Reliability Evaluation of Power Distribution System with Reliability Index Assessment (RIA)

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Abstract. Distribution network system reliability is a measure of the level of service of the system of electricity supply to consumers. This study aimed to get some reliability index value of the electricity distribution network system at PT PLN (Persero) APJ Bandung, namely the failure rate, the average output time, the average annual unavailability, SAIFI, SAIDI, CAIDI, ENS and then AENS. These results will be used as a reference for determining the level of reliability of the system. Search reliability index value itself is done by way of basic data recap interference on each unit in the network (UPJ) and then calculating the index of reliability by using formulas reliability index. The results of this study, the value of reliability indices SAIFI on the system 2.02 disorders / customer / year with a target of 1.27 disorders / customer / year, while the reliability index SAIDI on the system 0.28 hours / customer / year with a target of 0.21 hours / customer / year, with these results show electric power distribution network system of PT PLN (Persero) APJ Bandung could not reach the target reliability especially SAIFI and SAIDI. The results of this study are also expected to give an idea of the level of system reliability of electric power distribution network PT PLN (Persero) APJ Bandung.

1. Introduction
The amount of electrical energy needs required today shows that electrical energy has become a necessity that is very important to people's lives, need for electricity continues to increase this needs to be accompanied by efforts to improve the quality of service to customers of electricity [1], therefore PT. PLN (Persero) APJ (Area Services Network) Bandung as one part of Distribution West Java and Banten in charge of the management of power distribution in the city of Bandung and its surroundings, also participated in the improvement of service quality. But in improving the quality of service of course there are some problems that must be addressed. The most fundamental problem in the process of distribution of electrical power is on quality, continuity and availability of electric power service to customers. And one of the basic process of overcoming these problems is to determine the reliability (reliability) and availability (availability) system of electric power distribution network.

Reliability in the distribution network system is a measure of the availability or the level of service Provision of electricity from the system to the user within a certain period [2]. To determine the reliability of a service system or an electrical feeder then assigned a reliability index that scale to compare the appearance of a distribution system [1]. The indices of reliability include the failure rate (failures / year), the average time out (hours / failure), the average unavailability of annual (hours / year) there are also indices of reliability that is often used in assessing the reliability a power distribution network system is SAIFI, SAIDI, CAIDI [3, 4].
Therefore, the search value indices of reliability is very important, because the results of the search for these values can be used to determine all the measures to ensure the handling is really a problem, so it can be anticipated disruption of distribution due to the decreased level of reliability beyond the limits of adequate or due to lack of maintenance, which will result in a shortening of the lifespan of the equipment in question and would also affect the quality of electricity service to consumers.

2. Literature review

2.1. Electric power distribution system

The distribution system is part of a power distribution system that is on the side adjacent to the user or the load. The distribution system is useful to deliver electricity from a power source (Bulk Power Source) in the transmission network to the consumer. So the function of power distribution is the distribution or the distribution of electricity to some places (the customer), and a sub power system that directly relate to the customer, because the power supply to the load centers (customers) are served directly through the distribution network.

In the remote power distribution system, always use a voltage as high as possible in order to obtain the value of ‘losses' lowest of the low, using equipment transformers voltage step-up (step-up). The value of these very high-voltage (HV, UHV, and EHV) raises a number of consequences, among others: dangerous for the environment and the high price of equipment-equipment, in addition to being incompatible with the required voltage value on the load side. Therefore the central regions of the burden of high drain voltage is lowered again by using transformers lowering the voltage (step-down). As a result, when reviewed voltage value, starting from the source point to point load, there are parts of channels that have different voltage values. Besides, the number of connections between the distribution of electricity (transmission) and distribution of electrical power (distribution) and the low voltage network (JTR), resulting in a system often experience considerable interference. With the system configuration broad and complex load on the distribution, then increased the system becomes inefficient, critical interruption or failure affecting services to frequent outage.

Distribution of electricity carried out by PT. PLN is generally carried out in a radial system. But the shape of the distribution network radial has some modified form, among others: (a) Network Radial Type Center expenses, (b) Network Radial With Phase Area, (c) Distribution Network the Web (NET), and (d) Distribution Network spindle.

