Analysis of Delay Timing and Pick-Up Current Determination on Overcurrent Relay Based on MATLAB Simulation

Jerry Sihite, Siti Anisah, Pristisal Wibowo

Abstract

Overcurrent relay (OCR) is one of the important protection systems in the electricity distribution network, which functions to detect excess current and cut off the electricity flow to prevent equipment damage and reduce the area of disturbance. Determining the parameters of pick-up current and delay time is very crucial so that the protection coordination between the circuit breaker and the recloser can work selectively. In this study, an analysis of determining the OCR setting on the SN.03 ULP Medan Denai Feeder was carried out using MATLAB simulation. The data used includes the peak load of the feeder of 215 A at night, as well as the initial settings of the Micom P142 and Schneider relays with CT ratios of 800/5 and 1000/1, respectively. Simulations were carried out to re-evaluate the pick-up current and delay time settings based on the characteristics of the load and optimal protection coordination. The simulation results show that resetting the pick-up current and delay time provides more responsive and selective protection performance in dealing with overcurrent disturbances.

Keywords: Overcurrent Relay, Pick-Up Current, Time Delay, MATLAB, Protection Coordination, Feeder SN.03

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Introduction

The electric power distribution system plays an important role in ensuring the continuity and reliability of electricity supply to consumers. One of the main challenges in distribution systems is the handling of overcurrent faults that can cause equipment damage and widespread blackouts if not handled quickly and appropriately [1]. For this reason, protection systems such as Overcurrent Relay (OCR) are used to detect and break the current of interference automatically [2].

Overcurrent relays work on the principle of detecting current that exceeds a certain threshold (pickup current) and cutting off the power after a certain time delay. The determination of the appropriate pickup current value and delay time is essential to ensure the selectivity and reliability of the protection system, especially in a 20 kV distribution network such as in the SN.03 ULP Medan Denai Feeder. Coordination between the main relay and the recloser must be taken into account so that local interference can be handled without breaking the entire system.

This study aims to re-analyze the OCR settings on the feeder using MATLAB software. Through simulation, an evaluation of the existing setting is carried out and a proposal for readjustment to obtain the optimal setting. The data used includes the peak load of the feeder, relay specifications, CT ratio, and network characteristics based on a single line diagram. It is hoped that the results of this study can provide technical reference in determining appropriate and efficient OCR settings.

Literature Review

This section outlines the relevant theories underlying the research topic and provides a review of some of the relevant previous research and provides a reference and foundation for this research to be conducted. If there is a hypothesis, it can be stated as unexplicit and does not have to be in the question sentence.

2.1 Overcurrent Relay (OCR)

Overcurrent relays are protection equipment that works based on the magnitude of the current. OCR will respond when the flowing current exceeds the predetermined pickup value (Barker, 2021). The main components of OCR include pickup current setting and time delay setting. These two parameters need to be adjusted so that the relay works selectively, i.e. only cutting off the disturbed part of the network [3]. Overcurrent relays work on the principle that if the current flowing exceeds a certain limit (pickup), the relay will cut off the power after a certain time delay. OCR generally has two working elements, Inverse Time works based on the time curve to the magnitude of the current, Instantaneous works directly if the current reaches a very high limit.

2.2 Pickup Current

The pickup current is the minimum current that causes the relay to start working. The pickup value is determined based on the maximum load current and must be above the load current so that there is no maloperation [4]. This value is usually calculated as a multiple of the secondary nominal current CT. The pickup current is the minimum current threshold that makes

the relay start responding to the interference. This value is usually expressed as a percent of the nominal flow of secondary CT. The formula for determining the pickup current is:

$$I_{pickup} = Multiplikasi\ Setting \times I_{CT\ sekunder} \quad (1)$$

If CT with ratios is used:

$$\frac{CT_{primer}}{CT_{sekunder}} \quad (2)$$

So, the primary current is equivalent to:

$$I_{pickup,primer} = I_{pickup,sekunder} \times \frac{CT_{primer}}{CT_{sekunder}} \quad (3)$$

2.3 Time Delay *(TMS)*

Delay time is the time lag between the detection of excess current and the relay sending a trip signal (IEC, 2020). Delay timing serves to coordinate between primary and backup protection so that interference can be isolated as early as possible without cutting off the supply to the entire feeder.

