

# Analysis of KBL 02 Feeder Protection Coordination to Improve Reliability at PT PLN (Persero) Djty ULP Purwokerto City

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In 2017, the KBL02 feeder was recorded as having a low reliability level due to the high frequency of PMT and recloser tripping faults. Based on the fault data evaluation, most fault locations were downstream of the recloser, but the protection system actually caused the outgoing PMT to operate first. This condition resulted in a wider outage area and reduced electricity supply to customers, resulting in an increase in the SAIDI and SAIFI reliability index values at PT PLN (Persero) Purwokerto City ULP. The main problem was caused by inconsistencies in protection coordination between the outgoing PMT and the KBL02.067 recloser, which was influenced by recloser placement that was not aligned with the OCR and GFR settings. This study aims to evaluate protection coordination and determine recloser relocation based on fault current calculations and protection settings. The results are expected to improve protection system selectivity and enhance power distribution reliability at the KBL02 feeder.

**Keywords:** KBL02 feeder, protection coordination, recloser, system reliability

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## 1. Introduction

Distribution systems play a crucial role in delivering electrical energy from the source to customers through medium-voltage networks of 20 kV and low-voltage networks of 220 V/380 V. In practice, distribution networks in Indonesia still largely utilize open conductors, making them highly vulnerable to short circuits, both between phases and between phases to ground. These faults can be temporary or permanent, caused by various factors such as environmental conditions, insulation failure, and foreign objects impacting the conductors. To maintain the reliability of electrical power, a protection system that can operate selectively, quickly, and reliably is required. Protective equipment used in distribution networks includes overcurrent relays and ground fault relays, which are installed on outgoing PMTs and reclosers. Proper coordination between these protective devices is essential to localize disturbances and prevent outages across a wider area. Based on 2017 disturbance data, the KBL02 feeder at PT PLN (Persero) ULP Purwokerto Kota was recorded as experiencing disturbances with a fairly high frequency, namely 12 PMT trips and 3 recloser trips. This condition causes the KBL02 feeder to be categorized as a feeder with a low level of reliability. Data evaluation shows that even though the disturbance occurred on the downstream side of the recloser, the outgoing PMT actually worked first. This indicates that protection coordination and recloser placement are not optimal. Therefore, a re-evaluation of the protection coordination system and the determination of appropriate recloser locations are needed to improve the reliability of the distribution system.

## 2. Literature Review

### Electrical Power Protection

An electrical power protection system is a series of safeguards designed to protect equipment and networks from disturbances and overload conditions. This system works by detecting disturbances and isolating the disturbed part of the system, so that other parts can continue to operate normally. The success of a protection system is determined by several main characteristics, namely sensitivity to disturbances, selectivity in determining the location of disturbances, response speed, and the level of reliability of the protection equipment. The implementation of a good protection system in the distribution network aims to minimize equipment damage, reduce the area and duration of blackouts, and improve the quality of electricity service to customers.

The purpose of distribution protection equipment is:

- a. To reduce damage to installed equipment due to interference.
- b. To prevent the expansion of the fault area or blackout area.
- c. To minimize the duration of the disruption
- d. To provide optimal electricity services to consumers.
- e. To provide safety for humans and other objects around electrical equipment.

### Short Circuit Protection Equipment

#### 1. Current Transformer

A current transformer is an important component in a protection system that functions to adjust the current magnitude in the electric power network. The current flowing on the primary side with a relatively large value is reduced to a smaller secondary current so that it can be received by measuring instruments and safety relays. The current ratio between the primary and secondary sides depends on the ratio of the number of coil turns. If the primary current is expressed as  $I_{p1}$  and the secondary current as  $I_{s1}$ , with the number of primary turns  $N_1$  and secondary  $N_2$ , then the relationship between the two can be expressed as follows:

$$\frac{I_1}{I_2} = \frac{N_2}{N_1} \quad (1)$$

#### 2. Voltage Transformer (PT)

Voltage transformer or *potential transformer* A transformer is a device used to reduce high voltage levels to low voltages in alternating current systems. This equipment plays a crucial role in measurement and protection systems because it allows for safe network voltage monitoring and increases the reliability of protective equipment.

