Optimization of the 20 kV Protection System to Reduce the Number of Affected Customers and Improve Distribution Network Reliability at PT PLN (Persero) ULP Kisaran

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Abstract
The reliability of the electric power distribution system is a critical aspect in ensuring the continuity of energy supply to customers. One factor affecting reliability is suboptimal coordination of the protection system, which can lead to widespread outages due to non-selective relay operation. This study aims to optimize the protection relay settings in the 20 kV distribution system at the Kisaran Substation of PT PLN (Persero) ULP Kisaran to reduce the number of customers affected by outages and improve grid reliability. The research methodology involved analyzing existing conditions, calculating short-circuit currents, evaluating relay coordination, and optimizing the parameters of the Overcurrent Relay (OCR) and Ground Fault Relay (GFR) based on inverse characteristics in accordance with IEC standards. The optimization results show that the OCR pickup value on Feeder KN.04 was successfully reduced from 600 A to 310 A, while on Feeder KN.06 it was reduced from 600 A to 253 A. The OCR Time Multiplier Setting (TMS) was adjusted to 0.16 on KN.04 and 0.17 on KN.06, while the GFR TMS was increased from 0.15 to 0.45 on both feeder lines to achieve more selective protection coordination. Simulation results show that the optimized settings improve the sensitivity and selectivity of the relays, resulting in faster and more precise fault isolation. These improvements in protection coordination result in a reduction in the outage area and the number of affected customers, which in turn improves the System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI) in the 20 kV distribution system at the Kisaran Substation.

Keywords: protection system, OCR, GFR, relay coordination, distribution reliability.

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Introduction

The 20 kV distribution network plays a vital role in delivering electrical energy to customers, making its reliability a key indicator of PT PLN (Persero)'s service quality. Faults in the distribution network can cause outages and disrupt the continuity of electricity service[1] . The reliability of the electrical distribution system is generally evaluated using *the System Average Interruption Frequency Index* (SAIFI) and *the System Average Interruption Duration Index* (SAIDI). The SAIFI index indicates the average frequency of outages experienced by customers over a specific period, while SAIDI indicates the average duration of outages experienced by customers. The lower the SAIFI and SAIDI values, the higher the reliability of the operated power distribution system[2] . These reliability evaluation standards also refer to IEEE Std 1366, which is widely used as a guideline for assessing the performance of power distribution systems[3] .

Short-circuit faults are one of the main causes of reduced distribution system reliability. If the protection system does not operate quickly and selectively, faults can lead to the expansion of outage areas and an increase in the number of affected customers[4] . The number of affected customers can be minimized through a reliable protection system. Protection systems in 20 kV distribution networks play a critical role in detecting and isolating the portion of the system experiencing a fault to prevent it from affecting other parts of the network. Common protection equipment used in distribution feeders includes *Overcurrent Relays (OCR), Ground Fault Relays (GFR), Circuit Breakers (CB), and Reclosers*. The OCR is used to detect overcurrent faults and phase-to-phase short circuits, while the GFR is used to detect single-phase-to-ground faults. Proper coordination of settings between the OCR, GFR, PMT, and recloser is crucial to the success of the protection system in limiting the fault zone and maintaining the continuity of electric power service[5] .

Numerous studies have been conducted on the coordination and evaluation of protection systems. Research findings indicate that improper OCR and GFR settings can lead to a loss of protection selectivity, resulting in disconnections not only in the faulted area but also in the still-normal network. This condition leads to an increase in the number of customers experiencing outages and reduces the reliability of the electric power distribution system[6] . Therefore, optimizing protection relay settings is a crucial step in improving the reliability of the distribution network.

PT PLN (Persero) ULP Kisaran is a service unit that operates a 20 kV medium-voltage distribution network supplied by the Kisaran 150/20 kV Substation. This distribution network serves various types of customers, ranging from residential and business customers to industrial customers. As the demand for electrical energy increases and customer loads grow, the complexity of distribution network operations also rises, thereby increasing the potential for outages. These conditions require a protection system capable of operating quickly, selectively, sensitively, and reliably to isolate faults occurring on distribution feeders[7] .

Optimizing the protection system in the 20 kV distribution network is an effort to reduce the number of customers affected by outages and improve system reliability. Through the evaluation of OCR and GFR coordination, short-circuit fault analysis, and adjustment of relay settings according to actual conditions, the protection system is expected to isolate faults more quickly and selectively. Consequently, the extent of outage areas, the number of affected customers, and reliability indices such as SAIFI and SAIDI can be improved. Therefore, research on the optimization of the 20 kV protection system at PT PLN (Persero) ULP Kisaran is crucial as an effort to improve the quality of electricity service. The 20 kV distribution network is vulnerable to both temporary and permanent faults that directly result in customer outages. 's distribution network reliability is generally measured using the SAIDI (System

Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency Index)

Preliminary observations based on ULP Kisaran's operational data show that the SAIDI value in 2024 was recorded at 102.12 minutes per customer and the SAIFI at 1.2 times per customer; by 2025, the SAIDI had decreased to 32.664 minutes per customer and the SAIFI to 0.9028 times per customer. Although there has been improvement, these outage figures remain a concern and must continue to be minimized. Among the 14 feeder lines in operation, feeders KN.04 and KN.06 are the primary focus of attention due to their significant outage frequency. Historical data show that feeder KN.04 experienced 23 outages in 2024 and 23 in 2025, while feeder KN.06 experienced 21 outages in 2024, increasing to 28 in 2025. The high frequency of outages on both feeder lines indicates the need to evaluate and optimize their protection systems.

