Analysis of Main Protection Replacement of Bay Line Parepare - Suppa from Distance Relay to Line Current Differential Relay of 150 kv Parepare Substation

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Abstract- Bay Line Parepare - Suppa uses relay distance as the main safety. With a short transmission line distance, a reliable protection system is needed to overcome disturbances that occur in the system. With the development of time, and also to further improve the main transmission safety, the distance relay as the main protection is replaced with LCD (Line Current Differential) with changes in SPLN T5.002: 2010 to SPLN T5.002: 2021. This study aims to characterize the impedance value, the results of the SIR (Source Impedance Ratio) process and the effect of revenue obtained in replacing the main protection of the Parepare - Suppa bay line from relay distance to LCD (Line Current Differential) relay.

Based on the calculation of the impedance seen in the relay distance on the Parepare - Suppa high voltage overhead line, the results are very small (0.1286 - 0.321 ohms). The results of the analysis show that the Source Impedance Ratio (SIR) obtained on the Parepare - Suppa conductor is 4.015 Ohm, while after replacing the relay, the gain or profit obtained is Rp. 1,112,340,880, -

Keywords- Bay Line Parepare - Suppa, Relay, Distance, LCD (Line Current Diffrential), Impedance, SIR (Source Impedance Ratio), Gain.

I. Introduction

PT PLN (Persero) is a State - Owned Enterprise company engaged in the electricity sector. PLN or State Electricity Company has a long history as the main electricity provider in Indonesia. The electricity system generally consists of several parts, namely generators, transmission lines, distribution lines and loads. The transmission line is a channel that distributes electrical power from the generating center to the substation to consumers. So that the electrical energy generated from the generating center can be used by consumers. In the transmission line system, a higher voltage is used. This channel is an important part of the power system PT. PLN (Persero) is a State-Owned Enterprise company engaged in the electricity sector. PLN or State Electricity Company has a long history as the main electricity provider in Indonesia. The electricity system generally consists of several parts, namely generators, transmission lines, distribution lines and loads. The transmission line is a channel that distributes electrical power from the generating center to the substation to consumers. So that the electrical energy generated from the generating center can be used by consumers. In the transmission line system, a higher voltage is used. This channel is an important part of the electric power system.

With the development of time, and also to further improve the main transmission safety, the distance relay is replaced with an LCD (Line Current Diffrential) relay with the change of SPLN T5.002: 2010 to SPLN T5.002: 2021. With LCD relays work by comparing the incoming and outgoing currents of an electrical conductor. If a significant current difference is detected it can indicate a disturbance and is equipped with FO (Fiber Optic) communication so that the communication speed between relays is better than PLC (Power Line Carirer)

The Parepare-Suppa transmission line is a line that connects directly to the Suppa PLTD plant, the relay currently used is Distance Relay. However, the Parepare - Suppa conductor distance is less than 10 km, namely 7.5 km. On short lines it is not recommended to use Distance relays because the distance is too close.

With a short transmission line distance, a reliable protection system is needed to overcome disturbances that occur in the system. The protection system has an important role in isolating interference and securing parts that are not affected by interference and maintaining the reliability and safety of the power system. The right protection system is also useful for providing fast, reliable and selective electricity services. In this study, to analyse the replacement of main protection from distance relay to

LCD (Line Current Differential) relay along with the development of time and technology.

The literature review examines references from SPLN T5.002_2021 transmission line protection patterns [1], ESDM ministerial regulation No. 20 concerning the rules of the sulawesi power system network [2], and SK DIR 0520 revised 2024 concerning protection maintenance and conductor control [3], and previous studies related to transmission system reliability, especially those related to distance relays and LCD (line current diffrential). This is especially relevant for the Bay Line Parepare - Suppa at PT PLN (Persero) ULTG Parepare, where this research is applied.

II. Research Methhodology

A. Place and Time of Research

The research was conducted from January 2024 to June 2024 at PT PLN (Persero) ULTG Parepare. In the early stages, literature studies and data collection were carried out such as relay setting data, conductor length, CT and PT data, nominal voltage, line impedance as the basis for calculations.