#### 3. Circuit Breaker (PMT)

A circuit breaker is a safety device that functions as a separator and connector for electrical circuits in a power system. A circuit breaker is designed to operate under a variety of operating conditions, both during normal system conditions and during disturbances, including short-circuit currents, within its specified interrupting capacity.

#### 4. Over Current Relay(OCR)

An overcurrent relay is a protective device that works by detecting current increases exceeding the permitted setting value. This condition can be caused by short circuits or overloads, which can potentially damage electrical equipment. In addition to OCRs, ground fault relays are used to identify single-phase-to-ground faults. The configuration of these relays is generally represented in the form *single line diagram*.

**Short Circuit Current Equation**

A three-phase short circuit is a type of symmetrical fault in an electric power system. In this condition, the resulting fault current is influenced by the magnitude of the source voltage and the total impedance of the system through which the current flows from the point of generation to the fault location. Mathematically, the basic relationship between current, voltage, and impedance can be written as:

$$I = \frac{V}{Z} \dots\dots\dots(2)$$

With :

- I = is the fault current (A),
- V = is the source voltage (V),
- Z = is the total impedance of the network expressed as equivalent impedance ( $\Omega$ ).

In a three-phase power system, the network impedance is analyzed using the concept of symmetrical components consisting of positive sequence impedance ( $Z_{1Z\_1Z1}$ ), negative sequence impedance ( $Z_{2Z\_2Z2}$ ), and zero sequence impedance ( $Z_{0Z\_0Z0}$ ). In a balanced three-phase fault, only the positive sequence impedance plays a role. Therefore, the magnitude of the three-phase fault current can be expressed as:

$$I_{3\text{phase}} = \frac{V_{p-n}}{Z_1} \dots\dots\dots(3)$$

With :

- $I_{3\text{ phase}}$  = is the three-phase fault current (A),
- $V_{p-N}$  = is the phase voltage to neutral (V),
- $Z_1$  = is the positive sequence equivalent impedance ( $\Omega$ ).

Under normal conditions, a three-phase system has the same voltage across each phase with an angular difference of 120°. When a three-phase fault occurs, the currents in each phase flow toward the fault point at symmetrical values and angles, so that the vector sum of the currents in the neutral conductor is zero. Therefore, the analysis of this fault can be simplified using only one positive sequence circuit.

1. Two-phase fault

A two-phase fault occurs when two phase conductors are connected to each other, either directly or through a specific impedance. In this condition, the current flowing in both phases is the same magnitude, while the voltage that plays a role is the voltage between the phases. If the currents in phase A and phase B are stated as  $I_A$  and  $I_B$  respectively, then the following relationship applies:

$$I_A = I_B = I$$

Meanwhile, the magnitude of the voltage between phases can be written as:

$$E_{AB} = \sqrt{3}E_A.$$

In a two-phase fault, the current in one phase is in the same direction as the generated voltage sequence (positive sequence), while the current in the other phase is in the opposite direction to the voltage sequence (negative sequence). Therefore, the impedance that affects the magnitude of the fault current is a combination of the positive and negative sequence impedances arranged in series.

The two-phase fault current can be calculated using the following equation:

$$I_{2\text{Phase}} = \frac{V_{a-b}}{Z_1 + Z_2} \dots\dots\dots(4)$$

The values of  $Z_{1Z\_1Z1}$  and  $Z_{2Z\_2Z2}$  are the positive and negative sequence equivalent impedances of all system elements that have been simplified from series and parallel configurations.

2. Single phase ground fault

A single-phase-to-ground fault occurs when one of the phases, for example phase A, is connected directly or through a certain impedance to ground. The voltage that causes the fault current to flow in this condition is the phase-to-neutral voltage.

