Jurnal Teknologi Informasi dan Pendidikan
Volume 16, No. 2, September 2023
https://doi.org/10.24036/jtip.v16i2.785

P.ISSN: 2086 – 4981
E.ISSN: 2620 – 6390
tip.ppj.unp.ac.id

Power System Analysis of Steam Power Plant Using ETAP at ULPL Indralaya, South Sumatra

Thriska Dewi Umi Rasyda [1]*✉, Arif Nur Afandi [1] , Yuni Rahmawati [1]
[1]Faculty of Engineering, Universitas Negeri Malang, Indonesia
**Corresponding Author: thriskadewi.umi.2105348@students.um.ac.id*

Article Information

Article history:

No. 785
Rec. August 30, 2023
Rev. October 23, 2023
Acc. October 24, 2023
Pub. October 28, 2023
Page. 1 – 20

Keywords:

- *Load Flow*
- *Short Circuit*
- *Coordinating Relay*
- *ETAP 19.0.1*

ABSTRACT

PT PLN (Persero) UPDK Keramasan has three group work units in South Sumatra Province, which is the study area located in Ogan Ilir Regency, namely PT. PLN ULPL Indralaya. This study shows that one steam turbine generator unit often experiences shutdown due to several factors. One of them is out of service for the protection operating system on the 4 MVA to 11.5/6.9 kV transformer unit when there is a disturbance, so that there is an inter-trip to the upstream system, which results in a blackout system. We analyzed the disturbance using ETAP software. We made three analyses load flow, short circuit and relay coordination. As the study results submitted to PT PLN ULPL Indralaya are to scenario 3, for the analysis of the resulting lower flow, there is a decrease in load of about 63% for the short circuit value obtained between 0.011 and 50.776 kA. Also, relay coordination should include devices such as the IDMT curve Long Time Inverse.

How to Cite:

T. D. Umi Rasyda, "Power System Analysis of Steam Power Plant Using ETAP at ULPL Indralaya South Sumatra", JTIP, vol. 16, no. 2, pp. 1-20, Oct. 2023.

1. INTRODUCTION

PT. PLN ULPL Indralaya is a combined cycle plant with a high level of efficiency that utilizes the residual heat or exhaust gas of GT 1.1 and GT 1.2 to heat feed water so as to produce steam, which is then flowed to rotate the ST 1.0 steam turbine [1]. The source of production water for the Indralaya PLTGU is supplied from the river resource [2], water from the Klekat River in Klekat Village and Tanjung Seteko Village, North Indralaya District, Ogan Ilir Regency. PLN UPDK Keramasan Indralaya ULPL has 3 generator units : 2x40 MW (gas turbine generator) [3] and 1x40 MW (steam turbine generator) [4]. The steam turbine generator unit (ST 0.1) often experiences shutdowns due to several factors. One of them is out of service for the protection operating system on the 4 MVA, 11.5/6.9 kV transformer unit during a disturbance, so that an interruption occurs to the upstream system, which results in a blackout system [5]. In electric power systems, disturbances often occur, including symmetrical and asymmetrical [6].

Electrical energy in the house usually comes from PLN. Where in general, the generating company uses a steam power plant system to distribute electrical energy to each region. The steam turbine is an important component that cannot be ignored in an electricity system. In the steam turbine, the steam pressure energy will be converted into kinetic energy as the steam flows through the nozzle. The conversion of kinetic energy is done mechanically by working on the blades and rotors connected to the steam turbine generator, which functions as a mediator. The turbine generator collects mechanical energy from the rotor and converts it into electrical energy [7].

In a power system, to keep it safe to operate even though one or several elements are experiencing a disturbance, a power system analysis is needed. Power system analysis aims [8] as follows:

1. To model or perform phase analysis of power system components
2. To regulate voltage at different buses, real and reactive power flow between buses
3. To plan the future development of the current system
4. To analyze the system under different fault conditions and based on different scenarios
5. To design protection devices, as well as to investigate the ability of the system to handle small and large disturbances or any faults.

