Journal of Telecommunication, Electronic and Computer Engineering
ISSN: 2180 – 1843 e-ISSN: 2289-8131 Vol. 16 No. 2
jtec.utem.edu.my
DOI: https://doi.org/10.54554/jtec.2024.16.02.001

Melaka Network Overcurrent Protection & Coordination Analysis Using PSCAD Software

Mohd Hendra Hairi[1], Fairoz Roslee[2], M. N. Kamarudin[1], Ahmad Sadhiqin Mohd Isira[3], Mohamed Fauzi Packeer Mohamed[4]

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

[2]*Tenaga Nasional Berhad, Menara TNB Melaka Aras 10, Jalan MITC Hang Tuah Jaya 75450 Ayer Keroh, Melaka, Malaysia.*

[3]*Faculty of Electronics and Computer Technology and Engineering, 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.*

hendra@utem.edu.my

Article Info

Article history:
Received Jan 15th, 2023
Revised May 21st, 2024
Accepted June 28th, 2024
Published June 30th, 2024

Index Terms:
Overcurrent protection relay
plug setting
relay operation time

Abstract

This paper presents a study on the modeling of the 132/33/11kV PMU Pulau Gadong network and the Melaka radial distribution feeder. The study proposes a protection scheme by providing the appropriate relay Pickup current/Plug Setting (PS) and Time Multiplier Setting (TMS)/Time Dial Setting (TDS) for the discrimination process and evaluating the effect of parallel transformers during faults. For this study, the IEC std 255-3 standard inverse IDMT curve characteristic was chosen for the simulation using the Power System Computer Aided Design (PSCAD). The results show that these values were trustworthy, which provide adequate and reliable protection for the whole network.

I. INTRODUCTION

Overcurrent relay is one of the earliest forms of power system protection. Over time, the overcurrent protection relays have become more advanced, allowing for better discrimination of short-circuit protection. It is important not to confuse overcurrent protection with overload relay protection, which typically involves a relay that operates based on the thermal capacity of the equipment being protected. On the other hand, overcurrent relay protection is designed to handle extremely high short-circuit currents [1-3]. Protection relays play a significant role in ensuring all parts of power system apparatus function correctly, without any maloperation caused by relay or equipment failure,

An overcurrent relay operates by measuring the fault current in the power system and trips either instantaneously or with a delay, according to a specific time characteristic, to achieve discriminative fault clearance [4-6]. The Inverse Definite Minimum Time (IDMT) overcurrent relay is widely used due to its simplicity and economical design. The relay operating time is closely related to current transformer (CT) ratio, plug setting (PS) and time multiplier setting (TMS) [7-8]. To ensure the relay functions properly, this paper presents a study on the relay setting at *Pencawang Masuk Utama (PMU) Pulau Gadong 132/33 kV*. This paper focuses on verifying the overcurrent protection setting and coordination by using PSCAD software.

II. NETWORK MODEL

The local load at *Pulau Gadong* is supplied with 132kV from the *Pencawang Masuk Utama (PMU) Melaka* Substation grid through two PMU *Pulau Gadong* transformers (132/33 kV, 2x90 MVA), which step down the voltage to 33 kV for both feeders as shown in Figure 1. The network model has been simplified to facilitate modeling in PSCAD software. The model was used to investigate the operating time, coordination of overcurrent relays, as well as the effect of parallel transformers when subjected to faults.

Overcurrent relays, denoted as R1 – R7 and R10 – R15, were installed at the locations shown in Figure 1. Additionally, fuses were used for protection at locations R8, R9, R16 and R17. To verify the correct operation and discrimination of the respective relays, various faults were simulated at t = 2 sec. The relay tripping time and time coordination were then analyzed. A total of three cases were simulated. The relay curve was chosen to be IEC std 255-3 standard inverse [9-11]. Correct setting and discrimination of IDMT overcurrent relays are crucial to ensure that the protection relay furthest from the source has a current setting equal to or less than the protection relay behind it. This ensures that the primary current required to block the protection relay in front is always equal to or less than the current required to trip protection relay behind it [12].

