Optimization and Reliability Analysis Based on Saidi, Saifi Values on 20KV Distribution System Channels at PT. PLN ULP Labuhan Haji

Manda Asrul Sani
e-mail: mandaas288@gmail.com
Adisastra Pengalaman Tarigan
e-mail: adisastra_tarigan@yahoo.co.id
Siti Anisah
e-mail: sitianisah@dosen.pancabudi.ac.id

Universitas Pembangunan Panca Budi

Abstract
The level of reliability in distributing electrical energy to customers is very important. A system and a fast method are needed to produce reliability index values. This study uses a quantitative research method with the RIA (Reliability Index Assessment) method aimed at calculating the reliability index of the System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI) of the 20kV distribution system at PT. PLN (Persero) ULP Labuhan Haji. Based on the results of the study, the results were obtained Based on the calculation of the SAIDI, SAIFI and CAIDI values in 2023 PT. PLN ULP Labuhan Haji, the SAIDI value was 5.46 hours/customer/year and the SAIFI value was 8.60 times/customer/year while the CAIDI value was 7.15 Based on the provisions of SPLN 68-2: 1986 for SAIFI it has not met the Standard so that improvements need to be made, while the SAIDI value has met the standards and provisions of SPLN. Referring to the provisions of IEEE std 1366-2003, the electricity distribution system of PT. PLN ULP Labuhan Haji cannot yet be categorized as reliable.

***Keywords**:* Reliability, SAIDI, SAIFI, CAIDI

Introduction

The National Energy policy aims to provide electrical energy and maintain the continuity of its distribution. The most fundamental problem in the distribution of electrical power is the quality, continuity and availability of electrical power services to customers. The use of system reliability evaluation on the 20 kV distribution network is one of the important factors to improve and ensure proper handling of real problems that occur in the field, so that disruptions can be anticipated and losses due to unsupplied energy can be reduced in the distribution system. To determine the reliability of a feeder, a reliability index is determined, namely a quantity to compare the performance of a distribution system[1].

Reliability indices that are often used in a distribution system are SAIFI (System Average Interruption Frequency Index), SAIDI (System Average Interruption Duration Index), CAIDI (Customer Average Interruption Duration Index), ASAI (Average Service Availability Index). As a reference for determining the index, it is based on the PLN Standard which will later be used as a benchmark for the level of reliability of the distribution system.

One way to find out the reliability index is by using the FMEA method. Failure modes themselves refer to a step or mode that experiences failure, while effect analysis refers to a study that discusses the consequences of the failure [2], [3] .

Electrical energy is very important in supporting the process of community life. Progress in the fields of science, technology and population growth are factors that cause the demand for electrical energy to increase [4]. This will result in the distribution system becoming more complex and its reliability level decreasing because blackouts will occur more frequently, both intentional and scheduled [5]. PT. PLN (persero) is a State-Owned Enterprise (BUMN) managed by the state to meet the needs in the electrical energy sector. As an institution tasked with meeting the needs in the electrical energy sector, PT. PLN (Persero) continues to strive to meet all demands for electrical energy by providing services in the best quality and high levels of reliability [6] .

The 20 kV distribution system is not free from the possibility of small or large disturbances that will affect the reliability of the distribution of electric power to customers. The direct impact felt by customers from these disturbances is blackouts [7]. Indicators of the success of the electrical energy network can be seen from the number of requests that have been met, the quality of service, and the level of reliability. Reliability indices that are often used are the System Average Interruption Frequency Index (SAIFI) (average duration of service interruptions), and the System Average Interruption Duration Index (SAIDI) (average duration of service interruptions) and CAIDI (Customer Average Interruption Duration Index). From year to year the need for electrical energy in the service area PT. PLN (persero) ULP Labuhan Haji increasing, in line with the increasing population. The increasing need for electrical energy requires reliable distribution of good electrical power [8].

