Modelling Overcurrent Protection Relay Using PSCAD at Pencawang Masuk Utama Jasin

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Abstract – *This paper focuses on modelling 132/11kV Pencawang Masuk Utama (PMU) Jasin, Melaka for assessing the Inverse Definite Minimum Time (IDMT) overcurrent relay in terms of relay response time using PSCAD software. The relay is subjected to various fault conditions such as three phase fault, double phase, and single-phase fault at different point of the network to observe the operating time. To ensure the reliability of the overcurrent relay, the response time has been analysed. The response time were then being verified accordingly and the result shows that relay response time were successfully simulated.*

Keywords: *Overcurrent Relay, Pencawang Masuk Utama, Pickup Current, PSCAD, Time Multiplier Setting*

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I. Introduction

Modelling overcurrent protection usually uses PSCAD due to high voltage and to confirm the stability and dependability of the electrical grid. Protecting from electrical faults is important in power systems because the generators, transformers, transmission lines and burden possess a very high current. When electrical current has abnormal characteristics such as short circuits, the relay will detect the fault current and trip the circuit breaker to prevent damage to the equipment. Electrical engineers usually use PSCAD to design and analyze the circuit power flow current which is the safest way to simulate the fault [1] – [3].

PSCAD is used to analyze the network by simulating fault conditions, such as overloads and short circuits, to mimic the protective systems function as close to the actual used. From the simulation data, the relay can be resetting to improve overall system coordination, hence making sure the protection system is in optimal condition. Moreover this approach contributes significantly to the safety and reliability of electrical grids, preventing damage, maintaining power supply, and improving the overall system durability [4] – [6].

Basically, modelling overcurrent protection in PSCAD plays an important role in power system design and analysis. It enables engineers to survey the performance of protection devices within a controlled, simulated environment, and make sure the response works effectively due to fault current.

The purpose of the paper is to verify the two main settings of relay, mainly known as Plug Setting Multiplier (PSM) and Time Multiplier Setting (TMS) at Pencawang Masuk Utama Jasin power lines. Next the calculated PSM and TMS will be compared by the simulation to meet the requirements for selectivity and sensitivity of the overcurrent relay.

II. Methodology

The Pencawang Masuk Utama (PMU) Jasin is used in the simulation. The system voltage is 132kV and connected to an 11kV network via stepdown transformer to Stesen Suis Utama (SSU) *XINYI*, Pencawang pengagihan Utama (PPU) Selandar and PPU Jasin Bestari as shown in Fig. 1. Then from 11kv it was further stepdown to low voltage network (400V, 230V) for consumer usage.

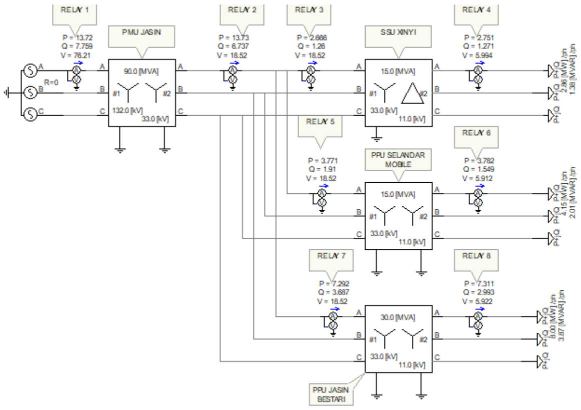

Fig. 1. PMU Jasin network

For the effective overcurrent relay operation in protecting the power system, the plug setting and the time response among different relay is crucial. Therefore, calculation for pick up current and Time Multiplier Setting (TMS) has been done manually. The plug-setting multiplier, PSM, is defined as follows [7] – [10]:

$$PSM=I_{relay}/PS \qquad (1)$$

where, I_{relay} is the current through the relay operating coil and PS is the plug-setting of the relay. Also, the operating time of the relay can be calculated as follows [7] – [10]:

$$T_{op}=0.14*(TMS)/(PSM^{0.02}-1) \qquad (2)$$

where, PSM is the plug-setting multiplier and TMS is the time-multiplier setting of the relay. Table I summarizes the TMS and Plug setting for the respective relay. After mathematical computation, the PSCAD software is utilized to simulate the relay operation. Typical faults such as three-phase to ground fault, double line, double to ground are simulated to observe the relay operating time