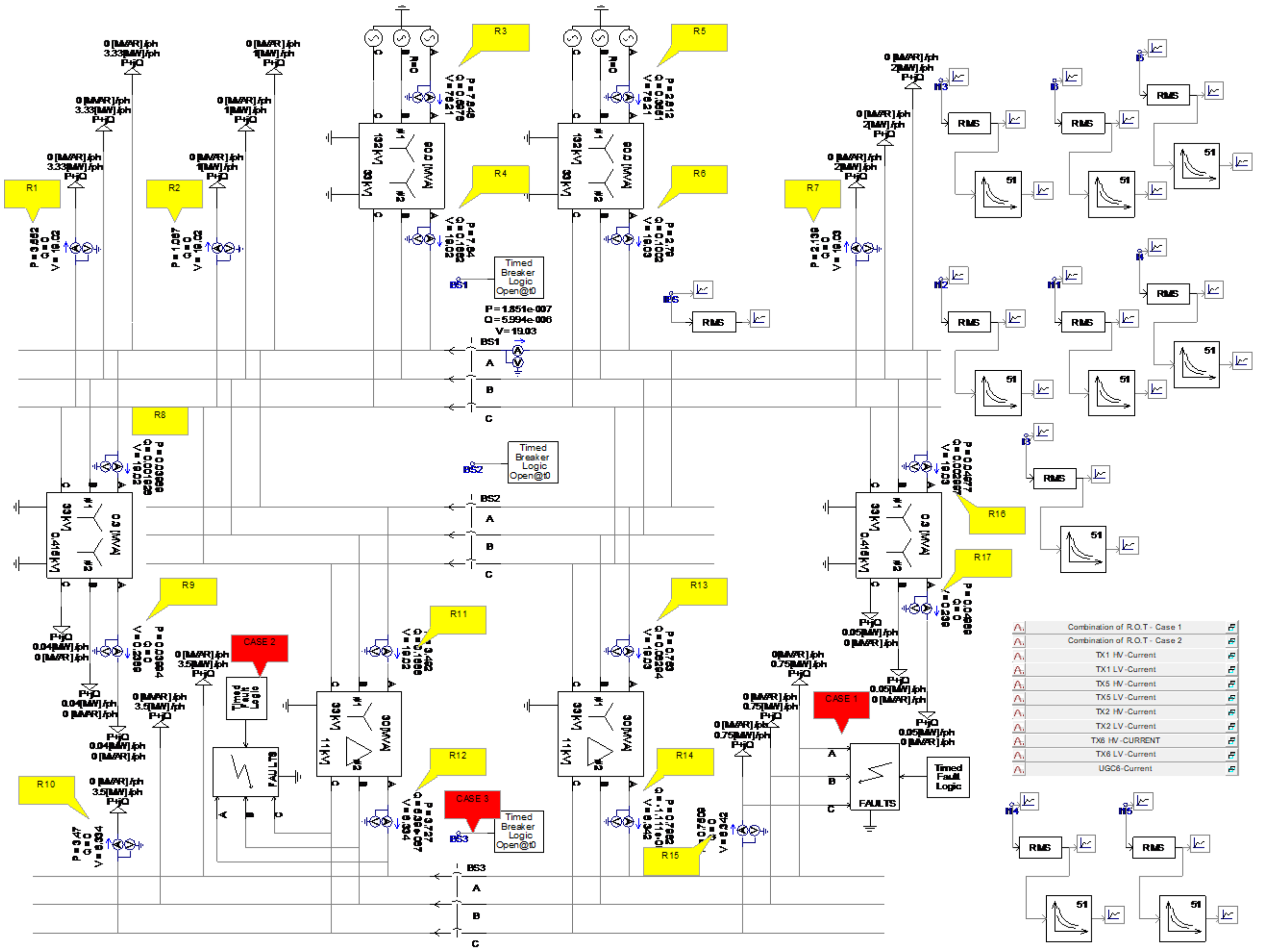

Figure. 1. PMU Pulau Gadong Distribution Network Model

To guarantee a dependable, fast, and safe operation of the overcurrent relay, the pickup current/plug setting and Time Multiplier Setting (TMS) must be chosen carefully [13]. Otherwise, the relay may not function properly (i.e., it may not trip). The pickup current/plug setting of the relay is calculated depending on its rated current. In this study, the pickup current for the overcurrent relay on the transformer (TX) side is set to 150% and on the underground cable (UGC) side, it is set to 100%. The TMS for this relay can be calculated using equation (1) [14-15]. Table 1 shows the summary of pickup current and TMS for these relays.

