Maneuver Protection of Feeder Lines at PT. Garuda Maintenance Facility Aeroasia Tbk

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Abstract*— The reliability of medium-voltage electrical distribution systems is strongly influenced by the performance of protection relay coordination, particularly during feeder maneuver operations that alter network configuration. PT Garuda Maintenance Facility (GMF) AeroAsia Tbk. receives electrical power through two 20 kV feeders, namely Garuda 1 as the primary feeder and Garuda 2 as the backup feeder, with a contracted load of 7.5 MVA. Operational disturbances occurring during the 2023–2024 period indicate the need to evaluate the existing protection coordination to ensure selective and reliable fault isolation. This study aims to analyze the coordination of Over Current Relay (OCR) protection before and after feeder maneuvering by calculating source, transformer, and feeder impedances, determining short-circuit fault currents, and evaluating relay settings based on the IEC 60255 standard. The protection system was modeled and simulated using ETAP software to compare the existing and proposed relay settings under various fault conditions. The simulation results show that the existing relay coordination does not fully satisfy the selective protection principle due to inappropriate relay operating sequences. After resetting the OCR parameters, the downstream relay setting was adjusted from 304 A, TMS 0.13 s to 237.6 A, TMS 0.08 s, while the upstream relay maintained proper backup protection. The proposed settings successfully improve relay selectivity, maintain coordination during feeder maneuver operations, and enhance the reliability of the 20 kV distribution system supplying PT GMF AeroAsia Tbk.

Keywords*— Load Flow, Manuver, Relay Protection, TMS

I. Introduction

Electrical energy has become an essential requirement in supporting industrial activities, particularly in strategic industries that demand a highly reliable and continuous power supply. Interruptions in electrical distribution systems may cause production downtime, equipment damage, financial losses, and operational safety risks. Therefore, distribution systems must be equipped with reliable protection schemes capable of detecting and isolating faults selectively while maintaining continuity of service for unaffected loads [1].

Protection systems in medium-voltage distribution networks generally consist of protective relays, circuit breakers, reclosers, load break switches (LBS), and other switching devices that operate in coordination to isolate only the faulted section of the network. Among these devices, the Over Current Relay (OCR) and Ground Fault Relay (GFR) play important roles in detecting overcurrent and earth-fault conditions. Proper relay coordination is required to ensure that the relay nearest to the fault operates first, while upstream protection devices provide backup protection if the primary relay fails to operate. This coordination principle improves the selectivity, sensitivity, speed, and reliability of the electrical protection system in accordance with IEC 60255 [2].

PT Garuda Maintenance Facility (GMF) AeroAsia Tbk. is one of the strategic industrial customers of PT PLN (Persero), operating continuously for aircraft maintenance services in the Soekarno-Hatta International Airport area. The electrical power system of PT GMF AeroAsia Tbk. is supplied through two independent 20 kV feeders, namely Garuda 1 as the primary feeder and Garuda 2 as the backup feeder, with a contracted demand of 7.5 MVA. The dual-feeder configuration improves supply reliability because electrical loads can be transferred from one feeder to another during maintenance activities or fault conditions through feeder maneuver operations. However, any change in network configuration caused by feeder maneuvering may alter the short-circuit current distribution and consequently affect the coordination of the protection system.

Based on operational data obtained from PT PLN (Persero) ULP Teluk Naga during the 2023–2024 period, the feeders supplying PT GMF AeroAsia Tbk. experienced several disturbances each year, including feeder outages and a complete blackout event involving both feeders. Under such conditions, PT GMF AeroAsia Tbk. relied on its standby generator system to maintain

operational continuity. These events indicate that feeder disturbances remain unavoidable and highlight the importance of evaluating protection relay coordination under both normal and feeder maneuver operating conditions to ensure the reliability of the electrical distribution system [3].

Several previous studies have investigated relay coordination in medium-voltage distribution systems by evaluating relay settings based on short-circuit calculations and protection coordination principles [4]–[6]. However, most of these studies focused on normal operating conditions and did not comprehensively evaluate the impact of feeder maneuver operations on relay coordination in industrial distribution systems utilizing dual incoming feeders. Consequently, there remains limited information regarding the suitability of existing relay settings after changes in network topology due to feeder transfer operations.

Therefore, this study evaluates the coordination of OCR protection in the 20 kV electrical distribution system supplying PT GMF AeroAsia Tbk. under both existing and feeder maneuver conditions. The study consists of impedance calculation, short-circuit analysis, relay setting calculation, and protection coordination simulation using ETAP software based on the IEC 60255 standard. The relay operating characteristics before and after resetting are compared to determine the effectiveness of the proposed protection settings.

The primary contribution of this research is the evaluation of relay coordination under feeder maneuver conditions in an industrial dual-feeder distribution system. Furthermore, this study proposes improved OCR setting values that enhance selectivity and backup protection coordination while maintaining the reliability of electrical power supply during feeder transfer operations. The results are expected to provide practical recommendations for improving protection system reliability in industrial power distribution networks, particularly for critical facilities requiring uninterrupted electrical service.

