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Sympathetic Trip Analysis in Distribution System of PLTU and PLTA Nagan Raya

Muhammad Mizwar[a], Tarmizi[a], Ramzi Adriman[a]

[a]Universitas Syiah Kuala

E-mail: mhd_m@mhs.unsyiah.ac.id

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Abstract

At the PT unit, PLN (Persero), there is an issue with the 20 kV electric power distribution system, such as feeder disruption. As a result, many felt sorry for the feeders of PLTA Krueng Isep and PLTU Nagan Raya, whose consumers were without power for extended periods of time. Of course, it can impact how well a business performs, particularly in terms of service and electrical revenue. In order to examine the causes of Sympathetic, study is required. In order to conduct the research, data on disturbances are gathered, tests are run, simulation results are analyzed using the ETAP application, non-directional relays are swapped out for directional relays, protection coordination is reset, and evaluation is done. The findings of this study have the potential to improve performance at PT. PLN (Persero) and decrease or even completely eradicate the incidence of sympathy in the 20 kV distribution network.

Keywords*: Sympathetic Trip, Directional Relay, Over Current, Ground Fault*

Abstrak

Terdapat permasalahan pada sistem penyaluran tenaga listrik distribusi 20 kV di unit PT. PLN (Persero), seperti terjadinya gangguan penyulang. Hal ini mengakibatkan Sympathetic pada penyulang PLTU Nagan Raya dan PLTA Krueng Isep, pelanggan merasakan pemadaman listrik dalam waktu yang lama. Tentu saja dapat mempengaruhi kinerja perusahaan terutama pelayanan dan pendapatan penjualan tenaga listrik. Oleh karena itu dibutuhkan suatu penelitian untuk menganalisa penyebab terjadinya Sympathetic. Metode penelitian yang dilakukan dengan mengumpulkan data gangguan yang terjadi, menganalisa dari hasil simulasi menggunakan aplikasi ETAP, melakukan pengujian, penggantian relai non direksional menjadi relai direksional, melakukan resetting koordinasi proteksi serta evaluasi. Hasil penelitian ini memberikan pengaruh dapat mengurangi bahkan menihilkan terjadinya Sympathetic pada jaringan distribusi 20 kV dan memberi dampak kepada peningkatan kinerja di PT. PLN (Persero).

Kata kunci*: Trip Simpatik, Relai Direksional, Over Current, Ground Fault*

Introduction

Reliability in the power distribution system, especially on the 20 kV distribution side, is something that must be prioritized by an electrical company, especially PT PLN (Persero). Moreover, the reliability of the 20 kV distribution system is one of the performance indicators that depict the quality of electricity service to the community [1]. The reliability of this system is also closely related to PLN's electricity sales revenue[2]. If the 20 kV distribution system is disrupted, then the power supply to customers is also disrupted, leading to power outages either momentarily or for extended periods. In fact, outages don't just occur in the disrupted system area but can also happen in areas where no fault has occurred at all, resulting in widespread power outages[3]. This can occur because the undisturbed protection system mistakenly reads or interprets the conditions of another protection system experiencing overcurrent or ground fault faults[4]. This event is commonly referred to as a Sympathetic Trip or Secondary Trip.

Coordinating protection on relays becomes more difficult in complex 20 kV distribution network systems, like spindle, loop, or branching parallel networks, because multiple relays will sense the fault currents of 3-phase short circuits, phase-to-phase, or phase-to-ground passing through them[5],[6]. These faults can cause voltage dips and transient over voltages at the common busbar in the junction substation or main substation. The occurrence of voltage dips can range from 0.1 s to 0.3 s, and Transient Over Voltage can occur in 0.001 s, and the direction of current flow will head to the point of fault. This implies that feeders that are left undisturbed may still trip[7]. This occurs because the installed system in the power distribution still uses a non-directional Over Current Relay / Ground Fault Relay and the protection coordination is not yet sufficient[8].