Many software packages [9], [10] are available for power system analysis studies, including ETAP [11], [12], Easy Power, DigSilent, Matlab, and others. Many things must be considered in an electrical system, including the distribution network (from the power source to the load). In this system, the power generated from several sources (PLN or generator) is not used at 100% load. This is due to the resistance of the line, which causes power losses to be converted into heat, and the type of load connected to the line (resistive, inductive, or capacitive). ETAP functions allow us to work with or analyze many things on a single line graph, including power flow analysis, short circuit, and overcurrent relay coordination. The software is designed with three main concepts, viz: virtual reality functionality, full data integration, and ease of data entry. ETAP 19.0.1 has several benchmarks, such as: standards used in the installation (ANSI or IEC), frequencies, and cell types (AC cells, instrument cells, or DC cells), different types of alarms and security types. ETAP 19.0.1 is the best software to analyze the entire power system [12]–[14].

2. THE COMPREHENSIVE THEORETICAL BASIS

2.1. Load Flow

Load flow is the power generated by generators and transmitted to the load through transmission lines. Load flow studies are the first step in designing a new system and also the first step in determining the appropriate equipment for the input power. It also has other functions to determine the bus voltage and phase angle as well as knowing the active and reactive power of the line.

There are 3 types of buses in the system, where buses can be defined as follows [8].

1. Slack Bus is connected to the generator and has a fixed magnitude and phase angle. This bus serves to include losses and is used to facilitate calculations.
2. PV bus (generator side), for this type of bus, the voltage and active power, reactive power and voltage phase angle are determined from the calculation results. The bus is connected to the generator.
3. BUS PQ for this type of bus is known active power and reactive power, the other two are obtained from the calculation results. The bus is connected to the load.

As following is the general power flow equation [6]:

$$P_i - JQ_i = V_i^* \sum_{j=1}^{n} Y_{ij} V_j \tag{1}$$

Where :

P = Active power
Q = Reactive power
V = Voltage
Y = Adminttance

The Newton Raphson method has advantages in mathematical calculations over other methods. Large power systems are suitable for using the Newton-Raphson method because it is more efficient and practical. The Newton Raphson method is a method used to solve power flow equations with one variable and multiple variables.

In this case, the separation of active power and reactive power at bus-i. This separation will produce a set of nonlinear simultaneous equations in polar coordinates [15].

$$|V_i| \angle \delta_i = |V_i| e^{j\delta} i \tag{2}$$

$$|V_j| \angle \delta_j = |V_j| e^{j\delta} j \tag{3}$$

$$|V_{ij}| \angle \delta_{ij} = |Y_{ij}| e^{j\delta} ij \tag{4}$$

Because of $e^{j(\delta_j - \delta_i + \theta_{ij})} = \cos(\delta_j - \delta_i + \theta_{ij}$ so, the separation of power at bus-i into real and imaginary components is [15].

$$\begin{aligned} P_i - JQ_i &= |V_i| \angle - \delta_i \sum_{j=1}^{n} Y_{ij} V_j \angle \theta_{ij} + \delta_i \\ &= |V_i|\, e^{-j\delta} \sum_{j=1}^{n} Y_{ij} V_j \angle \left(e^{j\left(\delta_j - \delta_i + \theta_{ij}\right)}\right) \end{aligned} \tag{5}$$

$$P_i = \sum_{j=1}^{n} |V_{ij}V_jY_{ij}|\cos(\delta_j - \delta_i + \theta_{ij}) \quad (6)$$

$$Q_i = \sum_{j=1}^{n} |V_{ij}V_jY_{ij}|\cos(\delta_j - \delta_i + \theta_{ij}) \quad (7)$$

The active power (P_i), reactive power (Q_i) values are known, but the voltage (V_i) and degree (δ_i) values are unknown except at the slack bus. The two nonlinear equations can be decomposed into a set of linear simultaneous equations by expressing the relationship between changes in active power ΔP_i reactive power ΔQ_i to changes in voltage magnitude ΔV_i voltage phase degree $\Delta\delta_i$.