$$t(s) = \frac{0.14\,(TMS)}{(PSM)^{0.02} - 1} \qquad (1)$$

where

t = relay operating in second
TMS = Time Multiplier Setting
PSM = Plug Setting Multiplier

Table 1
Load Current, CT Ratio, Plug Setting and Pickup Current

Relay	Load Current (kA)/Phase	CT Ratio (A)	Plug Setting (%)	Pickup Current (kA)
R1	0.187	300/5	100	0.3
R2	0.056	300/5	100	0.3
R3	0.103	400/1	150	0.6
R4	0.413	1600/1	150	2.4
R5	0.037	400/1	150	0.6
R6	0.147	1600/5	150	2.4
R7	0.112	600/5	100	0.6
R10	0.548	300/5	100	0.3
R11	0.184	600/5	150	0.9
R12	0.588	1600/5	150	2.4
R13	0.040	600/5	150	0.9
R14	0.126	1600/5	150	2.4
R15	0.118	600/5	100	0.6

III. RESULT AND DISCUSSION

The simulation was conducted with three different types of faults and location. The discrimination time between relays was observed and discussed in detail in the following section.

A. Case 1 (Three-phase-to-ground fault) at Underground Cable 6 (UGC 6)

A three-phase fault was applied near the R15 relay at t = 2s. Then, the tripping time for relays R15, R14, R13, R6 and R5 were recorded as shown in Figure 2. It can be observed from Figure 2 that the discrimination time between the relays is almost 0.5s. The TMS and PSM settings for the related relays are listed in Table 2. The recorded tripping times were then compared with the calculated values, as summarized in Table 3.

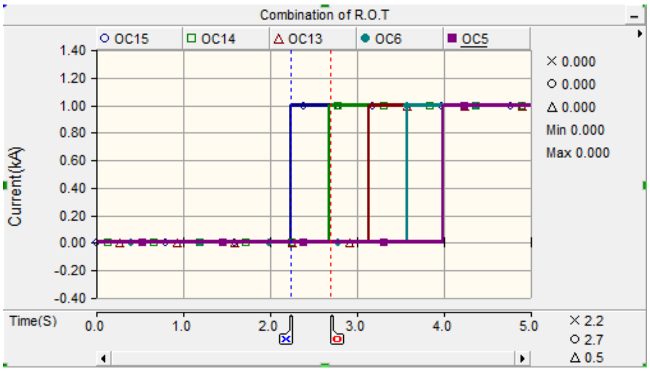

Figure 2. PSCAD simulation result

Table 2
Time multiplier setting and plug setting multiplier

Relay	Time Multiplier setting	Plug Setting Multiplier
R5	0.16	0.6
R6	0.12	2.4
R13	0.25	0.9
R14	0.16	2.4
R15	0.1	0.6

Table 3
Comparison between simulation time and calculation time

Relay	Calculation tripping time, t (s)	Timed fault logic (TFL) + t (s)	Relay tripping time Simulation (s)
R5	2.37	4.37	4.2
R6	1.75	3.75	3.7
R13	1.19	3.19	3.2
R14	0.68	2.68	2.7
R15	0.22	2.22	2.2

From Table 3, it can be seen that the calculated time (Timed Fault Logic (TFL) + t(s) and the simulation tripping times are closely matched. This indicates that all the settings for respective relays are performing well for a three-phase fault event at UGC 6.

B. Case 2 (Three-phase-to-ground fault) at Transformer 5-LV Side

The simulation was repeated for a three-phase-to-ground fault as shown in Figure 1. The relay tripping times for PSCAD were recorded as shown in Figure 3. Similarly, these time were then compared with the calculated values. The TMS and PSM of the related relays is shown in Table 4. The observed times were then compared with the calculated values and summarized in Table 5.