Method

The methodology is outlined in the research flowchart shown in Figure 1, as follows:

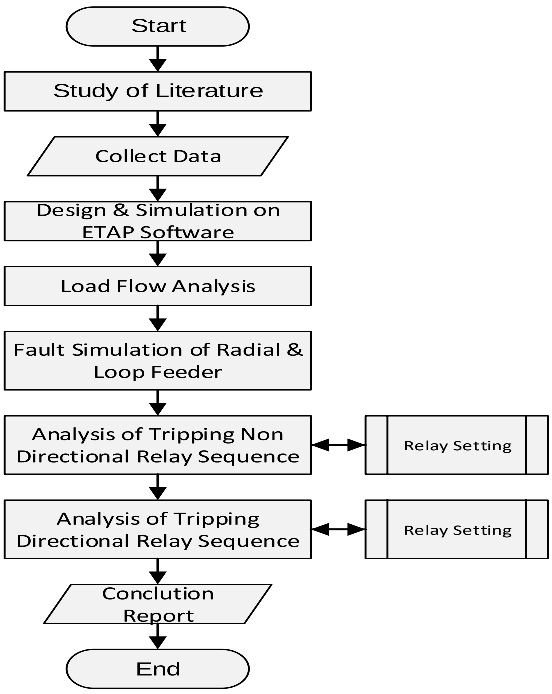


Figure 1. Research Flowchart

The first stage in doing this study is gathering basic data from PT. PLN (Persero) UP2D Aceh. Relay settings, CT ratios, and system loads are among the information gathered. The system must then be designed, and ETAP must be used to do simulations. Prior to receiving analysis results, it is necessary to ascertain the relay coordination sequence during a trip, do many fault checks on the system, and comprehend the power flow from that system.

a. Over Current Relay (OCR)

When there is an overcurrent fault, the Over Current Relay (OCR) functions by comparing the set current to the current on the relay's primary side. The relay does not function if the primary side current is less than the set current[4]. The relay functions when the primary side current exceeds the predetermined current. Depending on how they function, overcurrent relays can be divided into multiple categories [1], including; Instantaneous, the relay operates without any time delay. The set time is usually 0 milliseconds because the fault current flowing can be very large, possibly exceeding 2 times the nominal current[9].

Time Delay, when a time-delay relay is activated, it disconnects the system from problems after a predetermined amount of time—usually more than 0.1 seconds[10]. Inverse Time and Definite Time Delay are two more categories for characteristics involving time delays[4]. Definite Time Delay operates with a specific delay time; when the set threshold of fault current is reached, the relay will command the Circuit Breaker (CB) to trip. On the other hand, the Inverse Time Relay operates with varying times depending on the magnitude variation of the fault current. Based on the steepness of the curve, Inverse Time is further divided into Standard Inverse Time (SIT), Very Inverse Time (VIT), and Extremely Inverse Time (EIT)[7].

Standard Inverse (SI) $t = TMS \times \left(0{,}14 \big/ (PSM)^{0{,}02} - 1 \right)$ .... (1)

Very Inverse (SI) $t = TMS \times \left(13{,}5 \big/ PSM \quad -1 \right)$ .... (2)

Extremly Inverse (SI) $t = TMS \times \left(80 \big/ (PSM)^{2} - 1 \right)$ .... (3)

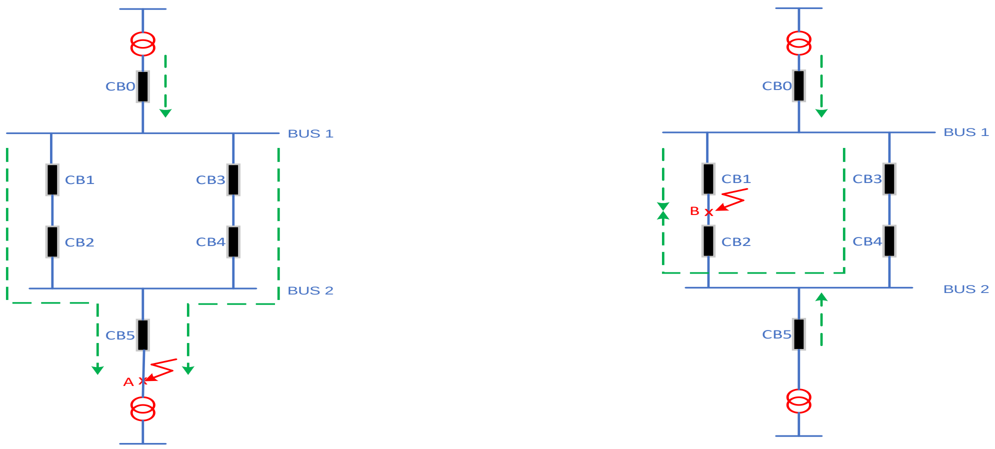
Long Time Standard Earth Fault (SI) $t = TMS \times \left(120 \big/ PSM - 1 \right)$ .... (4)

