017, it is known that there have been 1017 asset disturbances. Of the total disturbance, about 4% of the anomalies experienced cubicles. Data of the cubicle disorder, the author's main consideration to know more about the role and function of the aspect of the feasibility value.

There are several studies related to the feasibility study, such as, research on the feasibility study of CNC machine tool with method of failure mode and securities analysis (FMEA) on CNC machine tool based on Set Pair Analysis (SPA) to obtain RPN value for known value of feasibility of the tool [2]. Furthermore, there is a research that analyzes technical feasibility by using ACM-0001 method specifically to know the optimal use of biogas place. Then the study analyzes the economic feasibility of using NPV (Net Present Value), MIRR (Modified Internal Rate of Return) and Payback method [3].

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Then there is the study of the technical and economic model of the discounted cost used based on the linearization method that has been developed and studied to reduce the time and cost of the integrated voltage selection and configuration of the power grid [4].

In this study, the authors use cubicles in the repeater DMSY as the object of research, due to the main substation Dago Pakar there is one brand of cubicles that often experience anomalies. In this study, the authors conducted a feasibility study related to the feasibility of cultivation operation of DMSY coppers (Mekar Saluyu Village) in Dago Pakar substations based on simple load forecasting and RPN (Risk Priority Number) of FMEA (Failure Mode and Effect Analysis) cubicles and financial feasibility based on NPV (Net Present Value) and economic life of cubicles. This research was conducted to find out the feasibility level of coppers repeater DMSY based on the aspect of operation / technical or financial.

Feasibility Study

The feasibility study is an activity that deeply studies a business activity or business that will be run in order to determine whether or not the business is run [5]. The feasibility study is divided into five aspects, namely marketing and market aspects, technical aspects of production and technological, management aspects, legal aspects, and financial or financial aspects [6]. In this study, the focus of the discussion will be on the technical aspects and financial or financial aspects.

Technical aspects include project studies to assess whether a project is technically feasible [7]. This analysis is examined through various alternatives relating to the needs and the supply of personnel, the needs of infrastructure facilities and other needs. Therefore, technical analysis is more aimed at determining machinery and equipment, raw materials, human resources, production procedures, and so on. The financial or financial aspect has several points to be discussed as follows [6]:

- Estimated working capital
- Estimated investment cost
- Estimated cost of production
- Estimated profit and loss
- Balance sheet estimates
- Sources of financing
- Investment and feasibility analysis

1.1. FMEA (Failure Mode and Effect Analysis)

FMEA is a thorough engineering analysis to analyze product design or manufacturing process at the beginning of product development [8]. FMEA aims to find and correct errors before the product reaches the customer [9]. If this method is used effectively it will result in a significant increase in reliability, safety, quality, and cost.

FMEA has eleven components that are used to evaluate failure modes and effects on the problem of items, functions, potential failure modes, Potential Effects (s), Severity, Potential Cause (s) of failure, Occurrence, Current design controls (prevention and detection), Detection, RPN, and Recommended action(s) [10].

![Figure 1. FMEA worksheet.](image-url)

- Item is a tool that becomes the focus of FMEA analysis. Items are filled with components or subsystems to be analyzed using the FMEA method.
- Function is a component on FMEA that contains the function or performance of an item.
Failure mode is a potential failure that may occur on an item to meet the desired function or performance.

Effect mode is a consequence arising from the interference in a system.

Severity, Occurrence, and detection are the rank numbers associated with the level of damage, the intensity of the event, and the level of detection of failures that occur on an item. Below are ratings of severity, occurrence, and detection based on Failure Mode and Effects Analysis manuals from Automotive Industry Action Group (AIAG).

Cause is a specific reason for the cause of an interruption of an item.

Control is an existing or planned activities to reduce or eliminate the possibility of interference based on FMEA analysis.

RPN (Risk Priority Number) is the product of severity occurrence and detection used to determine the severity of the effect that may arise due to failure based on FMEA analysis. RPN can be used for feasibility analysis of an asset by considering severity occurrence and detection. The mathematical RPN equation can be written as follow:

$$RPN = S \times O \times D$$ (1)

Where,

- S = Severity
- O = Occurrence
- D = Detection

According on AIAG and discussions with PLN, Kubikel is considered feasible to operate technically if the RPN value of this cubicle is less than 27 and/or PT (Action Priority) is not more than the "medium" level.