Literature Review

Electric Power Distribution System

In general definition, distribution system is part of electrical equipment system between large power source (bulk power source, BPS) and customer service switcher that distribution system is part of electric power system. This distribution system is useful for distributing electric power from large power source (Bulk Power Source) to consumers. So the function of electric power distribution is as division or distribution of electric power to several places (customers), and is part of electric power system that is directly connected to customers [9].

The power distribution system is part of the electrical equipment system between large power sources and customer connection equipment. The power distribution network system is divided into 2 primary distribution systems (medium voltage distribution network) and secondary distribution systems (low voltage distribution network). The two systems are distinguished based on their working voltage. Generally, the working voltage in the primary distribution system is 6 kV or 20 kV, while the working voltage in the secondary distribution system is 380 V or 220 V.

Distribution Network

The distribution network consists of two parts, the first is the medium/primary voltage network (JTM), which distributes electrical power from the subtransmission substation to the distribution substation, the primary distribution network uses three wires or four wires for three phases. The second network is the low voltage network (JTR), which distributes electrical power from the distribution substation to consumers, where previously the voltage was transformed by a distribution transformer from 20 kV to 380/220 Volts, this network is also known as secondary distribution network. The secondary distribution network is located between the distribution transformer and the service connection (load) using open air conductors or cables with a three-phase four-wire system (three phase wires and one neutral wire) [1].