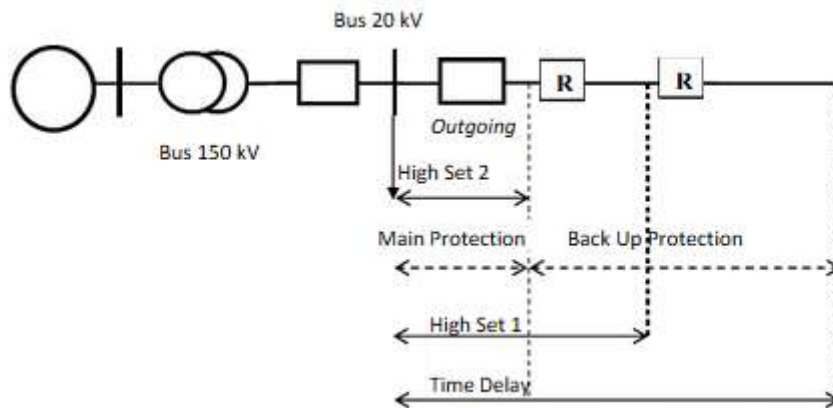
The fault current initially flows through an impedance that aligns with the sequence of the disturbed phase voltages, known as positive sequence impedance. The interaction of the magnetic fields within the electrical machine then produces a current component that opposes the voltage in the other phase, creating a negative sequence impedance. Furthermore, as the current returns through ground and the neutral point, a zero sequence current component also appears.

Thus, in a single-phase-to-ground fault, the positive, negative, and zero sequence impedances are arranged in series. These three current components have the same magnitude and flow only in the faulted phase. The fault current relationship can be expressed as:

$$I_0 = I_1 = I_2 = \left| \frac{V_{AB}}{Z_1 + Z_2 + Z_0} \right| \dots \dots \dots (5)$$

**Agreement on OCR Setting Values for 20 kV Feeders**

*Marksettings*The 20 KV feeder OCR or outgoing PMT is divided into Time Delay (TD), High Set 1 (HS1), and High Set 2 (HS2). This aims to divide the area and working time of the protection equipment in the feeder. In the outgoing PMT, the TD and HS1 working areas are back up protection for the main protection equipment in the network. The HS1 working area is from the substation to the second recloser. The OCR set at the HS1 level works with definite time delay characteristics. The TD working area is from the substation to the end of the feeder. The OCR set at the TD level works with Standard Inverse (SI) characteristics. HS2 as the main protection for the feeder from the substation to the first recloser. The OCR set at the HS2 level works with Instantaneous relay characteristics.



**Figure 1.** Outgoing PMT work area

*Determination of valuessettings*The OCR for all three levels is based on the protection agreement for 20 kV feeders made in 2016 for the distribution protection of 20 kV feeders P3B Java & Bali.

**Table 1.** 2016 protection agreements

20 Kv feeder	
Relay Types	: Non-Directional OCR
Iset	: 1.2 x In CCC or In CT
Ts	: 0.6 sec (lhs pp on 20kV bus) (SI)
Im1	: 2.0 x In Transformer (60MVA)
	2.2 x In Transformer (50MVA)
	2.4 x In Transformer (30MVA)

	3.0 x In Transformer (16MVA)
	3.2 x In Transformer (10MVA)
Tm1	: 0.3 s (Definite)
Im2	: 4.8 In Transformer
Tm2	: instantaneous

To calculate  $T_{MS}$  at the TD level using the formula:

$$TMS = \frac{t \times \left[ \left( \frac{1 \text{ hs2 fasa}}{I_{set}} \right)^{0,02} - 1 \right]}{0,14} \dots\dots\dots(6)$$

$T_{MS}$  or Time Multiple Setting is a value entered into the relay as a constant in the inverse Time Relay time calculation.

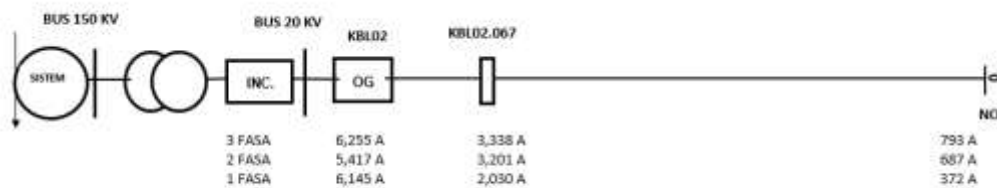
### 3. Research Methods

Complete, relevant and objective data collection, formulation, analysis and problem solving in the preparation of this final project report using several methods, namely: This method involves direct question and answer sessions on the issues being discussed to obtain a fundamental understanding and clarity. These interviews were conducted with supervisors, *engineer*, and technicians related to practical work materials. This method is carried out by observing, scrutinizing, and studying directly at the practical work location accompanied by a field supervisor in order to obtain accurate data and descriptions. This method is carried out by looking for references that support the final project report, namely *manual operation* and other supporting documents as well as previous final project reports related to the distribution network theme at PT PLN (Persero) Purwokerto Area.