B. Activity Procedure

The research lasted for six months starting from January 2024 to June 2024 at PT PLN (Persero) ULTG Parepare. Before carrying out the activity, a literature study was carried out first. The next step is to collect the necessary data. After obtaining the data, calculations are then carried out according to the needs of the problem formulation. Figure 1 shows the flowchart of activity procedures that will be carried out until the results and conclusions are obtained.

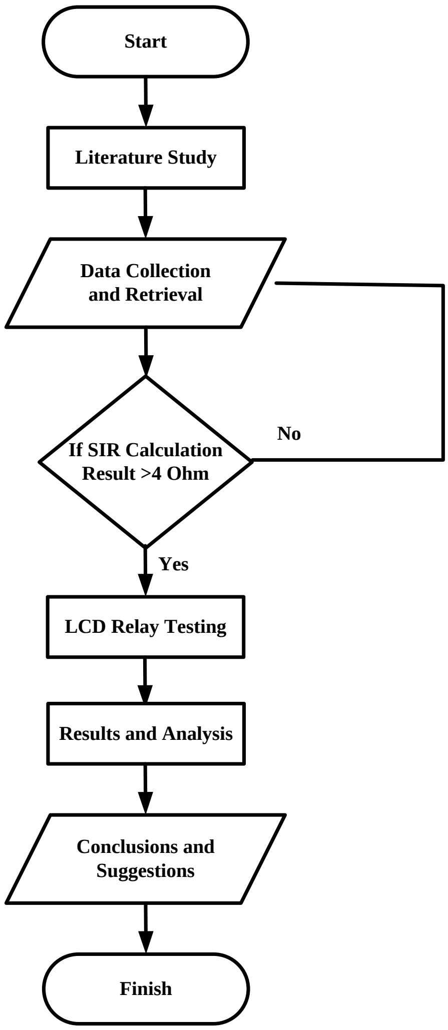

Figure 1. Flowchart of Activity Procedure

Based on the flowchart above, starting with a literature study then collecting data such as relay setting data, conductor length, CT and PT data, nominal voltage, line impedance. After the data is complete, calculate the SIR, after the SIR is fulfilled, LCD relay testing is carried out with the omicron CMC test equipment. This study aims to determine the value of the visible impedance relay, SIR (Source Impedance Ratio) and the benefits obtained by the company if the relay replacement is done.

C. Data collection technique

The data collection process carried out on the analysis of the replacement of the main protection relay of the Parepare-Suppa bay line from the distance relay to the LCD (Line Current Differential) relay of the 150 kV GI Parepare substation is observation (field study), literature study (library study) and interviews (interview).

1. Observation

Data collection using the observation method (field research), namely looking for technical field data directly. The data is in the form of relay setting data, conductor length, CT and PT data, nominal voltage, line impedance, equipment nameplate at PT PLN (Persero) ULTG Parepare.

2. Literature Study

   Data collection using library studies is carried out by reading, collecting and studying literature related to the thesis title which comes from journals, PT PLN (Persero) guidebooks, MTU data and settings.

3. Interview

   Data collection using the method (interview) is done by consulting directly with technical employees at PT PLN (Persero) ULTG Parepare.

D. Data Analysis Technique

The data analysis carried out is to calculate the SIR (Source Impedance Ratio), the impedance value seen by relays Z1, Z2, Z3, total suspension, capacitive reactance, charging current, setting diff and gain obtained are analyzed and conclusions are drawn.

III. Results and Discussion

A. *Overview*

As has been explained that the relay installed on the Parepare-Suppa 150 kV bay line relay currently used is a distance relay since 1997. The distance of the Parepare - Suppa conductor network is less than 10 km or 7.5 km. On short lines it is not recommended to use distance relay, because the distance is too close.

B. Impairment History Data

The history of Sulawesi UIP3B LCD relay interference from 2019-2024 is mostly due to lightning. Regarding record interference that has occurred in UPT Makassar, that on the Parepare-Suppa conductor for the past 5 years there is no data on interference in transmission. But there are several conditions that can cause interference such as interference due to kites, dredging of other parties' land, lightning due to proximity to the sea, trees and rusted insulator pins so that they can cause relays to be lacking.