1.2. Forecasting

In a feasibility study, forecasting is a method used to determine the business prospects of a project to be held [11]. In this study, the regression method used forecasting load and cost. Trend, regression and correlation methods are methods used to identify a number of input variables to predict a particular response or output behavior [12]. Regression method is divided into two types: linear regression and nonlinear regression. For simple linear regression it has the following equation [13]:

$$y = a + bx$$ (2)

Where:
- y = dependent variable, estimated cost to be calculated
- a = Constanta / Fixed cost
- b = regression coefficient / variable cost / unit
- x = independent variable

The values of an and b can be calculated using the equation below [13,14]:

$$a = \frac{(\Sigma y)(\Sigma x^2) - (\Sigma x)(\Sigma xy)}{\Sigma x^2 - (\Sigma x)^2}$$

$$b = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{n\Sigma x^2 - (\Sigma x)^2}$$

The nonlinear regression equation (polynomial) can be mathematically written as follows [5]:

$$y = a + bx + cx^2$$ (3)

Where:
- y = dependent variable (estimated cost to be calculated)
- a, b, and c = constants
- x = independent variable

The first step of solving the equation above, the author uses the equation below:
Then the three equations above are converted into 3x3 matrices as below:

\[
\begin{bmatrix}
\sum y - a \sum x + b \sum x^2 + c \sum x^3 \\
\sum xy = a \sum x + b \sum x^2 + c \sum x^3 \\
\sum x^2 y = a \sum x^2 + b \sum x^3 + c \sum x^4
\end{bmatrix}
\]

Then the equations above are solved using the Cramer method.

With the cramer method, the above matrix equation can be solved using the equation below [15].

\[
\begin{align*}
a &= \frac{D_a}{D} \\
b &= \frac{D_b}{D} \\
c &= \frac{D_c}{D}
\end{align*}
\]

Having obtained the results of forecasting of both methods, the authors compare the error rate of the two regression methods using the MSE (Mean Square Error) method where the smaller the MSE value, the smaller the error rate in the method. The MSE equation can be written as follows:

\[
MSE = \frac{\sum_{i=1}^{n} (y_i - \hat{y_i})^2}{n}
\]

Where,
- \( y_i \) = forecast value
- \( \hat{y_i} \) = true value
- \( n \) = total of data

1.3. Financial feasibility analysis

A financial feasibility study can be performed by analyzing the initial capital/asset investment, asset income and annual cost [16]. Measuring tool to determine the feasibility of a business or project based on a financial aspect or investment criteria can be done through Payback Period (PP) [17], Average Rate of Return (ARR), Net Present Value (NPV) [3], Internal Rate of Return (IRR) [18], and Profitability Index (PI) or Benefit Cost Ratio (BCR) [19].

In this study, the authors use EUAC (Equivalent Uniform annual cost) and NPV (Net Present Value) method to analyze the financial feasibility of cubicles. The EUAC method is used to analyze the economic life of cubicles. While the NPV method is used to determine the feasibility of cubicles based on Net Benefit. This net benefit has been discounted by using the social opportunity cost of capital (SOC) as a discount factor [11].

1.4. EUAC and economic age

EUAC (Equivalence Uniform Annual Cost) is a calculation of the equivalence of each expenditure in each year or period at any time, which then becomes annual cost by means of equivalence [20]. In determining the value of EUAC to find the economic life requires cost data and Capital recovery. After obtaining cost and capital recovery data, here is the final equation of EUAC to analyze the economic age:

\[
EUAC = F \text{ (EPSR)} - P \text{ (EPSSF)}
\]

Where:
- EUAC = Equivalent uniform annual cost
- F (EPSR) = Future (cost of future) using Equal Payment Series capital recovery method.
- P (EPSSF) = Present (cost of present) using Equal Payment Series Sinking Fund Factor method.
1.5. NPV (Net present value)
NPV is the method used to calculate the net present value of a future cash flow mix (F) based on predetermined interest rates [16]. There are several steps to utilize the NPV method to conduct a financial feasibility study [20]:

- Select the discount factor value (i) to use.
- Using the appropriate formula to make any future profit and expense (future) into present time (Present worth / PW) using the compound interest formula.
- Choose the feasibility alternative if it has an NPV value (PW benefit difference and PW expenditure), if greater than number 0.

