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A Coordination Analysis Of 20 kV Medium Voltage Distribution Protection System On LH 04 Gi Blang Pidie Feeder

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ABSTRACT

In the electrical energy distribution system, power distribution systems, especially in the SUTM network, SKTM, and 20 kV distribution substations, can experience various obstacles that stop the distribution of electrical energy to consumers. In addition, various disturbances also cause damage to electrical equipment. One way to minimize or minimize the outage area and damage to various components that are electrified due to interference, a protection system is needed. More specifically, in avoiding the duration (SAIDI) and frequency (SAIFI) of customer outages, it is necessary to set the protection relay properly as a form of protection or protection so as to minimize the position and place of interference. Coordination of the protection system pattern of a network is said to be good if it can minimize the number of outages as small as possible based on the distance and location of the disturbance. After calculating the protection coordination system with ETAP simulation. In the ETAP simulation, the sequence of protection coordination has run well and the protection works in the correct order according to the calculation settings that have been input. The advantage of good protection system coordination is that if there is a disturbance at one point of the distribution network, it does not interfere with the production process in other distribution networks so that the number of outages can be reduced and the affected area can be localized as small as possible. The results of the coordination of the installed protection system on the distribution network utilizing ETAP can be seen that the existing OCR and GFR settings are still not good, for example, if there is a disturbance in the LH 04 feeder network, the relay sequence that releases the contact is LH 03, causing many customers to go out that should not be included. resetting OCR and GFR protection on the distribution network can be based on the fault current that occurs along the network. Overcurrent disturbances are used for low setting and high setting on OCR and GFR protection, for curve characteristics using inverse time standards combined with instantaneous relays. By resetting the OCR and GFR on the distribution network, the reliability of the protection system coordination and the selectivity of the protection sequence are better than the existing conditions so as to create an ideal protection system coordination.

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INTRODUCTION

Electricity is a very important thing in our lives. Every job we do must be assisted by electricity (Innah, 2021). Electricity has become a basic necessity for people's lives in this world, especially in Indonesia, so the development of the electricity sector is a top priority for the Government of Indonesia. Electricity is a strategic commodity in the Indonesian economy because of its role as one of the main energy sources for the industrial sector and the general public, especially for lighting (Fauzi & Anisah, 2022).

To improve the quality of service to the community, PT PLN (Persero) is committed to continuously improving the reliability of supply and the process of channeling electricity to the community. PT PLN (Persero) in running the electricity business divides into three main parts, namely generation, transmission, and distribution which is the final part of the electricity process.

Electric power is produced or generated at power plants using generators. Transmission or delivery is the process of moving electric power from large-scale power plants to certain locations called substations. This substation distributes electricity to distribution substations, which then distribute it to users or consumers (Fauzi & Anisah, 2022). Testing of a prototype of an assembled tool is required to determine the functionality and performance of the tool (Syahputra & Tarigan, 2022). The part that will be tested on this tool is the software and hardware part, where the software includes data transmission and data processing, and the hardware includes calibrating the device readings and the physical condition of the tool components (such as test relays and contactors), web testing will also be carried out for the monitoring function (Syahputra & Tarigan, 2022).

The reliability of the electric power distribution system is highly dependent on the performance of the outgoing distribution of the 20 kV Step Down Substation, medium voltage network (JTM), 20 kV distribution substation, low voltage network (JTR) to the House Line and its kWh Meter.

Load imbalance can cause losses for PLN and consumers. PLN experiences losses in the form of energy that is not distributed, service voltage that is not reached, shorter equipment life, and frequent distribution disruptions. Consumers also experience losses due to low voltage quality which results in the use of electrical energy that does not meet their needs (Tharo, 2022). Voltage drop can also occur because the conductor used has resistance [3]. Therefore, long-distance distribution is very likely to cause voltage drops, so that a lot of voltage and electric current is lost. An important requirement in planning a network is to pay attention to channel quality issues, and good continuity of service to consumers (Anisah & Khaizairani, 2018).