C. Calculation and Analysis

Calculation before replacement of the distance relay, from the research results of the Parepare - Suppa transmission system in the form of impedance values in zone 1, zone 2, and zone 3. The data used in this study were obtained from UPT Makassar, namely:

1. Data ratio CT and PT
   CT = 1250:5
   PT = 150.000:110
2. The length of the Suppa Line transmission line from Tower 1 - 25 is 7.5 km.

The impedance value of the transmission system line length can be calculated as follows: Impedance of GI Parepare - GI Suppa line:

$ZL1 = 0{,}8790 + J\ 3{,}0670$

Zona 1

$Z1 = 0{,}8 \times ZL1$[4]

$Z1 = 0{,}8 \times (0{,}8790 + J\ 3{,}0670)\ \Omega$

$Z1 = 0{,}7032 + J\ 2{,}454\ \Omega$

The zone1 protection range is 0.8 x 7.5 = 6 km.

The zone uses an instant working time because it is the main safety guard.

t = 0 s.

Zona 2

$Z2 = 1{,}2 \times ZL1$ [4]

$Z2 = 1{,}2 \times (0{,}8790 + J\ 3{,}0670)$

$Z2 = 1{,}0548 + J\ 3{,}6804\ \Omega$

With zone 2 protection coverage is

= 1,2 x 7,5 km

= 9 km

The working time in zone 2 is longer than zone 1, namely t = 0,4 s

Zona 3

$Z3 = 1{,}2\ ZL1 + 0{,}8\ ZL2$ [4]

$Z3 = (1{,}2\ (0{,}8790 + J\ 3{,}0670) + 0{,}8\ (0{,}8790 + J\ 3{,}0670))$

$Z3 = (1{,}0548 + J\ 3{,}6804) + (0{,}7032 + J\ 2{,}454)$

$Z3 = 1{,}758 + J6{,}1344\ \Omega$

With zone 3 protection coverage is

= 2,0 x 7,5

= 15 km

The working time in zone 3 considering the length of protection is more than zone 1 and zone 2, then the zone 3 setting time is t = 1.6 s.

The impedance value that can be seen by the relay is obtained from the following equation:

Rasio CT = 1250:5 A[5]

Rasio PT = 150.000:110 V[6]

Z = (CT / PT) x Zona

Rasio CT = 1250:5 A

Rasio PT = 150.000 : 110 V

$n = \frac{PT}{CT}$

$n = \left(\frac{110}{150000}\right) x \left(\frac{1250}{5}\right)$

$n = \left(\frac{137500}{750000}\right)$

$n = 0{,}183$

Calculation on zone 1 that the relay sees:

= 0,183 (0,7032 + J 2,454)

= 0,1286 + J 0,449 Ω

Calculation on zone 2 that the relay sees:

= 0,183 (1,0548 + J 3,6804)

= 0,193 + J 0,662 Ω

Calculation on zone 3 that the relay sees:

= 0,183 (1,758 + J6,1344)

= 0,321 + J 1,122 Ω

The value impedance seen by the relay is obtained from the calculation of the Parepare - Suppa conductor of 0.1286 + J 0.449 Ω, the ability of the distance relay to protect the transmission system is very good because the transmission system distance is usually very far between the substations. But the distance relay is not too far away, the impedance read on the distance relay is very small (0.1286 - 0.321 ohms) because the conductor is short, selectivity is difficult to achieve when using an impedance type relay, so as a solution a differential type of relay is selected [1].

D. Calculation After Replacement of Line Current Differential

Table 1 Typical LCD Setting Data
(Source: UIP3B Sulawesi Protection Relay Approval Data)

Line Length (Ln)	: 7,5 km
Nominal Voltage (KV)	: 150000
CT Ratio (CT)	: 1250 / 5 A
PT Ratio (PT)	: 150000/110 V
Frequency (F)	: 50 Hz
Line Impedance	
Line Resistance (R1)	0,879 Ω/km
Line Reactance (X1)	3,067 Ω/km

1. Calculating Total Susceptance.

The calculation of the total susceptance value requires the value of the susceptance and the length of the Parepare - Suppa conductor line.