TABLE I
SETTING OF OVERCURRENT RELAY

Relay	TMS	Pickup Current	CT Rating	Plug Setting
R1	0.3732	250 A	250/1A	100 %
R2	0.2708	1000 A	1000/1A	100%
R3	0.293	200 A	200/1A	100%
R4	0.1206	562.5 A	750/1A	75%
R5	0.2428	300 A	300/1A	100%
R6	0.1031	800 A	800/1A	100%
R7	0.2497	500 A	500/1A	100%
R8	0.1	1500 A	1000/1A	150%

III. Results and Discussions

The simulations come with 5 different types of faults at 4 different locations (PMU Jasin, PPU Jasin Bestari, SSU XinYi, PPU Selandar Mobile). The discrimination time between relays is observed and discussed in every case.

A. Case 1 (PPU Jasin Bestari)

I. LLLG Fault

A three-phase bolted fault is applied at the PPU Jasin Bestari and tripping time at each Relay has been observed. Table II shows the relay operating time.

TABLE II
RELAY OPERATION TIME AND DISCRIMINATION
FAULT LLLG AT JASIN BESTARI (FAULT AT 0.5S)

RELAY	FAULT CURRENT	TRIPPING TIME	DISCRIMINATION TIME
R1	1,018.29 A	2.3058s	0.5002s
R2	4,059.47 A	1.8056s	0.4918s
R3	121.11 A	NO TRIPPING	.
R4	361.14 A	NO TRIPPING	.
R5	173.07 A	NO TRIPPING	.
R6	516.49 A	NO TRIPPING	.
R7	389.63 A	1.3138s	0.499s
R8	11,683.32 A	0.8148s	.

Based on Table II, it can be seen that Relay 8, Relay 7, Relay 2, and Relay 1 will trip in respectively. The simulation of operation times is followed the discrimination time range.

II. LLL Fault

A three-phase fault is applied at the PPU Jasin Bestari and tripping time at each Relay has been observed. Table III shows the relay operating time.

TABLE III
OPERATION TIME AND DISCRIMINATION
FAULT LLL AT JASIN BESTARI (FAULT AT 0.5S)

RELAY	FAULT CURRENT	TRIPPING TIME	DISCRIMINATION TIME
R1	1,017.52 A	2.2368s	0.5003s
R2	4,056.41 A	1.7365s	0.4707s
R3	121.11 A	NO TRIPPING	.
R4	361.15 A	NO TRIPPING	.
R5	173.07 A	NO TRIPPING	.
R6	516.46 A	NO TRIPPING	.
R7	3897.32 A	1.2658s	0.4745s
R8	11,686.11	0.7913s	.

Based on Table III, it can be seen that Relay 8, Relay 7, Relay 2, and Relay 1 will trip in respectively. The simulation of operation times is followed the discrimination time range.

III. LLG Fault

A line-line to ground fault is applied at the PPU Jasin Bestari and tripping time at each Relay has been observed. Table IV shows the relay operating time.

TABLE IV
OPERATION TIME AND DISCRIMINATION
FAULT LLG AT JASIN BESTARI (FAULT AT 0.5S)

RELAY	FAULT CURRENT	TRIPPING TIME	DISCRIMINATION TIME
R1	1,020.60 A	2.303s	0.4997s
R2	4,068.72 A	1.8035s	0.4893s
R3	126.82 A	NO TRIPPING	.
R4	415.38 A	NO TRIPPING	.
R5	172.93 A	NO TRIPPING	.
R6	516.08 A	NO TRIPPING	.
R7	3,893.38 A	1.3142s	0.499s
R8	11,674.30 A	0.8148s	.