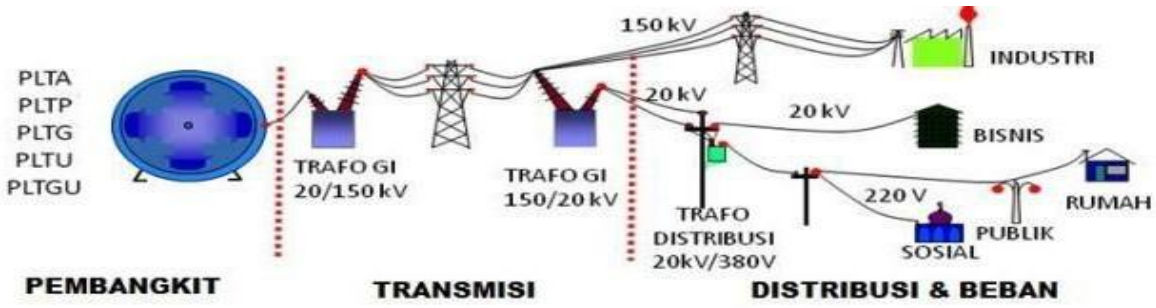

Figure 1. One line diagram of an electric power system

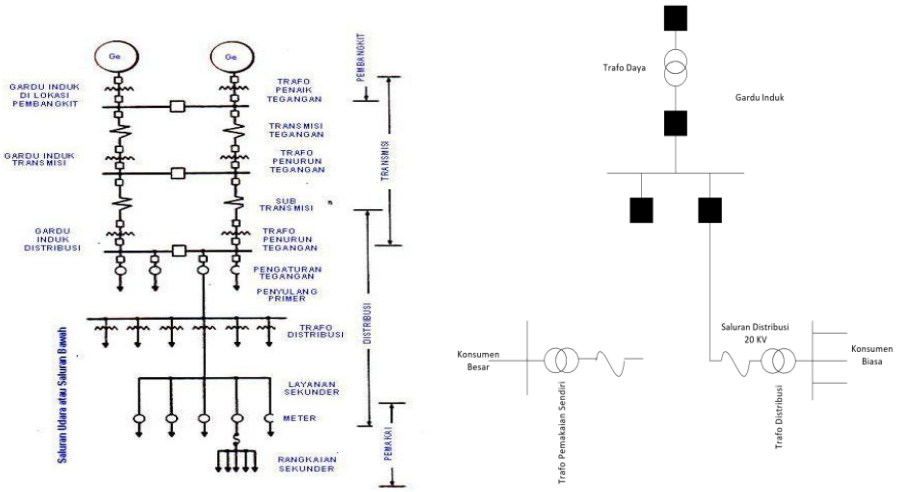

Figure 2. Electric power distribution system

Power Distribution System Disruption

Disturbances in the distribution system are disruptions to the electrical power system that cause the feeder safety relay to work to open the Circuit Breaker in the main substation which causes the power supply to be cut off. This is to protect the equipment through which the disturbance current passes from damage. So the function of the safety equipment is to prevent damage to the equipment and not to eliminate disturbances. Disturbances in the distribution network occur more often in distribution channels that are stretched in the air (SUTM) which generally do not use insulation compared to channels that are buried in the ground (SKTM) using wrapping insulation [10].

Disturbances in the distribution system are grouped into three types, namely disturbances

from within the system (internal), disturbances from outside the system (external), and disturbances due to human factors. For those originating from outside the system are caused by touching the conductor, lightning strikes, weather, humans, and animals. On the other hand, disturbances originating from within the system are usually in the form of failure of network equipment functions, damage to network equipment, damage to load breakers and errors in detection equipment. And the cause of disturbances from human factors is disturbances caused by operator carelessness or negligence, carelessness, disregard for self-protection regulations [11].

The consequences of disturbances that occur in the system are overload, short circuit, overvoltage, and loss of power source. For overload, it means that when a disturbance occurs, the system experiences an overload situation because the disturbance current enters the system, causing the system to become abnormal, and if left too long it will damage the system. Disturbances due to short circuits are temporary and permanent. Permanent disturbances can occur in 3-phase short circuits, 2 phases to ground, short circuits between phases or short circuits 1 phase to ground. While temporary disturbances are caused by flashover between conductors and ground, between conductors and poles, between conductors and ground wires. For overvoltage, it means the event of loss or decrease in load due to switching, AVR disturbances, overspeed due to loss of load. While the consequences of disturbances due to loss of power source mean the loss of power generation caused by disturbances in the generating unit, short circuit network disturbances, so that the relay and circuit breaker (CB) work.

Based on SPLN 52-3: 1983 on the 20 kV air voltage network, the disturbance that occurs is a type of disturbance that is temporary in nature. Temporary disturbances themselves are caused by various causes, including those that can occur due to contact with the conductor by trees or leaves, lightning strikes, humans, animals, and also bad weather. This temporary disturbance can be overcome by using equipment called a Recloser (Automatic Recloser) which can work to open and close automatically and can be set to work according to needs. One way that can be done to overcome the disturbance that occurs and prevent the occurrence of disturbances [12].

Distribution System Reliability

Reliability is the level of success of a system's performance. To be able to determine the level of reliability of a system, an examination must be carried out through calculations or analysis of the level of success of the performance or operation of the system being reviewed in a certain period and then comparing it with previously set standards [13]. Some basic parameters in reliability that are commonly used to evaluate radial distribution systems are the average failure rate (λs), average outage time (rs) and annual outage time (Us). A number of indices have been developed to provide a framework for evaluating the reliability of distribution system networks [14].

a. Failure Rate

   The failure rate is the average value of the number of failures in a certain observation time interval (T). In an observation, the failure rate value is stated as follows:

$$\lambda = \frac{f}{T}$$

   Where λ = Failure Rate (failures/year), f = Number of failures occurring at time T, T = Observation interval (years) The failure rate value will change. according to the age of the electrical system or equipment during operation

b. Failure Duration

   Failure duration is the average value of the number of failure durations in a certain time

interval of observation. In an observation, the failure duration value is stated as follows:

$$r = \frac{U}{\lambda}$$

Where U = Failure time per year (Hours/year), λ = Failure rate per year (Disruptions/year) r = Failure time (Hours)

c. Average Interruption Frequency Index (SAIFI) System

SAIFI is one of the reliability indexes where the calculation is the multiplication of the frequency of outages of a feeder with the number of customers experiencing outages divided by the total number of customers. The unit of calculation of the SAIFI index is outages per customer. The calculation of outages can be done in a certain period of time, either days, months or years (Ali Basrah Pulungan, 2010). Mathematically, the SAIFI index can be formulated:

$$SAIFI = \frac{\sum_{i=1}^{n} \lambda_i n_i}{N}$$

Where λi: Average number of failures (failures/year), Ni: Number of customers served at load point-i, N: Number of customers served Usually SAIFI is measured in interruption units per customer in one year.