Bt = B x Ln[7]

With:

Bt = Total Susceptance (S)

B = Susceptance (s/km)

Ln = Channel Length (km)

For the calculation of total susceptance in the Parepare - Suppa conductor

Bt = B x Ln

$Bt = (68{,}046 \text{ x } 10^{-6}) \text{x } 7{,}5$

Bt = 0,00051035 S

Bt = 5,1035 x 10^4 S

2. Calculation of Capacitive Reactance Value

$Xc = \frac{1}{Bt}$ [7]

With:

Xc = Capacitive Reactance (Ohm)

Bt = Total *Susceptance* (S)

To calculate the value of capacitive reactance on this conductor, it can be calculated as follows:

$Xc = \frac{1}{Bt}$

$Xc = \frac{1}{(5{,}1035 \text{ x } 10)^4}$

$Xc = \frac{1}{0{,}00051035}$

Xc = 1959,43 Ohm

3. Charging Current Calculation

To calculate the charging current, you can use the calculation with the primary side and the secondary side with the following equation:

a. Primary side charging current

$$Ic = \frac{kv \ x \ 10^3}{\sqrt{3} x \ Xc}$$

With:

Ic = Charging Current (A)

kV = Nominal Voltage (V)

primary side charging current can use the following equation:

$$Ic = \frac{\text{kv x } 10^3}{\sqrt{3}\text{x Xc}}$$

$$Ic = \frac{150000}{1{,}73\text{x } 1959{,}43}$$

$$Ic = \frac{150000}{3389{,}81}$$

Ic = 44,25 A

b. Secondary side charging current

$$Isc = \frac{Ic}{CT}$$

With:

Ic = Primary Charging Current (A)
Isc = Secundery Charging Current (A)
CT = Current Transformer Ratio (A)

$$Isc = \frac{Ic}{CT}$$

$$Isc = \frac{44{,}25}{1250/5}$$

$$Isc = \frac{44{,}25}{250}$$

Isc = 0,177 A

4. Pick Up Current

a. Relay Minimum Pick Up Current I_{S1}

The minimum pickup current value is I_{S1} calculated from the following equation:

$I_{S1} = 2{,}5 \text{ x } I_{Sc}$

With:

I_{S1}= Pick up Current
I_{Sc}= Secondary Charging Current

Then the minimum pickup current value of relay I_{S1} can be determined as follows:

$I_{S1} = 2{,}5 \text{ x } I_{Sc}$
I_{S1} = 2,5 x 0,177
I_{S1} = 2,5 x 0,177
I_{S1} = 0,4425 A

b. Relay Maximum Pick Up Current (I_{S2})

The value of In (nominal current) used is in accordance with the CT ratio used. The CT ratio used is 1250/5, nominal current 638 A (conductor load). Calculation of the setting value of relay I_{S2} is calculated using the following:

I_{S2} = 2 x In Relay
I_{S2} = 2 x 5 A
I_{S2} = 10 A

5. Setting Relay Line Current Differential (LCD)

The relay setting calculation is used to determine the minimum and maximum working currents. The calculation of the differential relay setting value is divided into 2 that is I_{S1} and I_{S2}, with equation as follows:

a. Setting Relay Line Current Differential (I_{S1})

Setting Relay I_{S1} is used to determine the minimum working current.

I_{S1} > (2,5 x Ic)

With:

Ic = Charging Current (A)
I_{S1} = Minimum pick up current (A)

Determine I_{S1}:

I_{S1}> (2,5 x 44,25)
I_{S1}> 110,625 A

b. Setting Relay Line Current Differential (I_{S2})

Setting relay I_{S2} is used to determine the maximum working current of the relay on the stability of the relay performance when a large disturbance occurs.