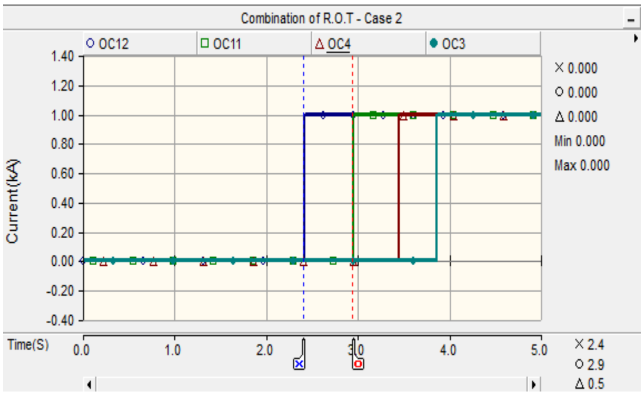

Figure 3. PSCAD simulation result

Table 4
Time multiplier setting and plug setting multiplier

Relay	Time Multiplier setting	Plug Setting Multiplier
R3	0.17	2.38
R4	0.17	2.4
R11	0.22	6.37
R12	0.1	7.24

Table 5
Comparison between simulation time and calculation time

Relay	Calculation tripping time, t (s)	Timed fault logic (TFL) + t (s)	Relay tripping time Simulation (s)
R3	1.90	3.9	3.9
R4	1.35	3.35	3.4
R11	0.83	2.83	2.9
R12	0.35	2.35	2.4

From Table 5, it can be seen that the calculated times (Timed Fault Logic (TFL) + t(s) and the simulation tripping times are closely matched. This indicates that the relay PS and TMS settings were well-chosen for a three-phase-faults-to-ground event at R12. The discrimination time between relays is 0.5s.

C. Case 3 (Three-phase-to-ground fault) at Transformer 5-LV Side When Bus Section 3 Close

The simulation for Case 2 was repeated with the bus section closed, effectively paralleling the transformers through bus section 3. Case 3 demonstrates the effect of parallel transformers and highlights the risk of a total blackout if the overcurrent relay fails to function to cut off the supply. The relay tripping times for PSCAD was recorded as shown in Figure 4.

Figure 4 shows the operation of the relays when a fault occurs with bus section 3 closed. All relays will operate because they are close to the fault, except for R15, which experiences a smaller current passing through it. This is due to the closed bus section or parallel transformer setup, where the fault current flows to transformers 2 and 6 through the bus section.

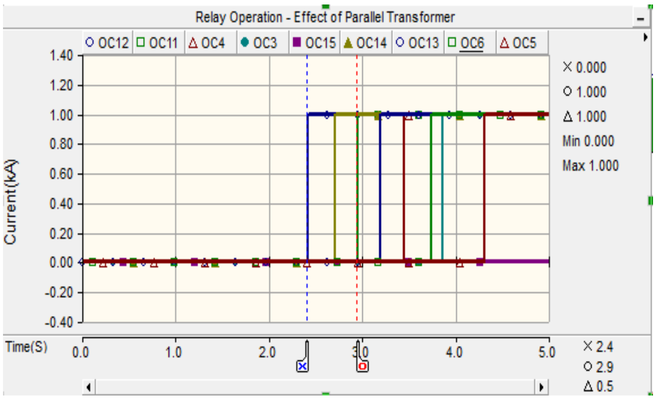

Figure 4. PSCAD simulation result

If the bus section were open when a fault occurs in R12, transformers 2 and 6 could still operate and carry the load, as the fault current would not pass through them. A parallel transformer creates a 'loop' through which current can flow, resulting in circulating currents. This can cause a total blackout on the network because all the transformers are out of service.

IV. CONCLUSION

The goal of overcurrent relay plug setting (PSM) and time multiplier setting (TMS) are to ensure that the relay will operate to isolate the faulty part as soon as possible with sequence of coordination. From the simulation the discrimination time margin/coordination time between each overcurrent relay is 0.4s- 0.5s which is acceptable. As a result, the proposed TMS and PSM are appropriate for the relay to operate successfully. The comparison between calculation and simulation also proved that the tripping time is closely match with each other.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the Universiti Teknikal Malaysia Melaka (UTeM) and Tenaga Nasional Berhad (TNB), Grid Maintenance, Melaka for providing the research platforms and facilities.