Plug Setting Multiplier (PSM) = $\left(I_f \big/ I_{pu} - CTRatio \right)$ .... (5)

Note :
TMS : *Time Multiplier Setting*
I_f : Fault Current
I_{pu} ; *Pick Up* Current of Relay

b. Directional Relay

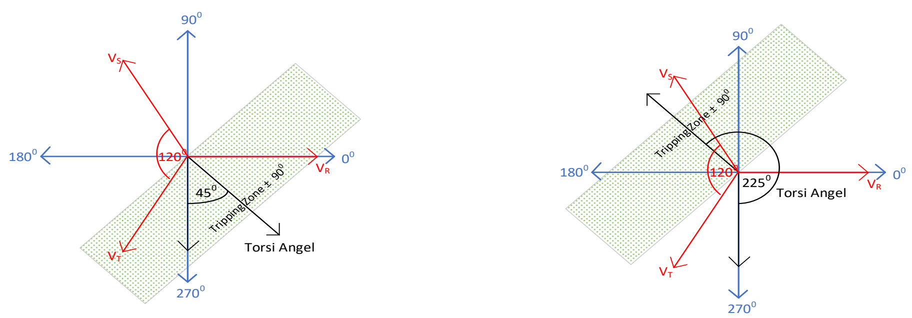
The protection system becomes complex when it stops being radial and becomes parallel or looping. Because of the complex relay coordination needed to isolate only the disturbed zone, relying only on overcurrent relays with a time delay is not sufficient[3]. In actuality, there's a chance that issues in one zone could cut off the supply to unaffected zones[1].



(a) (b)

Figure 2. (a) Loop System with fault at Point A and (b) Loop System with fault at Point B.

If we assume a disturbance occurs at Point A, then the current will flow from Bus 1 through CB1, CB2, CB3, and CB4, and from Bus 2 through CB5 towards Point A. As a result, the relay on each of those Circuit Breakers (CB) will detect this and command the CB to trip, potentially causing the entire load supplied from Bus 1 to be interrupted[11]. Similarly, if a disturbance occurs at Point B, the same kind of event that happened at Point A could possibly occur again. Thus, in order to solve this problem, directional relays must be used. The direction of the disturbance current flowing through the system is read by directional relays, and if the specified direction coincides with the disturbance, the relay will trigger a trip[10]. The relay will block (not trip) if it doesn't.



(a) (b)

Figure 3. (a) Forward Directional Relay Characteristics and (b) Reverse.

In Figure 3. (a), the phasor diagram for the Forward setting is shown. With a Torque Angle setting where the disturbance current lags by 45° relative to the voltage and the relay operates within a trip zone range of -90° to +90°. Thus, if a disturbance occurs in the direction of the trip zone range, the relay will operate; otherwise, the relay won't operate (blocking). Figure 3. (b) displays the phasor diagram for the Reverse setting, with a Torque Angle of 225° relative to the voltage (leading). The relay operates within a range of -90° to +90° relative to the Torque line. If a disturbance occurs with the disturbance current leading, the relay will command the Circuit Breaker (CB) to trip; otherwise, the relay won't operate (blocking).

c. System Design

The distribution grid system design for the Krueng Isep Hydroelectric Power Plant and the Nagan Raya Thermal Power Plant is shown below, using a sample of the highest load.