II. Research Methodology

A. Method

In conducting research, the main thing is to create a research procedure flowchart as shown in Figure 1 below:

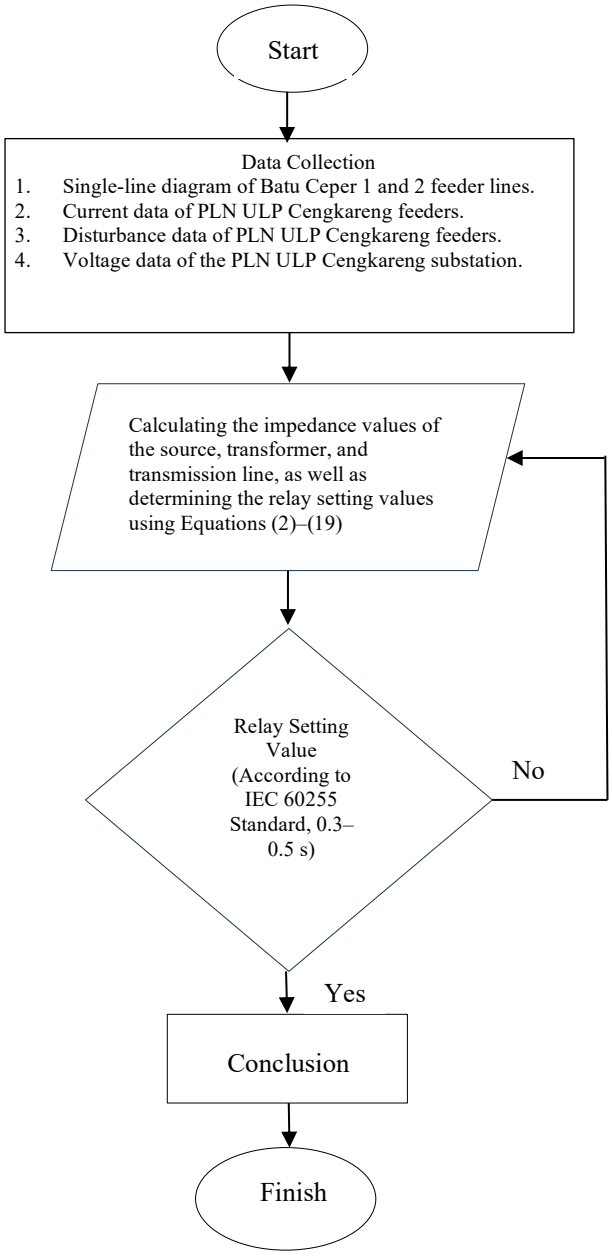


Figure 1. Research Flowchart

Based on figure 1, the research procedure flowchart above can be detailed as follows:

1) Data collection in the form of Single Line Diagram, Length of delivery channel, current data, disturbance data, and voltage data.
2) Calculating the impedance value of the source, transformer, and channel, and calculating the relay setting value.
3) Analysis of the relay setting value according to the IEC 60255 standard
4) Preparation of a report on the results of protection coordination on the relay setting value and the impact of maneuvers.

B. Data Collection Techniques

1) Observation Techniques

The author conducted observations and collected technical data according to the 2023-2024 update in the form of:

a) Transformer Data
b) Protection Relay Data
c) Data on the length of the delivery channel used,
d) Single Line Diagram

2) Literature Study

The literature study conducted by the author is by searching for information using various references related to the protection system.

B. Data Analysis Techniques

The data that has been collected will be analyzed to obtain the results of maneuvers and coordination of the protection system in the electrical network system that supplies PT. GMF Aeroasia Tbk. Where in data processing the author will calculate the impedance value (channel and transformer impedance), over current relay settings, and ground fault relay settings as follows:

1) Determining Source Impedance

To determine the source impedance on the secondary side bus, the source impedance on the primary side bus must first be determined. The source impedance on the primary side bus (*primary* side) can be determined using the equation:

Primary Side

$$Z_{s(primary)} = \frac{V_{primary}^2}{S_{sc}} \quad (1)$$

Secondary Side

$$Z_{s(secondary)} = Z_{s(primary)} \left(\frac{V_{secondary}}{V_{primary}}\right)^2 \quad (2)$$

where

$V_{primary}$= primary voltage (kV)

$V_{secondary}$= secondary voltage (kV)

S_{sc}= short-circuit capacity (MVA)

2) Determining Transformer Impedance

To determine the impedance of a transformer, the impedance value is taken, while the resistance is ignored because the value is small. Then the transformer impedance is

a) Determining the transformer impedance value at 100% or ZT (100%) = jXT (100%) for transformers on the secondary side, 52 using the equation:

$$Z_T = \frac{Z(\%) \times kV^2}{MVA} \quad (3)$$

b) The impedance value of positive and negative sequence transformers using the equation:

$$Z_1 = Z_2 = jX_T \quad (4)$$

c) For transformers with YY winding connections and do not have delta windings (Δ) in them, then to calculate the magnitude of the zero sequence transformer impedance using the equation.