2.4 Protection Coordination

Protection coordination is an important process in an electrical power protection system that aims to ensure that the protection device works selectively, quickly, and reliably in overcoming interference (NEMA, 2021; ERS, 2021). Protection coordination ensures that protective equipment works in sequence according to the hierarchy, starting from the closest to the interference. The main relay must work faster than backup protection such as PMT or upstream recloser. The main goal of protection coordination is to minimize the area affected by the interference and prevent the overall disconnection of the system, by regulating the working characteristics of the relay so that only the relay closest to the fault location will work first.

2.5 Matlab Simulation

MATLAB is a numerical computing software used for the analysis of power systems, including calculations and simulations of protection relay settings. Through MATLAB, the fault current characteristics, curve coordination, and operation time of the relay can be analyzed accurately. Through MATLAB simulations, the relay's work-time characteristics were tested based on the measured fault current value [5]. The results of this simulation are then used to determine the appropriate coordination settings, so that the relay operation time is within a safe coordination range and in accordance with protection standards (such as IEEE C37.112 or IEC 60255). This coordination also considers inverse time characteristics, which is the greater the interference current, the faster the relay works.

Research Methodology

The method includes a detailed description of the methods, instruments, and research analysis techniques used in solving problems. If it is *the result of a* literature review, then the order after the introduction is *a problem-solving analysis*. Problem Solving Analysis includes an objective description of problem solving. The distance between the subheading and the preceding text is one space. [Times New Roman – 12 pt].

This section contains the research design including the research design, population/research sample, data collection techniques and instruments, data analysis tools, and research models used. The common methods do not need to be written down in detail, but simply refer to reference references (e.g.: F-test formula, t-test, etc.). Testing the validity and reliability of research instruments does not need to be written in detail, but it is enough to reveal the results of the test and its interpretation. The description of the symbol on the model is written in a sentence [6].

3.1 Research Flow Diagram

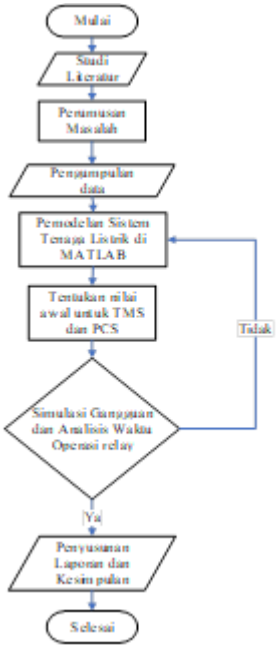

Figure 1. Research Flow Diagram

3.2 Type and Scope of Research

This research is included in the type of applied research with a quantitative approach, which aims to analyze and evaluate the regulation of the overcurrent relay (OCR) protection system in the electric power distribution system using MATLAB software simulation. The scope of this study includes:

Study on the 20 kV distribution network at the SN.03 Feeder which is under the work area of ULP Medan Denai.

Evaluate the existing settings of the OCR and recloser, in particular the parameters of the pickup flow and delay time.

Simulation of protection coordination using a time-current characteristic (TCC) curve.

The determination of new settings is based on the results of calculations and simulations in order to obtain optimal and selective protection coordination.

Data Collection Techniques

Data Analysis Methods

Load and nominal current analysis was calculated on the total feeder load and nominal current flowing based on transformer capacity and peak load data (215 A at night). This current is used as the basis for determining the lower limit of the relay pickup current. The initial calculation of the pickup current and TMS is based on the nominal current and CT ratio used (e.g. 800/5 and 1000/1), the initial calculation of the current and time multiplier setting (TMS) is carried out using the IEC standard formula for IDMT relays.