d. System Average Interruption Duration Index (SAIDI)
SAIDI is an index that states the duration of disruptions (blackouts) that occur within a certain time interval (1 year) to customers in a system as a whole. To obtain the SAIDI value, it can be seen in the equation:

$$SAIDI = \frac{\sum_{i=1}^{n} U_i n_i}{N}$$

Where Ui: Customer outage time in a certain period (hours/year) Ni: Number of customers served at load point-i, N: Number of customers served

e. Customer Avarage Interruption Duration Index (CAIDI)
CAIDI is an index that provides information about the average duration of consumer outages for each disruption that occurs. To calculate this index, the equation is use

$$CAIDI = \frac{SAIDI}{SAIFI}$$

f. Customer Avarage Interruption Frequency Index (CAIFI)
CAIFI is an index that states the number of disruptions that occur within a certain time period (1 year) for customers:

$$CAIFI = \frac{\sum_{i=1}^{n} \lambda_i n_i}{\sum_{i=1}^{n} U_i n_i}$$

Reliability Index Standard SPLN 68-2: 1986

The following is table 1 which shows the reliability index standard in SPLN.

Table 1. SPLN 68 - 2 Reliability Index Standard: 1986

Reliability Index	Value Standards	Unit
SAIFI	3.2	Times/Customer/Year
SAIDI	21.09	Times/Customer/Year

Source: PLN, 1986

Reliability Index Standard IEEE Std 1366 – 2003

The following is table 2 which shows the reliability index standards in IEEE std 1366-2003.

Table 2. IEEE std 1366-2003 Reliability Index Standards

Index Keandalan	Standar Nilai	Satuan
SAIFI	1.45	Times/Customer/Year
SAIDI	2.30	Times/Customer/Year

Source: IEEE, 2003

Research Methodology

Method of collecting data

The methods used in this study include:

Electricity distribution data from PT. PLN (Persero) ULP Labuhan Haji. From the findings and data collection obtained, an analysis of SAIDI and SAIFI can be carried out. The next step is to make an analysis of the reliability of the distribution system (SAIDI and SAIFI) to obtain a reliability index and then compare it with the applicable reliability standards. From the results of the analysis, it will be known what the system reliability index is and how to improve the reliability index.

Method RIA

The RIA (Reliability Index Assessment) method is an approach used to predict disruptions in distribution systems based on system topology and data regarding component reliability. Functionally, RIA records failures that occur in equipment comprehensively, then identifies the failure, and analyzes the failure mode.

