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Performance Study of OCR (Over Current Relay) and GFR (Ground Fault Relay) Relays as Protection In 20 Kv Cubicles in Selayang GH PT. PLN UP2D North Sumatra

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Power system protection is crucial for maintaining energy distribution reliability. This study aims to evaluate the performance of Over Current Relay (OCR) and Ground Fault Relay (GFR) as protection systems in 20 kV cubicles at Selayang Switching Station (GH) PT PLN UP2D North Sumatra. The research method used is descriptive quantitative with an engineering case study approach. Data were collected through field observations, short-circuit fault current calculations, and physical testing using the Omicron CMC 353 secondary current injection tool. The results show that the maximum short-circuit fault current of 14.4 kA is still below the circuit breaker's breaking capacity of 16 kA. The pick-up current settings on feeders SLY 05, SLY 06, and SLY 07 met the sensitivity criterion (1.2 x Imax), and the time coordination (grading margin) between protection devices was within the ideal range of 0.25 to 0.5 seconds. Validation through injection testing showed high accuracy with an average operating time deviation of less than 10% according to PLN standards. The conclusion of this study confirms that the protection system at GH Selayang operates efficiently, precisely, and reliably in securing network assets and ensuring the continuity of electricity supply.
Keywords: 20 kV cubicle; distribution system; GFR; OCR; protection coordination.

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1. Introduction

Protection systems in electric power play a vital role in ensuring safe, reliable, and sustainable energy distribution. Within this system architecture, Over Current Relay (OCR) and Ground Fault Relay (GFR) devices are key components that maintain network integrity. The OCR functions to protect the network from overloading by instructing the Circuit Breaker (PMT) to operate, while the GFR is optimized to detect single-phase to ground short circuits. Given the stochastic and unpredictable nature of short circuits in distribution systems, the implementation of protection units such as OCR and GFR with a high level of reliability is essential to mitigate the risk of permanent damage to power transformer assets (Multi & Addaus, 2022). In practice, a single-phase to ground fault (Single Line to Ground Fault/SLGF) is the most dominant type of fault that occurs in three-phase systems, which is often triggered by extreme weather factors, equipment degradation, or insulation failure. The urgency of handling this fault is very crucial, as explained by Suprihartini (2025) that if the ground fault is not handled quickly by the appropriate protection system, then a large magnitude of the fault current can appear and damage the stability of the system as a whole.

The effectiveness of a protection system depends heavily on the accuracy of the relay pick-up and drop-off settings. Precise settings enable the relay to operate with a fast and selective response, thus minimizing the potential for system instability (Corio et al., 2023). In PT PLN's 20 kV distribution network, these protection devices are generally integrated into distribution cubicles, such as the Schneider SM6,

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which is equipped with systematically protected breakers and relays. However, despite the support of sophisticated technology, the risk of setting errors and operational equipment failure remains a real technical challenge. The potential discrepancy between theoretical calculations during the setup stage and dynamic load conditions in the field often creates gaps that can disrupt electricity supply to customers. Therefore, coordination between protection devices is a determining factor in maintaining system selectivity. The effectiveness of a protection system in localizing and isolating faults depends heavily on a precise coordination scheme between safety devices to prevent widespread load shedding (Muhammad et al., 2025).

Based on these conditions, evaluating the performance of OCR and GFR in 20 kV cubicles at strategic points such as GH Selayang PT PLN UP2D North Sumatra is an urgent matter to be done. This study aims to conduct an evaluative study of the relay performance to ensure the speed and accuracy of fault disconnection. Through a comparative analysis between existing setting values, theoretical calculations, and physical testing using the Omicron CMC 353 secondary injection tester, it is hoped that the results of this study can provide technical recommendations to improve the reliability of the electricity distribution network in the North Sumatra region.

2. Literature Review

Electric Power Distribution System

The distribution system is the final stage in the distribution of electrical energy from the power plant to the consumer. The history of electricity development itself is inseparable from the innovation of Thomas A. Edison in 1879, which later developed into the integrated system we use today. According to Ajiatmo (2023), the electric power system is designed to ensure a reliable and secure supply by regulating power flow and protecting against disturbances. In its operation, electric power is distributed through two types of channels: primary distribution (Medium Voltage Network/JTM) with a voltage of 6 kV – 20 kV, and secondary distribution (Low Voltage Network/JTR) for customer needs (Sofwan, 2021). Furthermore, Suprihartini (2025) emphasizes that good network management is crucial to prevent unexpected blackouts, especially in densely populated areas.