A distributed operating system is one implementation of a distributed system, where a heterogeneous set of computers and processors are connected in a single network. These collections of objects work together to perform a particular task or job (Hulu, 2022). In the electrical energy distribution system, the power distribution system, especially in the SUTM network, SKTM, and 20 kV distribution substations, can occur various obstacles which are the cause of the cessation of electricity distribution to customers. The disturbances that occur cause damage to various electrical equipment.

How to minimize or minimize the area of outages and damage to various components that are electrified due to interference, a protection system is needed. More specifically, to avoid the duration (SAIDI) and frequency (SAIFI) of customer outages requires good protection relay settings as part of the protection system in order to minimize the position and place of interference.

LH 04 is one of the outgoing substations in Labuhan Haji Substation located in Labuhan Haji District, South Aceh Regency which serves electricity supply for Meukek and surrounding areas. The source of electricity for South Aceh comes from the Nagan Raya PLTU which is channeled through the Blang Pidie Substation through the Incoming Power Transformer (TD) cubicle and then issued through the BP 02 outgoing cubicle which is then channeled to the Labuhan Haji Substation with the incoming LH 03 cubicle, from LH 03 issued through 3 outgoing cubicles namely LH 01, LH 02, and LH 04.

Coordination of the protection system pattern of a network is said to be good if it can minimize the number of outages as small as possible based on the distance and location of the disturbance. But not in the condition of the existing protection system in the cubicle at Labuhan Haji Substation. From January to May, LH 04 has experienced outages due to interference 5 times with 2 protections through to LH 03 with an average outage of 10 minutes due to failed protection from the LH 03 cubicle relay. With the outage of LH 03, it resulted in widespread outages to LH 02 and LH 04.

From the SAIFI and economic point of view, the blackout that occurred widely was very detrimental to PT PLN (Persero) because there was ENS (Energy Not Sold). In addition, with the failure of the protection system, networks and customers that should not go out are affected by widespread blackouts.

Literature Review

Electric Power System

A good electric power system is a power system that can serve loads continuously at constant voltage and frequency (Hasibuan, 2018). The electric power system consists of generating units connected by channels to serve the load. Systems with multiple machines use interconnection channels to maintain power continuity and availability (Aryza, 2022).

The electric power system is divided into three important parts, namely the generation system, the distribution system (transmission & substation), and the distribution system. Distribution System is a series of electrical components that starts from the secondary side of the substation transformer (Medium Voltage Side) to the low voltage side at the consumer.

Types of Distribution Networks

The primary distribution network is an electric power line which connects the substation to several substations and distribution substations at primary voltage. In the distribution of primary distribution networks, there are several variations of distribution networks, each of which has its own weaknesses and advantages. In general, there are several basic forms of primary network systems, namely:

1. Radial Primary Distribution Network
2. Primary Distribution Network

3. Ring Distribution Network
4. Spindle Distribution Network
5. Grid Distribution Network
6. Cluster Distribution Network

Substation is an abbreviation of GH or Switching Substation which means a substation that has a function and role as a means of maneuvering electrical load controllers when there is a disruption in the flow of electricity, as well as maintaining continuity of service. Substations are substations that are used with the aim of facilitating loading maneuvers. 20Kv Medium Voltage Cubicles[2], Medium Voltage Cubicle is a system of electrical equipment installed in Substations and Distribution Substations / Substation has a function as a breaker, divider, connector, controller and safety of medium voltage power distribution systems.

Cubicle Function

The functions of the Medium Voltage Cubicles in the Substation / Substation include:

1. Incoming cubicle, has a function as a secondary side connection of the power transformer to the medium voltage rail at the Substation or connecting from the outgoing cubicle of the Substation to the Substation.
2. Outgoing Cubicle, which has a function to connect or distribute the Incoming Cubicle rail to the load.
3. Self-use cubicle (PS transformer), has a function as a connector from the rail to the self-use load of the Substation / Substation Hub
4. Kubikel Kopel (Bus Coupling), has a function as a link between one rail and another and also as a synchronizer between reinforcements at the Substation.
5. PT cubicle equipped with LA, has a function as a means of measurement and security connected to the protection relay.
6. Cubicle Bus Riser / Bus Tie (Interface), has a function as a connector between cubicles at the Substation.