2.2. Short Circuit

Short circuit faults are one of the causes of electrical system faults. This fault is caused by phase wires connected to the ground or other phase wires. As a result of this short circuit, a large current is generated at the fault point. This current comes from additional currents from the power grid, generators and AC electric motors, so the fault has a very high current value and can damage electrical equipment around the fault. As a result, the voltage around the fault can drop significantly. Short circuits can be caused by lightning, insulation failure or interference from tree branches and animals. Short faults can occur two phase, three phase, one phase to ground, two phase to ground or three phase to ground. The short circuit pattern itself can be classified into two groups, namely symmetrical short circuit patterns and asymmetrical short circuit patterns [8], [16].

Figure 1 shows the symmetry short-circuit fault or balanced short-circuit fault is a fault that occurs on all three phases, so that the current and voltage of each phase remain balanced after the fault occurs.

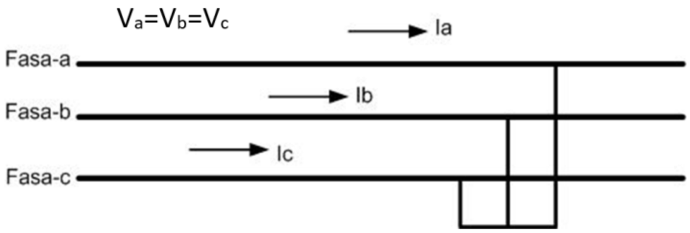


Figure 1. Three-Phase Short-Circuit disorder

This fault can be analyzed using the positive sequence component only [17], as in equation (8):

$$Isc_{3\emptyset} = \frac{V_{LN}}{Z_1} \quad (8)$$

Where :
$Isc_{3\emptyset}$= 3-phase short circuit current
V_{LN} = Nominal voltage
Z_1 = Positive sequence impedance viewed from the fault point

2.3. Coordinating Relay

Coordinating studies of electrical protection equipment or systems are studies or analyses to determine the settings of overcurrent protection relays and circuit breakers that have the main objective of obtaining an optimal compromise between protection and selectivity. The study includes the determination of fault clearing time and coordination of electrical protection equipment on the upstream side. Proper coordination and fault clearing time can help reduce damage to electrical equipment and protect workers from harm. The study and analysis of protection equipment coordination is one part of the power system study. Protection relay coordination analysis is performed after the power flow study and short circuit fault analysis are performed [8].

The function of the relay is to detect and identify faults and then instruct the circuit breaker to isolate the faulty device quickly. Overcurrent relays are very widely used for overcurrent protection in primary distribution networks at the downstream end of medium voltage (TM) power supplies, and are also used as ground fault overcurrent protection. This relay requires a protected flow in the form of current obtained through a current transformer (CT). The reference element (comparator) of the relay compares it with the limit value/current mark at which the relay operates (as a trigger), if the input current exceeds the set point and continues for different periods of time after detecting the overcurrent, then this is when the relay should be activated [18].

2.4. Electric Transient Analyzer Program (ETAP)

In Study and analyzing a power system, an application software is needed to represent the real conditions before a system is realized. ETAP is a software used for power systems. It can work offline for power simulation, and online for real time data management.

ETAP is used in this study as a supporting application to analyse disturbances and coordination of power system protection at PT PLN ULPL Indralaya, especially steam turbine generator unit-01. The type of ETAP used is ETAP 19.0.1. For ease of analysis calculation results can be displayed on a one-line diagram. ETAP Power Station makes it possible to work directly with a single line diagram image display [19].