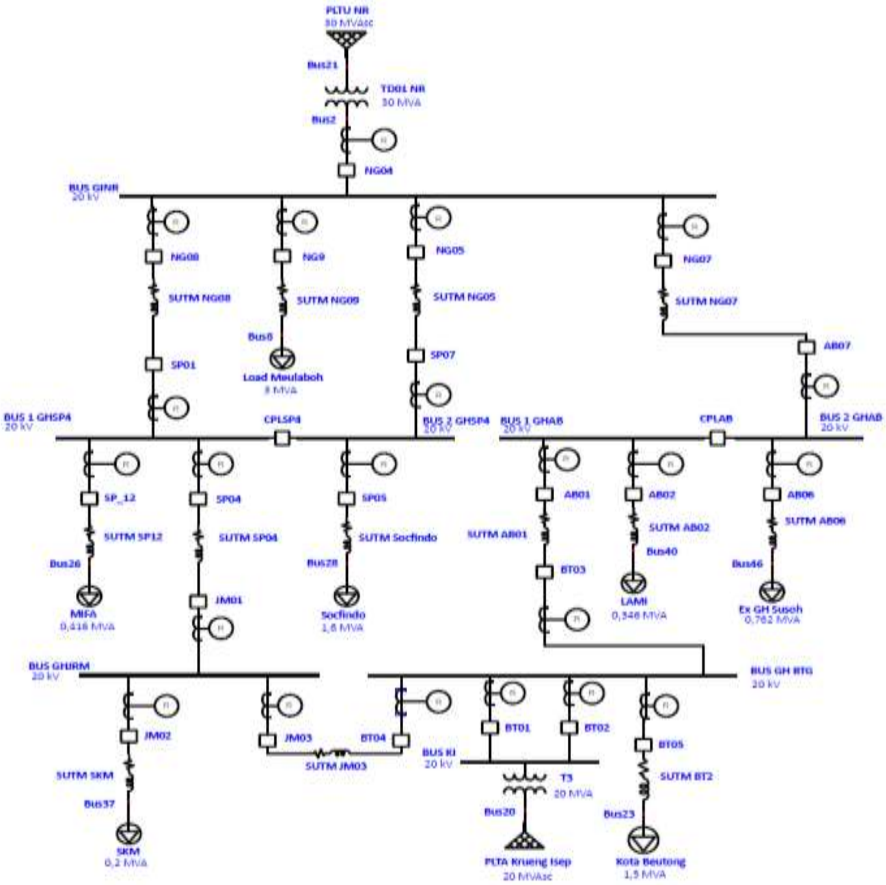


Figure 4. Single Line Diagram of the System

The installed power capacity supplying the Nagan Raya Main Substation (Bus GINR) is 30 MVA and the Krueng Isep Connection Substation (Bus KI) is 20 MVA. The incoming voltage from the Nagan Raya Thermal Power Plant system is stepped down from 150 kV to 20 kV, while the Krueng Isep Hydroelectric Power Plant is stepped up from 6 kV to 20 kV. This ensures that the systems can be synchronized. In this research, only a few radial and loop feeders from each connection substation and main substation were taken as samples for simulation and analysis. The GI Nagan Raya has 5 feeders, GH SP4 has 5 feeders, GH Alue Bilie has 4 feeders, GH Jeuram has 3 feeders, and GH Beutong has 5 feeders.

Table 1. Cable Data

Line/Cable/Busway	ohms or siemens per 1000 m per Conductor (Cable) or per Phase (Line/Busway)		Length									
ID	Library	Size	Adj (m)	% Tol.	#Phase	T (°C)	R1	X1	Y1	R0	X0	Y0
SUTM AB01	20OALS1	150	25000.0	0.0	1	75	0.2263007	0.3002000		0.6789020	0.7500000	
SUTM AB02	20OALN1	70	5000.0	0.0	1	75	0.5052937	0.3406000		1.5245520	0.8500000	
SUTM AB06	20OALS1	240	15000.0	0.0	1	75	0.1392107	0.2692000		0.3959071	0.2770000	
SUTM BT2	20OALN1	70	7000.0	0.0	1	75	0.5052937	0.3406000		1.5245520	0.8500000	
SUTM JM03	20OALS1	240	11000.0	0.0	1	75	0.1392107	0.2692000		0.3959071	0.2770000	
SUTM NG05	20OALS1	240	17500.0	0.0	1	75	0.1392107	0.2692000		0.3959071	0.2770000	
SUTM NG07	20OALS1	240	40000.0	0.0	1	75	0.1392107	0.2692000		0.3959071	0.2770000	
SUTM NG08	20OALS1	240	17500.0	0.0	1	75	0.1392107	0.2692000		0.3959071	0.2770000	
SUTM NG09	20OALS1	150	2400.0	0.0	1	75	0.2263007	0.3002000		0.6789020	0.7500000	
SUTM SKM	20OALN1	70	10000.0	0.0	1	75	0.5052937	0.3406000		1.5245520	0.8500000	
SUTM Socfindo	20OALS1	150	10000.0	0.0	1	75	0.2263007	0.3002000		0.6789020	0.7500000	
SUTM SP04	20OALS1	240	18000.0	0.0	1	75	0.1392107	0.2692000		0.3959071	0.2770000	
SUTM SP12	20OALS1	150	2400.0	0.0	1	75	0.2263007	0.3002000		0.6789020	0.7500000	

Line / Cable / Busway resistances are listed at the specified temperatures.

