Fault Detection and Response at Pencawang Pembahagian Utama, Banting Selangor: A focus on Overcurrent Protection Relay using PSCAD Software

M. H. Hairi[1*], A. S Mohd Isira[2], M. N. Kamarudin [3], M. F Packeer Mohamed[4]

[1,3] Faculty of Electrical Technology and Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

[2]Faculty of Electronic and Computer Engineering and Technology, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

[4] School of Electrical and Electronic Engineering, USM, Engineering Campus, Seberang Perai Selatan Nibong Tebal, Penang 14300 Malaysia

[*]Corresponding author's email: hendra@utem.edu.my

Abstract – *Overcurrent faults are prevalent issues in electrical distribution systems, characterized by electrical disturbances where the electric current exceeds the safe limit within a connection. 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 paper assesses the effectiveness of fault detection and tripping response of an overcurrent relay at the main distribution panel in Banting, Selangor, using PSCAD software as the research platform. This study analyses the overcurrent relay setting and tripping response, in detecting excessive current events, focusing on the different network configuration. Through data observation and analysis, the research verifies the effectiveness of the overcurrent fast relay response in the main distribution panel in the event of large fault current. The findings provide valuable guidance for the relay behavioral and proper enhancement of relay reevaluation which aims 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*

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I. 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]-[5]. 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. [6]-[9]

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

II. Network Model

Fig 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 33kV, 50Hz, Star-Grounded. PPU SGMAS uses two 30 MVA 33kV/11kV transformers and handles three loads (2.35 MW, 5.5 MW, 750 KW). PPU SGMS CABIN has one 30 MVA 33kV/11kV transformer and two loads (9.05 MW, 4 MW). PPU SGMS is equipped with one 15 MVA 33kV/11kV 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.

Fig 2 shows the network for the protection blinding 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. 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 33kV, 50Hz, Star-Grounded. At PPU SGMAS, two 30 MVA 33kV/11kV transformers are used, handling three loads (2.35 MW, 5.5 MW, 750 KW). PPU SGMS CABIN has one 30 MVA 33kV/11kV transformer with two loads (9.05 MW, 4 MW), while PPU SGMS is equipped with one 15 MVA 33kV/11kV transformer and one load (10.5 MW).

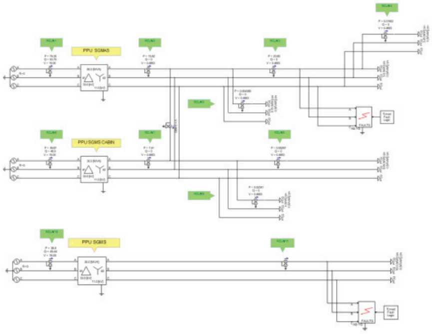

Fig 1: Network Model for Three -Phase Tripping Relay

Overcurrent relays are placed at various locations within the system (RELAY1 to RELAY11) to monitor and protect the network. 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.

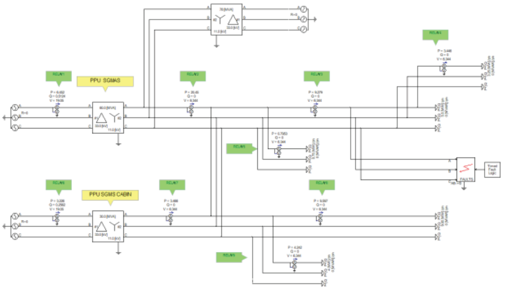

Fig 2: Network Model of Protection Blinding

Fig 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 33kV, 50Hz, with a Star-Grounded configuration. PPU SGMAS contains two 30 MVA transformers stepping down the voltage from 33kV to 11kV, 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.

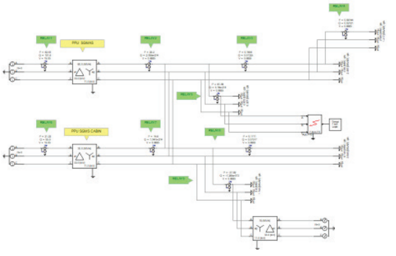

Fig 3: Network Model of Nuisance Tripping.

III. 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=3s. The tripping times for relays PPU SGMAS, SGMS CABIN, and SGMS are recorded as shown in Figure 4, Figure 5, and Figure 6, respectively. It can be observed from the figures that the discrimination time between the relays is approximately 0.5s. The table summarizes the simulation tests, indicating that all relay settings perform well for a three-phase fault

