

## ANALYSIS OF THE COORDINATION OF THE 20 KV SYSTEM PROTECTION ON THE 30 MVA 150/20 KV TOWN FEEDER TRANSFORMER AT THE 150KV SURALAYA SUBSTATION

By

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### ABSTRACT

*One type of protective relay that requires coordination in an electric power system is the overcurrent relay (OCR) and ground fault relay (GFR). The OCR/GFR function is crucial for protecting equipment in a substation from short circuits between phases or phase-to-ground faults. Therefore, setting the OCR/GFR relay requires careful and precise calculations to ensure a sensitive, selective, fast, and reliable power protection system. Observations of faults at several substations in the Cilegon Technical Implementation Unit (UPT) revealed discrepancies in the OCR/GFR coordination. The method used was to calculate the OCR/GFR setting values on the feeder side and the main transformer side to analyze the protection system coordination.*

**Keywords:** Protection System, Substation, Relay Coordination, OCR and GFR

## ANALISIS KOORDINASI SISTEM PERLINDUNGAN 20 KV PADA TRANSFORMATOR PENYALUR KOTA 30 MVA 150/20 KV DI GARDU INDUSTRI 150 KV SURALAYA

### ABSTRAK

*Salah satu jenis relai pelindung yang memerlukan koordinasi dalam sistem tenaga listrik adalah relai arus berlebih (OCR) dan relai gangguan tanah (GFR). Fungsi OCR/GFR sangat penting untuk melindungi peralatan di gardu induk dari gangguan arus berlebih antar fasa atau gangguan fasa ke tanah. Oleh karena itu, pengaturan relai OCR/GFR memerlukan perhitungan yang cermat dan presisi untuk memastikan sistem perlindungan tenaga listrik yang sensitif, selektif, cepat, dan andal. Pengamatan gangguan di beberapa gardu induk di Unit Pelaksana Teknis (UPT) Cilegon menunjukkan ketidaksesuaian dalam koordinasi OCR/GFR. Metode yang digunakan adalah menghitung nilai pengaturan OCR/GFR di sisi feeder dan sisi transformator utama untuk menganalisis koordinasi sistem perlindungan.*

**Kata kunci:** Sistem Perlindungan, Gardu Induk, Koordinasi Relai, OCR dan GFR

## INTRODUCTION

Electricity is used for lighting, transportation, communication, industry, and households, as well as to support various daily activities, resulting in an annual increase in electricity

demand. Transformers are important equipment in distributing electricity from the source to consumers, whether using high, medium, or low voltage.

The Suralaya Main Substation is one of the main substations that operates conventionally. In the electricity distribution system, it is possible for disturbances to occur, especially short circuits caused by excessive current. The protection system is set up in such a way that there is good coordination between the upstream and downstream sides of the feeder.

The purpose of protection system coordination is to prevent protection relays from causing malfunctions. One of the important protection relays to be coordinated in the power system is the overcurrent relay (OCR) and ground fault relay (GFR), which are usually referred to as OCR/GFR relays. In order for the relays to work according to their settings, routine maintenance is carried out every two years to maintain equipment performance and prevent sudden damage.

To improve safety, a non-cascade safety design was applied to the overcurrent relay in the 20 kV incoming transformer and feeder. The non-cascade safety pattern was designed to improve the previous safety system that used a cascade pattern, which showed weaknesses and vulnerabilities that hindered the optimal functioning of the current relay protection system.

## RESEARCH METHODS

In conducting research, data requirements analysis is necessary to obtain preliminary information for the research process. This is important so that the research conducted is appropriate to the conditions in the field. The following are the activities that need to be carried out at the requirements analysis stage:

### 1. Interview Method

Information is collected by interviewing the protection maintenance team of the Suralaya Transmission Service Unit and Substation (ULTG) involved in the maintenance and repair of the protection system at the substation, as well as substation operators relevant to the issue being studied. From these interviews, information was obtained, such as Single Line Diagram data on the Town Feeder Transformer side, Current Transformer on the incoming

and feeder sides along with the feeder ratio, and setting data on the incoming and feeder relays, so that the theoretical basis and concepts supporting this research could be understood.