Based on the data from Table IV, it can be seen that the Relay 8, Relay 7, Relay 2, and Relay 1 will trip in sequence. The operation and discrimination time is in proper coordination between the relays.

IV. LL Fault

A line-line fault is applied at the PPU Jasin Bestari and tripping time at each Relay has been observed. Table V shows the relay operating time.

TABLE V
OPERATION TIME AND DISCRIMINATION
FAULT LL AT JASIN BESTARI (FAULT AT 0.5S)

RELAY	FAULT CURRENT	TRIPPING TIME	DISCRIMINATION TIME
R1	966.06 A	2.356s	0.5205s
R2	3.852.44 A	1.8355s	0.5027s
R3	129.82 A	NO TRIPPING	.
R4	442.95 A	NO TRIPPING	.
R5	185.52 A	NO TRIPPING	.
R6	553.64 A	NO TRIPPING	.
R7	3,560.50 A	1.3328s	0.5155s
R8	10,676.64 A	0.8173s	.

Table V indicates that Relay 8 will trip first, followed by Relay 7, Relay 2, and finally Relay 1. The simulation shows that their operation times fall within the discrimination time range, ensuring that each relay trips in the correct order without overlapping.

B. Case 2 (SSU XinYi)

I. LLLG Fault

A line-line fault is applied at the SSU XinYi and tripping time at each Relay has been observed. Table VI shows the relay operating time.

TABLE VI
OPERATION TIME AND DISCRIMINATION
FAULT LLLG AT XINYI (FAULT AT 0.5S)

RELAY	FAULT CURRENT	TRIPPING TIME	DISCRIMINATION TIME
R1	641.85 A	3.1716s	0.7426s
R2	2,553.17 A	2.429s	1.1307s
R3	2,205.35 A	1.2983s	0.4815s
R4	6,612.64 A	0.8168s	.
R5	195.87 A	NO TRIPPING	.
R6	584.52 A	NO TRIPPING	.
R7	378.18 A	NO TRIPPING	.
R8	1,128.40 A	NO TRIPPING	.

Based on Table VI, it is obvious that Relay 4, Relay 3, Relay 2, and Relay 1 will trip in order. If we compare the values in Case 1 and Case 2, there is a big difference in the fault currents for Relay 1 and Relay 2 because the load at Case 2 is lower than in Case 1. Consequently, this will result in longer relay operating time.

II. LLL Fault

A three phase fault is applied at the SSU XinYi and tripping time at each Relay has been observed. Table VII shows the relay operating time.

TABLE VII
OPERATION TIME AND DISCRIMINATION
FAULT LLL AT XINYI (FAULT AT 0.5S)

RELAY	FAULT CURRENT	TRIPPING TIME	DISCRIMINATION TIME
R1	641.05 A	3.016s	0.7415s
R2	2,549.95 A	2.2745s	1.0307s
R3	2,205.62 A	1.2438s	0.4403s
R4	6,613.27 A	0.8035s	.
R5	195.87 A	NO TRIPPING	.
R6	584.53 A	NO TRIPPING	.
R7	378.20 A	NO TRIPPING	.
R8	1,128.42 A	NO TRIPPING	.

Based on Table VII, it's evident that Relay 4, Relay 3, Relay 2, and Relay 1 will trip in respectively. The simulation of operation times does not follow the discrimination time range, it is because Relay 2 and Relay 1 being set in Case 1, which represents the worst-case fault scenario. However, the relays are still tripping as expected in these cases.

III. LLG Fault

A line-line-groud fault is applied at the SSU XinYi and tripping time at each Relay has been observed. Table VIII shows the relay operating time.