### 4. Results

#### Calculation Impedance.

KBL 02 Feeder has a 3-phase network length of 10 km and a 1-phase network of 8.31 km. The 02 feeder has a recloser on the KBL 02.067 pole. The distance of the recloser from the Main Substation (GI) is 3.35 kms. The 02 feeder uses 240 mm<sup>2</sup> AAAC conductor wire for the phase and 150 mm<sup>2</sup> AAAC conductor



**Figure 2.** Single line diagram of KBL 02 feeder

#### 1. Source Impedance Calculation

The reactance (impedance) of the source includes: the impedance of the generating source, the impedance of the power transformer at the power plant, and the impedance of the transmission line. According to the P2B Semester 2 of 2017, the short-circuit current value at the 150 kV bus level at the Kalibakal Main Substation is  $I_{SC \text{ 3 Phase}} = 13.449 \text{ kA}$ .

$$\begin{aligned} MV_{ASC} &= 150 \times I_{SC \text{ 3 Phase}} \times \sqrt{3} \\ &= 150 \times 13.449 \text{ kA} \times \sqrt{3} \\ &= 3494.4 \text{ MVA} \end{aligned}$$

$$XSC = \frac{kV^2}{\frac{MVA_{sc}}{20^2}} = \frac{3494,4}{20^2} = 0.114\Omega$$

2. Feeder impedance calculation

The impedance of the feeder depends on the magnitude of the impedance per km (ohm/km) and refers to SPLN 64:1985 on the resistance and reactance of conductor types. In the Kalibakal 02 feeder, the conductors use AAAC 240 mm<sup>2</sup> for the phase conductors and 150 mm<sup>2</sup> for the neutral.

Table 2. Resistance and reactance of 20 kV AAAC conductors

Nominal cross-section (mm <sup>2</sup> )	Radius (mm <sup>2</sup> )	Tendon	GMR (mm)	Positive sequence impedance (( $\Omega$ /km)	Zero sequence impedance (( $\Omega$ /km)
16	2,2563	7	1.6380	2.0161 + j0.4036	2.1641 + j1.6911
25	2,8203	7	2.0475	1.2903 + j0.3895	1.4384 + j1.6770
35	3,3371	7	2.4227	0.9217 + j0.3790	1.0697 + j1.6665
50	3,9886	7	2,8957	0.6452 + j0.3678	0.7932 + j1.6553
70	4,7193	7	3,4262	0.4608 + j0.3572	0.6088 + j1.6447
95	5,4979	19	4,1674	0.3396 + j0.3449	0.4876 + j1.6324
120	6,1791	19	4.6837	0.2688 + j0.3376	0.4168 + j1.6251
150	6,9084	19	5.2365	0.2162 + j0.3305	0.3631 + j1.6180
185	7,6722	19	5,8155	0.1744 + j0.3239	0.3224 + j1.6114
240	8,7386	19	6.6238	0.1344 + j0.3158	0.2824 + j1.6033

The calculation of the impedance of the KBL 02 feeder can be calculated using the following formula:

Positive and negative sequence impedance:

$$Z1 = Z2 = L \times Z1/km \dots \dots \dots (7)$$

Zero sequence impedance:

$$Z0 = L \times Z0/km(4.2) \dots \dots \dots (8)$$

With length 3-phase network 10 km and 1-phase network 8.31 km then the positive sequence, negative sequence, and zero sequence impedance values for the network are

Table 3. AAAC 240 mm<sup>2</sup> length 10 km

	Ohm/km data		10 km	
	R	jX	R (ohms)	jX (ohm)
Z1 = Z2	0.1344	0.3158	1,344	3,158
Z0	0.2824	1.6034	2,824	16,034