Protection System

An electric power system is a series of equipment that has the possibility of experiencing disturbances caused by external factors or from the system factors themselves. Because of this, it is necessary to have a protection system that has the task of:

1. Conduct an assessment of existing disturbances by recognizing disturbances either in changes in current magnitude, phase, frequency or phase angle.
2. Separate the faulty system from the fault-safe system.

The protection system will not be able to eliminate the various causes of interference. But with this system at least various losses or obstacles that may occur can be minimized.

METHOD

The approach used in this research is a quantitative approach with descriptive and observative methods by taking data from several existing PT PLN (Persero) UP3 Subulussalam in this case is LH 04, and LH 03 in Labuhan Haji Substation and BP 02 in Blang Pidie Substation, where later calculations will be made regarding the coordination analysis of the protection system on the extension. In making this final report, the location of LH 03 and LH 04 in Susoh Substation and BP 02 in Blang Pidie Substation which is located at Jl. Pantai Perak, Kec. Susoh, Kab. Aceh Barat Daya, Nanggroe Aceh Darussalam (NAD). The authors conducted research and took the research data at PT PLN (Persero) UP3 Subulussalam. This activity was carried out in January 2024.

RESULTS AND DISCUSSION

Setting Current Relay

Setting the current on the overcurrent protection relay is based on the nominal current of the equipment (I_N) multiplied by the safety factor. Setting the current of the overcurrent relay is as follows:

1. Power Transformer Incoming Cubicles

   IS primary $= 1040.46\ A$

   Secondary IS $= 1040{,}46\ A \cdot \frac{1}{1000}$

   $= 1040\ A$

2. Repeater BP 02

   IS primary $= \frac{1{,}2}{1} \cdot 160\ A$ (I_N = Peak Load of Repeater BP 01)

   $= 192\ A$

   Secondary IS $= 192\ A \cdot \frac{5}{400}$

   $= 2{,}4\ A$

3. Incoming cubicle LH 03 (Labuhan Haji substation)

   IS primary $= \frac{1{,}2}{1} \cdot 160\ A$ (I_N = Peak Load BL 07)

   $= 192\ A$

   Secondary IS $= 192\ A \cdot \frac{5}{400}$

   $= 2.4\ A$

4. LH 04

   IS primary $= \frac{1{,}2}{1} \cdot 70\ A$ (I_N = Peak Load of BL 06 feeder)

   $= 84\ A$

   Secondary IS $= 84\ A \cdot \frac{5}{200}$

   $= 2.1\ A$

The minimum time setting on the overcurrent protection relay is not below 0.3 seconds. This is so that the relay does not trip caused by the Inrush current from the distribution transformer where the conditions in the field have been connected to the distribution network when the PMT cubicle is operated.

Source Impedance Calculation

The short circuit data on the 150 kV bus of the Blang Pidie Substation is 11.5 kA. Then converted to MVA_{SC} of 2987.79 MVA and obtained short ciruit impedance using equation 2.2 then obtained:

$$Xs\ (150kV) = \frac{kV^2}{MVAsc}$$

$$= \frac{150^2}{2987{,}79}$$

$$= 7{,}53 \text{ ohms}$$

The calculated short circuit fault current is a short circuit fault on the 20 kV side, so the source impedance is changed to the 20 kV side, and the short circuit fault current is obtained using the 20 kV voltage. To change the impedance on the 150 kV side to the 20 kV side, using the equation, it is obtained:

$$Xsc\ (20kV) = \frac{20^2}{150^2} \cdot 7.53 \text{ ohms}$$

$$= 0.133 \text{ ohms}$$

Transformer Reactance Calculation

The reactance value of the power transformer at the Blang Pidie Substation is 12.468%. By using the existing equation, the positive and negative sequence reactance values in Ω can be known, so it is necessary to calculate the Ω value at 100% of the length of the repeater, namely:

$$Xt = \frac{20^2}{30}$$

$$= 13.33 \text{ ohms}$$

Positive and negative sequence reactance values ($X_{t1} = X_{t2}$):

$$Xt_1 = 12.468\% \times 13.33 \text{ ohms}$$

$$= 1.66 \text{ Ohm}$$

Power Transformer 2 at the New Jakabaring Substation uses the YNyn0 + d winding so that the zero sequence reactance value is as follows based on equation 2.6:

$$Xt_0 = 3 \times 1.66$$

$$= 4.98 \text{ ohms}$$

Scavenger Impedance Calculation

The impedance value of the calculated feeder is highly dependent on the impedance value per km (ohm/km) of the calculated feeder, which is highly dependent on the cross-sectional area, type of conductor and STUM or SKTM network.

The power distribution network from BP 02 to GH Susoh incoming cubicle LH 03 uses SKTM network with Al type conductor, cross-sectional area of 240 mm^2 , and length of 6.5 km. At Susoh Substation LH 03 (incoming BP 02) is forwarded via busbar rail to LH 04 (Meukek). From the LH 04 cubicle, electricity is distributed using an Al conductor ground

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cable with a cross-sectional area of 240 mm^2 with a length of 2.2 km which is then connected to the A3C 240 mm SUTM network^2 with a length of 8.18 km until it is connected to the A3C 150 mm SUTM network^2 with a length of 15 km to the end of the recloser network (total load). Based on the formula equation 2.7 and tables 2.2 and 2.3 about resistance (R) and reactance (XL) SUTM A3C and XLPE ground cable with aluminum conductor, the positive, negative and zero sequence impedance is obtained:

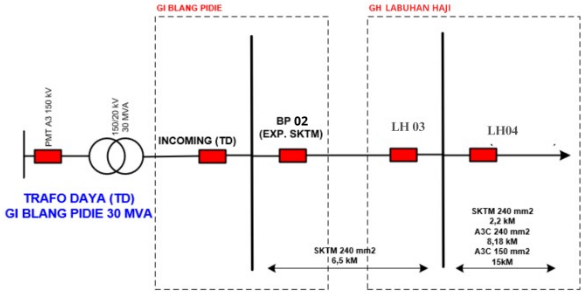

Figure 1. BP 01 network - BL 06 network end

Teble 1. Impedance conductor

Konduktor	Panjang (km)	R/X	R (ohm/km)	jX (ohm/km)	R (ohm)	jX (ohm)
XLPE 240 mm^2 Al	8,7	X_1	0,125	0,097	1,087	0,843
		X_0	0,275	0,029	2,392	0,252
A3C 240 mm^2 Al	8,18	X_1	0,1344	0,3158	1,099	2,583
		X_0	0,2824	1,6034	2,310	13,115
A3C 150 mm^2	15	X_1	0,2162	0,3305	3,243	4,957
		X_0	0,3631	1,6180	5,446	24,27
Rangkaian Seri			$X_1 = X_2 =$		**5,42**	**8,38**
			$X_0 =$		**10,14**	**37,63**

Based on the table above, it can be seen that the impedance of the Kalingga Repository to the end of the network is:

$X_1 = X_2 = 5.42 + j8.38$ ohms

$X_0 = 10.14 + j37.63$ ohms.

