Modeling an Overcurrent Relay Protection and Coordination in a Power System Network Using PSCAD Software

Mohd Hendra Hairi [1*], Muhammad Nizam Kamarudin [1],
Ahmad Sadhiqin Mohd Isira[2], Mohamed Fauzi Packeer Mohamed[3], Sharizal Ahmad Sobri[4]

[1] Centre for Robotics and Industrial Automation (CeRIA), Faculty of Electrical Engineering,
[2] Fakulti Kejuruteraan Elektronik & Kejuruteraan Komputer,
Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.
[3] School of Electrical and Electronic Engineering, USM, Engineering Campus, Seberang Perai Selatan Nibong Tebal, Penang 14300 Malaysia.
[4]Faculty of Bioengineering & Technology, Universiti Malaysia Kelantan, Kelantan, Malaysia.
[*]corresponding author: hendra@utem.edu.my

Abstract – *This paper presents a study on the modeling of 132/33/11kV Hutan Melintang network, Teluk Intan, Perak radial distribution feeder. The study proposed a protection scheme by providing the appropriate relay Pickup current/Plug Setting (PS) and Time Multiplier Setting (TMS)/ time dial setting (TDS) for discrimination process. For this study, the IEEE std. C37.112 moderately inverse IDMT curve characteristic is chosen for the simulation using the Power System Computer Aided Design (PSCAD). The result shows that the calculated PS and TMS are closely matched with the simulation result and therefore confirmed that these values were trustworthy.*

Keywords: *Overcurrent protection relay, plug setting, relay operation time, PSCAD, power system protection*

Article History
Received 31 May 2018
Received in revised form 24 January 2020
Accepted 23 February 2021

I. Introduction

There are three major components in the electrical power system which is consisting of generation, transmission, and a distribution system. The transmission system uses to link the generators to substations before the supply power reach of users through the distribution system. An electrical power system aims to supply a continuous electrical energy to the consumer. As a result, the design must be reliable and economical. It should be able to deliver the energy to a consumer without any interruptions. The system should be protected from power outages and disturbance by means of protective relay [1].

A report has been found that 80% of the interruptions occurred at the consumer side due to the short circuit [2] – [4]. To make the system become reliable and robust from faults, overcurrent relay is made applicable at the distribution side. Inverse definite minimum time (IDMT) overcurrent relay is widely used as an overcurrent relay device due to its simpleness and economical. The relay operating time is closely related to current transformer (CT) ratio, plug setting (PS) and time multiplier setting (TMS) [5].

Analysis of faults had become difficult in old era due to the complex's mathematical computing. However, it has become more convenient nowadays due to numerous fast and reliable computing methods such as PSCAD MATLAB, ETAP etc. [6].

This paper presents a study on the modeling of 132/33/11kV Hutan Melintang network, Teluk Intan, Perak radial distribution feeder. The study proposed a protection scheme by providing the appropriate relaying Plug Setting Multiplier (PSM) and Time Multiplier Setting (TMS) for discrimination process. For this study, the IEEE std. C37.112 moderately inverse IDMT curve characteristic is chosen for the simulation using the Power System Computer Aided Design (PSCAD).

II. Network Model

For power flow analysis, the massive single line diagram of Tenaga Nasional Berhad (TNB) Hutan Melintang, Teluk Intan has been reduced to ease the process of modeling in PSCAD software. The model was used to investigate the operating time and the coordination of overcurrent relay when subjected to faults.

The local load Hutan Melintang is supplied with 132kV from the Bagan Datoh grid through two Hutan Melintang Pencawang Masuk Utama (PMU) transformers of 132/33kV and stepped down to 33/11kV for both feeders as shown in Fig. 1 (refer Appendix 1). The Overcurrent relays denoted as A-F were installed at the location as shown in Fig. 1. To check the correct operation and discrimination of the respective relays, various of fault were simulated at t =1 sec. Then the relay tripping time and time coordination were analyzed. There are total of eight cases were simulated. The curve for relay is chosen to be IEEE std. C37.112 moderately inverse [7] – [8].