2.2. The concept of reliability methods reliability index assessment

Reliability (reliability) in general is a possibility the system will be able to function well for a certain period of time. Size reliability can be expressed as how often the system experienced a blackout, how long the outage occurred and how much time is required to recover from the outage occurred. The system has a high reliability will be capable of providing electrical power required at any time, while the system has a low reliability will lead to frequent outage. Research on the reliability of the distribution network system Reliability Index Assessment models are often referred to as RIA, previous researchers conducted through a simple network model is in reconfiguration [5, 6]. Then more specific research a case study by analyzing partially on electric power distribution system to Tuban cement plant to determine the level of reliability of the distribution by the RIA method [5].

The reliability of the distribution system [2] is "A measure of service availability of electricity from the system to the user. Size reliability can be stated how often the system experienced a blackout, how long the outage occurred and how much time is required to recover from a blackout that occurred (restoration) ". Meanwhile to measure the level of reliability of each point of load (load point) can be determined by a reliability index. Reliability index itself is a scale to compare the appearance of the electricity distribution system. According to [7] "To evaluate the reliability of the distribution network analytical techniques using the mathematical formula, the index of basic reliability used the failure rate \( \lambda \) (failures / year), the average time out (outage) \( r \) (hours / failure) and average annual unavailability \( U \) (hour / year), while the index based systems include the SAIFI and SAIDI ".

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Indicators of reliability in the form of basic reliability indexes and several index-based reliability assessment index system reliability include: (a) Failure Rate (λ), (b) Average Time Out Or Repair (r), (c) Average annual unavailability (U), (d) System Average Interruption Frequency Index (SAIFI). This reliability index informs about the average frequency interference experienced by each customer in a given period. Also can be defined as follows: (e) System Average Interruption Duration Index (SAIDI), (f) Customer Average Interruption Duration Index (CAIDI), (g) Energy not Supplied (ENS) and Average Energy not Supplied (AENS).

Whereas in determining the merits of a reliability of the reliability of the electricity distribution system itself other than to note the value of reliability we also need to compare these values with a target of reliability, as from this table standard category reliability index.

Table 1. Table category standard reliability index.

|                        | SAIFI, No. of Interruption/Year | SAIDI, No. of Interruption/Year |
|------------------------|---------------------------------|---------------------------------|
|                        | 25% 50% 75%                     | 25% 50% 75%                     |
| IEEE Std. 1366-2000    | 0.90 1.10 1.45                  | 0.89 1.50 2.30                  |
| EEI (1999) [excludes storms] | 0.92 1.32 1.71                  | 1.16 1.74 2.23                  |
| EEI (1999) [with storms] | 1.11 1.33 2.15                  | 1.36 3.00 4.38                  |
| CEA (2001) [with storms] | 1.03 1.95 3.16                  | 0.73 2.26 3.28                  |
| PA Consulting (2001) [with storms] | 1.55 3.05 8.35                  |                                  |
| IP & L Large City Comparison | 0.72 0.95 1.15                  | 1.02 1.02 2.41                  |

(Indianapolis Power & Light, 2000)

As for the various levels of reliability in the service can be divided into 3 (three): (a) The reliability of the system is low (Low Reliability System), (b) Reliability intermediate system (Medium Reliability System), and (c) the reliability of the system is high (High Reliability System).

3. Research methods

In this study the steps that need to be done to get the value of the indices is as follows: (1) Basic data collection period disruption in January 2013 until December 2013 from each unit in the network and data feeders medium voltage feeders, (2) recapitulation and calculation of the basic data for the disorder gets basic reliability indexes on system power distribution network and the feeder, (3) Having obtained the basic reliability indices with recapitations process data and calculations, then calculating reliability indices SAIFI, SAIDI, CAIDI, ENS and AENS system power distribution, (4) Comparing the results of the calculation by the calculation of the PT PLN (Persero) APJ Bandung that the calculation results as expected, (5) Drawing conclusions about the level of system reliability of electric power distribution network APJ Bandung when viewed from achieving the target reliability index set by PT PLN.

The following flow chart analysis study of system reliability of electric power distribution network:
4. Results and discussion

In the analysis of system reliability of electric power distribution network PT PLN (Persero) APJ Bandung in 2013 will be divided into several basic analysis, reliability analysis on each group of outages due to interference, reliability analysis on each medium voltage feeders, and analysis of the level of the reliability of electric power distribution network system of APJ Bandung in 2013.

System Reliability Analysis of Electric Power Distribution Network APJ Bandung on Each group Outages Due to Interference by 2013.

