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# Reliability Analysis of 20 kV Medium Voltage Air Line Distribution System at Semangga Switch Substation in Merauke Regency

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**ABSTRACT:** The breakdown of electrical energy can be caused by the unwanted failures that occur in the electric power system, especially in the distribution system, and have an impact on service continuity which can be a permanent failure, temporary failure, three phase short circuit failure, double phase short circuit failure, and black out. To anticipate this, a study needs to be done to analyze and find out how well the distribution system reliability index. Determination of the analysis was done by the method of data retrieval related to the analysis variable. Besides, in determining the results of the analysis, calculations using System Average Interruption Frequency Index (SAIFI), Customer Interruption Frequency Index (CAIFI), System Average Interruption Duration Index (SAIDI) and Customer Average Interruption Duration Index (CAIDI) analyses were performed. Based on the reliability of the distribution network, the SAIFI and CAIDI maximum threshold value setup by PT. PLN (The National Electricity Company) at the Semangga substation each worth 3.00 failures/customer.year and 3.00 failures/customerr while SAIDI and CAIDI each worth value of 3.40 hours/customer.year and 3.40 hours/customer.failure. All feeders installed at Semangga switch substation in realization gives reliability indices smaller than the target that has been set., it is mean that 20 kV medium voltage air line distribution system at Semangga switch substation still reliable and the duration of the failure time for each feeder was an average of 3 minutes of each failure and the number of failures every month was an average of 15 times of each feeder.

**KEYWORDS:** substation, reliability, SAIFI, SAIDI, CAFI, CAIDI, distribution system

## 1. INTRODUCTION

The quality of reliability of electrical energy services can be seen from the length of outages and how often blackouts occur in a certain period of time [1]. Reliability indices is a measure of reliability expressed in probability quantities [2]. Failures that occur in the distribution network will cause disruption of service continuity. This failure can be a permanent failure, temporary failure, three phase short circuit failure, double phase short circuit failure, and black out [3][4].

Reliability indices basically is a number or parameter that indicates the level of service or the level of reliability of electricity supply to consumers. The parameters of performance in electricity especially distribution system namely: SAIFI, CAIFI, SAIDI and CAIDI and the steps used were interviews and data retrieval of failures [5]. By calculated these parameters, it will be known how many indices are produced whether it is in accordance with the standards set by the National Electricity Company specially in the region of Merauke as shown in figure 1 [1], to be followed up so that in the future services in the distribution of electricity to customers do not experience many obstacles [6]. Therefore, a blackout analysis is needed in order to reduce the high level of blackouts so as to improve the quality of electricity and customer service [7].

There are several factors that must be known and calculated before carrying out an analysis of the reliability of the electrical distribution system, among others: the frequency of failure and duration / duration of failure, which comes from the failure of distribution network equipment or failure at its load point [8].

In this paper, it is proposed to determine the value of reliability and various indices related to the quality of service to customers. But this study decribed here focuses on three feeders that power electrical supplied by Semangga Switch Substation, namely: Kurik feeder, Tanah Miring feeder and Sidomulyo feeder by using the mathematical analysis by using equations theoritically. The problems in the calculation are [9]:

1. Determine the reliability indices of SAIDI, SAIFI and CAIDI, based on the failure rate and duration of outages experienced by customers.
2. Comparison of the calculated values with the threshold values applied at Semangga Switch Substation.

## 2. MATERIAL AND METHOD

### 2.1 Reliability Indices

This indices can then be combined with the customer composition in the distribution system to evaluate the system indices. In the distribution area, the usual indices are the load point failure rate (or frequency), the average outage duration, and the average annual outage time. Normal utility practise is to measure distribution system performance. This approach does not usually encompass any discussion or appreciation that the customerbased indices can exhibit considerable natural variability on an annual basis, while still having the expected values determined by the analytical approach.