In Table 2, one can observe the protection system settings for each feeder, using a combination of non-directional OC/GF relays and directional OC/GF relays. For OCR, the SIT (Standard Inverse Time) curve is used, OCR Instant uses the DI (Definite Time) curve, GFR uses the SIT curve, and GFR Instant uses the DI curve. However, the protection settings in the table still use non-directional relays[11]. As a result, some feeders experience sympathetic trip disturbances in the loop system, and radial feeders also trip when there's a disturbance in other feeders. The simulation sequence of feeder trips during disturbances can be seen in the subsequent discussion in the table.

Table 2. Actual Protection Settings

NO	GARDU INDUK/GARDU HUBUNG	NAMA PENYULANG	DATA SETTING RELAY												CT PRIMER	CT SEKUNDER
			50/51-1(OCR)			50/51-2(Inst OCR)			50N/51N-1(GFR)			50N/51N-2(Inst GFR)				
			Iset(A)	T.Dly(ms)	Kurva	Iset(A)	T.Dly(ms)	Kurva	Iset(A)	T.Dly(ms)	Kurva	Iset(A)	T.Dly(ms)	Kurva		
1	GI NAGAN RAYA (GINR)	NG04 / INC PLTU NR	800	110	SIT	5000	0	DEF	80	100	SIT	240	110	DEF	800	5
2		NG05 / EXP. GH SP4	400	110	SIT	2500	0	DEF	27	100	SIT	240	100	DEF	600	5
3		NG07 / EXP. GH ALUE BILIE	400	110	SIT	2500	0	DEF	28	100	SIT	240	100	DEF	400	5
4		NG08 / EXP. GH SP4	400	110	SIT	2500	0	DEF	28	100	SIT	240	100	DEF	400	5
5		NG09 / MEULABOH	400	110	SIT	2500	0	DEF	28	100	SIT	240	100	DEF	400	5
1	GH SP PEUT (GHSP4)	SP 01 / INC. NG 08	400	150	SIT	1000	0	DEF	28	150	SIT	150	50	DEF	400	5
2		SP 04 / EXP. JEURAM	400	150	SIT	800	0	DEF	28	120	SIT	120	30	DEF	400	5
3		SP 05 / SOCFINDO	120	80	SIT	500	0	DEF	20	80	SIT	100	0	DEF	200	5
4		SP 07 / INC NG 05	400	150	SIT	1000	0	DEF	28	150	SIT	150	50	DEF	400	5
5		SP 12 / MIFA	75	100	SIT	500	0	DEF	15	100	SIT	100	0	DEF	100	5
1	GH ALUE BILIE (GHAB)	AB 01 / INC SP PEUT	250	150	SIT	OFF	OFF	OFF	40	150	SIT	OFF	OFF	OFF	400	5
2		AB 02 / LAMI	100	120	SIT	200	100	DEF	40	100	SIT	80	90	DEF	100	5
3		AB 06 / EXP. GH SUSOH	200	150	SIT	250	100	DEF	30	150	SIT	50	100	DEF	200	5
4		AB 07 / INC NG 7	350	150	SIT	1000	0	DEF	40	150	SIT	150	80	DEF	400	5
1	GH JEURAM (GHJRM)	JM 01 / INC SP 04	400	120	SIT	600	0	DEF	22	120	SIT	120	20	DEF	400	5
2		JM 02 / SKM	80	100	SIT	250	0	DEF	15	100	SIT	80	0	DEF	100	5
3		JM 03 / EXP. BEUTONG	350	120	SIT	500	0	DEF	40	100	SIT	100	50	DEF	400	5
1	GH BEUTONG (GHBTG)	BT 01 / INC PLTA 630	250	250	SIT	3000	500	DEF	40	300	SIT	240	100	DEF	500	5
2		BT 02 / INC PLTA 240	250	200	SIT	1000	500	DEF	40	300	SIT	240	100	DEF	600	5
3		BT 03 / EXP. ALUE BILIE	250	100	SIT	500	100	DEF	40	100	SIT	150	100	DEF	400	5
4		BT 04 / EXP. JEURAM	350	100	SIT	500	0	DEF	40	100	SIT	80	50	DEF	400	5
5		BT 05 / KOTA BEUTONG	60	100	SIT	200	0	DEF	10	100	SIT	50	0	DEF	100	5