TABLE VIII
OPERATION TIME AND DISCRIMINATION
FAULT LLG AT XINYI (FAULT AT 0.5S)

RELAY	FAULT CURRENT	TRIPPING TIME	DISCRIMINATION TIME
R1	641.83 A	3.1715s	0.7425s
R2	2,553.11 A	2.429s	1.1307s
R3	2,205.33 A	1.2983s	0.496s
R4	6,024.18 A	0.8203s	.
R5	195.86 A	NO TRIPPING	.
R6	584.51 A	NO TRIPPING	.
R7	378.17 A	NO TRIPPING	.
R8	1,128.37 A	NO TRIPPING	.

Based on Table VIII, it's evident that Relay 4, Relay 3, Relay 2, and Relay 1 will trip in respectively. The simulation of operation times does not follow the discrimination time range (0.5s), which represents the worst-case fault scenario. However, the relays are still tripping as expected in these cases.

IV. LL Fault

A line-line fault is applied at the SSU XinYi and tripping time at each Relay has been observed. Table IX shows the relay operating time.

TABLE IX
OPERATION TIME AND DISCRIMINATION
FAULT LL AT XINYI (FAULT AT 0.5S)

RELAY	FAULT CURRENT	TRIPPING TIME	DISCRIMINATION TIME
R1	641.23 A	3.0945s	0.7426s
R2	2,550.66 A	2.351s	1.0865s
R3	2,205.49 A	1.2645s	0.4555s
R4	5,932.74 A	0.809s	.
R5	195.86 A	NO TRIPPING	.
R6	584.51 A	NO TRIPPING	.
R7	378.18 A	NO TRIPPING	.
R8	1,128.38 A	NO TRIPPING	.

Based on Table IX, it's evident that Relay 4, Relay 3, Relay 2, and Relay 1 will trip in order. The simulation of operation times does not follow the discrimination time range.

V. LG Fault

For a line to ground fault the result is shown in Table X.

TABLE X
OPERATION TIME AND DISCRIMINATION
FAULT LG AT XINYI (FAULT AT 0.5S)

RELAY	FAULT CURRENT	TRIPPING TIME	DISCRIMINATION TIME
R1	256.37 A	NO TRIPPING	.
R2	1,015.39 A	NO TRIPPING	.
R3	379.93 A	3.5775s	2.1265s
R4	1,313.11 A	1.451s	.
R5	223.21 A	NO TRIPPING	.
R6	666.12 A	NO TRIPPING	.
R7	430.98 A	NO TRIPPING	.
R8	1,285.93 A	NO TRIPPING	.

Based on Table X, it's obvious that Relay 4 and Relay 3 will trip in order, but Relay 2 and Relay 1 will not trip due to the fault current is below relay pickup current. Also discrimination time range is out due to Relay 2 and Relay setting.

C. Case 3 (PPU Selandar Mobile)

I. LLLG Fault

For a LLLG fault at PPU Selandar Mobile, the results are shown in Table XI.

TABLE XI
OPERATION TIME AND DISCRIMINATION
FAULT LLLG AT SELANDAR MOBILE (FAULT AT 0.5S)

RELAY	FAULT CURRENT	TRIPPING TIME	DISCRIMINATION TIME
R1	632.80 A	3.2142s	0.7534s
R2	2,516.92 A	2.4608s	1.168s
R3	137.36 A	NO TRIPPING	.
R4	409.48 A	NO TRIPPING	.
R5	2,210.14 A	1.2928s	0.4905s
R6	6,627.11 A	0.8023s	.
R7	379.01 A	NO TRIPPING	.
R8	1,130.85 A	NO TRIPPING	.

Based on Table XI, it is clear that Relay 6, Relay 5, Relay 2, and Relay 1 will trip in sequence. Also, discrimination time range is out.

II. LLL Fault

For a LLLG fault at PPU Selandar Mobile, the results are shown in Table XII.