The 20 kV distribution network protection system is a critical component that functions to detect, locate, and isolate the affected section of the network as quickly as possible, thereby minimizing the impact of outages on customers. The primary protection devices used include overcurrent relays (OCR) and ground fault relays (GFR) installed at the substation, as well as reclosers as automatic protection equipment along the feeder lines.Feeder KN.04 is equipped with an L.01/Binser recloser (Entec brand), while feeder KN.06 is equipped with an L.01/Simp. Pikkir recloser (Joongwon brand).

Proper coordination and settings of protective devices are critical factors in limiting the outage area and expediting fault response. Suboptimal settings can lead to widespread outages or equipment damage. In accordance with IEC 60255 and SPLN standards, coordination between protective devices must meet an operating time difference of 0.2–0.4 seconds. Therefore, an evaluation of the protection settings on feeders KN.04 and KN.06 needs to be conducted based on short-circuit current calculations and protection coordination to obtain optimal settings.

Literature Review

The electric power distribution system is part of the power system that functions to transmit electrical energy from the substation to customers. In a 20 kV medium-voltage distribution system, the continuity of electrical energy transmission is greatly influenced by the condition of the grid, protective equipment, and the characteristics of the load being served. Faults occurring in the distribution network can cause partial or total system outages if not addressed quickly and selectively[8] . The 20 kV distribution network generally uses a radial configuration because it has a simple structure and relatively low investment costs. However, the radial configuration has the drawback of a high impact of faults on customers if the protection system does not function optimally[9] .

A protection system is designed to detect abnormal conditions in the power system and isolate the affected section to prevent it from affecting other parts of the system. The primary objectives of a protection system are to maintain system reliability, protect electrical equipment, and ensure the continuity of power supply[10] . The reliability of a protection system is determined by several key characteristics: sensitivity, selectivity, response speed, and operational reliability. A good protection system must be able to accurately detect faults and trip only the affected section, thereby minimizing the outage area through the use of protection equipment[11] .

An Overcurrent Relay (OCR) is a protection relay that operates based on the magnitude of the current flowing through the system. The OCR detects overcurrent faults as well as short circuits between phases in the distribution network. When the fault current exceeds the specified setting value, the relay sends a trip signal to the circuit breaker to disconnect the affected part of the system[12] . The OCR setting must take into account the maximum load current, minimum short-circuit current, current transformer (CT) ratio, and coordination with other relays in the distribution system. Errors in setting determination can cause the relay to operate too slowly or even fail to detect a fault[13] . The Ground Fault Relay (GFR) is a protective relay used to detect single-phase-to-ground faults. This type of fault is the most common in medium-voltage distribution networks due to environmental conditions, conductor insulation, and contact with foreign objects[14] . Coordination between the OCR and GFR is crucial to ensure that the relay closest to the fault location operates first. With proper coordination, the extent of the outage can be minimized and the number of affected customers reduced[15] . A recloser is an automatic protection device that can open and reclose the network after a temporary fault occurs. Their use has been proven to improve system reliability because most faults in distribution networks are temporary[16] . Therefore, coordination between OCRs, GFRs, circuit breakers, and reclosers must be designed selectively so that faults can be properly isolated and chain tripping—which causes more widespread outages—can be avoided. Short-circuit analysis is used to determine the magnitude of fault currents that may occur in an electric power system. Short-circuit current data serves as the basis for determining the capacity of protective equipment and the relay settings used in distribution networks. Short-circuit current calculations typically include symmetrical and asymmetrical faults[17]] and are performed for three-phase, two-phase, two-phase-to-ground, and single-phase-to-ground faults. Fault current values are influenced by source impedance, transformer impedance, and distribution line impedance[18] .

Distribution system reliability is the system's ability to continuously deliver electrical energy to customers without experiencing significant interruptions. Reliability levels are typically expressed using the SAIFI (*System Average Interruption Frequency Index*) and SAIDI (*System Average Interruption Duration Index*). The SAIFI value indicates the average frequency of outages experienced by customers, while the SAIDI indicates the average duration of outages. High index values indicate that the distribution system has a low level of reliability, necessitating improvements to both the operational and protection systems[19] ,[20] .

Protection system optimization is achieved through relay coordination evaluation, adjustment of OCR and GFR settings, installation of reclosers at strategic points, and analysis of fault characteristics on distribution feeders. Research shows that protection system optimization can reduce the number of customers affected by outages, accelerate the fault isolation process, and improve the reliability of the distribution network[21] . The reliability of the electrical distribution system, as measured by the SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency Index), indicates that frequent faults affect system reliability, which directly impacts customer satisfaction with electrical distribution services. Analysis of power system reliability can also be conducted through testing of 150 kV circuit breakers (PMT)[22] .