d. Power Flow Simulation

In Figure 5, the power flow of the Nagan Raya Thermal Power Plant (PLTU) and Krueng Isep Hydroelectric Power Plant (PLTA) systems is synchronized. It can be seen that the power flow of the feeder supplied from the Nagan Raya Thermal Power Plant flows entirely to the Nagan Raya Main Substation (GI Nagan Raya). Some other loads are supplied from feeders NG05 and NG08 in parallel at GH SP4, while NG07 supplies power up to GH Alue Bilie, with a total active power of 4033 kW and reactive power of 2682 kVar. The largest load is supplied to feeder NG06, or the city load of Meulaboh, from the Nagan Raya Main Substation. The loads taken as samples at GH SP4 are feeders SP12 (MIFA) and SP05 (Socfindo). There is a distribution voltage drop at the bus of GI Nagan Raya from 20 kV to 19.76 kV (1.2%), while at bus 1 and bus 2 of GH SP4, the received voltage is 19.59 kV. The power flow in the Krueng Isep Hydroelectric Power Plant system supplies power entirely to GH Jeuram and GH Beutong and partly to GH Alue Bilie and GH SP4. The total power flowing from the Krueng Isep Hydroelectric Power Plant is 2632 kW with a reactive power of 1540 kVar. The received voltage at GH Jeuram is 19.72 kV, at GH Beutong it's 19.83 kV, and at GH Alue Bilie it's 19.53 kV.