Zero sequence

$$Z_0 = 3jX_T \quad (5)$$

where

Z_T= transformer impedance

X_T= transformer reactance

3) Impedance of the Leading or Feeding Line

a) The impedance of the positive sequence leading or feeding line (Z1p) is the same as the impedance of

the negative sequence leading or feeding line ($Z2$p) using the equation:

Positive sequence

$$Z_1 = L(R_1 + jX_1) \quad (6)$$

Negative sequence

$$Z_2 = L(R_2 + jX_2) \quad (7)$$

b) The impedance of the zero sequence leading or feeding line ($Z0$p) using the equation:

Zero sequence

$$Z_0 = L(R_0 + jX_0) \quad (8)$$

where

L= feeder length (km)

R= resistance (Ω/km)

X= reactance (Ω/km)

4) Equivalent network impedance

The equivalent network impedance can be calculated using the following equation:

a) Equivalent positive and negative sequence impedance ($Z1\ eq = Z2\ eq$) using the equation:

$$Z_{1\,eq} = Z_{2\,eq} = Z_{1S}(sisi\ sekunder) + Z_{1T} + Z_{1P}$$
$$Z_{1\,eq} = Z_{2\,eq} = \mathrm{jX}_{1S}(sisi\ sekunder) + \mathrm{jX}_{1T} + (R_{1P} + \mathrm{jX}_{1P}) \quad (9)$$

b) Zero sequence equivalent impedance ($Z0\ eq$) using the equation:

$$Z_{0\,eq} = Z_{0T} + 3R_n + Z_{0P} = \mathrm{jX}_{0T} + 3R_n + (R_{0P} + \mathrm{jX}_{0P}) \quad (10)$$

5) Short Circuit Fault Current

The calculation of short circuit fault current can be calculated using the basic formula, which equivalent impedance is entered into the basic formula is the type of three-phase, two-phase, or single-phase to ground short circuit fault. So the formula used for calculating three-phase, two-phase, and single-phase to ground short circuit current is different. The equations used are Equations (11, 12, and 13).

Three Phase Fault

$$I_{3\phi} = \frac{V}{\sqrt{3}Z_{1eq}} \quad (11)$$

Line-to-Line Fault

$$I_{LL} = \frac{V}{Z_{1eq} + Z_{2eq}} \quad (12)$$

Single Line-to-Ground Fault

$$I_{LG} = \frac{3V}{Z_{1eq} + Z_{2eq} + Z_{0eq}} \quad (13)$$

OCR Pick-Up Current

$$I_{set} = 1.1 \times I_{FLA} \quad (14)$$

Where:

I_{FLA}= full-load current

Time Multiplier Setting

Standard Inverse IEC 60255,

$$t = \frac{0.14 \times TMS}{\left(\frac{I_f}{I_{set}}\right)^{0.02} - 1} \quad (15)$$

TMS:

$$TMS = \frac{t\left[\left(\frac{I_f}{I_{set}}\right)^{0.02} - 1\right]}{0.14} \quad (16)$$

where

t= relay operating time (s)

I_f= fault current (A)

I_{set}= pickup current (A)

Ground Fault Relay

$$I_{set(GFR)} = 0.2I_n \quad (17)$$

Relay Operating Time

$$T_{op} = \frac{0.14 \times TMS}{\left(\frac{I}{I_{set}}\right)^{0.02} - 1} \quad (18)$$

Grading Time

$$CTI = T_{backup} - T_{primary} \quad (19)$$

where

CTI= Coordination Time Interval (s)

III. Result and Discussion

A. *Electrical Network System of PT. GMF Aeroasia Tbk.*

PT. GMF Aeroasia Tbk. is supplied from two feeders, namely Garuda 1 (main feeder) and Garuda 2 (backup feeder), which then enter the Cengkareng substation through a 20 kV medium-voltage distribution network, as shown in Figures 2 and 3. The data on transformers, relays, and line lengths can be seen in Tables 1, 2, and 3.

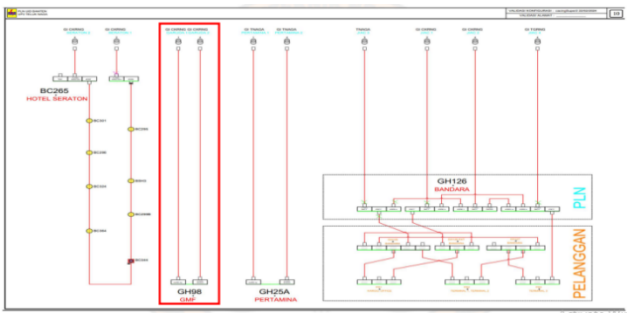


Figure 2. Single Line Diagram of Feeder 1 and 2 Supply PT.GMF Aeroasia Tbk (Source : PT.PLN (Persero) UP3 Teluk Naga)