Impedance of Repeater BP 02 - Incoming cubicle LH 03

The power distribution network from BP 02 to GH Labuhan Haji incoming cubicle LH 03 uses the SKTM network with an Al type conductor, a cross-sectional area of 240 mm2 , and a length of 6.5 km. Based on the existing equation of resistance (R) and reactance (XL) of XLPE ground cable with AL conductor, the positive, negative sequence impedance is obtained:

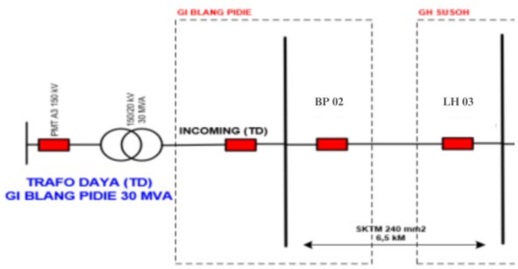

Figure 2. Network BP 02 - LH 0 3

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Table 2. Impedance Table of Repeater BP 02 - cubicle Incoming LH 03

Konduktor	Panjang (km)	R/X	R (ohm/km)	jX (ohm/km)	R (ohm)	jX (ohm)
XLPE 240 mm^2 Al	6,5	X_1	0,125	0,097	0,81	0,63
		X_0	0,275	0,029	1,78	0,18
Rangkaian Seri			**$X_1 = X_2 =$**		**0,81**	**0,63**
			$X_0 =$		**1,78**	**0,18**

Based on the table above, it can be seen that the impedance of BP 02 to LH 03 is:

$X_1 = X_2 = 0.81 + j0.63$ ohms

$X_0 = 1.78 + j0.18$ ohms

Impedance of LH 04 Repeater - End of Repeater

From the LH 04 cubicle, electricity is distributed using an Al conductor ground cable with a cross-sectional area of 240 mm^2 with a length of 2.2 km which is then connected to the A3C 240 mm SUTM network^2 with a length of 8.18 km until it is connected to the A3C 150 mm SUTM network^2 with a length of 15 km to the end of the recloser network (total load).

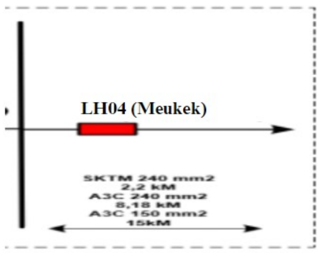

Figure 3. LH Network 04 - Network End

Table 3. Impedance of Feeder BL 06 - Network End

Konduktor	Panjang (km)	R/X	R (ohm/km)	jX (ohm/km)	R (ohm)	jX (ohm)
XLPE 240 mm^2 Al	2,2	X_1	0,125	0,097	0,27	0,21
		X_0	0,275	0,029	0,60	0,06
A3C 240 mm^2 Al	8,18	X_1	0,1344	0,3158	1,09	2,58
		X_0	0,2824	1,6034	2,31	13,11
A3C 150 mm^2	15	X_1	0,2162	0,3305	3,24	4,95
		X_0	0,3631	1,6180	5,44	24,27
Rangkaian Seri			**$X_1 = X_2 =$**		**4,60**	**7,74**
			$X_0 =$		**8,35**	**37,44**

Based on the table above, it can be seen that the impedance of LH 04 to the network extension is:

$X_1 = X_2 = 4.60 + j7.74$ ohms

$X_0 = 8.35 + j37.44$ ohms

Equivalent Impedance Calculation

Equivalent impedance calculation is the result of calculating positive (Z_1 eq), negative (Z_2 eq), and zero (Z_0 eq) impedances from the fault point to the relay source. Calculation of Z1eq and Z2eq can be done by adding all existing impedances, while Z0eq starts from the fault point to the Power Transformer whose neutral is grounded.

After obtaining the impedance of the source, transformer, and extension, then proceed to calculate the equivalent impedance. Where in the calculation of zero sequence equivalent impedance, the value of Rn (grounding resistance) used at the Blang Pidie Substation is 40 ohms, then the value of Rn = 3 x 40 ohms = 120 ohms.