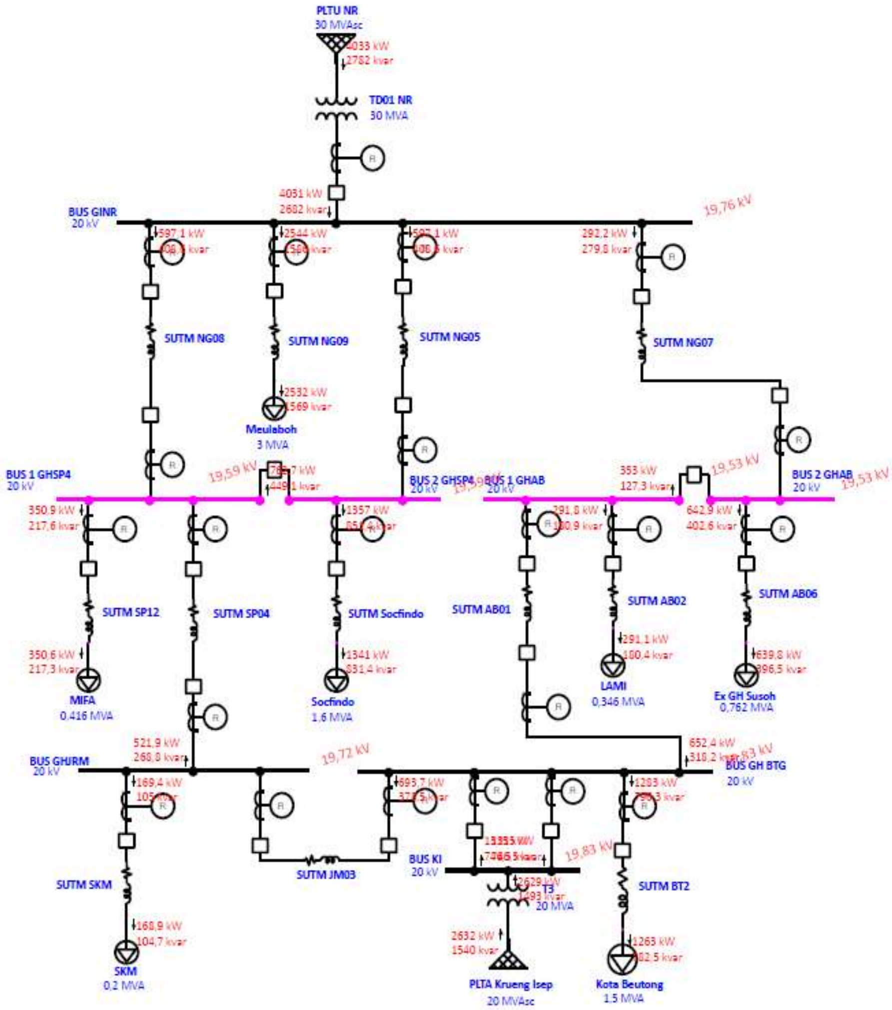


Figure 5. Power Flow Analysis

e. Short Circuit Analysis

The single line simulation of short-circuit disruptions at each bus is shown in Figure 6. Because the conductor's resistance decreases, the current flow is always directed toward the disturbance point. Consequently, this disturbance current will be detected by the relay that the current passes through. In this simulation, short-circuit current testing was conducted on the bus of each connection substation and main substation. The magnitude of the disturbance current at the Nagan Raya Main Substation (GI Nagan Raya) is 2.174 kA, at GH SP4 it's 1.948 kA, at GH Alue Bilie it's 1.37 kA, at GH Jeuram it's 1.658 kA, and at GH Beutong it's 1.754 kA.

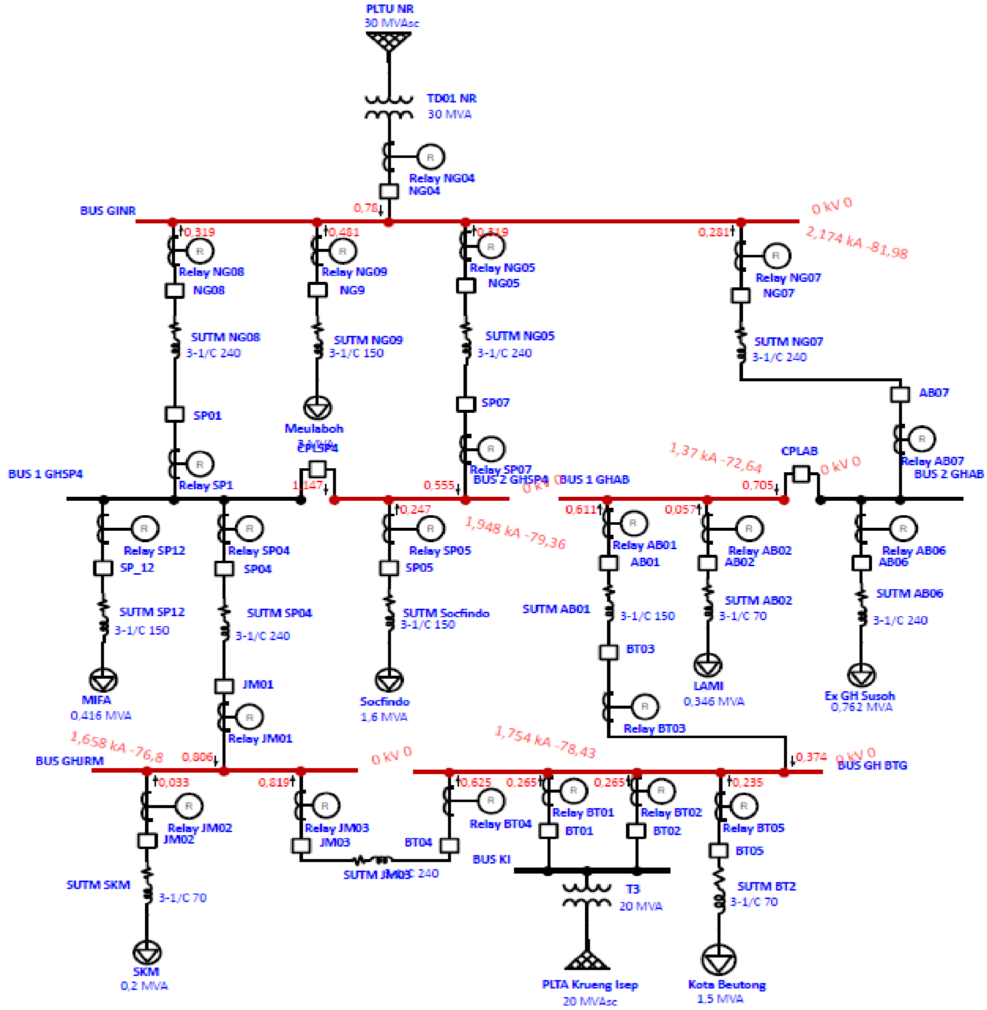


Figure 6. Short Circuit Analysis

Results and Discussion

a. Fault Simulation in Radial Network with Non-Directional Relay

For the disturbance simulation, the maximum limit set was for 9 Circuit Breakers (CB) to operate and to detect up to 9 levels from the bus whose feeder is disturbed, using the ETAP 19 application with the Adaptive Newton Raphson method. Table 3 shows testing on the radial network using non-directional relays. Seven radial feeders were taken as samples. The test results indicate that the relays operate as they should. This means that when a feeder is disturbed, the relay immediately commands the CB on that feeder to trip. If the CB on the disturbed feeder fails to operate, other CBs will be commanded by the relay to trip. However, it can be observed here that another radial feeder, BT05, during each relay test always detects the disturbance current, causing the CB to trip when it ideally shouldn't.

