Journal of Power and Energy Engineering, 2025, 13(10), 1-9
https://www.scirp.org/journal/jpee
ISSN Online: 2327-5901
ISSN Print: 2327-588X

A Study on Overcurrent Relay Coordination at Pencawang Masuk Utama Banting Selangor Using PSCAD Software

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How to cite this paper: Hairi, M.H., Isira, A.S.M., Kamarudin, M.N. and Mohamed, M.F.P. (2025) A Study on Overcurrent Relay Coordination at Pencawang Masuk Utama Banting Selangor Using PSCAD Software. *Journal of Power and Energy Engineering*, **13**, 1-9.
https://doi.org/10.4236/jpee.2025.1310001

Received: September 10, 2025
Accepted: October 14, 2025
Published: October 17, 2025

Abstract

Overcurrent faults are the critical issues in electrical distribution systems, characterized by high electrical current disturbances that exceed the safe limit for the electrical apparatus. These faults can be caused by equipment malfunctions, short circuits, or imperfections in protective devices, posing risks such as equipment damage, fires, and disruptions in the electricity supply. This research assesses the effectiveness of protective systems in the main distribution panel in Banting, Selangor, using PSCAD software as the research platform. The main distribution panel is critical for ensuring safe and reliable electrical power to end-users, and any faults within it can lead to widespread power supply issues. This study evaluates the overcurrent relay, a crucial component in detecting excessive current events, focusing on its configuration, programming, and operation. Through data collection and analysis, the research verifies the effectiveness of the protective system within the main distribution panel. The findings provide valuable guidance for the maintenance and enhancement of protective systems, aiming to improve the safety and stability of the electrical supply for end-users.

Keywords

Distributed Generation, Excessive Power, Renewable Energy, Three-Phase Grid-Connected PV System, Voltage Profile

1. Introduction

The electrical distribution system plays a pivotal role in ensuring the continuous and reliable electricity supply to end-users. Among the various challenges these systems face, fault detection and response, particularly overcurrent faults, are critical issues that demand immediate and effective solutions. The Pencawang Pembahagian Utama (PPU) in Banting, Selangor, serves as a crucial node within the electrical power distribution network, making its stability and safety paramount. Overcurrent problems, characterized by excessive electric currents surpassing safe operational limits, pose significant risks, including equipment damage, fire hazards, and interruptions in the power supply [1]-[4].

Overcurrent protection relays are integral components in safeguarding electrical distribution systems. These relays detect and respond to overcurrent faults, preventing equipment damage and mitigating hazardous situations. However, the high-voltage nature of the PPU electrical system renders real-world testing and trial-and-error approaches for protection system design impractical and risky. Consequently, simulation tools such as PSCAD become indispensable in this context. PSCAD allows electrical engineers to model and analyze the behavior of protective systems under various fault scenarios in a safe and controlled environment. This simulation capability is crucial for evaluating response times, fine-tuning overcurrent protection relay settings, and ensuring the seamless coordination of protective devices throughout the network [5]-[7].

Data analysis derived from these simulations is vital for understanding the system's overall efficacy. The primary objectives of overcurrent protection relays are reliability and efficiency, as their prompt response to fault currents can prevent large-scale power outages, protect equipment, and maintain a continuous supply of electricity to end-users in PPU Banting. As the electrical distribution system expands and power demand increases, robust fault detection and response systems become increasingly essential.

2. Network Model

Figure 1 illustrates the network for the three-phase tripping relay simulation test, based on the single line diagram of the Main Distribution Substation (PPU) TNB Banting, Selangor, which includes three substations: SGMAS, SGMS CABIN, and SGMS. Each substation has one generator operating at 33 kV, 50 Hz, Star-Grounded. PPU SGMAS uses two 30 MVA 33 kV/11 kV transformers and handles three loads (2.35 MW, 5.5 MW, 750 KW). PPU SGMS CABIN has one 30 MVA 33 kV/11 kV transformer and two loads (9.05 MW, 4 MW). PPU SGMS is equipped with one 15 MVA 33 kV/11 kV transformer and one load (10.5 MW). This network is used to test the response time of overcurrent relays at various locations when faults are simulated, to ensure the effectiveness of the relays in detecting and isolating faults for a reliable power supply.