Disturbances in the Electric Power System

Distribution networks cover a vast area, making them more susceptible to disruptions than transmission networks. Hayusman (2022) explains that these disruptions can be caused by internal factors such as equipment insulation damage, as well as external factors such as fallen trees, extreme weather, or lightning strikes. Generally, disruptions are divided into two main types: short circuits (very high currents) and overloads. The impact of these disruptions can trigger a drastic increase in current (overcurrent), which, if not promptly addressed, can permanently damage system components and endanger operator safety.

Protection Principles and Eligibility Requirements

The protection system functions to detect and isolate problematic network sections to prevent further damage. This mechanism involves collaboration between protective relays, Current Transformers (CTs), Voltage Transformers (VTs), and Circuit Breakers (PMTs). To be considered optimally functional, a protection system must meet certain eligibility requirements. These requirements include reliability to operate consistently, selectivity to disconnect only the affected area, operating speed to minimize damage, and simplicity and economy to ensure the system is easy to maintain and cost-effective.

Characteristics of OCR and GFR Relays

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A protective relay is an intelligent unit or the "brain" of an electrical power system, functioning to issue a tripping command when an abnormal condition is detected. The primary focus of a distribution protection system is the Over Current Relay (OCR) to mitigate interphase faults and the Ground Fault Relay (GFR) to protect against phase-to-ground faults.

The characteristics of the short-circuit fault current itself are significantly influenced by the line impedance value, which correlates with the distance to the fault point. The closer the fault location is to the power source, the greater the magnitude of the fault current, requiring a faster and more sensitive relay response to localize the fault area (Dasweptia et al., 2021).

Based on their operating time, Sofwan (2021) classifies relay operating characteristics into three main types: instantaneous, definite time, and inverse time. In the inverse type, the inverse proportionality principle applies, where the greater the detected fault current, the shorter the relay's operating time. The performance of this relay is highly dependent on the accuracy of the Pick-up Current (Iset) and Time Multiplier Setting (TMS) parameters in determining the sensitivity level and speed of protection coordination.

In determining the operating time limit, the minimum time setting (grading margin) on the overcurrent relay on the feeder side must consider the inrush current phenomenon in the distribution transformer. The ideal limit is recommended to be no less than 0.3 seconds to ensure selectivity and prevent nuisance tripping when the circuit breaker (PMT) is operated (Sunaya & Widharma, 2020). This aims to ensure the distribution network remains safe from thermal and mechanical damage due to continuous fault currents.

3. Research Methods

This research uses a descriptive quantitative method with an engineering case study approach located at the Selayang Distribution Substation (GH), PT PLN UP2D North Sumatra. The main focus of the research is to evaluate the performance of the OCR and GFR relays through numerical data analysis related to current parameters, trip time, and protection coordination in the 20 kV distribution system. The research objects include protective relay devices, Current Transformers (CT), and Circuit Breakers (PMT) integrated in the feeder cubicle. Data collection was carried out in an integrated manner through field observations using an Omicron CMC 353 current injection tool, semi-structured interviews with PLN engineers, and internal documentation studies. Relay performance validation was carried out through a series of secondary current injection tests to evaluate the pick-up, drop-off parameters, and actual operating time characteristics to ensure that the performance of the protection devices in the field is still in line with the planned theoretical setting values (Damogalad, et al., 2024).

The data collected in this study includes:

a. Primary data in the form of current settings (Iset), Time Multiplier Setting (TMS), and the actual CT ratio installed in the field.
b. Secondary data includes the Single Line Diagram (SLD) of GH Selayang, peak load data for each feeder, and historical disturbance statistics data.
c. The results of the short circuit fault current calculations (3 phases, and 1 phase to ground) on the busbar and critical points of the network.