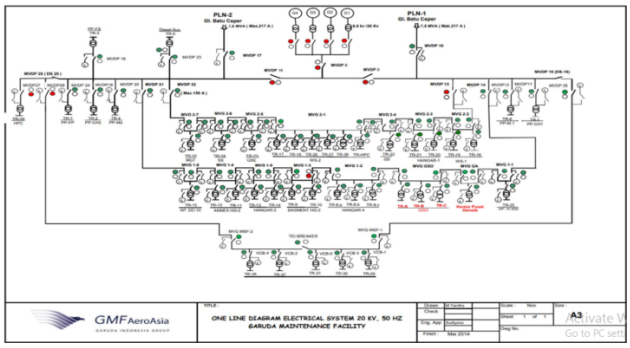


Figure 3. Single Line Diagram of System 20 KV PT. GMF Aeroasia Tbk (Source : PT. GMF Aeroasia Tbk File)

Table 1. Power Transformer Specification Data of Substation

No	Nama Transformator	Spesifikasi	
1	Transformator 1 GI Cengkareng	Merk	UNINDO
		Daya	60 MVA
		Tegangan	150/20 kV
		Hubungan Belitan	YNyn0+d
		Impedansi Z%	12,5%
		In Trafo	1732 A
		Ratio CT	800/5 A
		Tahanan Pentanahan	40 ohm
		Hubung Singkat	11425,67 MVA
2	Transformator 2 GI Cengkareg	Merk	UNINDO
		Daya	60 MVA
		Tegangan	150/20 kV
		Hubungan Belitan	YNyn0+d
		Impedansi Z%	12,5%
		In Trafo	1732 A
		Ratio CT	800/5 A
		Tahanan Pentanahan	40 ohm
		Hubung Singkat	10452,36 MVA

*Source : PT.PLN UP3 Teluk Naga

Table 2 Relay Incoming and Outgoing Specification Data

No	Nama	Spesifikasi *Relay Incoming*	Spesifikasi *Relay Outgoing*
1	Merk	SIEMENS	SIEMENS
2	*Type*	7SR2203	7SR2203
3	Karasteristik	SI (*Standar Inverse*)	SI (*Standar Inverse*)
4	Ratio CT	2000/5	800/5
5	Tms	0,1 s	0,1 s
6	I Beban	304 A	280,5 A

*Sumber : PT.PLN UP3 Teluk Naga

Table 3 Transmission Line Specification Data

No	Nama	Spesifikasi
1	Jenis Pengantar	NA2XSEYBY 12/20 (24) kV 3 x 95 mm2
2	Panjang (*l* p)	6,930 km
3	Impedansi Unit	0,125 + j0,193 ohm/km & 0,375 + j0,450 ohm/km
4	Tahanan	0,4110 ohm/km

*Sumber : PT.PLN UP3 Teluk Naga

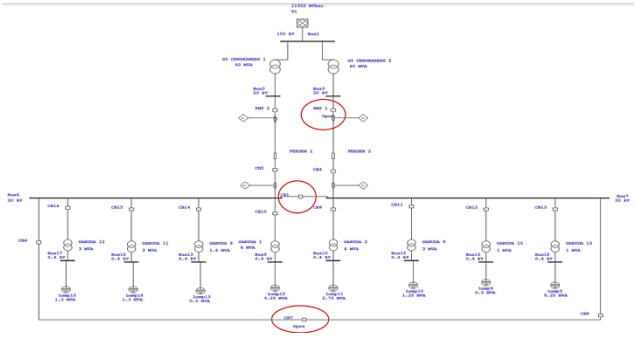


Figure 4. Etap Simulation Single Line Diagram

The single-line diagram of the 20 kV system at PT. GMF Aeroasia Tbk., depicted in Figure 4, represents a simplified simulation configured in a parallel arrangement via control circuit breakers CB1 and CB PMT 1 on the main feeder and CB 7 on the load, initially set to an open state. In the event of a disturbance or scheduled maintenance on the primary feeder line 1, a manual transfer to the secondary feeder line 2 is executed. This transfer process involves network synchronization through CB 7, which is closed, followed by the closure of CB PMT 1, ensuring a seamless transition.

B. Impedance Calculation

1) Calculating Source Impedance

Based on table 1 and table 2, the short-circuit capacity from PLN UP3 Teluk Naga to GI Cengkareng with transmission lines 1 & 2 is 11425.67 MVA and 10452.36 MVA, respectively. The source impedance can then be calculated using equations (1) as follows:

$$X_s(sisi\ 150\ kv) = \frac{kV^2}{MVA\ sc\ (150\ kV)} = \frac{150^2}{11425{,}67} = j1{,}969\ \Omega$$

To calculate the magnitude of the impedance on the secondary side, equation (2) is used as follows:

$$Z_s(Sisi\ Sekunder) = jX_s(sisi\ sekunder) = \frac{kV^{2\,(sisi\ sekunder)}}{kV^{2\,(sisi\ primer)}}\ x\ jX_s(sisi\ primer)\ \Omega$$

$$X_s(sisi\ 20\ kv) = \frac{kV^2}{MVA\ sc\ (150\ kV)} x\ jX_s(sisi\ primer) = \frac{20^2}{150^2} x\ j1{,}969$$

$$= j0{,}03347\ \Omega = j0{,}034\ \Omega$$

From the calculation of the source impedance above, the impedance value on the primary side is $j1{,}969\Omega$ while on the secondary side it is $j0.017\Omega$. Next, the impedance value of the transformer can be calculated.