Figure 2 shows the network for the protection blinding simulation test, based on the single line diagram of the Main Distribution Substation (PPU) TNB Banting,

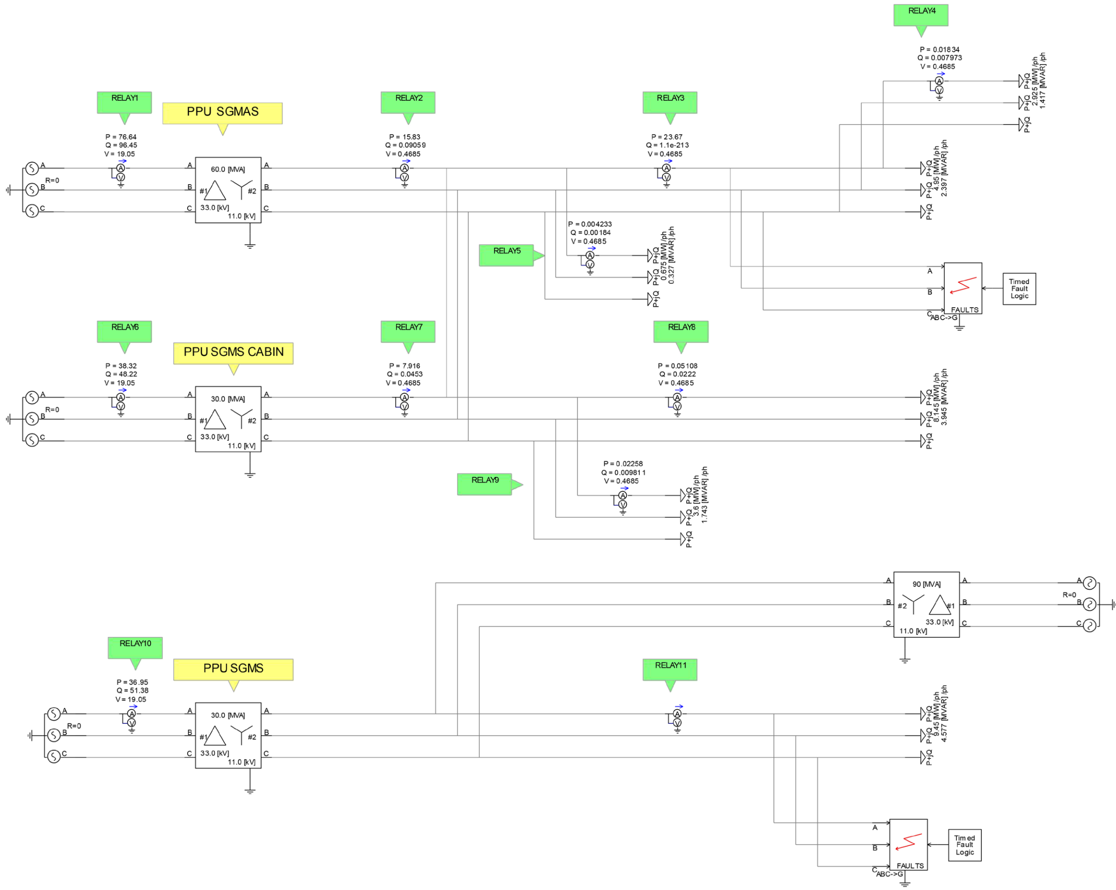

Figure 1. Network model for Three-Phase Tripping Relay.