Determine I_{S2}:

I_{S2} = 2 x ln Relay
I_{S2} = 2 x 5 A
I_{S2} = 10 A

Setting $I_{diff} = \frac{I_c+I_{f\,min}}{2}$

So I_{diff} (Primer) can be entered into the equation as follows:

$$I_{diff} = \frac{44{,}25+638}{2}$$

$$I_{diff} = \frac{682{,}25}{2}$$

I_{diff} =341,125

So that we get Idiff = 341,125 Ampere (primary).

To Idiff sekunder

$$I_{diff} = \frac{341{,}125}{1250}$$

I_{diff} =0,27

So that we get Idiff = 0,27 Ampere (Secundery).

Recommended settings Idiff = 0.2 – 0.3 A, so the maximum value is selected 0.30 A (secondary).

Working time t = 0 ms (instantaneous)

c. Relay Characteristics

Slope 1 = CT error + relay accuracy + safety factor

Recommended slope setting of 30% is adjusted with the relay manufacturer's recommendations with typical settings that provide stability for small CT mismatches, while ensuring good sensitivity to resistive faults under heavy load conditions.

Slope 2 = maximum short circuit current.

Recommended slope setting 150% adjusted with the relay manufacturer's recommendations with typical settings that provide stability under heavy fault current conditions.

Autoreclose Setting

1P trip Mode = 1-3
1P Dead Time 1 = 1 sec
Reclaim Time = 40 sec

Pulse Time = 0.2 sec

Relay line current differential is more recommended for installation on the Suppa - Parepare voltage overhead line than the distance relay, because this relay has no effect on impedance, only calculates the current at the substation in front of it. But the obstacle is the problem of costs that are more expensive than the installation of distance relays. Because the line current differential requires optical fibre. The longer the fibre optic installed, the greater the cost accumulated for the installation of fibre optic in the system.

E. Determination of Source Impedance Ratio

The conductor to be analysed is the Parepare - Suppa conductor. The data for the conductor is as follows:

$V_{\text{base L-N}} = 86{,}6 \text{ kV}$
$V_{\text{Relay}} = 57{,}7 \text{ kV}$
$I_{\text{Relay}} = 13{,}65 \text{ kA}$
$Z_{\text{Kabel}} = 0{,}0754 \text{ ohm/km}$
$L_{\text{Saluran}} = 7{,}5 \text{ km}$

With,

$V_{\text{base L-N}} = \text{Phase} - \text{ground voltage}$
$V_{\text{Relay}} = \text{Relay Voltage}$
$I_{\text{Relay}} = \text{Relay Current}$
$Z_{Conductor} = Conductor\ impedance$
$L_{Channel} = Channel\ Length$

Resulting in the following values as follows:

- $Z_{S_{3PH}} = \frac{V_{drop}}{I_{relay}} = \frac{V_{\text{base L-N}} - V_{relay}}{I_{relay}}$

  $Z_{S_{3PH}} = \frac{86{,}6\text{-}55{,}6}{13{,}65} = \frac{31}{13{,}65} = 2{,}271 \text{ Ohm}$
- $Z1_L = Z_{Conductor} \text{ x } L_{Channel}$

  $Z1_L = 0{,}0754 \text{ x } 7{,}5 = 0{,}5655 \text{ Ohm}$
- $\text{SIR} = \frac{Z_{S_{3PH}}}{Z1_L}$

  $\text{SIR} = \frac{2{,}271}{0{,}5655} = 4{,}015 \text{ Ohm}$

From the results of the calculation of the Source Impedance Ratio (SIR) on the conductor of the 150 kV Parepare - Suppa with a conductor length of 7.5 km, the resulting SIR (Source Impedance Ratio) value is 4.015 Ohms. In this case, it is in accordance with the 150 kV conductor protection (TT) SPLN T5.002-1: 2021, PM ESDM in 2020, revision of SKDIR 520 in 2024 which states that if the SIR value> 4.0 is included in the short line and from the above statement, the Parepare - Suppa conductor can be said to be a short conductor.

So that the 150 kV line protection used is for main protection using line current differential equipped with a distance relay function with dedicated and direct FO communication media (point to point).