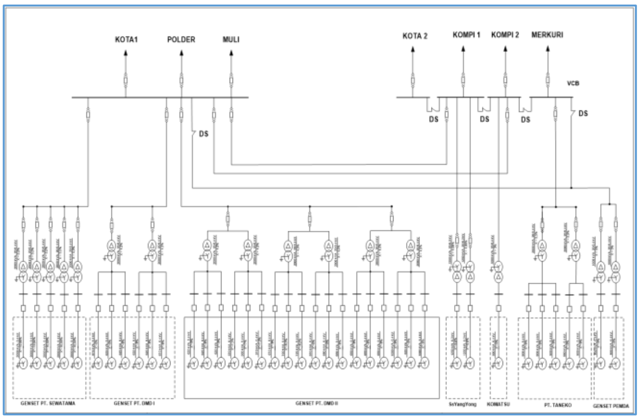


**Figure 1. Single line diagram of PLTD (diesel generation) Kelapa Lima Merauke**

Reliability analysis of a electrical system needed to show the ability of that system to prepare the continuity electrical power flow from the electrical generation to the consumers. Relationship between the number of failure and the operating life of the system can be shown in figure 2 [10]. In the *debugging area*, the failure can be caused by errors in the planning and installation of electrical equipment. The value of the failure rate in this area is very large and will decrease with time. In normal *operating or useful life area*, the failure tend to be constant because the system of an electrical equipment is operating stable so that the possibility of failure at any time is the same. Last, in the *wear out area*, its failure rate increases with time caused by the aging of electrical equipment so taht more failures will occur.

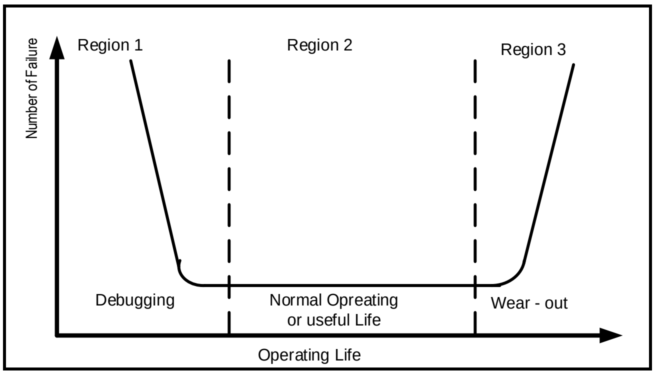


**Figure 2. Curve of number of failure with operating life**

In reliability analysis of distribution system, there are several factors that need to be determined and then referred as reliabilty indices. These indices are divided into two groups that are load point indices and system indices [11]. Average load point indices are calculated as [12]:

$$\lambda_t = \Sigma_i \ \lambda_i \qquad (1)$$

$$U_t = \Sigma_i \ \lambda_i \, r_i \qquad (2)$$

$$r_t = \frac{\Sigma_i \ \lambda_i \, r_i}{\Sigma_i \ \lambda_i} \qquad (3)$$

where,

$r_t$ = average outage time
$\lambda_t$ = average failure time
$U_t$ = average annual outage time

System indices are estimated as [10]:

*System Average Interruption Frequency Index* (*SAIFI*)

$$SAIFI = \frac{\Sigma\,(\lambda_i N_i)}{\Sigma\, N} \ (failure/customer.year) \qquad (4)$$

where,

$N$ = number of consumers failure
$N_i$ = number of consumers at load point *i*
$\lambda_i$ = average failure *(failure/year)*

*Customer Average Interruption Frequency Index* (*CAIFI*)

$$CAIFI = \frac{\Sigma\,(\lambda_i N_i)}{U_i\, N} \ (failure/customer) \qquad (5)$$

*System Average Interruption Duation Index* (*SAIDI*)

$$SAIDI = \frac{\Sigma\,(U_i N_i)}{\Sigma\, N} \ (hours/customer.year) \qquad (6)$$

where,

$N$ = number of consumers failure
$N_i$ = number of consumers at load point *i*
$U_i$ = average failure duration (*hours/year*)

*Customer Average Interruption Duration Index* (*CAIDI*)

$$CAIDI = \frac{\Sigma\,(U_i N_i)}{\lambda_i\, N} \ (hours/customer.failure) \qquad (7)$$