2) Calculating Transformer Impedance.

Based on the data in table 1 and Table 2, the impedance value of transformers 1 & 2 at GI Cengkareng is 12.5%, which indicates that under full load conditions, the voltage on the secondary side of the transformer can drop by 12.5% from its nominal voltage, i.e., from 20 kV to 17.5 kV. To calculate the values of the positive sequence impedance, negative sequence impedance, and zero sequence impedance, the total reactance X needs to be calculated first using equation (3) as follows:

$$X_t(100\%) = \frac{kV^2 sisi\ bus\ 20\ kV}{MVA\ (trafo)} = \frac{20^2 kV}{60\ MVA} = 5.33\ \Omega$$

After that, the positive and negative sequence impedances Xt1 = Xt2 can be calculated using equation (4) as follows:

$$X_{t1} = 12{,}5\%\ x\ 5{,}33\ \Omega = j0{,}666\ \Omega$$

The zero sequence impedance Xt1 is 3x from Xt1 can be calculated using equation (5) as follows:

$$X_{t0} = 3\ x\ (X_{t1}) = 3\ x\ 0{,}666\ \Omega = j1{,}998\ \Omega$$

From the calculation of transformer impedance above, the positive and negative sequence impedance values are j0.666 Ω while the zero sequence impedance is j1.998 Ω. Complete data of the calculation results for source impedance and transformer impedance can be seen in table 4.

Table 4. Calculation results of source impedance and transformer impedance

No	Transformator	Impedansi Sumber (ohm)		Impedansi Urutan Positif, Negatif, dan Nol (ohm)		
		Xs Primer	Xs Sekunder	Xt1	Xt2	Xt0
1	Garuda 1 Cengkareng	*j* 1,969	*j* 0,034	*j* 0,666	*j* 0,666	*j* 1,998
2	Garuda 2 Cengkareng	*j* 2,152	*j* 0,038	*j* 0,666	*j* 0,666	*j* 1,998

3) Calculating the Impedance of the Feeder Line

Based on the data in Table 4. The length of the feeder line is 6.930 km. The impedance of the feeder line can be calculated using equation 7 as follows:

$$Z_1 = Z_2 = 6{,}930\ km\ x\ (\ 0{,}125\ +\ j0{,}193)\Omega/km = \\ = 0{,}866 +\ j1{,}337\ \Omega$$

$$Z_0 = 6{,}930\ km\ x\ (\ 0{,}375\ +\ 0{,}450)\Omega/km = \\ = 2{,}598 +\ j3{,}118\ \Omega$$

For more details, it can be seen in table 5, and for the zero sequence impedance, it can be seen in the table below.

Table 5. Positive and Negative Sequence Line Impedance

Jarak Gangguan Saluran Pengantar dalam (%)	Jarak (km)	Impedansi Saluran Pengantar
1%	0,07	1% x (0,866 + j1.337) = 0,0086 + j0,01337 Ω
25%	1,73	25% x (0,866 + j1.337) = 0,2165 + j0,3343 Ω
50%	3,47	50% x (0,866 + j1.337) = 0,433 + j0,6685 Ω
75%	5,2	75% x (0,866 + j1.337) = 0,6495 + j1,0028Ω
100%	6,930	100% x (0,866 + j1.337) = 0,866 + j1.337Ω

C. *Calculating Single Line-to-Ground Fault Current.*

1) Single line-to-ground fault at 1% of the length of the feeder line is as follows:

$$I_{hs\,1\ fasa\ ke\ tanah} = \frac{3x\ \frac{V_{L-L}}{\sqrt{3}}}{2xZ_{1eq} + Z_{0eq}} = (Ampere)$$

$$I = \frac{3x\frac{20000}{\sqrt{3}}}{(0{,}0086 + j0{,}713) + (0{,}0086 + j0{,}713) + (120{,}026 + j1{,}9983)}$$

$$I = \frac{3x\frac{20000}{\sqrt{3}}}{(0{,}0172 + j1{,}426) + (120{,}026 + j1{,}9983)} = \frac{34641{,}01}{120{,}0432 + j3{,}4243}$$

$$I = \frac{34641{,}01}{120{,}0920\angle 1{,}63°} = 288{,}45\angle 1{,}63°\ A$$

2) Line-to-Line Fault Current.

Fault at 1% of the length of the feeder line is as follows:

$$I_{hs\,2\ fasa\ ke\ fasa} = \frac{V_{L-L}}{2xZ_{1eq}} = (Ampere)$$

$$I = \frac{20000}{(0{,}0086 + j0{,}713) + (0{,}0086 + j0{,}713)}$$

$$I = \frac{20000}{(0{,}0172 + j1{,}426)} = \frac{20000}{1{,}4261\angle 89{,}31\circ} = 14024{,}26\angle 89{,}31\circ A$$

3) Three-Phase Fault Current.