F. Saving

Saving is the cost that can be saved if the relay replacement solution is implemented. To calculate the total cost that can be saved when there is a disturbance in the conductor, the following data assumptions are given:

Table 2 Electricity tariffs and distributed power
(Source: Determination of Electricity Tariff Adjustment PT. PLN)

Electricity Tariff	Rp. 1699,53
Total power flow	27 MW (24 July 2024)

From the data assumptions in the table, the costs saved are as follows:

= Power flow x Electricity tariff x Number of bay lines x Number of operating hours

$= 27 \text{ KW x } 1000 \text{ x } \frac{1699{,}53}{\text{kWh}} \text{ x 2 x 24 jam}$

=Rp. 2.202.590.880,-

So, the saving obtained is: Rp. 2.202.590.880, -

G. *Gain*

Gain is the income that can be obtained if the relay replacement solution is implemented. To calculate the gain, it is necessary to calculate the expenditure first, assuming the following data:

Table 3 Price of FO Transmission
(Source: UP2B Sulawesi FO Cable Purchase Data)

Conductor Price	97.500/meter
Conductor Length Parepare-Suppa	7,5 Km

From the assumption of the data in table 3, it can be calculated if the expenditure is carried out, which is as follows:

Price of Pare-Suppa Fo Cable = Length of conductor x FO cable price per meter

= 7,5 x 1000 meter x Rp. 97.500,-=Rp.731.250.000,-

Table 4 LCD Relay Price
(Source: UIP3B Sulawesi LCD Purchase Contract Data)

LCD price includes supporting materials, dismantling services, installation services	179.500.000/unit
Installed LCD	2 Unit

From the assumptions of the data in table 4, it is possible to calculate the expenditure when done, which is as follows:

Installed LCD relay price

= LCD Price x Number of LCDs installed

=Rp. 179.500.000 x 2 Unit=Rp. 359.000.000,-

So, the expenditure gain:

Pare-Suppa FO Cable Price + Installed LCD Price

=Rp. 732.250.000,+Rp. 359.000.000,-

= Rp. 1.090.250.000,-

H. *Benefit*

Benefit is the profit generated. benefits that can be obtained after replacing the relay are:

Benefit = Saving (Cost savings) - Gain (Cost Expenditure)

= 2.202.590.880-1.090.250.000

=Rp. 1.112.340.880

So, the benefit or profit obtained after replacing the relay is Rp. 1.112.340.880,-

Other benefits that result after replacing the relay on the conductor include:

a. The potential for load outages due to interference in the conductor is reduced. With the LCD (Line Current Diffrential) relay, the disturbance detected by the relay is limited to internal only while external disturbances are not read so that the conductor disturbance is reduced.

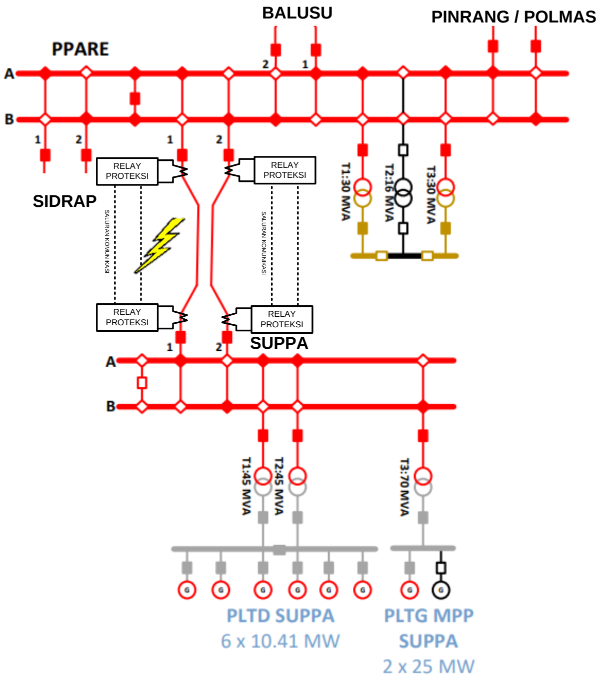

Figure 2 Single line diagram of internal fault Parepare - Suppa
(Data source: SLD Sulbangsel)