Based on a literature review, one of the causes of the high number of customers experiencing outages on the 20 kV distribution network is the suboptimal coordination of the protection system between the OCR, GFR, circuit breakers, and reclosers. Inappropriate relay settings can reduce protection selectivity, thereby expanding the outage area and increasing the SAIFI and SAIDI values. PT PLN (Persero) ULP Kisaran operates a 20 kV distribution network with a high demand for service continuity; however, faults on feeder lines still have the potential to cause large-scale customer outages. Therefore, this study was conducted to optimize the protection system through an evaluation of OCR and GFR coordination, short-circuit current analysis, and a review of protection settings based on actual network conditions.

The results of this study are expected to yield recommendations for more selective and reliable protection settings to minimize the number of customers affected by outages and improve the reliability of the distribution network at the Kisaran ULP.

Research Methodology

This study employs a quantitative method using a case study approach to examine the 20 kV distribution system of PT PLN (Persero)'s Kisaran ULP. This method was chosen because it provides objective and measurable results in evaluating the performance of the protection system based on technical parameters that can be calculated mathematically, such as short-circuit current, relay settings, protection coordination, and distribution network reliability indices such as SAIFI (System Average Interruption Frequency Index) and SAIDI (System Average Interruption Duration Index).

The case study approach was chosen because it allows for an in-depth analysis of the actual characteristics of the distribution network on feeders KN.04 and KN.06. Additionally, this method can illustrate the relationship between protection system settings and the level of network reliability, as indicated by the number of customers affected by outages and the duration of those outages.

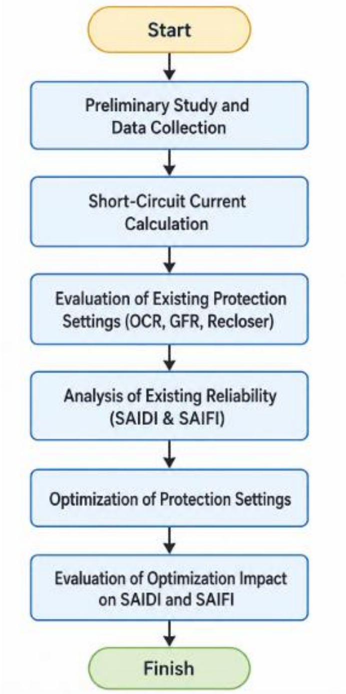

Figure 1. Research Stages

Based on the research flowchart in Figure 1, the study began with data collection, which included the Single Line Diagram (SLD) of the 20 kV distribution network, power transformer data, feeder conductor data for KN.04 and KN.06, OCR and GFR settings on PMTs and reclosers, CT ratios, feeder lengths, fault data, the number of customers, and the SAIFI and SAIDI reliability indices. This data then undergoes an initial data processing stage to ensure its validity and consistency, including verification of protection parameters, conversion of primary and secondary relay data, calculation of maximum load current, and determination of the impedance of the source, transformers, and lines as the basis for modeling the distribution network.

The next stage is short-circuit analysis, which involves calculating three-phase and single-phase-to-ground fault currents at various points in the network using the equivalent impedance and symmetrical component methods. The results of this analysis are used to determine the maximum and minimum fault currents, which serve as the basis for assessing the sensitivity and selectivity of the protection system's . Subsequently, protection coordination is evaluated by comparing the existing OCR and GFR settings against the calculated fault currents, including an evaluation of *the pickup current*, *time dial setting* (TDS), instantaneous setting, and grading time between the PMT and the recloser to ensure that the protection device closest to the fault location operates first.

Based on the results of this evaluation, the reclosers on feeders KN 04 and KN 06 were optimized by adjusting the OCR and GFR settings, specifically by fine-tuning the pickup current and time dial settings to achieve more selective, sensitive, and reliable protection coordination. The optimization criteria used were that the relay should not trip under maximum load conditions, be capable of detecting the smallest possible fault, have a grading time of approximately 0.3–0.4 seconds, and avoid crossing the protection characteristic curve. The final stage is a system reliability analysis, which involves evaluating the impact of protection optimization on distribution network performance by calculating the SAIFI and SAIDI indices before and after optimization. The analysis results are used to assess the success of the optimization in reducing the number of customers affected by outages, accelerating fault restoration, and improving the reliability of the 20 kV distribution system at PT PLN (Persero) ULP Kisaran.

Results

The results of the protection system analysis on the 20 kV distribution network of PT PLN (Persero) ULP Kisaran, which includes 14 feeder lines, focus on the KN.04 and KN.06 feeder lines in the distribution system. *The single-line diagram of* the system is shown in Figure 2.