The data analysis procedure is carried out through five systematic stages to test the feasibility of the existing protection system. The initial step begins with the calculation of the theoretical fault current and the determination of the relay working time (t) using the Inverse Definite Minimum Time (IDMT) curve equation according to applicable standards. In this calculation model, the relay working time is expressed as a function of the TMS value, fault current (I), and setting current (Is). Relay performance evaluation is

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carried out individually to test sensitivity, where the OCR setting current (Iset-OCR) must be between the peak load current and the minimum fault current. Next, a system coordination analysis is carried out by plotting the time-current characteristic curve (TCC). The core of this evaluation is to ensure the Coordination Time Interval (CTI) value, which is the time difference between two consecutive protection devices, is in the range of 0.3 to 0.5 seconds. The flow of research steps is depicted in the flowchart below:

Figure 1. Research Flowchart

4. Results and Discussion

Technical and Operational Data of GH Selayang

The data collection process in this study was carried out at the Selayang Distribution Substation (GH) during the period of August 2025. The technical data collected included equipment specifications on three main feeders, namely OUT SLY 05, OUT SLY 06, and OUT SLY 07. Based on the results of field observations, the specifications of the primary and secondary equipment on the three feeders can be seen in Table 1.

Table 1. Technical Specifications of Equipment at the Selayang GH Feeder

Component	Main Parameters	OUT SLY 05	OUT SLY 06	OUT SLY 07
Cubicle	Type	SM6-DM1A	SM6-DM1W	SM6-DM1A
	Rated Current	630 A	630 A	630 A
PMT	Type	SF1	SF1	SF1
	Breaking Capacity	16 kA/1s	16 kA/1s	16 kA/1s
Relay	Manufacturer/Type	MICOM P127	MICOM P123	MICOM P123
	Production year	2022	2018	2018
CT	Ratio	200-400/5 A	200-400/5 A	200-400/5 A
	Class	0.2S - 5P15	0.2S - 5P15	0.2S - 5P15

The data in Table 1 shows uniformity in PMT capacity and CT ratio, which facilitates the application of uniform coordination principles. Although there are different relay types (MiCOM P127 and P123), both still have the basic OCR and GFR functions required in a protection system. In addition to technical specifications, the determination of the pick-up value on the relay is highly dependent on the peak load current that occurs in the system to avoid nuisance tripping. The maximum feeder loading data as of August 26, 2025, is presented in Table 2.

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Table 2. Maximum Feeder Load Current Data

Feeder	Voltage (kV)	I Maximum Load (A)	PMT Capacity (A)
OUT SLY 05	20.7	22.62	630
OUT SLY 06	20.7	47.99	630
OUT SLY 07	20.7	61.96	630

Based on Table 2, all feeders were operating well below their rated capacity (630 A). Feeder SLY 07 had the highest load of 61.96 A, which then became the reference in determining the minimum overcurrent protection setting limit so that the system remains sensitive but does not easily trip due to normal loads.

Short Circuit Current Analysis

The initial evaluation stage is carried out by calculating the short-circuit fault current to determine the system's ability to withstand the fault current and the relay setting limits. With the source impedance calculated based on the busbar short-circuit capacity, the maximum fault current value is obtained, which is presented in Table 3.

Table 3. Results of Short Circuit Current Calculation

Types of Disorders	Location of Disturbance Point	Calculation Results (A)	PMT capacity (kA)
3 Phase Short Circuit	GH Selayang Bus Bar	14,433	16
Single Phase Short Circuit - Ground	GH Selayang Bus Bar	962.25	-

Analysis of this value shows that the magnitude of the fault current of 14.4 kA is still below the PMT breaking capacity (16 kA), so that the primary equipment is declared mechanically and thermally safe. For ground faults, the current is significantly limited to 962.25 A by the Neutral Grounding Resistor (NGR) 12 Ω, which aims to protect the cable insulation from overheating when a single phase to ground fault occurs.

OCR and GFR Relay Performance Evaluation

Performance evaluation was conducted by comparing actual field settings with PLN coordination standards. For the OCR function, the main parameters reviewed were pickup sensitivity (1.2 x Imax) and runtime. The results of the OCR sensitivity evaluation are summarized in Table 4.

Table 4. Evaluation of OCR Current Setting Sensitivity

Feeder	Maximum Load Current (Imax)	Calculation (1.2 x Imax)	Actual Set (A)	Information
SLY 05	22.62 A	27.14 A	400 A	Qualify
SLY 06	47.99 A	57.58 A	248 A	Qualify
SLY 07	61.96 A	74.35 A	320 A	Qualify

The data in Table 4 shows that all feeders have settings well above the peak load current, thus avoiding the risk of false tripping due to load. However, the wide margin on the SLY 05 (400 A) needs to be considered to ensure it can still detect small current disturbances at the end of the network. Furthermore, the evaluation of time coordination using the Time-Current Curve (TCC) shows that the working time difference (CTI) between protection devices is in the range of 0.25 to 0.5 seconds. This is in accordance with the concept of protection coordination where the downstream protection must operate faster than the upstream protection.