The calculated data is used as input in the MATLAB software to model the time-current characteristic curve (TCC). This simulation generates a relay work curve against various fault current values, including instant and inverse responses. The curve of the simulation results is compared between the OCR relay and the recloser. The evaluation is carried out by looking at whether the OCR working time is above the recloser and whether there is enough lag time (marginal time interval ≥ 0.2 seconds) for the protection to work selectively

Setting adjustments are made iteration on the pickup current and TMS values until a coordination curve that meets the requirements for selectivity and operation speed is obtained. The final result is suggested as the optimal setting. The final setting is analyzed as a whole to ensure conformity with the actual conditions of the system and the principle of protection coordination. Validation was carried out by comparing the simulation results with standard references and local PLN practices.

Results 4.1 Research Data

The data of this study was obtained from the 20 kV distribution network of the SN.03 ULP Medan Denai Feeder. The primary purpose of data collection is to evaluate the initial overcurrent relay (OCR) settings and make adjustments based on MATLAB simulations to obtain optimal and selective protection coordination. The system data and relay specifications can be seen in the following Table 1:

Table 1. System data and relay soecifications

No.	Parameter	Value
1	Total Connected Power	12,525 kVA
2	Peak Load (Day/Night)	160 A / 215 A
3	Conveyor Wire Cross-Section	150 mm²
4	CT PMT (Micom P142)	800/5
5	PMT Initial Pickup Flow	568 A

6	PMT Initial Delay Time	0.11 TMS
7	Instantaneous PMT	3400 A (100 ms)
8	CT Recloser (Schneider)	1000/1
9	Arus Pickup Recloser	250 A
10	Recloser Delay Time	0.07 TMS
11	Instantaneous Recloser	2500 A

4.2 Data Analysis

Calculation of Nominal Feeder Flow

$$S_{total} = 12.525\ kV, \qquad V = 20\ kV \ (4)$$

3-phase system

$$I_{nominal} = \frac{S_{total}}{\sqrt{3}\ .\ V} = \frac{15{,}525 \times 10^3}{\sqrt{3}\ .\ 20{,}000} = 361.9\ A \ (5)$$

Based on the actual load observations, the daytime load is 160 A, the nighttime load is 215 A. Pickup current should be adjusted to the actual load, not just the transformer capacity.

Evaluation of the Existing Setting, the PMT Micom P142 Relay with a pickup current of 568 A, is too high compared to the actual load (215 A). The instantaneous value is 3400 A, too high for a 20 kV distribution system. The Schneides recloser with a pickup current of 250 A, is close enough to the load current. Instantaneous value of 2500 A. If there is a disturbance with current in the range of 600–1000 A, then the recloser will work, but the PMT will not respond because the pickup is too high. This can lead to in-selective coordination if interference occurs after the recloser.

Setting adjustment with PMT's new pickup current determination:

$$I_{pickup} = 1.5 \times I_{beban\ maksimum} = 1.5 \times 215 = 322.5\ A \ (6)$$ Since the CT PMT is 800/5, the secondary current:

$$I_{pickup,sekunder} = \frac{322.5 \times 5}{800} = 2.02\ A \ (7)$$

The setting in the relay is adjusted at about 2.0 A secondary.

TMS determination using an inverse curve (IEC Standard Inverse), MATLAB simulations show that the TMS is set so that the PMT works slower than the recloser (time difference ≥ 0.2 seconds). PMT working hours at 1000 A interference should not < recloser working hours

The simulation was carried out using MATLAB with a pickup current input setting of 322.5 A and a TMS of 0.3. The fault current varies from 400 A to 3000 A. The following results of the relay working time calculated using the IEC Standard Inverse curve characteristics can be seen in Table 2.