The types of levels of reliability in electrical distribution services can be divided into three levels, among others :

a) *High reliability system*: under normal conditions, the system will provide sufficient capacity to provide power at peak loads with good voltage variations. And in an emergency when there is a disruption in the network, then this system of course requires some equipment and enough security to avoid any kind of interference with the system.
b) *Medium reliability system*: under normal conditions the system will provide sufficient capacity to provide power at peak loads with good voltage variations. And in an emergency when there is a disruption in the network, the system can still serve part of the load even under peak load conditions. So in this system required quite a lot of equipment to overcome and overcome these disturbances.

c) *Low reliability system*: under normal conditions, the system will provide sufficient capacity to provide power at peak loads with good voltage variations. But if there is a disruption in the network, the system cannot serve the burden at all. So it needs to be fixed first. Of course in this system the safety equipment is relatively very few in number.

## 2.2 Failure Modes And Effects Analysis

An analysis of the modes of failure effects can vary at each reported level, depending on the detailed requirements and the availability of information needed. In a particular critical load analysis that is dominant, and to the point of endangering safety, an evaluation analysis using the FMEA method must be carried out. The advantages of doing an evaluation analysis using the FMEA method are an end product that truly prioritizes safety, and the system goes according to its function. FMEA helps designers to identify and eliminate dangerous failure modes, minimizing damage to the system and the operators and users of the system. As the FMEA evaluation evaluation becomes more accurate, the possibility of failure can be localized and if a system or subsystem fails, it will not spread to other systems and subsystems in the process.

Failure Modes and Effect Analysis (FMEA) is a structured method for analyzing a system. The FMEA method for evaluating the reliability of a distribution system is based on how a failure of an equipment affects the operation of the system. The effects or consequences of individual equipment failures are systematically identified by analyzing what happens if the disturbance occurs. Then each equipment failure is analyzed from all load points.

*Condition of FMEA method*: a) feeder configuration for 20 kV distribution network systems. The system is defined in sections and the load point (load point); b) consumen data, namely: number of consumers and failure data, and c) reliability data of the system.

*Assumtion of FMEA method*: a) The failures are not interconnected, each equipment can be analyzed separately. If equipment failures are connected, the calculation of system reliability becomes more complex. So that, to simplify the calculation by assuming that each failure is not interconnected; b) If interference from equipment in a system is assumed to be independent, each load point reliability is a minimum cut set function that is connected in series.

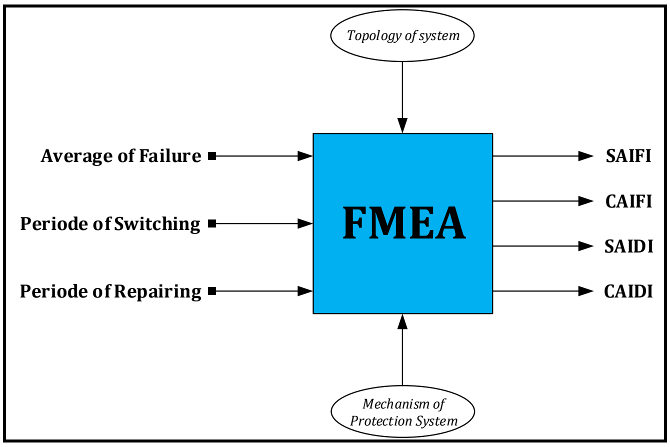


**Figure 3. Single line diagram of Semangga switch substation**

The philosophy of this method is to evaluate the reliability of the 20 kV medium voltage distribution network by calculating the reliability indices for each load point. If interference from equipment in a system is assumed to be independent, each load point reliability is a minimum cut set function that is connected in series. Therefore, the minimum cut set consists of all equipment that has an influence on the availability load point. From these reliability indices, we can know which load points need to be improved. The reliability index calculated is the load point indexes and the overall system indexes. FMEA functionally assumes a failure, then identifies the failure, and analyzes how the failure effects. A system approach that usually involves a bottom-up analysis in which an analysis of the specific failure modes of the sub-system, seen its effect on the whole system

## 2.3 Assesment of Reliability Indices

The 20 kV medium voltage of distribution system at Semangga switch substation on Merauke regency consist of 3 feeder, namely : Tanah Miring feeder, Kurik feeder and Sidomulyo feeder. The data of each feeder, shown in table 1.