Analysis of system reliability distribution network in each group extinction due to this interference aimed to compare the performance between parts of the system so that the electrical power distribution network can be seen which part is often impaired, and may also facilitate the work of PT. PLN (Persero) APJ Bandung in making efforts to repair and maintenance to system components that are often impaired.
Table 2. Group outages due to impaired.

| Code | Cause Crashes | Outages Due To Interference |
|------|---------------|----------------------------|
| 00   | Electricity connection group & guides & Measurement Tools |
| 10   | Groups of low voltage network |
| 20   | Group distribution transformer substation |
| 30   | Group of electricity poles TR and TM |
| 40   | Medium voltage air channels (SUTM) |
| 50   | Medium Voltage cable channels (SKTM) |
| 60   | Interruption of transmission and substation |
| 70   | Power outages group resources |
| 80   | Group of natural disasters |

Here is the presentation of data on the calculation of system reliability analysis of electrical power distribution network PT. PLN (Persero) APJ Bandung on each group of outages due to interference.

Table 3. Calculation of reliability index based on each group outages due to impaired.

| No  | Code Disorders | Total Disruption | The average time out (Hours) | The duration Disorders (Hour) |
|-----|----------------|------------------|-----------------------------|-------------------------------|
| 1   | A.00           | 15994            | 0.6649                      | 10633.8886                    |
| 2   | A.10           | 1182             | 0.5856                      | 692.1936                      |
| 3   | A.20           | 121              | 0.7423                      | 89.8238                       |
| 4   | A.30           | 3                | 0.6016                      | 1.8049                        |
| 5   | A.40           | 316              | 0.4793                      | 151.4611                      |
| 6   | A.50           | 236              | 0.1802                      | 42.5191                       |
| 7   | A.60           | 6                | 1.1417                      | 6.8499                        |
| 8   | A.70           | 8                | 2.2354                      | 17.8833                       |
| 9   | A.80           | 8                | 0.2313                      | 1.8500                        |
| Total |                | 17874            | 0.6511                      | 11638.2747                    |

Table 4. Result of reliability index calculation of index-SAIFI, SAIDI, CAIDI, ENS and AENS.

| No  | Code Disorders | SAIFI  | SAIDI  | CAIDI  | ENS     | AENS     |
|-----|----------------|--------|--------|--------|---------|----------|
| 1   | A.00           | 0.0244594 | 0.0163030 | 0.0080461 | 3255839.17 | 4.8668343 |
| 2   | A.10           | 0.0031182 | 0.0015789 | 0.0007792 | 945633.13 | 1.4135341 |
| 3   | A.20           | 0.2579983 | 0.0481261 | 0.0237522 | 71032.60 | 0.1061797 |
| 4   | A.30           | 0.0000045 | 0.0000027 | 0.0000013 | 438.86 | 0.0006560 |
| 5   | A.40           | 0.8886597 | 0.0842517 | 0.0415816 | 300147.11 | 0.4486613 |
| 6   | A.50           | 0.8209018 | 0.1236873 | 0.0610447 | 128389.34 | 0.1851153 |
| 7   | A.60           | 0.0000090 | 0.0000010 | 0.0000051 | 6766.67 | 0.0101148 |
| 8   | A.70           | 0.0000120 | 0.0000267 | 0.0000132 | 1605.00 | 0.0023992 |
| 9   | A.80           | 0.0310127 | 0.0072301 | 0.0000132 | 1.00 | 0.0000015 |
| Total |                | 2.0261755 | 0.2812164 | 0.1352366 | 4705303.48 | 7.0334962 |

4.1. Reliability analysis of medium voltage feeder-feeder

Analysis of the reliability of medium voltage feeder-feeder at PT PLN (Persero) APJ Bandung was conducted to determine the extent to which the performance of each feeder. Medium voltage feeders APJ Bandung counted until the end of December 2013 alone amounted to 176 feeders, with a total length peyulang SUTM 1,328,481.43 km and a total length of feeder SKTM 330092.71 km. Analysis keadalalan on this feeder will be very useful in order to keep the electrical energy distribution systems to customers
in addition to the results of these calculations can also be used to determine feeder-feeder anywhere that requires monitoring, maintenance and even replacement.

Here is the presentation of data on the reliability index calculation results feeder-medium voltage feeders at PT PLN (Persero) APJ Bandung in the Year 2013.