Table 4. Simulation of Non-Directional Radial Feeder Trip

No	Fault Reader	1	2	3	4	5	6	7	8	9
1	NG09	NG09	BT05	JM01	NG04	NG09	SP04	SP05	BT04	JM03
2	SP12	SP12	NG05	NG08	BT05	SP05	BT04	JM01	JM03	NG09
3	SP05	SP05	BT04	BT05	JM01	JM03	NG08	SP01	SP04	SP07
4	AB02	AB02	NG07	AB01	BT03	BT05	AB06	SP05	NG09	NG04
5	AB06	AB06	NG07	AB01	AB07	BT03	BT05	SP05	NG09	NG04
6	JM02	JM02	BT04	BT05	JM01	JM03	SP04	SP05	NG08	SP01
7	BT05	BT05	BT04	JM01	JM03	SP04	Ab01	BT03	SP05	NG09

b. Fault Simulation in Loop Network with Non-Directional Relay

Table 5 displays the results of the simulation sequence of trips in feeders that are looped with other feeders. There were 12 disturbance simulations conducted on looped feeders. The results show that all feeders did not operate as expected. In the first simulation, the disturbance occurred near the CB NG08, and the first CB commanded by the relay to trip was CB NG08, which was correct. However, since the system is still looped (in parallel) with others, the next relay that should operate is the one at SP01, so the CB SP01 trips to interrupt the disturbance current flowing from all directions. But this relay didn't work; instead, the NG09 relay and subsequent ones commanded the trip. The same issue arose in tests on other samples, such as feeder NG05. The first CB that the relay commanded to trip was correct, which is CB NG05, but the subsequent CB that should have tripped is SP07, not CB NG09, BT05, and so on. This could result in widespread power outages, and the system might even go into a blackout.

Table 5. Simulation of Non-Directional Loop Feeder Trip

No	Fault Reader	1	2	3	4	5	6	7	8	9
1	NG08	NG08	NG09	BT05	BT04	JM01	JM03	NG04	SP04	SP05
2	SP01	SP01	NG05	NG08	BT05	SP05	SP01	BT04	JM01	JM03
3	NG05	NG05	NG09	BT05	BT04	JM01	JM03	NG04	SP04	SP05
4	SP07	SP07	NG05	NG08	BT05	SP05	SP01	BT04	JM01	JM03
5	NG07	NG07	NG09	BT05	BT04	JM01	JM03	NG04	SP04	SP05
6	AB07	BT03	NG07	BT05	AB01	AB07	AB06	NG09	NG04	BT04
7	SP04	SP04	NG05	NG08	BT05	SP05	BT04	JM01	JM03	NG09
8	JM01	BT04	JM01	JM03	SP04	BT05	SP04	SP05	NG08	SP01
9	AB01	BT03	NG07	BT05	AB01	AB07	AB06	SP05	AB02	NG09
10	BT03	BT04	BT05	JM03	BT03	AB01	JM01	JM03	SP04	SP05
11	JM03	BT04	JM01	JM03	SP04	BT05	SP04	SP05	NG08	SP01
12	BT04	BT04	BT05	JM03	AB01	BT03	JM01	JM03	SP04	SP05

It is clear from the outcomes of the two simulations above that there are still issues with the relay coordination in the system. Therefore, in order to achieve greater synchronization, a more selective relay setting is required. Using a Directional Relay is an additional option in addition to adjusting settings.

Conclusion

From the analysis results of the relay coordination simulation in the Nagan Raya Thermal Power Plant (PLTU) and Krueng Isep Hydroelectric Power Plant (PLTA) systems, it can be concluded that a more complex relay coordination system is required.

The system may experience widespread outages, even leading to a blackout. This is due to the synchronization (parallel connection) of several buses or multi-tiered keypoints. Additionally, a more selective type of relay is needed, namely the use of directional relays in parallel feeder systems.

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