## 2. Literature Study Method

Information was collected by studying several books, such as SKDIR 520, the Java Bali Transmission and Substation Protection System Manual and Guidelines, and the PT PLN (Persero) UIT JBB OCR (Over Current Relay) & GFR (Ground Fault Relay) Setting Agreement. In addition, journals and websites related to the issues under study were also examined to gather the necessary information.

## 3. Observation

Observation was conducted by observing problems occurring in the research object, followed by identifying these problems. Next, data was collected. This research is quantitative in nature because the data source comes from primary data obtained directly through testing and measurement in the field. The research data took the form of a case study analyzing maintenance results that did not meet the standards applicable at PT PLN (Persero).

## RESULTS AND DISCUSSION RESULTS

### 1. Calculations and Analysis

#### 1) Source Impedance Calculation ( $X_s$ )

To calculate the source impedance ( $X_s$ ) value, we first need to know the shortcircuit power (MVASC) using the formula in equation 2.10:

$$[2.10] MVASC = \sqrt{3} \times I_{sc}(20kV) \times V_{ph}(150kV)$$

Where:

$I_{sc}(20kV)$  = Short-circuit current on the 20 kV side

$V_{ph}(150kV)$  = Voltage (phase-phase) on the 150 kV side

From the technical data of the Jamali Load Control Unit at the 150 kV Suralaya Substation, it is known that the short-circuit current on the 20 kV network side is 25 kA (PT. PLN (Persero) Cilegon Transmission Implementation Unit, 2021). With a voltage on the primary side of 150

kV, the  $MVA_{sc}$  value can be calculated as follows:

$$[2.10] \quad MVA_{sc} = \sqrt{3} \times I_{sc}(20kV) \times V_{ph}(150kV)$$

$$MVA_{sc} = \sqrt{3} \times 25 \text{ kA} \times 150 \text{ kV}$$

$$MVA_{sc} = 6.495 \text{ MVA}$$

After determining the  $MVA_{sc}$  value, the source impedance value on the 150 kV primary side can be calculated using the formula in equation 2.11:

$$[2.11] \quad X_{s(150kV \text{ side})} = \frac{kV(\text{transformer primary side})^2}{2 MVA_{sc}}$$

Where: kV (primary side of transformer) = 150 kV

$$MVA_{sc} \text{ (short-circuit power)} = 4,85 \text{ MVA} \text{ Then:}$$

$$X_{s(150kV \text{ side})} = \frac{150^2}{6,495 \text{ MVA}}$$

$$X_{s(150kV \text{ side})} = 4,634 \text{ Ohms}$$

So, the source impedance value of 150 kV is 4.634 ohms or j 4.63. However, since we want to find the short-circuit current on the 20 kV secondary side, the source impedance value used is the source impedance value on the 20 kV secondary side. The calculation method is similar to the method used to calculate the source impedance on the 150 kV primary side earlier. The result of calculating the source impedance on the 20 kV secondary side is as follows:

$$[2.12] \quad X_{s(20 \text{ kV side})} = \frac{kV(\text{secondary side of transformer})^2}{2} \times X_{s(150 \text{ kV side})} \frac{kV(\text{primary side of transformer})}{kV}$$

Where:

$$kV \text{ (primary side of transformer)} = 150 \text{ kV}$$

$$kV \text{ (secondary side of transformer)} = 20 \text{ kV}$$

$$X_{s(150 \text{ kV side})} = 4,634 \text{ ohms}$$

Therefore:

$$X_s(20 \text{ kV side}) = 150^{2022} \times 4,634$$

$$X_s(20 \text{ kV side}) = 0,082 \text{ ohms}$$

Therefore, the impedance value of the 20 kV source is 0.082 or j 0.082.