Table 2. Relay working time with IEC Standard Inverse curve characteristics

Current Interference (A)	TMS 0,1	TMS 0,2	TMS 0,3	TMS 0,4	TMS 0,5
400	3,2434	6,4867	9,7301	12,9734	16,2168
500	1,5893	3,1787	4,7680	6,3574	7,9467
600	1,1205	2,2411	3,3616	4,4822	5,6027
700	0,8963	1,7925	2,6888	3,5851	4,4814
800	0,7635	1,5270	2,2905	3,0541	3,8176
900	0,6751	1,3502	2,0253	2,7004	3,3755
1000	0,6116	1,2232	1,8348	2,4464	3,0580
1100	0,5635	1,1271	1,6906	2,2542	2,8177
1200	0,5258	1,0515	1,5773	2,1031	2,6288
1300	0,4952	0,9904	1,4855	1,9807	2,4759
1400	0,4698	0,9397	1,4095	1,8793	2,3492
1500	0,4484	0,8969	1,3453	1,7937	2,2422
1600	0,4301	0,8602	1,2903	1,7203	2,1504
1700	0,4141	0,8283	1,2424	1,6566	2,0707
1800	0,4001	0,8003	1,2004	1,6006	2,0007
1900	0,3877	0,7755	1,1632	1,5510	1,9387
2000	3,7660	0,7533	1,1299	1,5066	1,8832
2100	0,3667	0,7333	1,1000	1,4666	1,8333
2200	0,3576	0,7152	1,0728	1,4304	1,7880
2300	0,3494	0,6987	1,0481	1,3974	1,7468
2400	0,3418	0,6836	1,0254	1,3672	1,7090
2500	0,3349	0,6697	1,0046	1,3394	1,6743
2600	0,3284	0,6569	0,9853	1,3137	1,6422
2700	0,3225	0,6450	0,9674	1,2899	1,6124
2800	0,3169	0,6339	0,9508	1,2677	1,5847
2900	0,3118	0,6235	0,9353	1,2470	1,5588
3000	0,3069	0,6138	0,9207	1,2277	1,5346

After the input of the pickup current setting and TMS, the simulation results in the form of a Time-Current Characteristic (TCC) curve are shown in Figure 2.

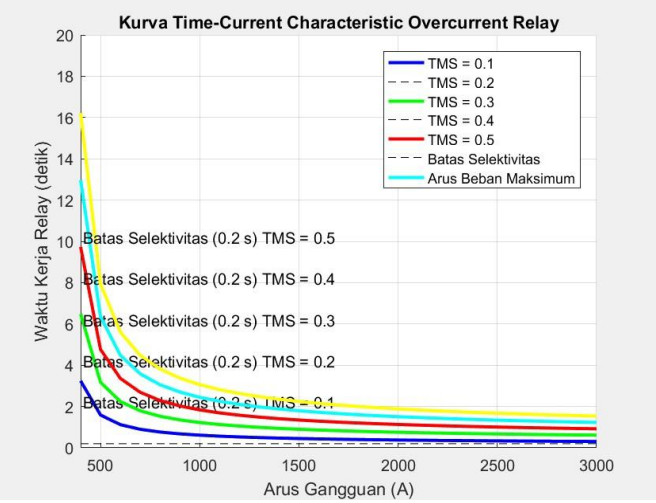

Figure 2. kurva Time-Current Characteristic (TCC)