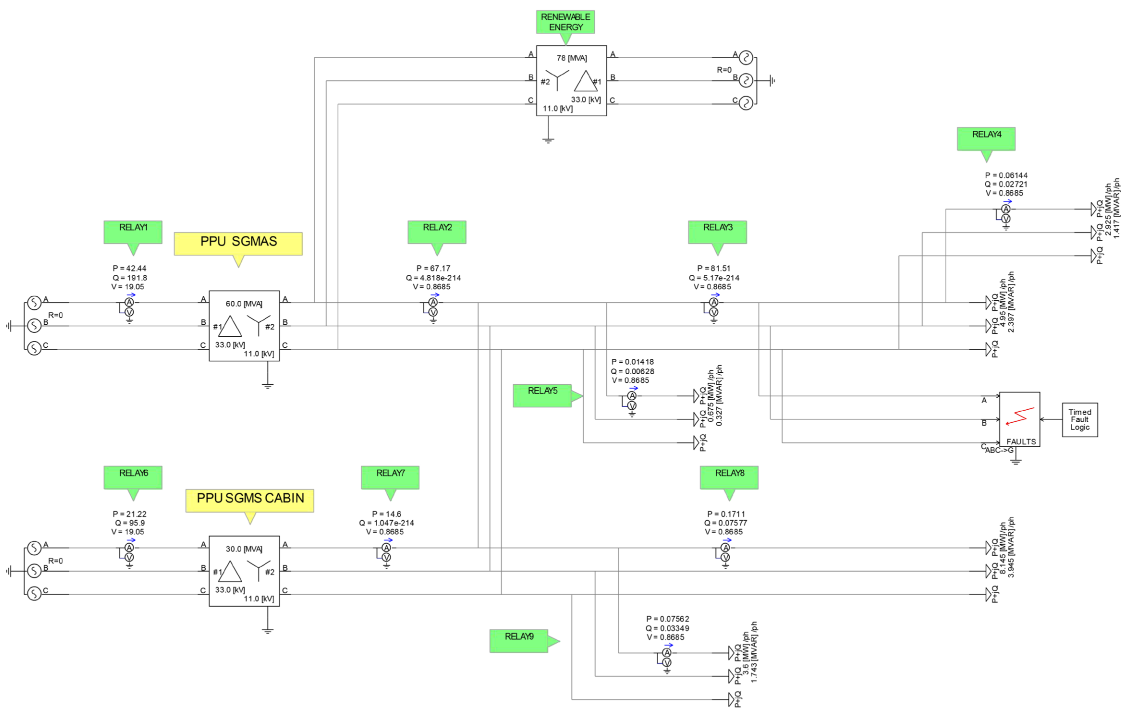

Figure 2. Network model for Protection Blinding.

Selangor, which includes three substations: SGMAS, SGMS CABIN, and SGMS. Protection blinding happens when a relay, which must operate to clear the fault, is rendered inoperative [8] [9]. Each substation is equipped with one generator operating at 33 kV, 50 Hz, Star-Grounded. At PPU SGMAS, two 30 MVA 33 kV/11 kV transformers are used, handling three loads (2.35 MW, 5.5 MW, 750 KW). PPU SGMS CABIN has one 30 MVA 33 kV/11 kV transformer with two loads (9.05 MW, 4 MW), while PPU SGMS is equipped with one 15 MVA 33 kV/11 kV transformer and one load (10.5 MW).

Overcurrent relays are placed at various locations within the system (RELAY1 to RELAY11) to monitor and protect the network. The relays setting is summarized in **Table 1**. This diagram shows that renewable energy is injected between RELAY1 and RELAY2, adding complexity to the network protection. The test aims to evaluate the response time and coordination of these relays under fault conditions, ensuring rapid fault detection and isolation to maintain the stability and reliability of the power supply. Coordination time is chosen to be between 0.4 to 0.5 s as explained in **Table 2**. All PSCAD models are validated by comparing its simulation results against manual calculations.

Table 1. Relay performance.

Relay	Plug setting	TMS	Curve type
Relay 1	100%	0.437	Standard inverse
Relay 2	150%	0.246	Standard inverse
Relay 3	100%	0.1	Standard inverse
Relay 4	100%	0.1	Standard inverse
Relay 5	100%	0.10	Standard inverse
Relay 6	75%	0.437	Standard inverse
Relay 7	75%	0.246	Standard inverse
Relay 8	100%	0.1	Standard inverse
Relay 9	100%	0.1	Standard inverse
Relay 10	100%	0.244	Standard inverse
Relay 11	100%	0.1	Standard inverse

Table 2. Relay margin.

Relay error	Margin (s)
Relay	0.1
overshoot	0.05
breaker	0.15
Contact gap	0.1
Total margin	0.4

Figure 3 illustrates the network for the nuisance tripping simulation test, where renewable energy is injected at RELAY9 and a fault occurs at RELAY5. The primary objective of this network model is to test how the system handles false trips that could cause unnecessary power outages. The generators and transformers at each PPU (SGMAS, SGMS CABIN, and SGMS) operate at 33 kV, 50 Hz, with a Star-Grounded configuration. PPU SGMAS contains two 30 MVA transformers stepping down the voltage from 33 kV to 11 kV, handling loads of 2.35 MW, 5.5 MW, and 750 KW. PPU SGMS CABIN has one 30 MVA transformer with loads of 9.05 MW and 4 MW, while PPU SGMS with one 15 MVA transformer managing a load of 10.5 MW. Overcurrent relays (RELAY1 to RELAY11) are placed at various locations to monitor and protect the system. In this test, injecting renewable energy at RELAY9 and simulating a fault at RELAY5 helps assess the effectiveness and efficiency of the relays in detecting and distinguishing between actual faults and false trips, ensuring the reliability and stability of the power supply.