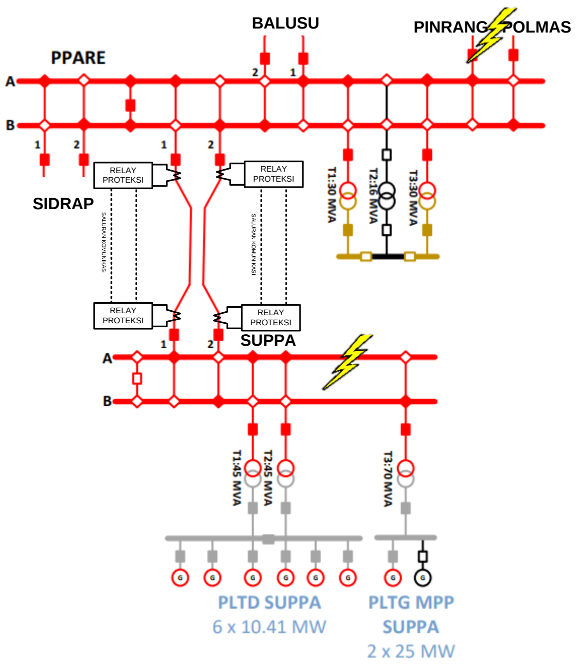

Figure 3 Single line diagram of external fault Parepare - Suppa
(Data source: SLD Sulbangsel)

b. Accelerate the time to find the cause of the disturbance. With the replacement of the LCD relay, the cause of the disturbance can be found as soon as possible because it only detects between CT in the suppa line of GI Parepare With CT line parepare PLTD Suppa. FL (Fault locator) will be more precise in calculating the fault distance in KM±2%. data attached in appendix 14 [8]

c. Increased consumer confidence due to improved power system reliability. With the reduction of disturbances, the distribution of electricity from the Suppa PLTD plant to the system so that consumers enjoy electricity without blackouts. The Pare - Suppa conductor is supplied by the Suppa PLTD plant with a capacity of 62.4 MW and MPP Suppa with a capacity of 50 MW so that all operate at 112.4 MW. If there is a disturbance in the Parepare - Suppa segment, the power that is not distributed is 112.4 MW.

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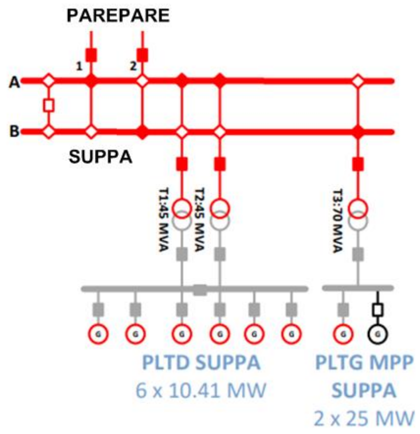

Figure 4 Single line diagram of PLTD Suppa (Data source: SLD PLTD Suppa)

IV. Conclusions

From the results of calculations and analysis, the following conclusions can be drawn:

1. The impedance calculation seen in the relay distance on the Parepare - Suppa high voltage overhead line is very small (0.1286 - 0.321 ohm) because the conductor is short, selectivity is difficult to achieve when using an impedance type relay, so as a solution a differential type of relay is selected.

2. Source Impedance Ratio (SIR) obtained on the Parepare - Suppa conductor is 4.015 Ohm. In this case it is in accordance with the 150 kV conductor protection (TT) SPLN T5.002-1: 2021, PM ESDM in 2020, revised SKDIR 520 in 2024 which states that if the SIR (Source Impedance Ratio) value of the line is short, if SIR> 4.0 (four point zero), With the main protection scheme LCD + Teleprotection DEF + Z Teleprotection DEF and Z (zone 1 and teleprotection Z) are active if LCD communication fails.

3. The effect of revenue earned after the replacement of relay distance amounted to Rp.1,112,340,880, -.

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