For the GFR function, the evaluation shows a very high level of sensitivity, where the setting current is below 5% of the maximum ground fault current (962.25 A). The SLY 06 even uses a Definite Time characteristic of 0 seconds with an Iset of 16 A to respond instantly to ground faults due to critical loads.

Performance Validation Through Omicron CMC 353 Testing

To ensure the physical reliability of the relay, secondary current injection testing was carried out using the Omicron CMC 353 tool. The test results showed a high level of accuracy between the theoretical working time and the actual working time of the relay in the field, as shown in Table 5.

Table 5. Relay Trip Time Accuracy Test Results

Feeder	Function	t-Theory (ms)	t-Actual (ms)	Deviation (%)	Status
SLY 05	OCR	501.5	481.5	-3.98	Passed
SLY 06	OCR	250.7	230.7	-7.97	Passed
SLY 07	OCR	401.2	381.2	-4.98	Passed
SLY 06	GFR	0.0	0.0	0.00	Passed

All test results have deviation values below the PLN standard tolerance (±10%), which proves that the processing algorithm on the MiCOM P127 and P123 relays works with high precision.

Discussion Analysis.

After conducting a series of technical data analysis and field testing, this section presents a synthesis of the discussion that systematically answers the research problem formulation. First, regarding the operating conditions and characteristics of the protection system at GH Selayang, it was found that the use of Schneider MiCOM digital protection devices type P127 and P123 has been integrated with the primary equipment PMT SF1 which has a breaking capacity of 16 kA. The characteristics of this system have been adjusted to the network load profile, where the use of the Standard Inverse curve on the time delay function and the Definite characteristic on the instantaneous function provides a solid protection framework in dealing with system short circuit currents reaching 14.4 kA. This confirms that the applied protection characteristics are in accordance with the technical capabilities of the available primary equipment.

Second, regarding the suitability of the settings to PLN's protection coordination standards, the evaluation results show a high level of compliance with distribution standards. The determination of the pick-up current on the SLY 05, SLY 06, and SLY 07 feeders consistently follows the reliability rules with values above the peak load (1.2 x Imax), which prevents unwanted load shedding. Meanwhile, in terms of time coordination, the TMS value ranging from 0.025 to 0.05 has created an ideal grading margin scheme. This condition ensures that the protection selectivity is maintained, where the protection system in the switchgear substation will only operate if the protection on the downstream side fails to isolate the fault. These results are in line with previous research by Thaha et al. (2022) which explained that the coordination scheme in the 20 kV cubicle requires the working time setting of the relay on the downstream side (outgoing) to operate faster than the upstream side (incoming), which is in accordance with the IEC 60255 protection selectivity standard to maintain distribution continuity in areas not affected by the fault.

Third, the analysis of the relay response performance to overcurrent and ground faults demonstrated excellent effectiveness. Through physical testing using the OMICRON CMC 353, it was proven that the relay was able to respond to faults with a high level of accuracy, characterized by minimal operating time deviation (average 3% to 8%). This performance is crucial in responding to ground faults, especially on the SLY 06 feeder which exhibited an instantaneous response strategy (0 ms) for small fault currents (16

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A). The findings regarding this time deviation are also in line with the results of previous research by Soewono & Noprianti (2020) which indicated that protection performance analysis must consider the dynamics of operational loads in the field, where mismatches between relay settings and actual load conditions can result in coordination time deviations that do not meet the standard specifications of the device manual precisely. Overall, the synthesis of this discussion proves that the protection system at GH Selayang operates efficiently, precisely, and reliably, thus ensuring the continuity of electric power distribution while protecting network assets from the impact of damage due to disturbances.

5. Conclusion

Based on the results of the research and analysis that have been carried out, it can be concluded that the OCR and GFR relay protection systems in the 20 kV cubicle at GH Selayang PT PLN UP2D North Sumatra operate with reliable and precise performance. The pick-up current settings on all feeders have met the sensitivity criteria because they are above the peak load current but are still able to respond to minimum short circuit fault currents. The time coordination between protection devices is also in the ideal range between 0.25 to 0.5 seconds, which guarantees the selectivity aspect of the system where faults can be isolated without causing extensive blackouts. Validation through secondary injection testing using Omicron CMC 353 strengthens this finding with a very low working time deviation value (below 10%), proving that the relay hardware is still in very good operational condition.

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