TABLE XII
OPERATION TIME AND DISCRIMINATION
FAULT LLL AT SELANDAR MOBILE (Fault At 0.5s)

Relay	Fault Current	Tripping Time	Discrimination Time
R1	632.06 A	3.0583s	0.7526s
R2	2,513.94 A	2.305s	1.0752s
R3	137.36 A	NO TRIPPING	.
R4	409.51 A	NO TRIPPING	.
R5	2,210.37 A	1.2305s	0.4458s
R6	6,627.78 A	0.7847s	.
R7	379.02 A	NO TRIPPING	.
R8	1,1308.80 A	NO TRIPPING	.

Based on Table XII, it is apparent that Relay 6, Relay 5, Relay 2, and Relay 1 will trip in order. Also, the time range of discrimination is out.

III. LLG Fault

For an LLG fault at PPU Selandar Mobile, the results are shown in Table XIII.

TABLE XIII
OPERATION TIME AND DISCRIMINATION
FAULT LLG AT SELANDAR MOBILE (FAULT AT 0.5S)

RELAY	FAULT CURRENT	TRIPPING TIME	DISCRIMINATION TIME
R1	634.24 A	3.2078s	0.7515s
R2	2,522.66 A	2.4563s	1.1636s
R3	140.35 A	NO TRIPPING	.
R4	439.46 A	NO TRIPPING	.
R5	2,209.19 A	1.2927s	0.4902s
R6	6,624.26 A	0.8025s	.
R7	378.83 A	NO TRIPPING	.
R8	1,130.34 A	NO TRIPPING	.

Based on Table XIII, it is apparent that Relay 6, Relay 5, Relay 2, and Relay 1 will trip in order. Also, discrimination time range is out.

IV. LL Fault

For an LLG fault at PPU Selandar Mobile, the results are shown in Table XIV.

Based on Table XIV, it is apparent that Relay 6, Relay 5, Relay 2, and Relay 1 will trip in order. Also, discrimination time range is out.

TABLE XIV
OPERATION TIME AND DISCRIMINATION
FAULT LL AT SELANDAR MOBILE (FAULT AT 0.5S)

RELAY	FAULT CURRENT	TRIPPING TIME	DISCRIMINATION TIME
R1	627.59 A	3.2032s	0.7622s
R2	2,498.32 A	2.441s	1.137s
R3	141.89 A	NO TRIPPING	.
R4	454.60 A	NO TRIPPING	.
R5	2,010.91 A	1.304s	0.496s
R6	6,029.98 A	0.808s	.
R7	391.53 A	NO TRIPPING	.
R8	1,168.21 A	NO TRIPPING	.

V. LG Fault

For a LG fault at PPU Selandar Mobile, the results are shown in Table XV.

TABLE XV
OPERATION TIME AND DISCRIMINATION
FAULT LG AT SELANDAR MOBILE (FAULT AT 0.5S)

RELAY	FAULT CURRENT	TRIPPING TIME	DISCRIMINATION TIME
R1	633.92 A	3.2093s	0.7522s
R2	2,521.38 A	2.4571s	1.1643s
R3	144.41 A	NO TRIPPING	.
R4	439.43 A	NO TRIPPING	.
R5	2,209.53 A	1.2928s	0.4903s
R6	6,625.28 A	0.8025s	.
R7	378.89 A	NO TRIPPING	.
R8	1,130.52 A	NO TRIPPING	.

Based on Table XV, it is apparent that Relay 6, Relay 5, Relay 2, and Relay 1 will trip in order. Also, discrimination time range is out

D. Case 4 (PMU Jasin)

For all faults at PMU Jasin, the results are shown in Table XVI, XVII, XVIII, XIX and XX respectively

TABLE XVI
OPERATION TIME AND DISCRIMINATION
FAULT LLLG AT PMU JASIN (FAULT AT 0.5S)

RELAY	FAULT CURRENT	TRIPPING TIME	DISCRIMINATION TIME
R1	3,937.16 A	1.3793s	0.251s
R2	15,740.75 A	1.1283s	.
R3	1.35 A	NO TRIPPING	.
R4	19.08 A	NO TRIPPING	.
R5	1.93 A	NO TRIPPING	.
R6	5.79 A	NO TRIPPING	.
R7	3.72 A	NO TRIPPING	.
R8	11.10 A	NO TRIPPING	.