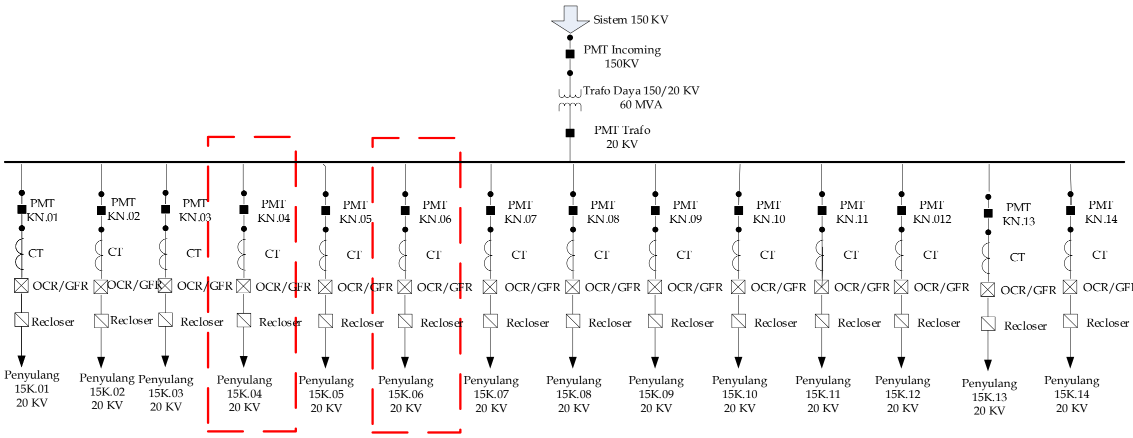

Figure 2. SLD of the Kisaran-Asahan 150/120 kV Substation

Figure 2 shows the SLD of the Kisaran-Asahan 150/120 kV Substation. The initial stage of the analysis involved calculating short-circuit currents to determine the maximum and minimum fault currents that could occur on the feeder lines. The data, including measurement element data, network data, and power transformer data, are presented in Tables 1, 2, and

Table 1. Measurement Element Data

Parameter	Value
PT Nominal Voltage	2200 Volts
CT Ratio	600/5 A
DC Source Voltage	110 volts DC

Table 2. 20 kV Feeder and Distribution Network

Parameter	Feeder KN.04	Feeder KN.06
Conductor Type	AAAC 240	AAAC 240
Voltage	20 kV	20 kV
Feeder Length	108 km	53 kms
Peak Load/Power Factor	7.6 MW / 0.85	6.2 MW / 0.85
KHA	514 A	514 A
Max Current (Imax Peak Load)	291.67 A	291.67 AA
Reactance/km	0.1801 Ω/km	0.1801 Ω/km
Total reactance	19.45 Ω	9.55 Ω
Resistance/km	0.3239 Ω/km	0.3239 Ω/km
Total resistance	34.98 Ω	17.17 Ω
Equivalent impedance in the (+;-;0) sequence For each feeder	Z1 = 0.1379 pu Z2 = 0.1379 pu Z0 = 0.2210 pu Zf= 0.3302 pu	Z1= 0.1379 pu Z2= 0.1379 pu Z0= 0.2210 pu Zf= 0.5971 pu

Table 3. Transformer Data

Parameter	Value
Capacity	60 MVA
Transformer Impedance	12.29%
Primary Voltage	150 kV
Secondary Voltage	20 kV
Minimum Short-Circuit MVA	400 MVA

4.1. Analysis Results and Discussion

4.1.1. Analysis of OCR and GFR Settings on Feeders 0.4 and 0.6

Analysis of nominal current on the 20 kV side: $I_n = \frac{S}{\sqrt{3}x\,V}$,$I_n = \frac{60x10^6}{\sqrt{3}x\ 20x10^3}$ = 1.732 kA

Analysis of the maximum short-circuit current on the 20 kV bus: since S_{SC}= 4000 MVA

Therefore, the source impedance value in Perunit (PU) is $X_s = \frac{60}{400} = 0{,}15\ pu$

Transformer impedance: X_t = 12.29% = 0.1229 Pu, so the total equivalent impedance is:

X_{eq}= 0.1229 + 0.015 = 0.1379 Pu

From this data analysis, the three-phase short-circuit analysis can be calculated

$$I_{sc} = \frac{V_{f(pu)}}{X_{eq}(pu)}$$

$$I_{sc} = \frac{1\ pu}{0.1379\ pu} = 7{,}25\ pu$$

Isc (three-phase fault current) in amperes:

$I_{sc}(A) = Isc\ (pu)x\ In = 7{,}25\ pu\ x1{,}732\ kA$ = 12,559 A = 12.56 kA.

Alternatively, it can also be obtained using the formula:

$$I_{sc} = \frac{I_{n(pu)}}{X_{eq}(pu)} = \frac{1{,}732\ kA}{0.1379\ pu} = 12{,}56\ kA$$

SPLN (State Electricity Company Standard) in the Distribution Network Protection and Control Manual**:** PLN officially uses a multiplier factor ranging from 1.1 to 1.3 times the maximum load current (\(I_{max}\)). The setting current for OCR relays, on both the primary and secondary sides of the transformer, must be greater than the maximum load current.

Additionally, for fault *pickup*, the setting current value must comply with *the British Standard for Pickup*, which is between 1.05 and 1.2 times the Iset value . For the OCR relay settings on the 20 kV feeder and the *incoming* side of the power transformer in this study, a value of 1.2 was selected, as this is the most commonly used midpoint value by field practitioners in Indonesia. These fault analysis parameters serve as a reference for calculating the relay settings.

4.1.2. Analysis of OCR and GFR Settings on Feeder KN.04: RECLOSER L.0 /BINSER

According to SPLN and PLN Pickup OCR practices: Set = 1.05–1.3 × $I_{loadfeeder\ 0.4}$
With feeder load: I_{load}= 291.67 A,
Iset is selected as 1.2 × 291.67 A
Iset = 350 A

The fault multiple (M) is determined by the ratio of the maximum short-circuit current to the setting current.