Research Flow Chart

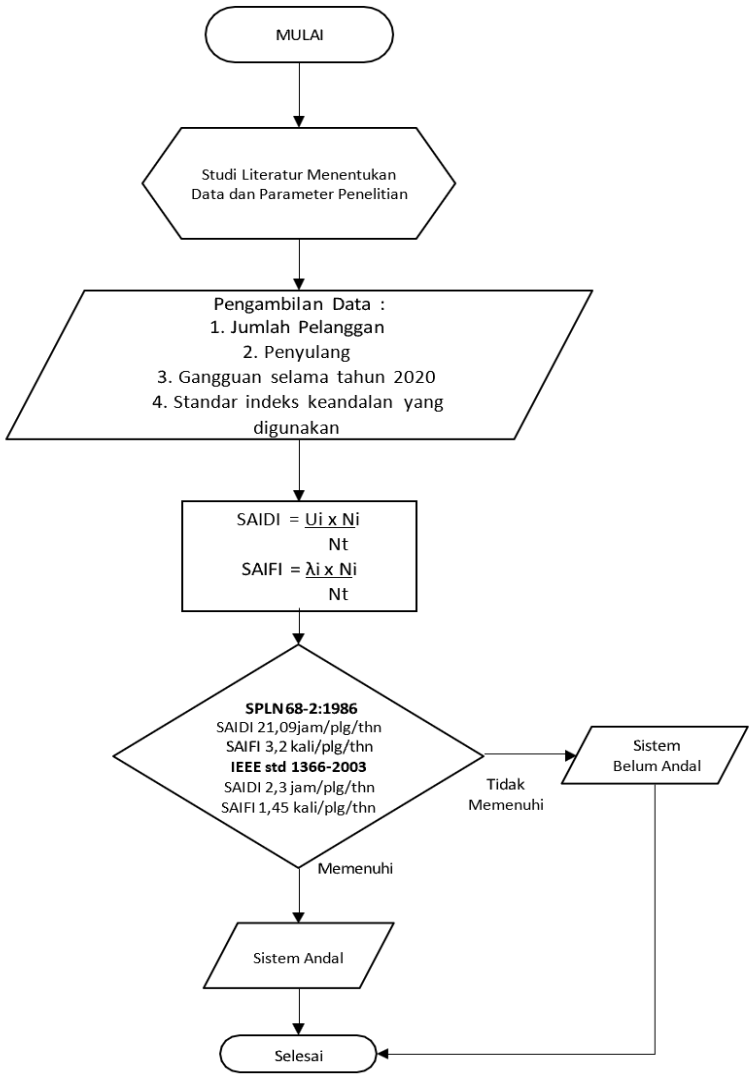

Figure 3. Research Flowchart

Research Data

The data used in this study are as follows:

1. Data on the number of customers of PT. PLN (Persero) ULP Labuhan Haji.
2. Data on feeders of PT. PLN (Persero) ULP Labuhan Haji.
3. Disturbance data during January - December 2023 and 2024.
4. Reliability index standards used

Results

Based on the results of field data and measurement data, the following results were obtained:

Table 3. Customer Disruption Data for 2023

Month	Causes of Disorders	Total Customers	Customer Outages	O'clock X Number of Customer Outages	Disorders	Long time out (Jam)
Januari	Total Kelompok Distribusi	18009	6,096	3,080.86	56	0.567
Februari	Total Kelompok Distribusi	18009	6,248	3,137.41	118	0.981
Maret	Total Kelompok Distribusi	18092	6,381	3,180.41	174	1.314
April	Total Kelompok Distribusi	18113	6,440	3,205.70	218	1.594
Mei	Total Kelompok Distribusi	18140	6,497	3,237.37	245	1.785
Juni	Total Kelompok Distribusi	18140	13,593	8,976.76	313	2.311
Juli	Total Kelompok Distribusi	18195	14,668	9,615.80	708	5.636
Agustus	Total Kelompok Distribusi	18246	14,871	9,730.12	817	6.576
September	Total Kelompok Distribusi	18289	14,976	9,782.30	893	7.227
Oktober	Total Kelompok Distribusi	18326	15,095	9,845.11	969	7.874
November	Total Kelompok Distribusi	18422	26,189	18,054.31	1093	8.846
Desember	Total Kelompok Distribusi	18520	26,342	18,111.00	1204	9.569

Calculation of SAIDI, SAIFI, every month in 2023:

Januari:

$$SAIDI = \frac{\sum_{i=1}^{n} U_i n_i}{N} = \frac{3080.86}{18009} = 0{,}17 \text{ Times/Customer/Year}$$

$$SAIFI = \frac{\sum_{i=1}^{n} \lambda_i n_i}{N} = \frac{6{,}096}{18009} = 0{,}34 \text{ Times/Customer/Year}$$

$$CAIDI = \frac{SAIDI}{SAIFI} = \frac{0{,}17}{0{,}34} = 0{,}51 \text{ Times/Customer/Year}$$