## 2. Calculation of 20 kV Side Transformer Impedance

The next calculation is to calculate the transformer impedance on the 20 kV side using formula 2.13 as follows:

$$[2.13] X_{t(100\%)} = \frac{kV (\text{secondary side})^2}{MVA \text{ transformer}}$$

Where:

$$kV (\text{secondary side of transformer}) = 20 \text{ kV}$$

$$MVA \text{ transformer} = 30 \text{ MVA}$$

$$\text{Therefore: } X_{t(100\%)} = \frac{20^2}{30}$$

$$X_{t(100\%)} = 13,33 \text{ ohms}$$

Therefore, the impedance value of the 20 kV side of the transformer is 13.33 ohms.

After obtaining the  $X_t$  value at 100%, the positive and negative sequence impedance values can be calculated using formula 2.14 as follows:

$$[2.14] X_{t120} = X_t (100\%) \times \% \text{ known Where:}$$

$$X_t (100\%) \text{ 20 kV side} = 13,33 \text{ Ohms}$$

$$\text{Transformer impedance (\% ) on the nameplate} = 12,60 \%$$

Therefore:

$$X_{t120} = 13,33 \times 12,60 \%$$

$$X_{t120} = 1,68 \text{ ohms}$$

Thus, the positive and negative sequence impedance values of the 20 kV side of the transformer are 1.68 ohms or j1.68.

Next is to calculate the zero-sequence impedance of the transformer on the 20 kV side. Based on the data obtained at the 150 kV Suralaya Town Feeder Transformer Substation, the transformer has a vector group YNyn0+d, which means that the transformer has star windings

on the primary and secondary sides. Usually, the zero sequence reactance value is equal to the positive/negative sequence impedance value. Therefore, the zero sequence reactance value ( $X_{t0}$ ) of the transformer can be calculated according to the following formula 2.15:

$$[2.15] X_{t020} = 10 \times X_{t1}$$

Where:

$$X_{t020} \text{ (zero-sequence transformer impedance)} = \dots \text{ Ohm}$$

$$X_{t1} \text{ 20 kV side} = 1,68 \text{ ohm}$$

Therefore:

$$X_{t020} = 10 \times 1,68$$

$$X_{t020} = 16,8 \text{ ohms}$$

Therefore, the impedance value of the zero-sequence transformer on the 20 kV side is 16.8 ohms.

### 3. Calculation of 20 kV Feeder Impedance

The technical data obtained at the 150 kV Suralaya Substation consists of 4 feeders, but only 2 feeders were used in the analysis. The two feeders selected were the Komplek feeder and the OG6 feeder, which are the furthest and closest feeders. The conductor used is AAACS (A3CS) cable with a diameter of 150 mm<sup>2</sup>, and each feeder has a different length. The positive and negative sequence impedance values of the conductor are  $0.2162 + j 0.3305$ , while the zero sequence impedance is  $0.3631 + j 1.6180$ . These values are then considered to occur at disturbance points, namely at positions 0%, 25%, 50%, 75%, and 100% of the feeder length at the 150 kV Suralaya Substation. Thus, the impedance values at the Complex feeder and the OG6 feeder can be determined. a. Complex Feeder. For the Complex feeder, the cable used is of the AAACS (A3CS) type with a diameter of 150 mm<sup>2</sup> and a feeder length of 5.3 km. Based on SPLN 64: 1985, the cable impedance values for the positive and negative sequences are  $Z_1 = 0.2162 + j 0.3305$ , while for the zero sequence it is  $Z_0 = 0.3631 + j 1.6180$ . Thus, the impedance values for the complex feeder can be determined as follows:

#### 1) Positive/Negative Sequence

Table 1 Positive/Negative Sequence Impedance of Complex Feeders

Point (%)	Distance (Km)	Calculation	Positive/Negative Sequence Impedance ( $Z_1 = Z_2$ )
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0 %	0	$0 \times 0,2162 + j 0,3305$	0
25 %	1,325	$1,325 \times 0,2162 + j 0,3305$	$0,2864 + j 0,4379$
50 %	2,65	$2,65 \times 0,2162 + j 0,3305$	$0,5729 + j 0,8758$
75 %	3,975	$3,975 \times 0,2162 + j 0,3305$	$0,8593 + j 1,3137$
100 %	5,3	$5,3 \times 0,2162 + j 0,3305$	$1,1458 + j 1,7516$

### Zero Sequence

Table 2 Zero Sequence Impedance of Complex Feeders

Point (%)	Distance (Km)	Calculation	Zero Sequence Impedance ( $Z_{0eq}$ )
0 %	0	$0 \times 0,3631 + j 1,6180$	0
25 %	1,325	$1,325 \times 0,3631 + j 1,6180$	$0,4811 + j 2,14385$
50 %	2,65	$2,65 \times 0,3631 + j 1,6180$	$0,9622 + j 4,2877$
75 %	3,975	$3,975 \times 0,3631 + j 1,6180$	$1,4433 + j 6,4315$
100 %	5,3	$5,3 \times 0,3631 + j 1,6180$	$1,9244 + j 8,5754$

### b. OG6 feeder

The OG6 feeder uses AAACS (A3CS) type cable with a diameter of 150 mm<sup>2</sup> and a feeder length of 39.95 km. According to SPLN 64: 1985, the cable impedance for the positive and negative sequences is  $Z_1 = 0.2162 + j 0.3305$ , while for the zero sequence it is  $Z_0 = 0.3631 + j 1.6180$ . Thus, the impedance values for the complex feeder can be determined as follows:

### Positive/Negative Sequence

Table 3 Positive/Negative Sequence Impedance of OG6 Transmission Line

Point (%)	Distance (Km)	Calculation	Positive/Negative Sequence Impedance ( $Z_1 = Z_2$ )
0 %	0	$0 \times 0,2162 + j 0,3305$	0
25 %	9,9875	$9,9875 \times 0,2162 + j 0,3305$	$2,1592 + j 3,300$
50 %	19,975	$19,975 \times 0,2162 + j 0,3305$	$4,3185 + j 6,6017$

75 %	29,9625	$29,9625 \times 0,2162 + j0,3305$	$6,4778 + j 9,9026$
100 %	39,95	$39,95 \times 0,2162 + j 0,3305$	$8,8637 + j 13,2034$

Zero Sequence

Table 4 Zero Sequence Impedance of OG6 Transmission Line

Point (%)	Distance (Km)	Calculation	Zero Sequence Impedance Zero ( $Z_{0eq}$ )
0 %	0	$0 \times 0,3631 + j 1,6180$	0
25 %	9,9875	$9,9875 \times 0,3631 + j 1,6180$	$3,6264 + j 16,1597$
50 %	19,975	$19,975 \times 0,3631 + j 1,6180$	$7,2529 + j 32,3195$
75 %	29,9625	$29,9625 \times 0,3631 + j1,6180$	$10,8793 + j 48,4793$
100 %	39,95	$39,95 \times 0,3631 + j 1,6180$	$14,5058 + j 64,6391$

#### 4. Calculation of Equivalent Impedance 20 kV

To determine the value of positive and negative sequence equivalent impedance ( $Z1_{eq} = Z2_{eq}$ ), we can use the following formula:

$$[2.16] Z1_{eq} = Z2_{eq} = X_s(150kV) + X_{t1} + Z1 \text{ feeder}$$

Where:

$X_s$  (20 kV) = 20 kV source impedance

$X_{t1}$  = +/- sequence transformer reactance

$Z1$  = +/- sequence impedance of the conductor (according to the fault point)

To find the zero sequence equivalent impedance value, we use the following formula:

$$[2.17] Z_{0eq} = X_{t0} + 3RN + Z_0 \text{ feeder}$$

Where:

$X_{t0}$  = Zero sequence transformer reactance

$RN$  = Neutral resistance

$Z0$  = Zero-sequence impedance of the conductor (according to the fault point)

Using the same method and formula for calculating equivalent impedance ( $Z1_{eq}$ ,  $Z2_{eq}$ ,  $Z0_{eq}$ ), the equivalent impedance values for the complex feeder and OG6 feeder are obtained as

follows:

a. Equivalent Impedance of Complex Feeder

Positive/Negative Sequence

Table 5 Positive/Negative Equivalent Impedance of Complex Feeder

Point (%)	Distance (Km)	Calculation	Equivalent Impedance Positive/Negative Sequence ( $Z_1 = Z_2$ )
0 %	0	$j 0,082 + j 1,68$	$j 1,762$
25 %	1,325	$0,2864 + j 0,4379 + j 1,762$	$0,2864 + j 2,1999$
50 %	2,65	$0,5729 + j 0,8758 + j 1,762$	$0,5729 + j 2,6378$
75 %	3,975	$0,8593 + j 1,3137 + j 1,762$	$0,8593 + j 3,0757$
100 %	5,3	$1,1458 + j 1,7516 + j 1,762$	$1,1458 + j 3,5136$

Zero Sequence

Table 6 Equivalent Impedance Zero Sequence Complex Feeder

Point (%)	Distance (Km)	Calculation	Zero Sequence Impedance ( $Z_{0eq}$ )
0 %	0	$j 16,8 + (3 \times 0,4) + 0$	$1,2 + j 16,8$
25 %	1,325	$0,4811 + j 2,1438 + 1,2 + j 16,8$	$1,6811 + j 18,9438$
50 %	2,65	$0,9622 + j 4,2877 + 1,2 + j 16,8$	$1,7729 + j 21,0877$
75 %	3,975	$1,4433 + j 6,4315 + 1,2 + j 16,8$	$2,6433 + j 23,2315$
100 %	5,3	$1,9244 + j 8,5754 + 1,2 + j 16,8$	$3,1244 + j 25,3754$

b. Equivalent Impedance of OG6 Transmission Line

Positive/Negative Sequence

Table 7 Positive/Negative Equivalent Impedance of OG6 Transmission Line

Point (%)	Distance (Km)	Calculation	Equivalent Impedance of Positive/Negative Sequence ( $Z_1 = Z_2$ )
0 %	0	$j 0,082 + j 1,68$	$j 1,762$
25 %	9,9875	$2,1592 + j 3,300 + j 1,762$	$2,1592 + j 5,062$
50 %	19,975	$4,3185 + j 6,6017 + j 1,762$	$4,3185 + j 8,3637$
75 %	29,9625	$6,4778 + j 9,9026 + j 1,762$	$6,4778 + j 11,6646$
100 %	39,95	$8,8637 + j 13,203 + j 1,762$	$8,8637 + j 14,965$

### Zero Sequence

Table 8 Zero Sequence Equivalent Impedance of OG6 Feeder

Point (%)	Distance (Km)	Calculation	Zero Sequence Impedance ( $Z_{0eq}$ )
0 %	0	$j 16,8 + (3 \times 0,4) + 0$	$1,2 + j 16,8$
25 %	9,9875	$3,6264 + j 16,1597 + 1,2 + j 16,8$	$1,6811 + j 32,9597$
50 %	19,975	$7,2529 + j 32,3195 + 1,2 + j 16,8$	$1,7729 + j 49,1195$
75 %	29,9625	$10,879 + j 48,4793 + 1,2 + j 16,8$	$2,6433 + j 65,2793$
100 %	39,95	$14,5058 + j 64,6391 + 1,2 + j 16,8$	$3,1244 + j 81,4391$

### 5. Protection Coordination

Calculations to check the selectivity of relay operation using the following formula:

Calculation of OCR operating time on feeders and incoming lines, if the fault location is at 50%, which is 2.65 km from the length of the complex feeder line, as follows:

Complex Feeder (Primary Iset = 504 A and TMS = 0,26 S)

$K$

$t_{act} = \frac{K}{I_s^\alpha - 1} \times TMS$

)

$I_s$

0,14

$$t_{act} = \frac{0,14}{(4.278)^{0,02} - 1} \times 0,26$$

504

$$act = 0,832 \text{ S}$$

Incoming (Primary Iset = 910,4 A and TMS = 0,28 S)

*K*

$$t_{act} = \frac{0,1}{\left(\frac{I_f}{I_s}\right)^{\alpha} - 1} \times TMS$$

$$t_{act} = \frac{0,1}{(4.278)^{0,02} - 1} \times 0,28$$

( )

910,4

$$act = 1,479 \text{ S}$$

Calculation of GFR operating time on the feeder and incoming, if the fault location is at 50%, which is 2.65 km from the length of the complex feeder line, as follows:

Complex Feeder (Primary Iset = 105,4 A and TMS = 0,23 S)

*K*

$$t_{act} = \frac{0,14}{(I_f)^{\alpha} - 1} \times TMS$$

)

*I<sub>s</sub>*

0,14

$$t_{act} = \frac{0,14}{(1.306)^{0,02} - 1} \times 0,23$$

) 105,4

$$act = 0,750 \text{ S}$$

Incoming (Primary Iset = 527 A and TMS = 0,16 S)

*K*

$$t_{act} = \frac{0,14}{(I_f)^{\alpha} - 1} \times TMS$$

)

*I<sub>s</sub>*

0,14

$$t_{act} = \frac{0,14}{(1.306)^{0,02} - 1} \times 0,16$$

)

527

$$act = 1,23 S$$

Using this calculation method, we can also determine the relay operating time based on three-phase and single-phase fault currents of 10% of the feeder length. The calculation results are entered into the following table to facilitate checking the differences in relay operating times.

Table 9 OCR Working Time

L	ocation and Fault Current		OCR Trip Time (s)		
	%	Km	3 Phase (A)	Incoming	Feeder
0	0		6.553	0,973	0,697
25	1,325		5.206	1,107	0,772
50	2,65		4.278	1,247	0,832
75	3,975		3.616	1,402	0,905
100	5,3		3.125	1,574	0,979

Table 10 GFR Working Time

L	ocation and Fault Current		OCR Trip Time (s)		
	%	Km	3 Phase (A)	Incoming	Feeder
0	0		1.701	0,945	0,562
25	1,325		1.477	1,075	0,594
50	2,65		1.306	1,22	0,631
75	3,975		1.166	1,40	0,654
100	5,3		1.054	1,605	0,683

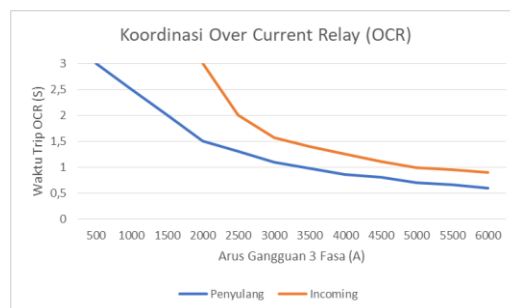


Figure 1 Coordination of Incoming OCR Relay and Feeder

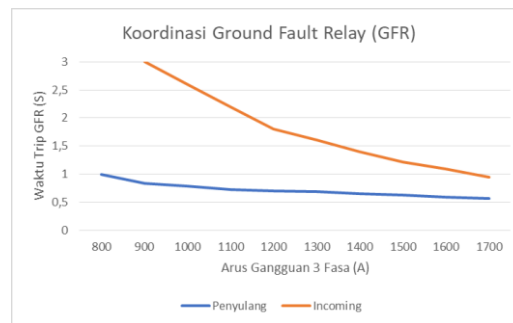


Figure 2 Coordination of Incoming GFR Relay and Feeder

If a three-phase or single-phase disturbance occurs on the distribution network cable, the relay on the feeder will operate and break the circuit within a maximum of 0.7 seconds. If there is a trip failure on the feeder, the incoming relay will trip with an Overcurrent Relay (OCR) time of 0.973 seconds and a Ground Fault Relay (GFR) time of 0.945 seconds. Thus, the time gradient value or delta T between the incoming and feeder is approximately 0.3 seconds.