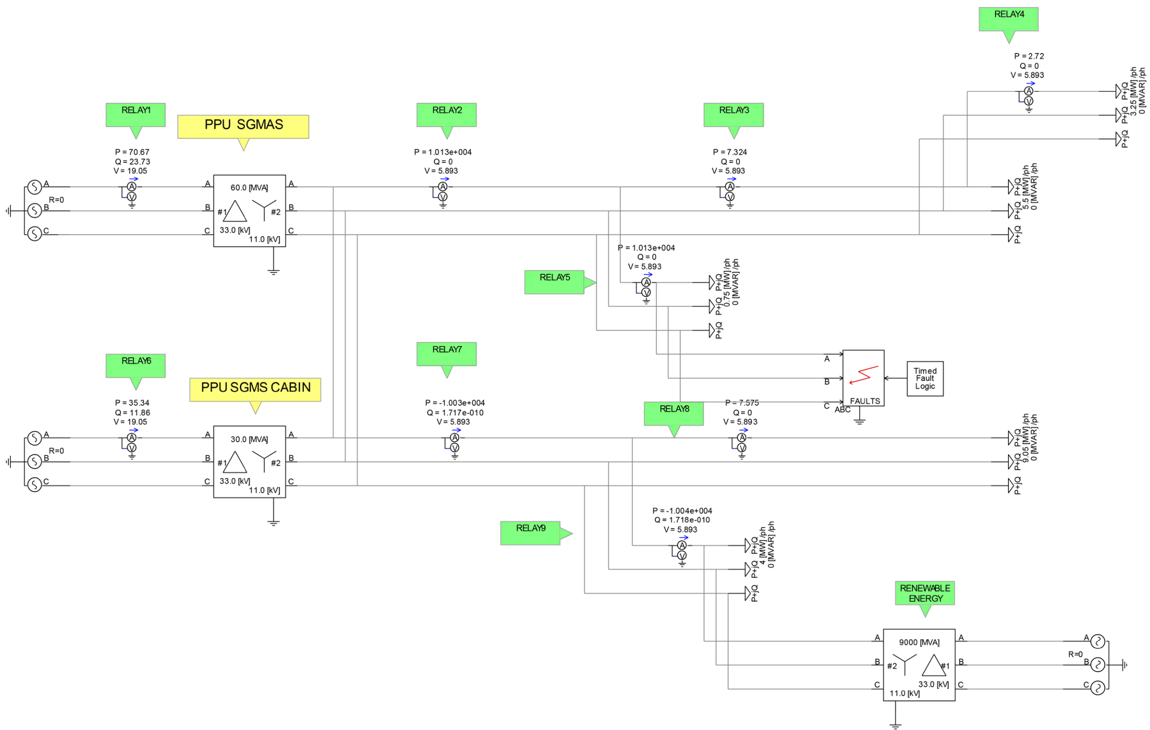

Figure 3. Network model for Nuisance Tripping.

Two scenarios that have been simulated are PSCAD: Scenario 1 is a fault occurring at Condition A, which is at PPU SGMAS, and Scenario 2 is a fault occurring at Condition B, which is at PPU SGMS CABIN. Based on the relay tripping time results, the tripping times shown in Condition A and Condition B are the same, with each relay having a discrimination time of 0.5 seconds. In Condition A, there are three relays that trip at PPU SGMAS, starting with relay 3, then relay 2, and finally relay 1. Relay 2 trips 0.5 seconds after relay 3, and relay 1 trips 0.5 seconds after relay 2. This demonstrates that the overcurrent protection system at PPU

SGMAS is effective, safe, and reliable. Based on the TNB single line diagram, PPU SGMAS is parallel to PPU SGMS CABIN. Relays 3, 6, and 7 are relays at PPU SGMAS that are parallel with PPU SGMS CABIN if a fault occurs at Condition A. The relays will trip starting with relay 3, followed by relay 6, and finally relay 7, with each relay tripping time having a discrimination time of 0.5 seconds.

3. Results and Discussion

This simulation involves three conditions, which are three-phase tripping time, protection masking, and nuisance tripping. The discrimination time between relays is recorded and discussed in detail in the following section.

A. Case 1 (three-phase tripping time relay)

A three-phase fault occurs at Load 2 near relay 3 at t = 3 s. It can be observed from the simulation that the discrimination time between the relays is approximately 0.5 s. **Table 3** summarizes the simulation tests, indicating that all relay settings perform well for a three-phase fault.

Table 3. Relay performance.