REFERENCES

[1] M. H. Hairi, M. N. Kamarudin, A. M. Isira, M. F. P. Mohamed, and S. A. Sobri, "Overcurrent protection of radial distribution network," IJEEAS, vol. 5, no. 2, 2022.

[2] M. H. Hairi, W. X. Juan, M.N. Kamarudin, A.S M. Isira, M.F.P. Mohamed, and S. A. Sobri, "Impact of DG on voltage profile and power losses for 33/11kV PPU Bakar Batu and PPU Century (Johor Bharu) using PSCAD software," IJEEAS, vol. 5, no. 1, 2022.

[3] M. H. Hairi, M. S. Mohd Aras, F. Hanaffi, and M. Sulaiman, "Performance evaluation of overcurrent protection relay based on relay operation time (ROT)", IJEEAS, vol. 1, no. 1, pp. 1–8, 2018.

[4] Q. Tu et al., "Arm overcurrent protection and coordination in MMC-HVDC," in Proc. of 2018 IEEE Power & Energy Society General Meeting (PESGM), 2018, pp. 1-5, doi: 10.1109/PESGM.2018.8585924.

[5] M. H. Hairi, M. N. Kamarudin, A. S. M. Isira, M. F. P. Mohamed and S. A. Sobri, "Modeling an overcurrent relay protection and coordination in a power system network using PSCAD software," IJEEAS, vol. 4, no. 1, 2021.

[6] M. H. Hairi, A. S. Mansor, A. S. M. Isira, and M. N. Kamarudin, "Investigation of overcurrent relay tripping time protection using PSCAD software," IJEEAS, vol. 6, no. 1, 2023.

[7] M. H. Hairi, M. N. Kamarudin, L. Q. Fang, A. S. M. Isira, and M. Fauzi P. Mohamed, "Dual-slope percentage bias differential relay (87) protection strategy for 11kV underground power cable," IJEEAS, vol. 3, no. 1, 2020.

[8] N. A. Fadzil et al., "A research of islanding detection method for distributed generation: mechanism, merits and demerits," Inter. J. of Innovative Tech. and Exploring Engineering, vol. 8 , 2019.

[9] S. Acharya, S. K. Jha, R. Shrestha, A. Pokhrel and B. Bohara, "An analysis of time current characteristics of adaptive inverse definite minimum time (IDMT) overcurrent relay for symmetrical and un-symmetrical faults," 2017 International Conference on Smart grids, Power and Advanced Control Engineering (ICSPACE), Bangalore, India, 2017, pp. 332-337, doi: 10.1109/ICSPACE.2017.8343453

[10] Y. G. Paithankar and S. R. Bhide, Fundamentals of Power System Protection: Phi Learning, 2022.

[11] D. K. Jain, P. Gupta and M. Singh, "Overcurrent protection of distribution network with distributed generation," in Proc. of 2015 IEEE Innovative Smart Grid Technologies - Asia (ISGT ASIA), Bangkok, Thailand, 2015, pp. 1-6, doi: 10.1109/ISGT-Asia.2015.7387143.

[12] S. V. John and M. Ebenezer, "Relay coordination in DG integrated system," 2021 Fourth International Conference on Electrical, Computer and Communication Technologies (ICECCT), Erode, India, 2021, pp. 1-5, doi: 10.1109/ICECCT52121.2021.9616874

[13] P. Mehta and V. Makwana, "Modelling of overcurrent relay with inverse characteristics for radial feeder protection using graphical user interface," 2017 International Conference on Intelligent Computing, Instrumentation and Control Technologies (ICICICT), Kerala, India, 2017, pp. 74-79, doi: 10.1109/ICICICT1.2017.8342537.

[14] R. S. Tiwari and O. Hari Gupta, "Study of Combined Time & Current Grading Protection Scheme for Distribution System," 2020 International Conference on Power Electronics & IoT Applications in Renewable Energy and its Control (PARC), Mathura, India, 2020, pp. 443-448, doi: 10.1109/PARC49193.2020.236651

[15] A. G. Phadke, "Computer relaying: its impact on improved control and operation of power systems," IEEE Computer Applications in Power, vol. 1, no. 4, pp. 5-10, 1988, doi: 10.1109/67.20545.