Short Circuit Current Calculation

The next step that is carried out when the equivalent impedance value has been found is to calculate the short-circuit fault current in the Blang Pidie Substation Kubikel BP 02 - incoming GH Labuhan Haji (LH 03) and LH 04 - End of Network, Short-circuit fault current is required:

1. For OCR (Over Current Relay) settings, the Incoming Substation is obtained from the 0% 3-phase short circuit fault current in front of the Substation, while the Outgoing Substation, Incoming Substation, and Outgoing Substation are taken 3-phase short circuit fault currents at the 1% location in front of the Substation and Substation.
2. For the Incoming Substation GFR (Ground Fault Relay) setting, it is obtained from a 1-phase short circuit fault current of 0% in front of the Substation, Outgoing Substation, Substation, Incoming Substation, and Outgoing Substation, a 1-phase fault current to the ground is taken at the location 100% in front of the Substation and 100% in front of the Substation (end of the network) to anticipate if the conductor is touched by a tree, where the tree resistance is large (tree resistance 26-52 ohms) which can minimize the magnitude of the 1-phase short circuit fault current to the ground.

CONCLUSION

Based on the calculation, it is obtained that the value of short circuit current (If) against the distance of LH 04 extension at point 100% is 1002 A (3 Phase) / 224 A (1 Phase), at point 75% is 1246 A (3 Phase) / 238 A (1 Phase), at point 50% is 1644 A (3 Phase) / 252 A (1 Phase), at point 25% is 2416 A (3 Phase) / 266 A (1 Phase), at point 1% is 4369 A (3 Phase) / 279 A (1 Phase). Then on the BP 02 extension at the 100% point is 4524 A (3 Phase) / 279 A (1 Phase), at the 75% point is 4929 A (3 Phase) / 282 A (1 Phase), at the 50% point is 5386 A (3 Phase) / 284 A (1 Phase), at the 25% point is 5897 A (3 Phase) / 286 A (1 Phase), at the 1% point is 6428 A (3 Phase) / 288 A (1 Phase). From the calculations carried out, the value for OCR setting the pickup current (Is) relay at LH 04 is 84 A (low) and 1747.6 A (high), at LH 03 is 192 A (low) and 2184.5 A (high), at BP 02 is 192 A (low) and 3535.4 A (high), and at the incoming TD (Power Transformer) 20 kV is 1040.36 A (low) and 3870 A (high). The TMS (Time Multiple Setting) time setting at BL 06 is 0.18 (low), at LH 03 is 0.28 (low), at BP 02 is 0.47 (low), and at Inc. TD is 0.32 (low). Based on the calculation obtained values for GFR setting pickup current (Is) relay at LH 04 is 22.4 A (low) and 111.6 A (high), at LH 03 is 22.4 A (low) and 139.5 A (high), at BP 02 is 27.9 A (low) and 158.4 A (high), and at incoming TD (Power Transformer) 20 kV is 27.9 A (low) and 173.1 A (high). The TMS (Time Multiple Setting) time setting at LH 04 is 0.11 (low), at LH 03 is 0.22 (low), at BP 02 is 0.31 (low), and at Inc. TD is 0.41 (low).

For the selection of OCR & GFR time in low settings using a time lag of 0.3 s each relay, namely LH 04 (0.3 s), LH 03 (0.6 s), BP 02 (0.9 s), and Inc. TD (1.2 s). In addition, the

High setting (instant) uses a time of 0 s on each relay cubicle. Simulation results using the existing current and time settings compared to using the calculation formula show differences where the existing settings still do not show good protection system coordination because the sequence of active relays is not appropriate (BP 02-LH 04-BL LH03). However, when using the calculation formula shows good coordination results where the active relay sequence is appropriate (LH 04-LH 03-BP02).

The characteristic curve chosen is the inverse standard curve (SI) and in combination with the Instantaneous relay curve. This aims to get a good relay setting coordination between each relay Inc. TD 20 kV, BP 02, LH 04, and LH 04. Comparison of the number of outages based on simulation of existing settings with calculations shows a significant difference, when using existing settings the number of outages reaches 13744 customers because BP 02 releases the first contact. Meanwhile, when using the calculation setting, the relay coordination is in order where LH 04 releases the first contact when it senses a disturbance in the LH 04 extension so that the outage customers can be reduced to 1735 customers with a difference of 12009 customers.

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