**Table 1. Feeder data on Semangga switch substation**

| No. | Feeder | Outgoing | Current (Ampere) | Load (kW) |
|---|---|---|---|---|
| 1 | Kurik | 1 | 52.5 | 1765 |
| 2 | Tanah Miring | 1 | 50.4 | 1666 |
| 3 | Sidomulyo | 1 | 20.1 | 660 |

On the other data for single line diagram of Semangga switch substation, shown in figure 4 [13].

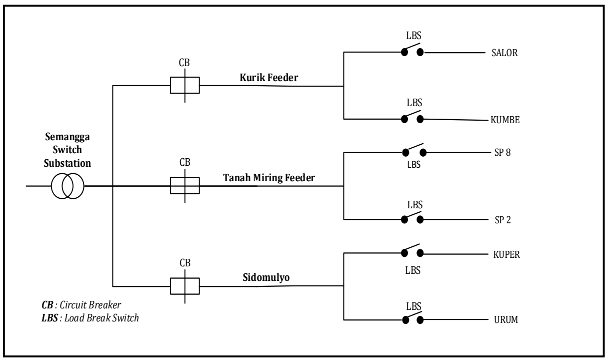


**Figure 4. Single line diagram of Semangga switch substation**

The duration of the interruption and outages time each month for each feeder on the Semangga switch substation can be seen in table 2 and table 3.

According to table 2 and table 3, by using equation 1 then the value of average failure times ($\lambda$) of each feeder is obtained as follows:

$\lambda_{Kurik\ Feeder}$ = *2.75 times/year*
$\lambda_{Tanah\ Miring\ Feeder}$ = *2.91 times/year*
$\lambda_{Sidomulyo\ Feeder}$ = *3.16 times/year*

then, average annual outage time ($U$) obtained :

$U_{Kurik\ Feeder}$ = *0.75 hours/year*
$U_{Tanah\ Miring\ Feeder}$ = *0.77 hours/year*
$U_{Sidomulyo\ Feeder}$ = *0.76 hours/year*

Based on assesment of average failure time and average annual outage time, by using equation 4, 5 and 6 then system indices of Kurik feeder obatained:

***Kurik Feeder :***

$$SAIFI = \frac{2.75 \ x\ 6298}{(6298+7244+2892)} = 1.053 \ \ failures/customer.year$$

$$CAIFI = \frac{2.75 \ x\ 6298}{0.75 \ x\ (6298+7244+2892)} = 1.406 \ \ failures/customer$$

$$SAIDI = \frac{0.75 \ x\ 6298}{(6298+7244+2892)} = 0.287 \ \ hours/customer.year$$

$$CAIDI = \frac{0.75 \ x\ 6298}{2.75 \ x\ (6298+7244+2892)} = 0.104 \ \ hours/customer.failure$$

In the same way to Tanah Miring feeder and Sidomulyo feeder, then system indices of those feeders obatained:

***Tanah Miring Feeder*** :

$$SAIFI = \frac{2.91 \ x\ 7244}{(6298+7244+2892)} = 1.282 \ \ failures/customer.year$$

$$CAIFI = \frac{2.91 \ x\ 7244}{0.77 \ x\ (6298+7244+2892)} = 1.665 \ \ failures/customer$$

$$SAIDI = \frac{0.77 \ x\ 7244}{(6298+7244+2892)} = 0.339 \ \ hours/customer.year$$

$$CAIDI = \frac{0.77 \ x\ 7244}{2.91 \ x\ (6298+7244+2892)} = 0.011 \ hours/customer.failure$$

***Sidomulyo Feeder*** :

$$SAIFI = \frac{3.16 \ x\ 2892}{(6298+7244+2892)} = 0.556 \ \ failures/customer.year$$

$$CAIFI = \frac{3.16 \ x\ 2892}{0.76 \ x\ (6298+7244+2892)} = 0.731 \ \ failures/customer$$

$$SAIDI = \frac{0.76 \ x\ 2892}{(6298+7244+2892)} = 0.121 \ \ hours/customer.year$$

$$CAIDI = \frac{0.76 \ x\ 2892}{3.16 \ x\ (6298+7244+2892)} = 0.042 \ \ hours/customer.failure$$