TABLE XVII
OPERATION TIME AND DISCRIMINATION
FAULT LLL AT PMU JASIN (FAULT AT 0.5S)

RELAY	FAULT CURRENT	TRIPPING TIME	DISCRIMINATION TIME
R1	3939.21 A	1.3242s	0.2334s
R2	15,749 A	1.0908s	.
R3	2.54 A	NO TRIPPING	.
R4	13.46 A	NO TRIPPING	.
R5	2.67 A	NO TRIPPING	.
R6	7.81 A	NO TRIPPING	.
R7	8.89 A	NO TRIPPING	.
R8	26.27 A	NO TRIPPING	.

TABLE XVIII
OPERATION TIME AND DISCRIMINATION
FAULT LLG AT PMU JASIN (FAULT AT 0.5S)

RELAY	FAULT CURRENT	TRIPPING TIME	DISCRIMINATION TIME
R1	3,937.46 A	1.3793s	0.2513s
R2	15,741.83 A	1.128s	.
R3	54.38 A	NO TRIPPING	.
R4	277.14 A	NO TRIPPING	.
R5	2 A	NO TRIPPING	.
R6	5.97 A	NO TRIPPING	.
R7	150.04 A	NO TRIPPING	.
R8	447.67 A	NO TRIPPING	.

TABLE X1X
OPERATION TIME AND DISCRIMINATION
FAULT LL AT PMU JASIN (FAULT AT 0.5S)

RELAY	FAULT CURRENT	TRIPPING TIME	DISCRIMINATION TIME
R1	3,496.33 A	1.3963s	0.2558s
R2	13,978.57 A	1.1405s	.
R3	79.85 A	NO TRIPPING	.
R4	410.22 A	NO TRIPPING	.
R5	114.11 A	NO TRIPPING	.
R6	340.52 A	NO TRIPPING	.
R7	220.32 A	NO TRIPPING	.
R8	657.38 A	NO TRIPPING	.

TABLE XX
OPERATION TIME AND DISCRIMINATION
FAULT LG AT PMU JASIN (FAULT AT 0.5S)

RELAY	FAULT CURRENT	TRIPPING TIME	DISCRIMINATION TIME
R1	3,937.51 A	1.3793s	0.251s
R2	15,742.18 A	1.1283s	.
R3	53.58 A	NO TRIPPING	.
R4	273.60 A	NO TRIPPING	.
R5	1.91 A	NO TRIPPING	.
R6	5.71 A	NO TRIPPING	.
R7	147.85 A	NO TRIPPING	.
R8	441.13 A	NO TRIPPING	.

In all cases it is clear that Relay 2, and Relay 1 will trip accordingly. Moreover, the discrimination time is out of range due to Relay 2 and Relay 1 setting. However, the relays are still tripping as expected in these cases.

IV. Conclusion

To sum up, the simulation proves that relay Time Multiplier Setting (TMS) and pickup current setting were tested under various fault conditions in PSCAD simulation trip successfully. Although the discrimination time is slightly out of range, the respective relay still trip for different fault scenarios such as line-to-ground (LG), line-to-line (LL), double line-to-ground (LLG), three-phase (LLL), and three-phase line-to-ground (LLLG) faults for various locations. The results confirmed that the relay operates reliably, providing effective protection and maintaining system stability.

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Conflict of interest

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

Author Contributions

M. H. Hairi: Data collection, analysis, writing – original draft preparation.
A. S. Mohd Isira: Supervision, draft review and editing, investigation.
M. N. Kamarudin: Conceptualization, review.
M. F. Packeer Mohamed: Supervision, editing
S. A. Sobri- proofreading

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