Fault at 1% of the length of the feeder line is as follows:

$$I_{hs\,3\ fasa} = \frac{V_{L-N}}{Z_{1eq}} = \frac{\frac{V_{L-L}}{\sqrt{3}}}{Z_{1eq}} = (Ampere)$$

$$I = \frac{\frac{20000}{\sqrt{3}}}{(0{,}0086 + j0{,}713)} = \frac{11547{,}34}{(0{,}0086 + j0{,}713)}$$

$$= \frac{11547{,}34}{0{,}7131\angle 89{,}31\circ} = 16193{,}1566\angle 89{,}31\circ A$$

Table 6. Short circuit current fault magnitudes

Panjang Saluran pengantar (%)	Jarak (km)	Arus Hubung Singkat (A)		
		1 Fasa ke Tanah	Fasa ke Fasa	3 Fasa
1%	0,07	288,45∠1,63°	14024,26∠89,31°	16193,1566∠89,31°
25%	1,73	285,8641∠2,29°	9463,4239∠78,18°	10927,7373∠78,18°
50%	3,47	283,1834∠2,95°	6964,5158∠72,45°	8042,4432∠72,45°
75%	5,2	280,5145∠3,59°	5487,1190∠69,12°	6335,9890∠69,12°
100%	6,930	277,8634∠4,23°	4517,8342∠66,97°	5217,0145∠66,97°

D. *Simulation of Existing Data of the 20 kV Network System of PT. GFM Aeroasia Tbk and Protection Maneuver Analysis*

For the protection relay setting data that has been installed on the feeder line serving PT. GMF Aeroasia Tbk, on the incoming side, it can be seen in the following table:

Table 7. Customer Relay Setting Power

No	Nama (item)	Spesifikasi Relay Incoming Garuda 1	Spesifikasi Relay Incoming Garuda 2
1	Merk	SCHNEIDER ELECTRIC	SCHNEIDER ELECTRIC
2	Type	MICOM P123	MICOM P123
3	Karasteristik	SI (Standar Inverse)	SI (Standar Inverse)
4	Ratio CT	800/5	800/5
5	TMS	0.13	0.13
6	I Beban	304 A	304 A

Based on the data in the table above, a simulation can be made in the ETAP application to get the load flow results of the protection relay coordination system when a fault occurs.

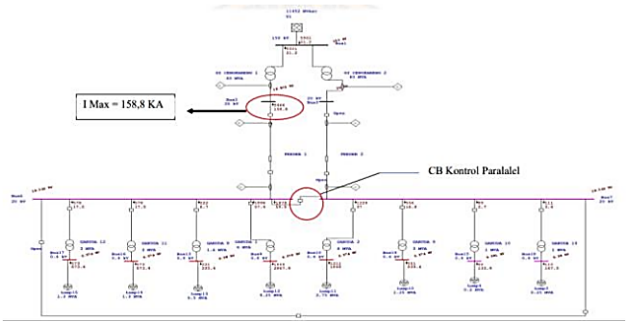


Figure 5. Load flow simulation of 20 kV system

From the simulation results in figure 5, it can be seen that Feeder 1 and Feeder 2 are connected in parallel where the CB acts as a control for the circuit between feeders supplying all loads at PT. GMF Aeroasia Tbk. The maximum current value on the transformer under load conditions is 158.8 kA. This value is close to the actual maximum current used by PT. GMF Aeroasia Tbk, which is 155 kA. The voltage on the bus is still in a stable condition at 19.558 kV, in accordance with the standards used by PT. PLN (Persero) and SNI 04-0225-200, which are -10% and +5%.

After the load flow simulation was carried out, a simulation was then carried out with a phase-to-phase short circuit fault at two fault locations, namely a fault on the load side and a fault on the bus side as shown in the figure below.

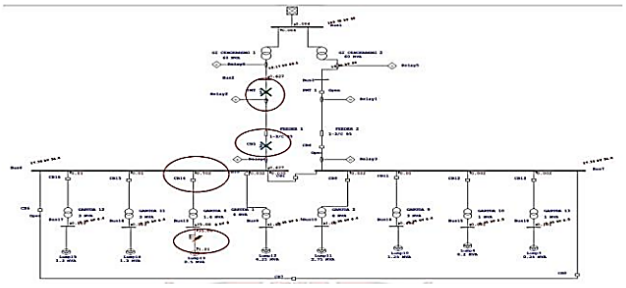


Figure 6. Phase-To-Phase Short Circuit Simulation With Existing Relay Settings Of 20 Kv System

Based on the simulation results shown in the figure above, it is seen that the fault location is on the load side at bus 13, CB14 with a fault current of 0.7020 kA (7020 A). This value is close to the calculated phase-to-phase short circuit current of 6964 A (0.6964 kA) at 50% distance (3.47 km) of the total line length of 6.930 km as shown in table 4. Therefore, PMT 2 at GI Cengkareng 1 experiences a trip due to the protection relay setting value of PT. GMF Aeroasia Tbk load being greater (TMS = 0.13) than the relay setting at GI Cengkareng (TMS = 0.1). After that, followed by the trip of CB5, so it is necessary to re-set the protection relay on the load side so that the relay coordination is in accordance with the basic coordination rules in chapter II (Schneider Electric, 2019) when a fault occurs.