Relay	Tripping time
Relay 5	nil
Relay 4	0.31 s
Relay 3	0.31 s
Relay 2	0.81 s
Relay 1	1.31 s

B. Case 2 (three-phase protection blinding)

In this scenario, the simulation test for protection blinding occurs when renewable energy is applied to PPU SGMAS between relay 1,2 and relay 3. The introduction of renewable energy significantly alters these dynamics. Specifically, the discrimination time between Relay 2 and Relay 1 decreases to 0.34 seconds, below the required 0.5 seconds. This is shown in **Table 4**. This reduction causes protection blinding, potentially preventing Relay 1 from operating properly before Relay 2 acts. Conversely, the discrimination time between Relay 3 and Relay 2 increases to 0.7 seconds, indicating a delayed response that complicates the protection scheme. These changes underscore the need for recalibrating relay settings and possibly implementing adaptive protection schemes that dynamically adjust to renewable energy presence, ensuring reliable and safe power system operation.

Adaptive protection schemes are essential to mitigate the effects of altered dynamics due to renewable energy. These schemes dynamically adjust relay settings in response to real-time grid conditions and renewable energy presence. Thorough coordination studies are crucial to optimize relay settings and ensure effective discrimination. Advanced fault detection algorithms play a key role in accurately assessing renewable energy contributions, enhancing fault detection, and improving relay operation. Furthermore, deploying directional relays with enhanced sensitivity can effectively manage the variability and directional changes introduced by renewable energy sources.

Table 4. Relay performance.

Relay	Tripping time
Relay 3	0.21s
Relay 2	0.61s
Relay 1	1.31s

C. Case 3 (three-phase nuisance tripping)

In the case of nuisance tripping, a three-phase fault occurs at load 3 near relay 5, with renewable energy introduced at load 5 near relay 9. Prior to the introduction of renewable energy, the relay system maintained a stable discrimination time of 0.5 seconds, ensuring sequential tripping of relays without interference. In the absence of renewable energy, Relay 5 trips at 0.29 seconds, followed by Relay 2 at 0.79 seconds, demonstrating a clear discrimination characteristic of Inverse Definite Minimum Time (IDMT) relays. This timing ensures proper relay operation sequence, facilitating effective fault isolation and system protection.

The introduction of renewable energy disrupts the system's stability due to the increasing fault current shown in **Table 5** causing intermittent and fluctuating nature of power from renewable sources. This disruption leads to reduced discrimination times and unintended relay operations. The altered fault current with the introduction of renewable energy will lead to nuisance tripping. In the nuisance tripping scenario, Relay 5 trips at 0.26 seconds, followed by Relay 9 at 0.33 seconds, Relay 2 at 0.68 seconds, and Relay 7 at 0.86 seconds are shown in **Table 6**. The discrimination times between these operations are significantly shorter than the required 0.5 seconds, causing the relays to operate in quick succession without adequate coordination. This results in unnecessary tripping of multiple relays, leading to an unstable protection system are shown in **Table 5** [8]-[11].

Table 5. Normal and fault current with and without RE.

Relay	Normal current (without RE injection)	Normal current (with RE injection)
Relay 1	767.050A	419.852
Relay 2	2288.352	2866.047
Relay 3	1331.918	1353.87
Relay 4	494.737	502.891
Relay 5	114.17	116.052
Relay 6	383.525	209.926
Relay 7	1144.176	623.054

Continued

Relay 8	1377.599	1400.304
Relay 9	608.84	618.875
Relay 10	527.187	153.484
Relay11	1575.408	1632.911

Table 6. Relay performance.

Relay	Tripping time
Relay 5 (PPU SGMAS) non-renewable	0.29 s
Relay 2 (PPU SGMAS) non-renewable	0.79 s
Relay 5 (PPU SGMAS) nuisance	0.26 s
Relay 9 (PPU SGMAS) nuisance	0.33 s
Relay 2 (PPU SGMAS) nuisance	0.68 s
Relay 7 (PPU SGMAS) nuisance	0.86 s
Relay 5 (PPU SGMAS) resetting	0.25 s
Relay 2 (PPU SGMAS) resetting	0.75 s
Relay 7 (PPU SGMAS) resetting	1.25 s
Relay 9 (PPU SGMAS) resetting	1.75 s

4. Conclusion

In this study, the relay response times according to the American standard (IEEE C37.112) and the British standard (IEC 60255) were evaluated and contrasted in the context of three-phase faults within the power system network. A model of the overcurrent relay was developed using PSCAD software. Simulation results indicate that the IEEE C37.112 standard demonstrates superior sensitivity compared to the IEC 60255 standard. This heightened sensitivity enhances the effectiveness of fault isolation and ensures safer operation during fault conditions.

Acknowledgements

The authors wish to acknowledge the Universiti Teknikal Malaysia Melaka (UTeM) for providing the research platforms and facilities.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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