Februari:

$$SAIDI = \frac{\sum_{i=1}^{n} U_i n_i}{N} = \frac{3137.41}{18054} = 0{,}17 \text{ Times/Customer/Year}$$

$$SAIFI = \frac{\sum_{i=1}^{n} \lambda_i n_i}{N} = \frac{6248}{18054} = 0{,}35 \text{ Times/Customer/Year}$$

$$CAIDI = \frac{SAIDI}{SAIFI} = \frac{0{,}17}{0{,}35} = 0{,}50 \text{ Times/Customer/Year}$$

The same steps were taken for March to December, resulting in the results as in the following table:

Table 5. Monthly SAIDI, SAIFI and CAIDI Data for 2023

Month	Total Customers	Customer Outages	O'clock X Number of Customer Outages	Saidi	Saifi	Caidi
Januari	18009	6,096	3,080.86	0.17	0.34	0.51
Februari	18054	6,248	3,137.41	0.17	0.35	0.50
Maret	18092	6,381	3,180.41	0.18	0.35	0.50
April	18113	6,440	3,205.70	0.18	0.36	0.50
Mei	18140	6,497	3,237.37	0.18	0.36	0.50
Juni	18195	13,593	8,976.76	0.49	0.75	0.66
Juli	18246	14,668	9,615.80	0.53	0.80	0.66
Agustus	18289	14,871	9,730.12	0.53	0.81	0.65
September	18326	14,976	9,782.30	0.53	0.82	0.65
Oktober	18379	15,095	9,845.11	0.54	0.82	0.65
November	18422	26,189	18,054.31	0.98	1.42	0.69
Desember	18520	26,342	18,111.00	0.98	1.42	0.69
Total Pertahun				**5,46**	**8,60**	**7,15**

In graphic form, the conditions of SAIDI, SAIFI and CAIDI in 2023 are as follows:

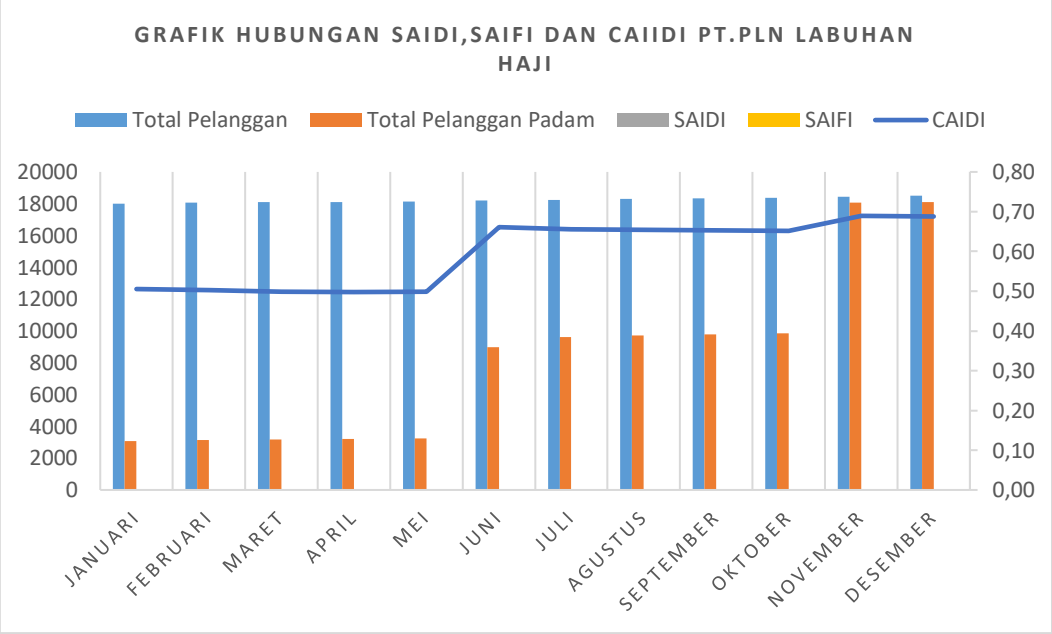

Figure 4. Graph of the Relationship between SADI, SAIFI and CAIDI

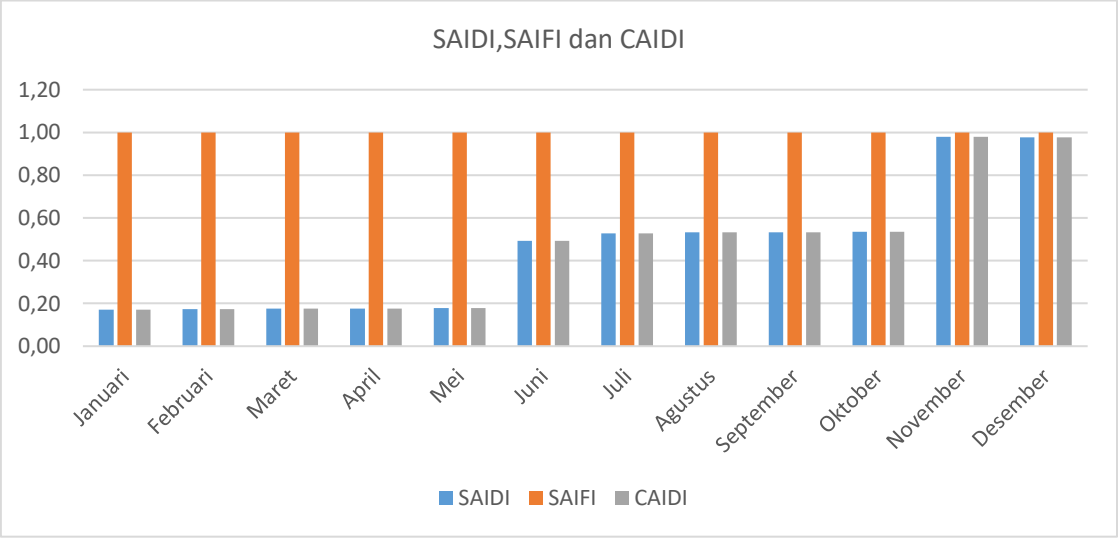

Figure 5. SAIDI, SAIFI and CAIDI

Conclusion

1. Based on the calculation results of the SAIDI, SAIFI and CAIDI values in 2023 PT. PLN ULP Labuhan Haji, the SAIDI value was 5.46 hours/customer/year and the SAIFI value was 8.60 times/customer/year while the CAIDI value was 7.15
2. Based on the provisions of SPLN 68-2:1986, SAIFI has not met the Standard so improvements need to be made, while the SAIDI value has met the standards and provisions of SPLN.
3. Referring to the provisions of IEEE std 1366-2003, the electricity distribution system of PT. PLN ULP Labuhan Haji cannot be categorized as reliable.

References

[1] S. Anisah and A. Khaizairani, "Journal of Electrical and System Control Engineering Analisis Perbaikan Tegangan Ujung Pada Jaringan Tegangan Menengah 20 KV Express Trienggadeng Daerah Kerja PT PLN (Persero) Area Sigli Rayon Meureudu Dengan Simulasi E-Tap Edge Tension Repair Analysis," vol. 2, no. 50, 2018.

[2] A. Azzam, "Analisis Keandalan Sistem Jaringan Distribusi 20 Kv Pt. Pln (Persero) Up3 Metro Menggunakan Metode Reliability Network Equivalent Approach (Rnea)," *J. Inform. dan Tek. Elektro Terap.*, vol. 12, no. 1, 2024, doi: 10.23960/jitet.v12i1.3813.