$M = \frac{I_{SC}}{I_{Set}}$; $M = \frac{12559}{350} = 35,88$ This M value is used to determine the *Time Multiplier Setting* (TMS).

Secondary CT setting current with a CT ratio of 1000:1

The *Time Multiplier Setting* (TMS) is determined using the *standard Inverse* (IEC) curve, with the equation:

$t = \frac{0,14\ xTMS}{M^{0.02}-1}$; If the target operating time for the feeder OCR is (t = 0.2 s), then TMS can be calculated as:

$$t = \frac{0,14\ x\ TMS}{M^{0,02-1}}$$

$$TMS = \frac{t\ (M^{0,02} - 1)}{0,14}$$

$$TMS = \frac{0,2\ (45,88^{0,02} - 1)}{0,14} = \frac{0,2(1,07432 - 1)}{0,14}$$

$$TMS = \frac{0,2\ x\ 0,07432}{0,14} = 0,10$$

Resetting analysis for Instantaneous OCR, taking into account the calculation of the 3-phase short-circuit current ($(I_{HS-3\emptyset})$) on feeder KN.04, for positive-sequence impedance and system fault impedance, while ignoring the equivalent system resistance value since this is a short-circuit fault analysis (Z_1= 0.1379 and Z_f = 0.3302). Therefore, the short-circuit current$I_{HS-3\emptyset}$ is

$$I_{HS-3\emptyset} = \frac{V_f}{Z_1 + Z_f} = \frac{1}{0,1379 + 0,3302} = 2,136\ pu;$$

The maximum short-circuit current on feeder KN.04 in amperes:

$I_{HS-3\emptyset}$(A) = ($I_{HS-3\emptyset}$ $(pu) x\ In$
= 2.136 pu × 1732 A
$I_{HS-3\emptyset}$ (A) = 3,700.04 kA

Therefore, the Isett value for resetting the Instantaneous OCR

$I_{Set\_Inst} = \left(0,8 \frac{s}{d} 0.85\right) x\ I_{hs\ max}$; a constant of 0.80 is selected for the Instantaneous OCR setting current, so we obtain:

I_{set_Inst} = 0.80 × 3700.04 A = 2960.051; however, considering the maximum short-circuit current and the grading for the recloser, $I_{set_Inst}$is selected as 3000 A.

4.1.3. Analysis of OCR Settings on Feeder KN.06: RECLOSER L.01 / SIMP. PIKKIR

Feeder load: I_{load}= 291.67 A; therefore, Iset is selected as 1.2 × 291.67 A; thus, Iset = 350 A

The fault multiple (M) is determined by the ratio of the maximum short-circuit current to the current:
$M = \frac{I_{SC}}{I_{Set}}$; $M = \frac{12559}{350} = 35{,}88$. This M value is used to determine *the Time Multiplier Setting* (TMS).
Therefore:
$M = \frac{12559}{350} = 49{,}64$. This M value is used to determine *the Time Multiplier Setting* (TMS).

The *Time Multiplier Setting* (TMS) is determined using the standard Inverse (IEC) curve, with the equation:
$t = \frac{0{,}14\ xTMS}{M^{0.02}-1}$; the target operating time for the feeder OCR (t = 0.1 s), Feeder 06 in the Critical/Sensitive Sector on Recloser L.01 / SIMP. PIKKIR supplies a load that is more sensitive to *voltage sags* . Faults on this line must be isolated as quickly as possible with a target of t = 0.1 s; therefore, the TMS can be calculated as follows:

$$t = \frac{0{,}14\ x\ TMS}{M^{0{,}02-1}}$$

$$TMS = \frac{0{,}1\ (M^{0{,}02}-1)}{0{,}14} == \frac{0{,}1\ (1{,}07432-1)}{0{,}14}$$

$= \frac{0.007432}{0{,}14} = 0{,}0531 = 0{,}05$
TMS = 0.05

Resetting analysis for Instantaneous OCR, taking into account the calculation of the 3-phase short-circuit current($I_{HS-3\emptyset}$) on feeder KN.04, for positive-sequence impedance and system fault impedance, while ignoring the equivalent system resistance value since this is a short-circuit fault analysis (Z_1 = 0.1379 and Z_f = 0.5971). Therefore, the short-circuit current$I_{HS-3\emptyset}$ is:
$I_{HS-3\emptyset} = \frac{V_f}{Z_1+Z_f} = \frac{1}{0{,}1379+0{,}5971} = 1{,}4605\ pu$;

Maximum short-circuit current on feeder KN.04 in amperes:
$I_{HS-3\emptyset}$(A) = ($I_{HS-3\emptyset}$ $(pu) x\ In$
= 1.3605 pu × 1732 A
$I_{HS-3\emptyset}$ (A) = 2,656.46 A

Therefore, the reset current (Isett) for the Instantaneous OCR
$I_{Set\_Inst} = \left(0{,}8 \frac{s}{d} 0.85\right) x\ I_{hs\ max}$; a constant of 0.80 is selected for the Instantaneous OCR setting current, so we obtain:
I_{set_Inst} = 0.80 × 2656.46 A = 1885 A; considering the grading for the recloser, $I_{set_Inst}$is selected as 1800 A