The NPV equation can be written as:

$$\text{NPV} = \sum_{t=1}^{n} NB_t (1 + i)^{-t}$$  \hspace{1cm} (7)

Or can be written as:

$$\text{NPV} = \sum_{t=1}^{n} B_t - C_t$$  \hspace{1cm} (8)

where:

- NB : Net Benefit
- C : costs (operational costs + investment costs) that have been discounted
- B : Benefit that have been discounted
- i : discount factor
- n : period (years)

This calculation can also be done using Microsoft excel with the following equation,

$$\text{NPV} = \text{NPV} \left(\text{rate};\text{value1:valuen}\right)$$  \hspace{1cm} (9)

where:

- rate : discount factor
- (value1: valuen) : the value of cash flow or net benefit from the first year to year n

1.6. Cubicle
The cubicle is an asset that serves as a divider, breaker, connector, controller and safety of power supply system [1]. cubicles consist of main components and supporting components. The main components of cubicles are PMT (breaker), rail (busbar), the current transformer (CT), voltage transformer (VT), and PMS (separator). As for the cubicle supporting components of relays and meters, control and indicator lights, heater, cubicle handle and lock and interlock system.

2. Research methods
The following flow chart is the stages of the research conducted:

![Figure 2. Research flowchart.](image-url)
3. Results and discussion

3.1. Technical age

![Figure 3. The average peak load of the DMSY feeder.](image)

From the graph above, the following calculation results and MSE load forecasting values based on linear and nonlinear regression methods.

Viewed from a comparison of MSE between linear trend with nonlinear trend hence simple load forecasting in this research use nonlinear trend because of MSE value of nonlinear trend smaller than linear MSE value. This shows that the nonlinear trend error rate is smaller than the linear trend.

Based on the results of load forecasting in this study, it can be concluded that in 2018, technically, cubicles are declared feasible to operate because the burden processed by DMSY caster cysts is still within the limits of cubic capability.

3.2. FMEA

From cubicle disturbance data and the calculation of RPN FMEA of cubicle components of DMSY, it can be known operationally that the cubicle of DMSY is still feasible to operate because, during operation, the DMSY cubicle does not get any interference or anomaly in all its compartments.

3.3. Economic age

According the calculation results are known based on data, maintenance costs and downtime can only be calculated until 2017. Therefore, to be analyzed until the year 2031 such as EUAC, the authors to forecast maintenance costs and downtime costs using linear trend method as shown in the attachment. Judging from the calculation in the appendix, the economic life of cubicles is four years where the average annual cost of the minimum cubic is in 2015. From the calculation and analysis of the average annual cost of cubicles, it can be seen that in 2018 DMSY cubicles are economically viable not feasible to operate.

3.4. Net Present Value (NPV)

After getting the benefit, the writer performs PV benefit (benefit per P / F ratio) and net benefit which will then be able to find the value of NPV cubicle repeater DMSY, where net benefit = PV benefit - PV cost. The calculation result of net benefit value can be seen based on the net benefit calculation and using the equation (9), the NPV value of the feeder cubicle DMSY from 2011 to 2018 is,

\[
\text{NPV} = \text{NPV} (12\%;\text{value1:valuen})
\]

\[
\text{NPV} = \text{Rp 35,576,912,923,27, -}
\]

With the NPV value greater than expected, the DMSY cubicle in 2018 is feasible to operate.

4. Conclusion

According on the results of processing and data analysis related to cubicle feasibility study, it can be concluded that:

- Operationally, cubicle feeder of DMSY is still feasible to operate. This is because in 2018 the load received by cubicle feeder DMSY is still within safe limits that is less than 630 A or 10.71
MW. Based on asset disruption data, the feeder cubicle of DMSY is not subject to interference except for interference in some parts of the DMSY repeater network which only causes the PMT on this cubicle trip so based on the FMEA analysis and the disturbance data, the feeder cubicle DMSY is declared feasible to operate.

- Economically, cubicles are still feasible to operate even though based on the economic age analysis of cubicles using the Equality Uniform Annual Cost (EUAC) method, the economic age of Cubicle DMSY until 2015. The feasible consideration of operating financially is seen also based on the analysis of Net Present Value (NPV) amounting to Rp 35,576,912,923,27, -. Therefore, in the analysis of financial feasibility, the cubicles of DMSY are declared eligible to operate.

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