To guarantee a reliable, fast, and safe operation of overcurrent relay, the pickup current/plug setting and TMS should be chosen carefully. Otherwise, the relay will not properly be functioning (not tripping). The pickup current/plug setting of the relays is calculated depending on their rated current. In this study the pickup current for overcurrent relay is set to 150%. The TMS/TDS for this relay can be calculated by equation (1) [9] – [10]. Table I shows the summary of pickup current and TMS for these relays.

$$t(s) = TDS\left[\frac{A}{\left(\frac{I_f}{I_s}\right)^p - 1} + B\right] \tag{1}$$

Where

t = relay operating in second
I_f = Fault current
I_s = Pick current
TDS = Time Dial Setting

TABLE I
PICKUP CURRENT AND TIME DIAL SETTING

Relay	Rated Current (kA)	Pickup Current (kA)	Time Dial Setting
A1	0.287	0.43	0.59
A2	1.149	1.72	0.44
C1	0.297	1.45	0.47
C2	0.891	1.35	0.24
C3	0.434	0.65	0.01
B1	0.882	1.28	0.30
B2	2.553	3.83	0.12
D1	0.300	0.45	0.78
D2	1.193	1.79	0.59
F1	0.778	1.17	0.48
F2	2.327	3.49	0.26
F3	0.308	0.46	0.08
E1	0.415	0.62	0.63
E2	1.243	1.86	0.41

III. Results and Discussions

The simulations are conducted with 8 different type of faults and locations. The discrimination time between relays is observed and discussed in detail in the following section.

A. *Case 1(Three*-phase-*to-ground fault)*

A three phase fault is applied near C3 relay at t =1s. Then tripping time for relays A1, A2, C1, C2 and C3 are recorded as shown in Fig. 2. It can be seen from Fig. 2 that the discrimination time between the relays is almost 0.2s. The time is then being compared with the calculation value and are summarized in Table II.

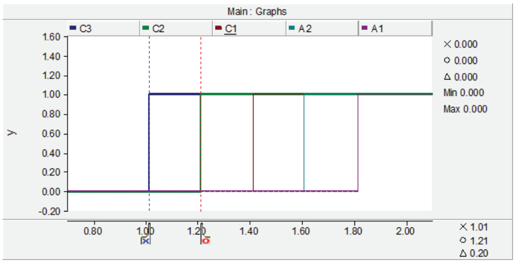

Fig. 2. PSCAD simulation result

TABLE II
COMPARISON BETWEEN SIMULATION TIME AND CALCULATION TIME

Relay	Calculation tripping time, t(s)	Timed fault logic (TFL)+t(s)	Relay tripping time Simulation (s)
A1	0.82	1.82	1.81
A2	0.61	1.61	1.61
C1	0.41	1.41	1.41
C2	0.21	1.21	1.21
C3	0.01	1.01	1.01

It can be seen from Table II, the calculated time (timed fault logic (TFL) + t(s)) and simulation tripping time are closely matched, which indicated that the all the setting for respective relays is performing well for a three phase fault event.

B. *Case 2 (Two-phase-to-ground fault)*

The simulation has been repeated for a two-phase-to-ground fault as shown in Fig. 2. The relays tripping time from PSCAD is recorded as shown in Fig. 3. Similarly, the time is then being compared with calculation value. Table III shows the summary of the comparison time between simulation and calculated value.

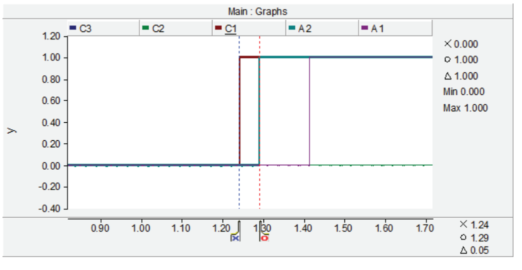

Fig. 3. PSCAD simulation result

TABLE III
COMPARISON BETWEEN SIMULATION TIME AND CALCULATION TIME

Relay	Calculation tripping time, t(s)	Timed fault logic (TFL)+t(s)	Relay tripping time Simulation (s)
A1	0.41	1.41	1.41
A2	0.29	1.29	1.29
C1	0.24	1.24	1.24

It can be seen in Table III that the calculated (timed fault logic (TFL) + t(s)) and simulation tripping time are closely matched, which indicates that the relay PS and TMS setting are well chosen for a double phase fault to ground event. The discrimination time between relay C1 and A2 is 0.05s; while between relay A2 and A1 is 0.13s.