4.2. Analysis of GFR Time-Delay and GFR Instantaneous Settings on Feeder KN.04 and KN.06.

Analysis of Ground Fault Relay (GFR) Setting Calculations: Since the CT ratio is 1000:1, the secondary current setting for a CT with a ratio of 1000:1 and a CT conversion factor of 1000:1 means that 1 ampere on the secondary side equals 1000 amperes on the primary side. Determining the secondary pickup current of the relay
For a numerical relay with a CT ratio of 1000/1, the *ground fault pickup* current ranges from 0.01 to 0.05 A, as specified in KN 04. A value of 0.025 amperes is selected. Therefore:
$I_{Pickup_primer} = I_{Pickup_{sekunder}}$x CT ratio conversion factor
= 0.025 × 1000
= 25 amperes

The reset current setting for the time-delay (I_{setTD}) on feeder KN.04 is set to 25 amperes. For the instantaneous GFR setting, based on the TD pickup value, 8–10 × the pickup value on KN.04 is selected; therefore, the instantaneous GFR reset current = 8 × 25 = 200 amperes.
The reset current for the pickup relay on Feeder KN.06 is set slightly lower to increase sensitivity, since the feeder is shorter and the minimum ground fault current is lower. With a TD setting multiplier of 0.018, the calculation is:$I_{Pickup_primer} = I_{Pickup_{sekunder}}$x CT ratio conversion factor

$$= 0.018 \times 1000$$
$$= 18 \text{ amperes}$$

The Timedelay current setting (I_{setTD}) for feeder KN.06 is set to 18 amperes
For the Instantaneous GFR setting, based on the TD pickup value of 8–10 × pickup on KN04, the Instantaneous GFR setting is 10 × 18 = 180 amperes.
From the results of the calculation analysis, the reset values for optimizing the recloser settings on KN 04 RECLOSER L.01 / BINSER and RECLOSER L.01 / SIMP. PIKKIR were obtained, as shown in Table 2

Table 2. Comparison of OCR and GFR Settings for Feeders 04 and 06.

FEEDER	CONDITION	BRAND	CT RATIO	OCR TD			INSTANT OCR		GFR TD			INSTANT GFR	
				I SET (A)	T (TMS)	KRV	I SET (A)	T (Ms)	I SET (A)	T (TMS)	KRV	I SET (A)	T (Ms)
KN.04 RECLOSER L.01 / BINSER	Existing	Micom P142	600/5	600	0.15	SI	5440	0	30	0.15	SI	240	60
	Existing	Entec	1000/1	150	0.03	NI	600	0	15	0.05	NI	120	0
	Resetting	**Entec**	**1000/1**	**350**	**0.1**	**NI**	**3000**	**0**	**25**	**0.1**	**NI**	**200**	**0**
KN.06 RECLOSER L.01 / SIMP. PIKKIR	Existing	Micom P142	600/5	600	0.15	SI	5440	0	30	0.15	SI	240	20
	Existing	Joongwon	1000/1	347	0.05	NI	867	0	25	0.05	NI	125	0
	Resetting	**Entec**	**1000/1**	**350**	**0.05**	**NI**	**1800**	**0**	**18**	**0.05**	**NI**	**180**	**0**

Time Relay Characteristics (Krv) Description:
- **SI** = Standard Inverse (IEC)
- **NI** = Normal Inverse (IEC)

*Ab**breviations:** OCR (Overcurrent Relay), GFR (Ground Fault Relay), TD (Time Delay), INSTAN (Instantaneous).*

The optimization results show that resetting the Overcurrent Relay (OCR) and Ground Fault Relay (GFR) on Feeder KN.04 and KN.06 can improve the coordination of the protection system compared to the existing conditions. For the OCR relays, the pickup values on both feeder lines were standardized to 350 A, while the Time Multiplier Setting (TMS) was set to 0.10 for KN.04 and 0.05 for KN.06. Additionally, the instantaneous OCR pickup current was increased to 3,000 A on KN.04 and 1,800 A on KN.06. These adjustments were made to ensure the relays do not trip under maximum load conditions, while still maintaining sufficient sensitivity to detect fault currents and preserving operational time coordination (grading time) with the incoming relays at the substation and other protective equipment .

For ground fault protection, the GFR pickup values were changed to 25 A on KN.04 and 18 A on KN.06, with TMS values of 0.10 and 0.05, respectively, while the instantaneous GFR was set at 200 A and 180 A. These settings enhance the relays' sensitivity to single-phase-to-ground faults while ensuring the relays operate only within their respective protection zones , thereby reducing the likelihood of non-selective trips.

Overall, the results of resetting the OCR and GFR demonstrate better protection coordination compared to the existing conditions. The new settings improve sensitivity, selectivity, and fault isolation speed, thereby minimizing the extent of the outage area. Consequently, the number of customers affected by the fault has the potential to decrease, which ultimately supports improved reliability of the Kisaran 20 kV GI distribution system through reductions in SAIFI and SAIDI values.

Conclusion

Overall, the optimization results produced relay settings that better reflect the actual operating conditions of the network. Lowering the OCR pickup value increases the relay's sensitivity in detecting faults, while adjusting the OCR TMS and GFR values improves the coordination of operating times among protection devices. Consequently, the protection systems on Feeder KN.04 and KN.06 become more sensitive, selective, and reliable, and are capable of isolating faults more effectively compared to the existing conditions

References

[1] S. Nasional and T. Elektro, "Evaluation of the Selectivity and Reliability of OCR and GFR Relays in Distribution Network Protection Systems," In *Snte-Fortei 2025*, pp. 353–359.