[3] S. N. Manalu, A. S. P. Tarigan, and Solly Aryza, "An Increasing Insulation Resistance of Poly Vinyl Formaldehid (PVF) Wire in Avoiding Voltage Breaking Electrical Installations," *Int. J. Econ. Technol. Soc. Sci.*, vol. 3, no. 1, pp. 202–207, 2022, doi: 10.53695/injects.v3i1.761.

[4] Z. Tharo, S. Anisah, and S. Aryza, "An Enhance of Renew Source for Homes".

[5] H. Hamdani, Z. Tharo, S. Anisah, and S. Aryza, "Economical value comparison using generator sets, solar power plants and rechargeable batteries as a backup power source in residential home," *Int. J. Civ. Eng. Technol.*, vol. 9, no. 11, pp. 2179–2185, 2018.

[6] C. I. Cahyadi, K. Atmia, and A. Fitriani, "Analisis Pengaruh Rugi-Rugi Daya Pada Jaringan Transmisi 150 kV Menggunakan Software Etap 12.6," *Jambura J. Electr. Electron. Eng.*, vol. 4, no. 2, pp. 126–130, 2022, doi: 10.37905/jjeee.v4i2.13306.

[7] M. A. Risnandar, L. Faridah, and R. Nurdiansyah, "Analisis Rugi Daya Trafo Distribusi Pada Penyulang Tamansari Kota Tasikmalaya," *J. Energy Electr. Eng.*, vol. 4, no. 1, pp. 13–19, 2022.

[8] W. P. Perdana, R. N. Hasanah, and H. S. Dachlan, "'Evaluasi Keandalan Sistem Tenaga

Listrik Pada Jaringan Distribusi Primer Tipe Radial Gardu Induk Blimbing,'" *Eeccis*, vol. 3, no. 1, pp. 6–12, 2009.

[9] M. Imran, "Analisa Keandalan Sistem Distribusi Tenaga Listrik Untuk Wilayah Kota Lhokseumawe Di Pt. Pln (Persero) Rayon Kota Lhokseumawe," *J. Energi Elektr.*, vol. 8, no. 1, p. 42, 2019, doi: 10.29103/jee.v8i1.2410.

[10] Kumala Mahda Habsari, H. D. fidya Amaral, and H. Farhan, "Profil Tegangan Surja Petir pada Generator Impuls RLC Sebagai Simulasi Tegangan Lebih," *ELPOSYS J. Sist. Kelistrikan*, vol. 9, no. 1, pp. 24–27, 2022, doi: 10.33795/elposys.v9i1.88.

[11] Z. Syamsudin, I. Pujotomo, and F. Ramadhan, "KAJIAN RELE JARAK DAN ARUS LEBIH PADA SADA SALURAN UDARA TEGANGAN TINGGI GARDU INDUK 150kV SRONDOL," *J. Sutet*, vol. 5, no. 1, pp. 1–7, 2015, [Online]. Available: https://stt-pln.e-journal.id/sutet/article/view/603

[12] C. Widyastuti, O. Handayani, and T. Koerniawan, "Keandalan Sistem Penyaluran Listrik Berdasarkan Saidi Dan Saifi Sebelum Dan Sesudah Pemasangan Kubikel Arrester di PT PLN UP3 Serpong," *Energi & Kelistrikan*, vol. 13, no. 2, pp. 95–103, 2021, doi: 10.33322/energi.v13i2.1031.

[13] P. Wibowo and S. Aryza, "A Quality Distribution Networks with Unbalanced Load Management Distribution Transformator," *Peer-Reviewed, Ref. Index. J. with IC*, vol. 4, no. 10, pp. 2455–0620, 2018.

[14] M. Alwi *et al.*, "Dampak Indeks Saidi Dan Saifi Terhadap Keandalan Sistem Distribusi Pada Penyulang Da.05 Kota Medan," pp. 717–725, 2023.