C. *Case 3 (Two-phase-line-to-line fault)*

Two-phase-line to line fault is simulated and the result is shown in Table IV.

TABLE IV
COMPARISON BETWEEN SIMULATION TIME AND CALCULATION TIME

Relay	Calculation tripping time, t(s)	Timed fault logic (TFL)+t(s)	Relay tripping time Simulation (s)
A1	0.44	1.44	1.44
A2	0.32	1.32	1.32
B1	0.20	1.20	1.21
B2	0.08	1.08	1.09

It can be seen from Table IV that the calculated (timed fault logic (TFL) + t(s)) and simulation tripping time are again closely matched, which indicates that the correct relay setting, and discrimination is performing well for double phase faults. The discrimination time between relay B1 and A2 is 0.11s.

D. *Case 4 (Single-phase-to-ground fault)*

Single-phase-to-ground is simulated, and the result is shown in Table V.

TABLE V
COMPARISON BETWEEN SIMULATION TIME AND CALCULATION TIME

Relay	Calculation tripping time, t(s)	Timed fault logic (TFL)+t(s)	Relay tripping time Simulation (s)
A1	0.44	1.41	1.41
A2	0.32	1.29	1.29

It can be seen in Table V that the calculated (timed fault logic (TFL) + t(s)) and simulation tripping time are closely matched. The relay operating time and discrimination process are performing well for a single phase faults condition. The discrimination time between relay A1 and A2 is 0.12s.

E. *Case 5 (Single-phase-to-ground fault)*

Single-phase-to-ground is simulated, and the result is shown in Table VI.

TABLE VI
COMPARISON BETWEEN SIMULATION TIME AND CALCULATION TIME

Relay	Calculation tripping time, t(s)	Timed fault logic (TFL)+t(s)	Relay tripping time Simulation (s)
D1	0.83	1.86	1.86
D2	0.65	1.65	1.65
F1	0.46	1.46	1.45
F2	0.25	1.25	1.25
F3	0.05	1.05	1.05

It can be seen in Table VI that the calculated (timed fault logic (TFL) + t(s)) and simulation tripping time are closely matched, for a single-phase-to-ground fault. The average discrimination time between each relay is 0.2s.

F. *Case 6 (Two-phase-to-ground fault)*

Two-phase-to-ground fault is simulated, and the result is shown in Table VII.

TABLE VII
COMPARISON BETWEEN SIMULATION TIME AND CALCULATION TIME

Relay	Calculation tripping time, t(s)	Timed fault logic (TFL)+t(s)	Relay tripping time Simulation (s)
D1	0.57	1.57	1.57
D2	0.39	1.39	1.39
F1	0.29	1.29	1.29

It can be seen in Table VII that the calculated (timed fault logic (TFL) + t(s)) and simulation tripping time are closely matched. Again, the relay setting, and discrimination time are functioning well for two-phase-to-ground fault. The discrimination time between each relay range from 0.1 and 0.2s.

G. *Case 7 (Two-phase-line-to-line fault)*

Two-phase-line-to-line fault is simulated, and the result is shown in Table VIII.

TABLE VIII
COMPARISON BETWEEN SIMULATION TIME AND CALCULATION TIME

Relay	Calculation tripping time, t(s)	Timed fault logic (TFL)+t(s)	Relay tripping time Simulation (s)
D1	0.52	1.52	1.52
D2	0.40	1.40	1.40

It can be seen in Table VIII that the calculated (timed fault logic (TFL) + t(s)) and simulation tripping time are closely matched, which imply that the relay setting, and discrimination process are consistent for a two-phase-line-to-line fault event. The discrimination time between relay D1 and D2 is 0.12s.

H. Case 8 (Two-phase-to-ground fault)

Finally, a two-phase-to-ground fault is simulated, and the result is shown in Table IX.