### Table 5. Calculation results reliability index values SAIFI.

| No. | Feeder | SAIFI       |
|-----|--------|-------------|
| 1   | KMO    | 0.1432363954|
| 2   | CKK    | 0.1358834652|
| 3   | CKM    | 0.1165347504|
| 4   | UGB    | 0.1051219385|
| 5   | KPO    | 0.1021801685|

### Table 6. Results of reliability index value calculation SAIDI and CAIDI.

| No. | Feeder | SAIDI   | CAIDI   |
|-----|--------|---------|---------|
| 1   | CKK    | 0.0259793319 | 0.0126796334 |
| 2   | TBC    | 0.0179594211  | 0.0087653862 |
| 3   | TE     | 0.0170039936  | 0.0082990743 |
| 4   | NAK    | 0.0155635777  | 0.0075960560 |
| 5   | TJSI   | 0.0135229489  | 0.006600941  |

### Table 7. Results of reliability index value calculation ENS and AENS.

| No. | Feeder | ENS        | AENS    |
|-----|--------|------------|---------|
| 1   | NBN    | 12402.1970 | 0.0185  |
| 2   | TJSI   | 12088.4903 | 0.0181  |
| 3   | NPI    | 10448.8828 | 0.0156  |
| 4   | CHM    | 9225.9170  | 0.0138  |
| 5   | CPDU   | 7522.0977  | 0.0112  |

4.2. *Achievement of target index system reliability of electric power distribution network*

This discussion aims to determine the extent to which performance of the system in servicing and maintaining the continuity of distribution of electrical energy to customers and to determine the level of achievement of the target reliability index during 2013, especially reliability indices SAIFI and SAIDI reliability indices. The results of the reliability analysis can also be used as an evaluation of system performance and as a basis for determining future steps for the system to work the electricity distribution network become better or more reliable.

The following graph of the results of the index calculation reliability and reliability index value growth also attainment targets SAIFI and SAIDI reliability of the electricity distribution APJ Bandung during 2013.
Figure 2. Graph of growth and target reliability index values SAIFI system reliability.

Figure 3. Graph of growth values and target reliability index SAIDI system reliability.

From the analysis results obtained electricity distribution network system of PT PLN (Persero) APJ Bandung in 2013 has the reliability indices SAIFI at 2.02 disorders / customer / year while the reliability index SAIDI for 0.28 jam / customer / year. Due to the high value of reliability indices SAIFI and SAIDI reliability indices on the system, in the year 2013 PT PLN (Persero) APJ Bandung cannot meet reliability targets that have been set forth. SAIFI reliability index value of 0.75 was higher than the target only 1.27 disorders / customer / year, while the SAIDI reliability indices are higher than the target only 0.07 0.21 hours / customer / year. So it can be said to be based on the achievement of value indices of reliability especially reliability indices SAIFI and SAIDI reliability indices of power system distribution network PT PLN (Persero) APJ Bandung in 2013 is still not reliable.

5. Conclusions

From the analysis of the reliability of the power distribution network system of PT PLN (Persero) Distribution West Java area network services in 2013 can be summarized as follows:

- The system power distribution network PT PLN (Persero) Distribution West Java area of Bandung has a service network reliability indices as follows: (a) The rate of failure (failure rate) on mencapai17874 system disorders/year; (b) Average time of output or improvements to the system mencapai0.65 hours/ interruption; (c) The average annual unavailability on reach 11,638.27 system; (d) SAIFI reliability indices in the system reaches 2.02 disorders/customer/year; (e) SAIDI reliability indices in the system reaches 0.28 jam/customers/year and the system reliability index CAIDI mencapai0.13 hours/ customer outages/year; (f) The amount of energy that is not channeled
(ENS) during 2013 commencing reached 4,714,299.49 kWh / year with an average energy is not channeled to the customer (AENS) commencing reach 7.046943492 kWh / customer / year.

- Due to the high value of reliability indices SAIFI and SAIDI reliability indices on the system, in the year 2013 PT PLN (Persero) Distribution West Java Bandung area network services can not meet the reliability targets that have been set forth. SAIFI reliability index value of 0.75 was higher than the target only 1.27 disorders / customer / year, while the SAIDI reliability indices are higher 0.07 than the target only 0.21 hours / customer / year.

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