Table 4. AAAC 150 mm<sup>2</sup> length 8.31 km

	Ohm/km data		8.31 km	
	R	jX	R (ohms)	jX (ohm)
Z1 = Z2	0.2162	0.3305	1,796	2,746
Z0	0.3631	1,618	3,017	13,445

Series impedance between 240 mm AAAC conductors<sup>2</sup> and AAAC 150 mm<sup>2</sup> with a total feeder length of 18.31 km is

**Table 5.** AAAC 240 mm<sup>2</sup> and 150 mm<sup>2</sup> length 18.31 km

	R (ohms)	jX (ohm)
Z1 = Z2	3.14	5,904
Z0	5,841	29,479

Feeder impedance for the fault location from the GI (0%) to *dead end*(100%) are as follows:

**Table 6.** KBL02 feeder impedance based on fault location

Distance (in %)	Z1= Z2		Z0	
	R	jX	R	jX
0%	0	0	0	0
1%	0.0314	0.05904	0.05841	0.29479
5%	0.157	0.2952	0.29205	1.47395
10%	0.314	0.5904	0.5841	2.9479
15%	0.471	0.8856	0.87615	4.42185
20%	0.628	1.1808	1.1682	5.8958
25%	0.785	1,476	1.46025	7.36975
30%	0.942	1.7712	1.7523	8.8437
35%	1,099	2.0664	2.04435	10.31765
40%	1,256	2.3616	2.3364	11,7916
45%	1,413	2.6568	2.62845	13.26555
50%	1.57	2,952	2.9205	14.7395
55%	1,727	3.2472	3.21255	16.21345
60%	1,884	3.5424	3.5046	17,6874
65%	2,041	3.8376	3.79665	19.16135
70%	2,198	4.1328	4.0887	20.6353
75%	2,355	4,428	4.38075	22.10925
80%	2,512	4.7232	4.6728	23.5832
85%	2,669	5.0184	4.96485	25.05715
90%	2,826	5.3136	5.2569	26.5311
95%	2,983	5.6088	5.54895	28.00505
100%	3.14	5,904	5,841	29,479

When a disturbance occurs in a three-phase disturbance with a short circuit current of 3496 A which is at a distance of 4.53 kms from the PMT *outgoing* pole KBL02.90 *section* third from the KBL02 feeder.