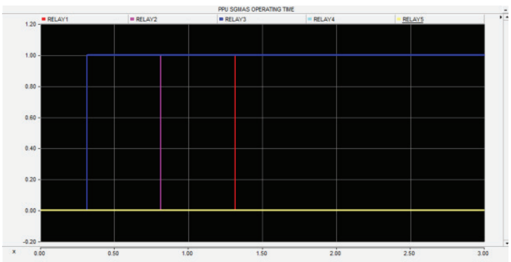

Fig 4: PPU of SGMAS

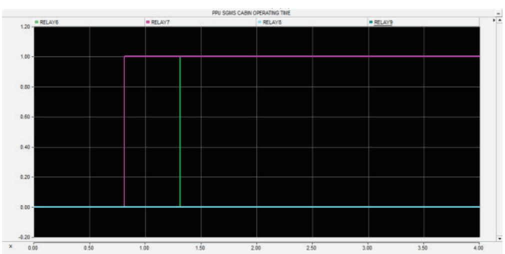

Fig 5: PPU of cabin

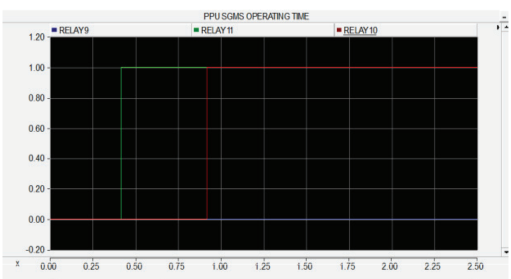

Fig 6: PPU of SGMS

TABLE I
RELAY COORDINATION AT PPU SGMAS

Relay	CT	Plug Setting	TMS	Tripping Time
Relay 5	-	-	-	-
Relay 4	2000/1	100%	0.1	0.31s
Relay 3	2000/1	100%	0.1	0.31s
Relay 2	2000/1	150%	0.246s	0.81s
Relay 1	900/1	100%	0.437s	1.31s

TABLE II
RELAY COORDINATION AT PMU CABIN

Relay	CT	Plug Setting	TMS	Tripping Time
Relay 9	-	-	-	-
Relay 8	2000/1	100%	0.1	0.31s
Relay 7	2000/1	75%	0.246	0.81s
Relay 6	600/1	75%	0.437	1.31s

TABLE III
RELAY COORDINATION AT PPU SGMAS

Relay	CT	Plug Setting	TMS	Tripping Time
Relay 11	2000/1	100%	0.1	0.91s

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 and relay 2. 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 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.

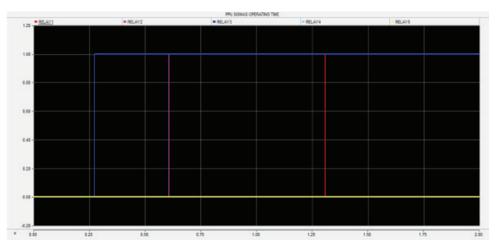

Fig 7: Result of Protection Blinding

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 IV
TIME OPERATING RELAY FOR SMALL CAPACITY 78MVA

Location	Relay	Tripping Time	Sequence
PPU SGMAS	Relay 3 Relay 2 Relay 1	0.21s 0.61s 1.31s	Relay 3-Relay 2- Relay 1

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.

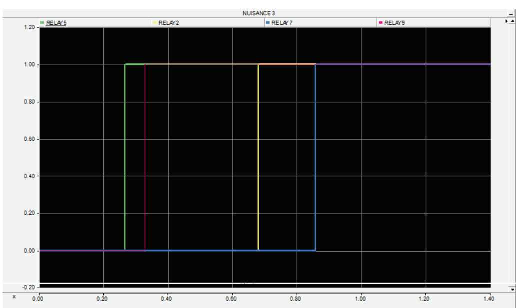

Fig.8: Result of Nuisance Tripping

The introduction of renewable energy disrupts the system's stability due to the intermittent and fluctuating nature of power from renewable sources. This disruption leads to reduced discrimination times and unintended relay operations. 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. 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. [10]-[15]

TABLE V
PPU SGMAS//PPU SGMAS CABIN

Event	Relay	Tripping Time	TMS
Relay Without Renewable Energy	Relay 5	0.29s	0.1s
	Relay 2	0.79s	0.286
Event	Relay	Tripping Time	TMS
Nuisance Tripping Relay	Relay 5 Relay 9 Relay 2 Relay 7 Relay 5	0.26s 0.33s 0.68s 0.86s 0.26s	0.1s 0.1s 0.324s 0.313s 0.1s
Event	Relay	Tripping Time	TMS
Relay Resetting	Relay 5 Relay 2 Relay 7 Relay 9	0.25s 0.75s 1.25s 1.75s	0.1s 0.364s 0.630s 0.803s

IV. 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, protection blinding in the vicinity of renewable energy and nuisance tripping within power system network. A model of the overcurrent relay was developed using PSCAD software. Simulation results indicate that blinding protection could cause extremely relay malfunction. Through carefully relay resetting, that relay demonstrates superior sensitivity compared to the original setting. This sensitivity enhances the effectiveness of fault isolation and offers safer operation during any faulty conditions in the network.

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Conflict of Interest

The authors declare no conflict of interest in the publication process of the research article.

Author Contributions

Author 1: Data collection, analysis, writing – original draft preparation; Author 2: Supervision, draft review and editing, investigation; Author 3: Conceptualization, review; Author 4: Funding acquisition, project administration.

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