[2] T. Sucita, M. Somantri, D. Fahrizal, and M. Agista, "Reliability Analysis of a 20 kV Electric Power Distribution System on the CWRU Feeder," Vol. 13, No. November, pp. 282–289, 2024, DOI: 10.22146/Jnteti.V13i4.12510.

[3] J. A. Martinez-Velasco and G. Guerra, "Reliability Analysis of Distribution Systems with Photovoltaic Generation Using a Power Flow Simulator and a Parallel Monte Carlo Approach," 2016, DOI: 10.3390/En9070537.

[4] J. D. et al. Asgutian, Deadi, "The Role of Protection System Reliability as a Strategy for Optimizing Electricity Distribution in Medium-Voltage Networks," *Proceedings of* .

[5] R. Silviharyani Mendrofa, Muhammad Erpandi Dalimunthe, "Analysis of the Performance and Reliability of the Electric Power System in a 20 kV Distribution Network at PT PLN," Vol. 6, No. 1, pp. 835–845, 2025, DOI: 10.30596/Jcositte.V6i1.23677.

[6] T. W. Retno Ayu, Subuh Isnur, "Analysis of the Reliability of the Coordination System for Overcurrent Relays (OCR) and Ground Fault Relays (GFR) at the 150 …□," *JTEIN; J. Tek. Elektro Indones. 2024*, p. 150.

[7] G. F. Relay and I. Introduction, "Analysis of OCR Protection Coordination," Vol. 1, pp. 30–38, 2023.

[8] Z. Zhu and L. Liang, "International Journal of Electrical Power and Energy Systems: An Optimization Model for Identifying Backbone Networks to Enhance the Resilience of Distribution Networks," Vol. 170, No. January, 2025.

[9] T. A. Aldy Bagas, Risna Defi M, Noor H, "Reliability Analysis of the Sutm Distribution System at PT. PLN (Persero) UP3 Yogyakarta," *J. Simetris, ISSN 2252-4983*, pp. 107–126, 2023.

[10] B. R. Les H, **Protection, Practical Power Systems**. London, 2005.

[11] W. D. W. I. Siswanto, "Coordination of OCR and GFR Protection Systems for PT PLN's 20 kV Distribution Transformers with Neutral Grounding Resistors Using Zero-Sequence Impedance," pp. 36–49, 2025.

[12] E. H. Arya and J. Hendri, "Analysis of Overcurrent Relays (OCR) and Ground Fault Relays (GFR) in 20 kV Distribution Networks," Vol. 11, No. 2, pp. 755–764, 2024.

[13] S. Thaha, A. W. Indrawan, and Y. J. Pongkiding, "Analysis of the Protection Coordination System for Overcurrent Relays (OCR) and Ground Fault Relays (GFR) in a 20 kV Transformer Bay at the Sanga-Sanga Substation in East Kalimantan," Vol. 19, No. 2, pp. 116–122, 2022.

[14] M. R. Albarokah, "Analysis of OCR and GFR Protection Coordination on the Seluma Express Feeder of PT PLN (Persero) ULP Manna Using ETAP Software," 2025.

[15] S. Kajat S., Martin D., "Analysis of the Coordination of the 20 kV System Protection on the 30 MVA 150/20 kV Town Feeder Transformer at the 150 kV Suralaya Substation," *J. Ilm. Metadata*, Vol. 8, No. 1, pp. 92–110, 2026, DOI: 10.47652/Metadata.V8i1.944.

[16] Ganesha Ardha Ibrahmasa, "Analysis of Protection Relay Coordination Settings in the 20 kV Brenggolo Feeder Distribution Network at PT PLN UP3 Kediri Pare Substation," *J. Electrical Eng. UI*, Vol. 12, No. 01, pp. 28–36, 2022.

[1] S. Nasional and T. Elektro, "Evaluation of the Selectivity and Reliability of OCR and GFR Relays in Distribution Network Protection Systems," In *Snte-Fortei 2025*, pp. 353–359.

[2] T. Sucita, M. Somantri, D. Fahrizal, and M. Agista, "Reliability Analysis of a 20 kV Electric Power Distribution System on the CWRU Feeder," Vol. 13, No. November, pp. 282–289, 2024, DOI: 10.22146/Jnteti.V13i4.12510.

[3] J. A. Martinez-Velasco and G. Guerra, "Reliability Analysis of Distribution Systems with Photovoltaic Generation Using a Power Flow Simulator and a Parallel Monte Carlo Approach," 2016, DOI: 10.3390/En9070537.

[4] J. D. et al. Asgutian, Deadi, "The Role of Protection System Reliability as a Strategy for Optimizing Electricity Distribution in Medium-Voltage Networks," *Proceedings of* .

[5] R. Silviharyani Mendrofa, Muhammad Erpandi Dalimunthe, “Analysis of the Performance and Reliability of the Electric Power System in a 20 kV Distribution Network at PT PLN,” Vol. 6, No. 1, pp. 835–845, 2025, DOI: 10.30596/Jcositte.V6i1.23677.