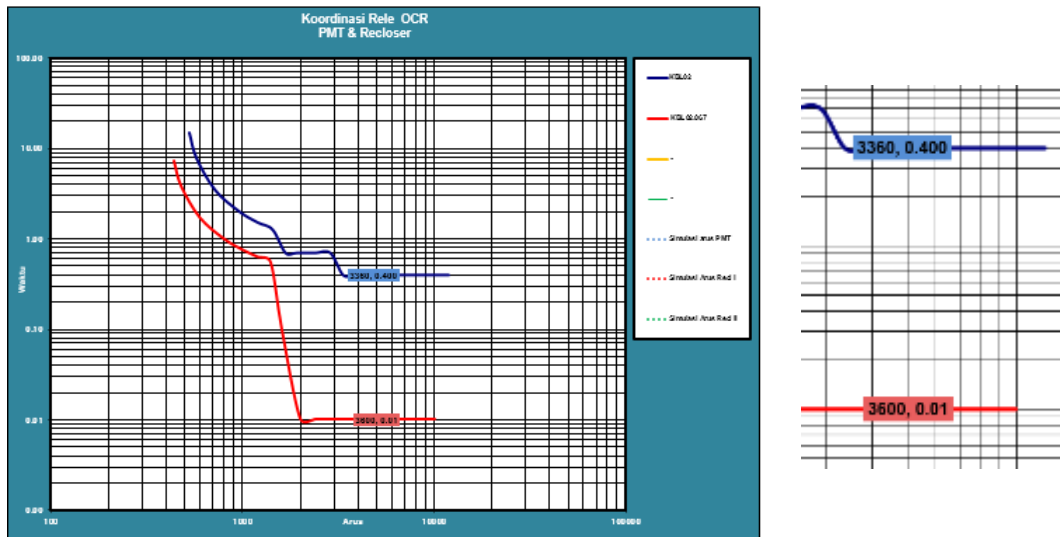


Figure 3. Coordination of the OCR PMT KBL02 relay and the KBL02.067 recloser

## 5. Conclusion

Based on the results of the protection coordination evaluation on the KBL02 feeder, it can be concluded that the mismatch in coordination between the outgoing PMT and the recloser causes the PMT to operate first when a disturbance occurs downstream of the recloser. This condition has an impact on the extent of the outage area and a decrease in the level of distribution system reliability. Repositioning the recloser based on the results of the protection coordination calculation can increase system selectivity and reduce the possibility of unnecessary PMT trips. Thus, the implementation of appropriate protection coordination can improve the reliability of electric power distribution on the KBL02 feeder.

## 6. References

- Afrizal, M., Anisah, S., & Wibowo, P. (2022). Overcurrent relay protection system coordination analysis and ground fault relay on 20 kV feeder substations at Muara Tebo Substation. *Proceedings of the International Conference on Data Science, Engineering and Technology (ICDSET)*, Universitas Pembangunan Panca Budi, 215–221.
- Aryza, S., Wibowo, P., & Saputra, D. (2022, July). Design and Construction of a Heating Process Control Tool for Biodiesel Production from Used Cooking Oil Based on Arduino Mega. In *Proceedings of the National Seminar on Social, Humanities, and Technology* (pp. 121-127).
- Sarimun, Ir. Wahyudi. (2012). *Protection of Electric Power Distribution Systems*: Garamond, DepoK.
- SPLN 72.1987. *Design Specifications for Medium Voltage Networks (MVNets) and Low Voltage Networks (LVNets)*. Jakarta: PT. PLN (Persero)
- Sarimun, Wahyudi. (2011). *Pocket Book of Technical Services (Yantek)*. Depok: Garamond
- PT PLN (Persero) Udiklat Semarang (2013). *K3 Inspection Management and SOP*. Semarang. TLM Academy
- Saraswati, Aprilia. (2009). *Reconfiguration of the 20 kV Medium Voltage Network System of PT. PLN (Persero) APJ Purwokerto*. Final Project Report. Electrical Engineering. Jenderal Soedirman University, Purwokerto.
- Nugraha, Bima Cahya. (2015). *Coordination of PMT PLR 9 and Recloser PLR19-81 in the 20 kV Medium Voltage Network Protection System in the Work Area of PT. PLN (Persero) Rayon Palur*. Final Project Report. Diploma III in Electrical Engineering. Diponegoro University. Semarang.

- Putra, FA, Anisah, S., & Andriana, M. (2021). Analysis of the evaluation of OCR and GFR relay protection coordination on the YB-02 feeder of PT PLN ULP Natal using ETAP simulation. *Journal of Electrical Engineering, Panca Budi Development University*, 9(2), 85–92.
- Hakiki, F., Tarigan, ASP, & Hamdani. (2022). Analysis of short circuit faults and protection coordination on the 20 kV PLTD Aneuk Laot ULP Sabang network using ETAP 21.0.1 simulation. *National Journal of Computer Technology*, 6(1), 45–52.
- Hamdani H. et al (2023) Study of the Development of a 50 kg Capacity Smart Freight Lift Using a Solar Power Plant (PLTS). *INTECOMS: Journal of Information Technology and Computer Science*, 6(1), 429-433.
- Lumban Tobing, JMS (2021). Analysis of protection coordination between Padang Sidempuan Substation and Pal XI Substation in PT PLN Padang Sidempuan Area. *Journal of Electrical Engineering, Panca Budi Development University*, 8(1), 30–37.
- Tharo, Z., Anisah, S., Putra, FA, & Andriana, M. (2022). Evaluation analysis of OCR and GFR relay protection coordination on feeder YB-02 PT PLN ULP Natal. *Budapest International Research and Critics Institute-Journal*, 5(1), 1234–1242.
- Tharo, Z., & Hamdani, H. (2020). Cost analysis of household-scale rooftop solar power plants (PLTS). *Journal of Electrical and System Control Engineering*, 3(2), 65-71.