E. Analysis of Protection Setting Values

1) Resetting Protection

In this problem, the relay setting uses the standard inverse characteristic of IEC 60255. After knowing the phase-to-phase short circuit fault current value according to figure 6 of 0.702 kA and I_{base} of 216 A in accordance with the contract value of PT. GMF Aeroasia Tbk with PT. PLN (Persero), in this case PLN UP3 Teluk Naga of 7.5 MVA as shown in figure 4.2, the relay setting value can be calculated using equation 18 as follows.

$$I_{Set\ relay} = 1,1\ x\ I_{base}$$

$$I_{Set\ relay} = 1,1\ x\ 216 = 237,6\ A$$

In accordance with the load current value (I) obtained for setting the TMS (Time Multiplier Setting) value, equation 19 is used as follows:

$$TMS = \frac{tx\ T\ operasi\ ((\frac{I_f}{I_{set}})^{0,02} - 1)}{0,14} = \frac{0,5\ ((\frac{702}{237,6})^{0,02} - 1)}{0,14}$$

$$= 0.078\ s = 0,08\ s$$

F. Simulation of Protection Re-setting

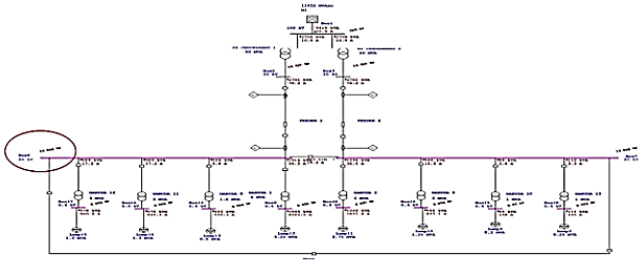


Figure 7. Load Flow Simulation Of 20 Kv System Of PT. GMF Aeroasia Tbk After Setting

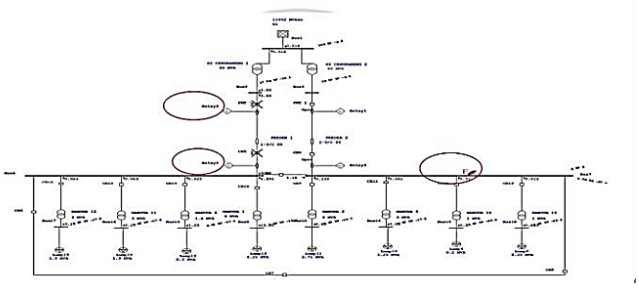


Figure 8. Phase-To-Phase Short Circuit Simulation With New Relay Settings Of 20 Kv System Of PT. GMF Aeroasia Tbk On The Bus

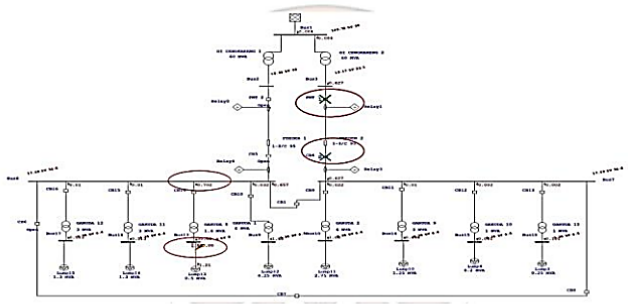


Figure 9. Phase-To-Phase Short Circuit Simulation With New Relay Settings Of 20 Kv System Of PT. GMF Aeroasia Tbk On The Load

Based on Figures 8 and 9 above, it shows that the protection coordination system works in series where the relays that will work first when a fault occurs are relays 3 and 4 with mark (X1) on the load incoming side compared to relays on the GI incoming side, namely relays 1 and 2 with mark (X2). Where relays 3 and 4 will instruct Circuit Breaker (CB) 4 and 5 to open or trip. When relays 3 and 4 (main relays) do not work, they will be backed up by relays 1 and 2 (backup relays). For more details, the comparison data of the current values in the existing condition and the resetting values are shown in the table below.

Table 8. Comparison of Existing and Resetting Protection Setting Calculations

No	Jarak % dari 6,930 Km	Arus Gangguan (A)			Nilai Setting (s)	
		Perhitungan	Simulasi Eksisting	Simulasi Resetting	Eksisting	Resetting
1	50% (3,47 Km)	6964	7020	7020	0,13	0.08
2	100% (6,930 Km)	4517	4360	4360	0,13	0.08

From the results of this simulation, it can be said that the coordination of protection relays on the load side with relays on the GI side is in good condition in accordance with the coordination principle of protection systems working in series. Meaning, each system must isolate only the damaged part of the power system network, so that other parts of the system are not disturbed (Schneider Electric, 2019). Likewise for the settings used based on the inverse characteristic where the greater the fault current, the faster the relay performance, and the farther the fault distance, the smaller the short circuit fault current value.