**Table 2. Interruption data of each feeders**

| **Item** | | **Kurik feeder** | **Tanah Miring feeder** | **Sidomulyo feeder** |
|---|---|---|---|---|
| **Number of Customers** | | 6298 | 7244 | 2892 |
| **Interruption Time / month (minutes)** | Jan | 51 | 38 | 60 |
| | Feb | 64 | 80 | 26 |
| | Mar | 45 | 0 | 39 |
| | Apr | 51 | 68 | 15 |
| | May | 0 | 42 | 64 |
| | Jun | 76 | 85 | 36 |
| | Jul | 36 | 34 | 0 |
| | Aug | 48 | 39 | 56 |
| | Sep | 15 | 0 | 45 |
| | Oct | 57 | 70 | 75 |
| | Nov | 28 | 30 | 84 |
| | Des | 70 | 72 | 52 |
| | | 541 | 558 | 552 |

| | | | | |
|---|---|---|---|---|
| **Total Number of Interruption** | | | | |

Table 3. Outage data of each feeders

| **Item** | | **Kurik feeder** | **Tanah Miring feeder** | **Sidomulyo feeder** |
|---|---|---|---|---|
| **Number of Customers** | | 6298 | 7244 | 2892 |
| **Interruption Time / month (minutes)** | Jan | 3 | 2 | 4 |
| | Feb | 4 | 5 | 2 |
| | Mar | 3 | 0 | 3 |
| | Apr | 3 | 4 | 1 |
| | May | 0 | 3 | 4 |
| | Jun | 4 | 5 | 2 |
| | Jul | 2 | 2 | 0 |
| | Aug | 3 | 3 | 4 |
| | Sep | 1 | 0 | 3 |
| | Oct | 3 | 5 | 5 |
| | Nov | 2 | 2 | 6 |
| | Des | 5 | 4 | 4 |
| **Total Number of Outage** | | 33 | 35 | 38 |

## 3. RESULT AND DISCUSSION

Target value of system indices set by the National Electrical Company at Semangga switch substation for SAIFI is 3.00 failure/customer.year, SAIDI is 3.40 hours/customer.year, CAIFI is 3.00 failures/customer and CAIDI is 3.40 hours/customer. Result of reliability assessment in detail can be described as shown figure 5, figure 6, figure 7 and figure 8.