## 2. Discussion

Based on the above calculations, when the smallest fault current occurs, the relay must be able to detect and respond to the current so that the PMT is disconnected. The smallest fault current in the complex feeder is a single-phase-to-ground current of 1.054 A. In this case, the overcurrent relay in the complex feeder will operate and command the PMT to disconnect because it detects the fault current setting for GFR. The PMT will disconnect within 683 ms or 0.6 seconds. With the same fault current, the relay on the incoming will command the PMT to disconnect within 1.605 seconds. This result is in accordance with protection coordination, namely that the feeder relay must be able to isolate faults on the feeder faster than the incoming relay.

In tests conducted using a non-cascade scheme, it can be concluded that when a fault occurs with a current of 3,500 A on the feeder, the fault indication is visible on the annunciator and the LED works. The feeder PMT trip time is 340 ms while the incoming PMT is not interrupted. The feeder successfully isolates the overcurrent fault. Furthermore, in tests with injection currents of 3,500 A and 12,000 A, both on the feeder and incoming, both the

annunciator and LED showed indications of OCR moment or overcurrent moment working. The purpose of this test was to determine the start moment because the CBF signal was interrupted and the feeder failed to disconnect the PMT, so that the start moment dataset input worked and the incoming received the signal, thereby commanding the incoming PMT to disconnect within 725 ms. The final test was conducted with the same current on the feeder and incoming, resulting in an OCR moment indication. The annunciator on the incoming unit shows indications of OCR moment and CBF, meaning the incoming unit detects the presence of moment current. CBF indicates that the feeder failed to disconnect its PMT, causing the incoming PMT to disconnect within 552 ms, which is faster than in the second test when the CBF signal was interrupted.

## CONCLUSION

The results shown below are the results of the discussion, calculations, and analysis carried out in this chapter.

The magnitude of the fault current and the duration of relay operation are influenced by the length of the network or the location of the fault in the short-circuit current calculation. The distance between the fault location and the source (substation) is inversely proportional to the magnitude of the short-circuit current and directly proportional to the relay operating time.

In the OCR setting calculation on the incoming side, a primary Iset of 910.4 A and TMS of 0.28 were obtained with an actual operating time of 1 second. For the GFR setting, a primary Iset of 527 A and TMS of 0.16 were obtained with an actual operating time of 1 second. Meanwhile, in the OCR calculation on the feeder side, the primary Iset value obtained was 504 A and TMS 0.26 with an actual operating time of 0.69 seconds. In the GFR calculation, the primary Iset obtained was 105.4 A and TMS 0.23 with an actual operating time of 0.68 seconds. These calculations show that the feeder relay operating time is faster than the incoming relay. There is a difference between the calculation results and the application in the field. This is due to the settings applied by PT. PLN Disbanten, which are adjusted to the conditions in the field, namely that the load of each transformer in the substation is different. The location of the disturbance also affects the magnitude of the disturbance current and the operating speed of the relay, and contributes to variations in the relay response time. The

greater the distance from the location of the disturbance, the greater the difference in the operating duration of the 20 kV incoming relay. The objective is for the relays on the feeder to function as primary protection in the event of a short circuit on the network, while the incoming relays function as secondary backup in the event of feeder relay failure. Furthermore, when looking at the coordination curve between the incoming and feeder relays, it can be seen that they do not intersect. Therefore, it can be concluded that the OCR relays on the 20 kV incoming and feeder are well coordinated.

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