With appropriate relay settings, the protection coordination is also considered good where the protection that works first is the protection on the load side then backed up by protection on the source side (GI), this is because Over Current Relay (OCR) and Ground Fault Relay (GFR) are interrelated in terms of performance, so that other systems are not affected when a fault occurs.

IV. Conclusion

This study evaluated the coordination of the Over Current Relay (OCR) protection system in the 20 kV electrical distribution network supplying PT Garuda Maintenance Facility (GMF) AeroAsia Tbk. under both normal operating conditions and feeder maneuver scenarios. The evaluation was carried out through impedance calculations, short-circuit analysis, relay setting calculations based on the IEC 60255 standard, and protection coordination simulations using ETAP.

The analysis showed that the existing relay settings did not fully satisfy the selective protection coordination principle because the operating sequence between downstream and upstream protection devices was not properly coordinated. Consequently, there was a possibility that upstream protection could operate before the downstream relay during certain fault conditions, reducing the selectivity and reliability of the protection system.

After resetting the OCR parameters, the relay coordination achieved the desired protection hierarchy, where the downstream relay operated as the primary protection while the upstream relay functioned as backup protection. The proposed relay settings improved the selectivity of the protection system, reduced unnecessary

feeder interruptions, and ensured that faults were isolated only within the affected section of the network.

Furthermore, the simulation results demonstrated that feeder maneuver operations between Garuda 1 and Garuda 2 did not compromise protection coordination after the proposed relay resetting. The protection system remained properly coordinated under both normal and transfer operating conditions, thereby maintaining the reliability and continuity of electrical power supply for PT GMF AeroAsia Tbk.

The findings of this research provide practical recommendations for optimizing protection relay settings in industrial medium-voltage distribution systems utilizing dual-feeder configurations. Future research may focus on implementing adaptive protection schemes and automatic feeder transfer systems integrated with SCADA to further improve protection system reliability and operational efficiency.

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References

[1] Abdul Azis dan Irine Kartika Febrianti, 2019. Analisis Sistem Proteksi Arus Lebih Pada Saluran pengantar atau penyulang Cendana Gardu Induk Bungaran Palembang. Jurnal Ampere, Volume 4, No2.

[2] Adhitya Indrajaya Putra, dkk, 2017. Evaluasi Setting Relay Arus Lebih dan Setting Relay Gangguan Tanah Pada Gardu Induk 150KV Bawen.Semarang: Departemen Teknik Elektro Universitas Diponegoro. Online. Diakses 22 Juli 2024.https://ejournal3.undip.ac.id/index.php/transient/article/download/181 09/17158.

[3] Anderson, P.M, 1999. Power Sistem Protection. IEEE PRESS PEOWER ENGINEERING SERIES., New York. Online. (https://archive.org/details/POWERSISTEMPROTECTIONP.M.Anderson/page/n1/mode/2up?view=theater), diakses 07 des 2023.

[4] Anang dan Adnan, 2017. Modul Pelatihan Etap. Yogyakarta.: Jurusan Pendidikan Teknik Elektro Fakultas Teknik Universitas Negeri Yogyakarta.

[5] Djoko Laras Budiyo Taruno, 2018.Unit Trainer Panel Kubikel 20 kV. Yogyakarta: Jurusan Pendidikan Teknik Elektro Universitas Yogyakarta. Online. Diakses 19 Desember 2023. https://staffnew.uny.ac.id/upload/131808670/penelitian/UNIT%20TRAINER%20PANEL%20KUBKEL%2020k V.pdf.

[6] Imam Sandi Taufiq, 2020. Analisis Koordinasi Proteksi 20 kV Saluran pengantar atau penyulang Feeder KLU 3. Teknik Elektro : Fakultas Teknik,Universitas Semarang, Semarang.

[7] Kelas Teknisi, 2023. Pemutus Tenaga (PMT) atau Circuit Breaker. Oniline (https://www.kelasteknisi.com), diaksess 19 Desember 2023.

[8] I. M. Ibrahim et al., "Web server performance improvement using dynamic load balancing techniques: A review," system, vol. 19, p. 21, 2021.

[9] Lutfi Lastiko Wibowo, 2011. Transformator Arus Dan Pemeliharaan Transformator Arus Pada Pt. Pln (Persero) P3b Region Jawa Tengah & Diy Upt Semarang Gis 150kv Simpang Lima. Semarang: Fakultas Teknik Universitas Diponegoro, Online. https://adoc.pub/transformator-arus-dan pemeliharaan-transformatorarus-pada-.html, diakses 19 Desember 2023.

[10] PT PLN (Persero) No. 0520-2.K/DIR/2014. Buku Pedoman Pemeliharaan Pemutus Tenaga. Jakarta.
PT.PLN (Persero), 2014. Buku Pedoman Kubikel Tegangan Menengah. Jakarta: https://www.slideshare.net/slideshow/bukupedoman kubikeltegangan-menengah/119542463, diakses 16 Juli 2024