The results of the above study are calculated with the help of a formula that has been made in the M-file matlab to produce the TCC Overcurrent Relay curve which is shown as below:

```
% Simulasi Kurva TCC Overcurrent Relay (OCR)
% Setting: Pickup = 322.5 A, TMS untuk beberapa nilai, IEC Standard
Inverse clc; clear; close all;

% === Parameter Relai ===
I_pickup = 322.5;   % Arus pickup (A)
TMS_values = [0.1, 0.2, 0.3, 0.4, 0.5];  % Beberapa nilai Time Multiplier
Setting (TMS)

% === Konstanta IEC Standard Inverse ===
alpha = 0.02; beta = 0.14;

% === Arus Gangguan ===
I = 400:100:3000;

% === Siapkan data untuk Tabel === t_relay_matrix = [];  %
Matriks untuk menampung hasil waktu relay

% === Plot Kurva TCC ===
figure; hold on;

% Warna untuk setiap TMS colors =
['b', 'g', 'r', 'c','y'];

% Iterasi untuk setiap TMS dan perhitungan waktu relay for
i = 1:length(TMS_values)
    TMS = TMS_values(i);  % Ambil nilai TMS
    t_relay = (TMS * beta) ./ (((I ./ I_pickup) .^ alpha) - 1);  % Hitung
waktu relay untuk tiap TMS
    plot(I, t_relay, 'LineWidth', 2, 'Color', colors(i));  % Plot kurva
```

```
    % Tambahkan data waktu relay ke dalam matriks tabel
    t_relay_matrix = [t_relay_matrix; t_relay];  % Menambahkan data per
TMS ke tabel

    % Tambahkan garis batas waktu selektivitas untuk setiap TMS
y_selectivity = 0.2;
    line([400 3000], [y_selectivity y_selectivity], 'Color', 'k',
'LineStyle', '--');
    text(410, y_selectivity + (i * 2), ['Batas Selektivitas (0.2 s) TMS
= ' num2str(TMS)], 'Color', 'k'); end

% === Tambahkan garis vertikal untuk Beban Maksimum === x_beban
= 215;
line([x_beban x_beban], [0 20], 'Color', 'm', 'LineStyle', '--');
text(x_beban + 10, 75, 'Beban Maksimum (215 A)', 'Color', 'm',
'Rotation', 90);

% === Label dan Tampilan === title('Kurva Time-Current
Characteristic Overcurrent Relay'); xlabel('Arus Gangguan
(A)'); ylabel('Waktu Kerja Relay (detik)'); grid on;

% === Legenda === legend({'TMS = 0.1', 'TMS = 0.2', 'TMS = 0.3', 'TMS
= 0.4', 'TMS = 0.5', 'Batas Selektivitas', 'Arus Beban Maksimum'},
'Location', 'northeast');

% === Batas Tampilan Sumbu ===
xlim([400 3000]); ylim([0
20]);
```

Based on the data of the peak load measurement of 215 A, the initial pickup current at PMT of 568 A is considered too high. If there is a disturbance with the current in the range of 600–1000 A, then the recloser will work, but the PMT will not respond due to the pickup value being too large. This poses a risk of indiscriminate protection.

The adjustment was made by lowering the pickup current value to approximately 322.5 A based on a CT ratio of 800/5 and a secondary current of 2.0 A. TMS is set to 0.3 so that the relay running time curve remains above the recloser curve with a minimum time margin of 0.2 seconds. Simulations show that with this configuration, PMT OCR works slower than the recloser, maintaining selective protection coordination.

Conclusion

Based on the results of the analysis and simulation that has been carried out on the SN.03 ULP Medan Denai Feeder, several conclusions were obtained, namely, the initial setting of PMT OCR (pick-up current 568 A and instantaneous 3400 A) is not effective in detecting medium current disturbances (600–1000 A), so it has the potential to reduce the reliability of the protection system. Schneider's recloser has a setting that is closer to the actual condition of the

distribution system, but the coordination with PMT does not meet the requirements for optimal selectivity.

The adjustment of the pick-up current to 322.5 A and TMS of 0.3, based on MATLAB simulations, resulted in a time-current curve that was able to meet the criteria of protection selectivity. PMT works slower than recloser with a safe time margin of ≥ 0.2 seconds. MATLAB simulations have proven to be effective for modeling OCR characteristic curves and helping to design more reliable, selective, and intrusion-responsive protection systems.

Suggestion

As a follow-up and development of this study, several things are suggested, namely, periodic evaluation of OCR and recloser protection settings based on actual load data and disturbance events in the field to maintain the reliability of the distribution system. The use of MATLAB simulations can be combined with other software (such as ETAP or DigSILENT) for further validation and comparison of results. It is important to conduct a physical coordination test in the field after the implementation of the new setting to ensure the actual performance of the protection in accordance with the simulation results.

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