[6] T. W. Retno Ayu, Subuh Isnur, “Analysis of the Reliability of the Coordination System for Overcurrent Relays (OCR) and Ground Fault Relays (GFR) at the 150 … □,” *JTEIN; J. Tek. Elektro Indones. 2024*, p. 150.

[7] G. F. Relay and I. Introduction, “Analysis of OCR Protection Coordination,” Vol. 1, pp. 30–38, 2023.

[8] Z. Zhu and L. Liang, “International Journal of Electrical Power and Energy Systems: An Optimization Model for Identifying Backbone Networks to Enhance the Resilience of Distribution Networks,” Vol. 170, No. January, 2025.

[9] T. A. Aldy Bagas, Risna Defi M, Noor H, “Reliability Analysis of the Sutm Distribution System at PT. PLN (Persero) UP3 Yogyakarta,” *J. Simetris, ISSN 2252-4983*, pp. 107–126, 2023.

[10] B. R. Les H, **Protection, Practical Power Systems**. London, 2005.

[11] W. D. W. I. Siswanto, “Coordination of OCR and GFR Protection Systems for PT PLN’s 20 kV Distribution Transformers with Neutral Grounding Resistors Using Zero-Sequence Impedance,” pp. 36–49, 2025.

[12] E. H. Arya and J. Hendri, “Analysis of Overcurrent Relays (OCR) and Ground Fault Relays (GFR) in 20 kV Distribution Networks,” Vol. 11, No. 2, pp. 755–764, 2024.

[13] S. Thaha, A. W. Indrawan, and Y. J. Pongkiding, “Analysis of the Protection Coordination System for Overcurrent Relays (OCR) and Ground Fault Relays (GFR) in a 20 kV Transformer Bay at the Sanga-Sanga Substation in East Kalimantan,” Vol. 19, No. 2, pp. 116–122, 2022.

[14] M. R. Albarokah, “Analysis of OCR and GFR Protection Coordination on the Seluma Express Feeder of PT PLN (Persero) ULP Manna Using ETAP Software,” 2025.

[15] S. Kajat S., Martin D., “Analysis of the Coordination of the 20 kV System Protection on the 30 MVA 150/20 kV Town Feeder Transformer at the 150 kV Suralaya Substation,” *J. Ilm. Metadata*, Vol. 8, No. 1, pp. 92–110, 2026, DOI: 10.47652/Metadata.V8i1.944.

[16] Ganesha Ardha Ibrahmasa, “Analysis of Protection Relay Coordination Settings in the 20 kV Brenggolo Feeder Distribution Network at PT PLN UP3 Kediri Pare Substation,” *J. Electrical Eng. UI*, Vol. 12, No. 01, pp. 28–36, 2022.

[17] B. Agus Junaidi, Rahmaniar, Rudi Salman, Joni S. Rambey, Abd. Hamid, “Modeling and -Simulation of Symmetrical and Unsymmetrical Faults on a 1444-Bus IEEE Power System,” *J. Theor. Appl. Inf. Technol.*, Vol. 99, No. 20, pp. 4704–4715, 2021.

[18] R. Apda E, Parlin Siagian, “Performance Study of OCR (Overcurrent Relay) and GFR (Ground Fault Relay) as Protection in 20 kV Cubicles at Selayang GH PT. PLN UP2D North Sumatra,” *Journal of Science and Information*, Vol. 16, No. 02, pp. 250–257, 2026.

[19] I. Hajar and M. H. Pratama, “Analysis of Saidi-Saifi Values as an Index of Electricity Supply Reliability in the Cahaya Feeder of PT. PLN (Persero) Ciputat Area,” *J. of Energy and Electrical Engineering*,

[20] S. A. Manda Asrul Sani, Adi Sastra Tarigan, “Optimization and Reliability Analysis Based on Saidi and Saifi Values for 20 kV Distribution System Feeder Channels at PT PLN ULP Labuhan Haji,” Medan: ICDSET, 2025, pp. 298–308.

[21] P. W. Abdila N., Hmadani, “Analysis of SAIDI and SAIFI Values as Reliability Indices for the Electric Power System at PT PLN ULP Sinabang,” *J. Multidisciplinary Sci. Studies*, Vol. 9, No. 3, pp. 10–17, 2025.

[22] M. Guideline *et al.*, “Analysis of Power Distribution System Reliability Using the System Average Interruption Duration Index (SAIDI) and the System Average Interruption Frequency Index (SAIFI) on Feeder KR04,” *Int. J. Econ. Technol. Soc. Sci.*, 2024.

[23] G. N. Obiora, G. Abdulhamid, G. O. Igbinosa, C. B. Fiemobebefa, and O. A. Bamido, “Grid Protection Through Optimal Overcurrent Relay Coordination Using the Hybrid FA-PSO Technique,” Vol. 22, No. 5, pp. 20–32, 2025.

[24] A. R. I., Y. A. Rahman, M. Maryantho, K. Agustinus, and S. P. Yulius, “Analysis of Overcurrent Relay (OCR) Protection Settings for the 30 MW Generator at the Poso Hydropower Plant, PT Poso Energy,” *J. Foristek*, Vol. 14, No. 1, 2024.