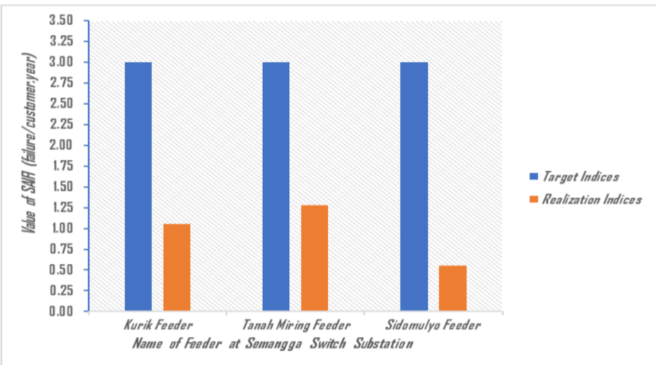


**Figure 5. Comparison between target and realization indices of SAIFI**

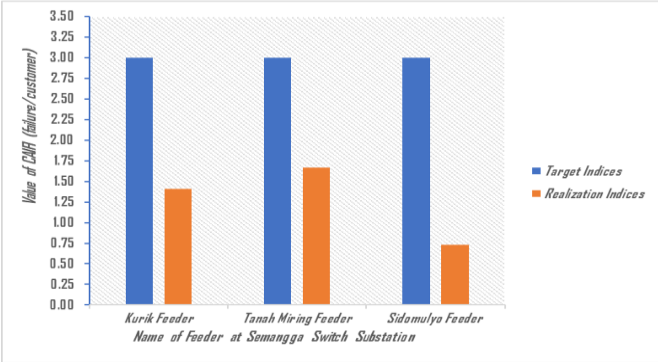


**Figure 6. Comparison between target and realization indices of CAIFI**

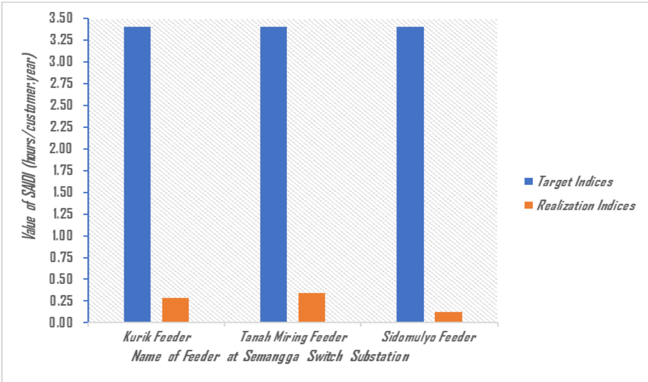


**Figure 7. Comparison between target and realization indices of SAIDI**

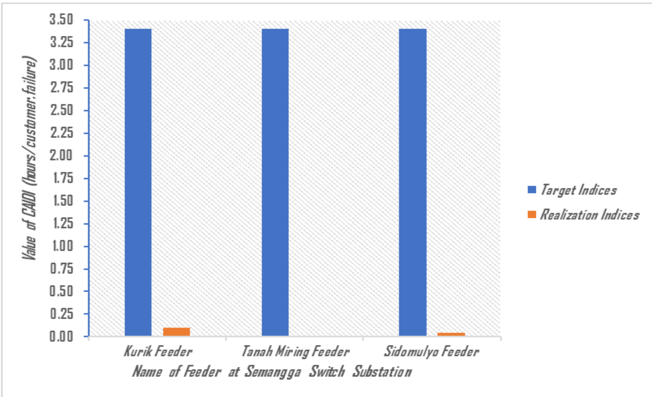


**Figure 8. Comparison between target and realization indices of CAIDI**

As shown on figure 5, figure 6, figure 7 and figure 8, asessment result of all system indices at feeder of Semangga switch substation, namely: Kurik feeder, Tanah Miring feeder, and Sidomulyo still samallest than the spesific target setup by the National Elecrical Company of Indonesia to Semangga switch substation at Merauke regency.

Comparison reliable indices of three feeders, shown that Sidomulyo feeder has the smallest indices from other feeder. Then, it can be said that Sidomulyo feeder more reliable than the other two feeder. However, the difference in the system indices of each feeder is generally caused by the environment around the feeder installed, so most failures occur because of factors outside the electrical distribution network that are temporary failures.

Based on the results obtained previously, Sidomulio feeder has an reliable indices that is better than other feeders, apart from the previous data factors, it can be concluded that other factors cause differences in index values between feeders, namely the length of the feeder path. The longer feeder path will have the greater possibility of failure than the feeder with a shorter path. This can be seen in Sidomulyo feeder which has a shorter path than other feeders. In the otherhand, average number of failure gives 3 times/month and average duration of failure gives 15 minutes/month of each feeder instaled at Semangga switch substation.

There are a number of actions which are expected to reduce the failure rate of Semangga Substation, among others: 1) Maintaining the relay, so that later the relay can work properly; 2) Maintaining the network, especially Kurik feeders which network is in the areas of forests and swamps; 3) Installing bat nets on the network that often disrupted by bats; and 4) Making improvements about the tap connector that has started to fail due to the bolt that has started to rust.

## 4. CONCLUSION

Based on reliability analysis of 20 kV medium voltage air line ditribution at Semangga switch substation, the following conlusion obtained :

1. Calculation of system reliability indices as: SAIFI, CAIFI, SAIDI and CAIDI in realization still smaller than target indices set by the National Electrical Company of Indonesia, especially at Semangga switch substation in Merauke regency.
2. Duration of the failure time for each feeder was an average of 3 minutes of each failure and the number of failures every month was an average of 15 times of each feeder.

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