TABLE IX
COMPARISON BETWEEN SIMULATION TIME AND CALCULATION TIME

Relay	Calculation tripping time, t(s)	Timed fault logic (TFL)+t(s)	Relay tripping time Simulation (s)
D1	1.03	2.03	2.01
D2	0.77	1.77	1.76
E1	0.57	1.57	1.56
E2	0.37	1.37	1.36

It can be seen in Table IX that the calculated (timed fault logic (TFL) + t(s)) and simulation tripping time are closely matched, which signify that the relay plug setting and TMS are appropriately chosen for a two-phase-to-ground fault event. The discrimination time between relay B1 and A2 is 0.11s.

IV. Conclusion

The purposed of overcurrent relay plug setting and time multiplier setting are to minimize the damage and isolate the faulty as soon as possible. The discrimination time margin/coordination time between each overcurrent relay is 0.3s and 0.4s for electromechanical relays; and from 0.1s to 0.2s for microprocessor-based relays. As the relay at Hutan Melintang network is in the form of electromechanical type, it was found that the discrimination time is in the range of 0.3-0.4s which is acceptable. As a result, the proposed TMS and PS 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) for providing the research platforms and facilities.

References

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

[2] Mohd Hendra Hairi, Farhan Hanaffi, Azhan b. Rahman, Muhammad Nizam Kamarudin, Ahmad Sadhiqin Mohd Isira., "Design and Modelling of Single-Phase Grid-connected Photovoltaic at Low Voltage Network using PSCAD Software," *International Journal of Electrical Engineering and Applied Sciences (IJEEAS), 2019*.

[3] M. H. Hairi, at.el, "Impact of a Single-Phase Grid-Connected Photovoltaic at Low Voltage Network Using PSCAD Software," *International Journal of Electrical Engineering and Applied Sciences (IJEEAS), 2018*

[4] Y. G. Paithankar and S. R. Bhide, Fundamentals of Power System Protection: PHI Learning, 2010.

[5] J. Lewis Blackburn, "Protective Relaying Principles and Applications" Third Edition, 2006,

[6] A. Yazdani, Modern Distribution Systems with PSCAD Analysis: Taylor & Francis, 2018.

[7] A. T. Johns, S. K. Salman, and I. o. E. Engineers, Digital Protection for Power Systems: P. Peregrinus, 1995.

[8] W. A. Elmore, Protective Relaying: Theory and Applications: Taylor & Francis, 2003.

[9] N. Tleis, Power Systems Modelling and Fault Analysis: Theory and Practice: Elsevier Science, 2007.

[10] John S. Levine, P.E, "The Art and Science of Protective Relays and Tools to Assist Designers and Users, 20

Appendix 1

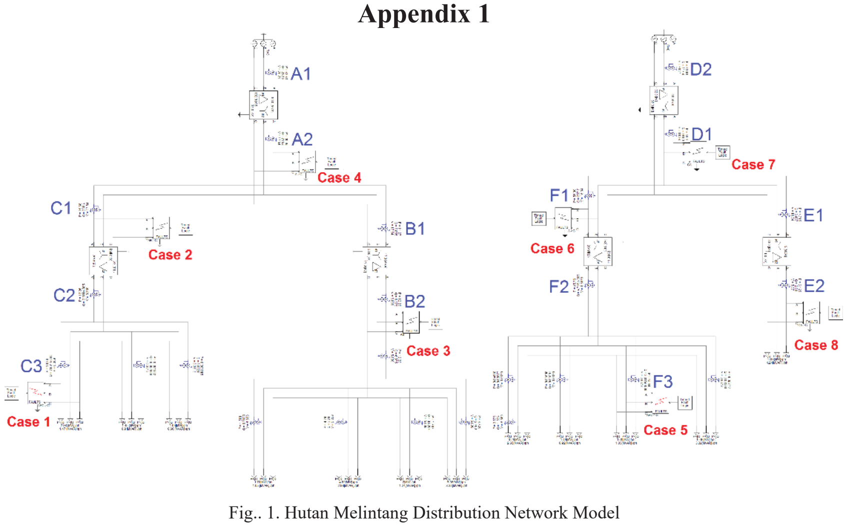

Fig.. 1. Hutan Melintang Distribution Network Model