3. RESEARCH METHOD

This study uses a quantitative approach. This method was chosen because quantitative research is research that uses numbers, starting with data collection, analysis, and testing the results. This method was chosen because the quantitative research method is a research method that uses data in the form of numbers, emphasizing objective measurement [20] and analysis of the results shown in **Figure 2.**

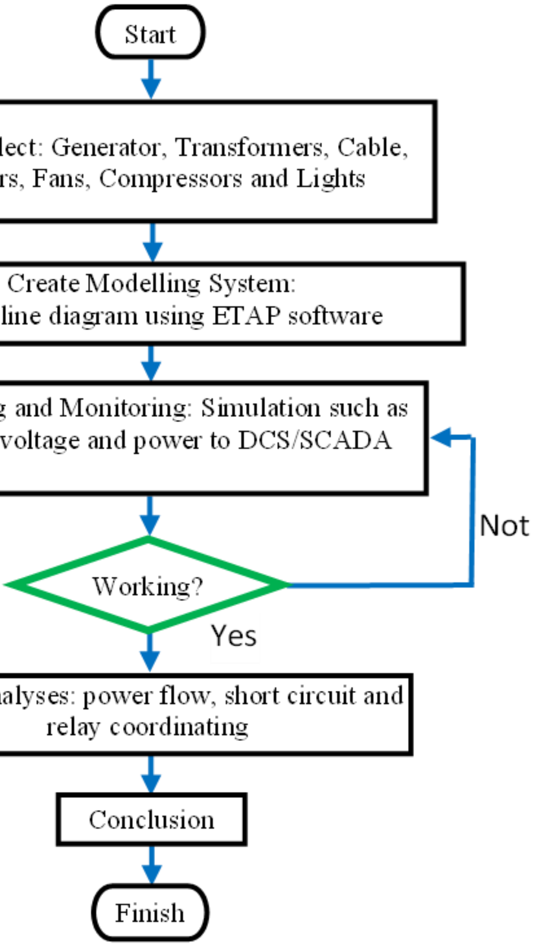


Figure 2. Research Flowchart

To get a solution the problem, the framework is structured as follows:

1. Data collection, at this stage the data is in the form of generator, transformer, cable, motor, fan, compressor, and light data.
2. Single line diagram modeling, for this stage the single line diagram modeling must be in accordance with the actual system using ETAP 19.0.1 Software
   a. Enter system component data (machine data, transformer data, cable data, and switchgear data)
   b. Simulation of system components :
      1. Load flow simulation
      2. Short-circuit simulation
      3. Coordination relay simulation

3. Testing, analysis, and evaluation, at this stage this is carried out on the system response in accordance with predetermined standards.
    a. Provide input to optimize system conditions
    b. Testing system condition optimization.
    c. Analyze system test results.
    d. Evaluate the results of the system analysis.
4. Conclusion of test results, analysis, and evaluation.

Details of the discussion on solving problems with the steam turbine generator unit are:

1) Load flow will be created in 3 scenarios consisting of:
    a. Scenario 1 where the ST 1.0 Generator is energized with its own usage load according to current conditions.
    b. Scenario 2 where the ST 1.0 Generator goes out and is energized by the source from the 20 kV PLN network.
    c. Scenario 3 where the ST 1.0 Generator and PLN 20 kV are turned off and the source is energized by a 1 MW Caterpillar Genset.
2) Short Circuit, there are three scenarios in the simulation with several areas with line to ground (LG), double line to ground (LLG), and three phases (LLL) fault types, which include:
    a. Area 1: A short circuit occurs at 11.5kV busbar.
    b. Area 2: Short circuit occurs in 6.9kV switchgear MV busbar.
    c. Area 3: A short circuit occurred in the LV busbar of 0.415kV SUS 1 switchgear.
    d. Area 4: A short circuit occurred in the LV busbar of 0.415kV SUS 2 switchgear.
    e. Area 5: A short circuit occurred in the LV switchgear busbar of the 0.415kV ATS unit.
3) Coordination relay on 4MVA, 11.5/6.9 kV transformer unit

4. RESULTS AND DISCUSSION

Figure 3 illustrated the system data used was initially supplemented with data collection from the field and then updated with a version called "Simplified One Line Diagram" from ETAP 19.0.1.

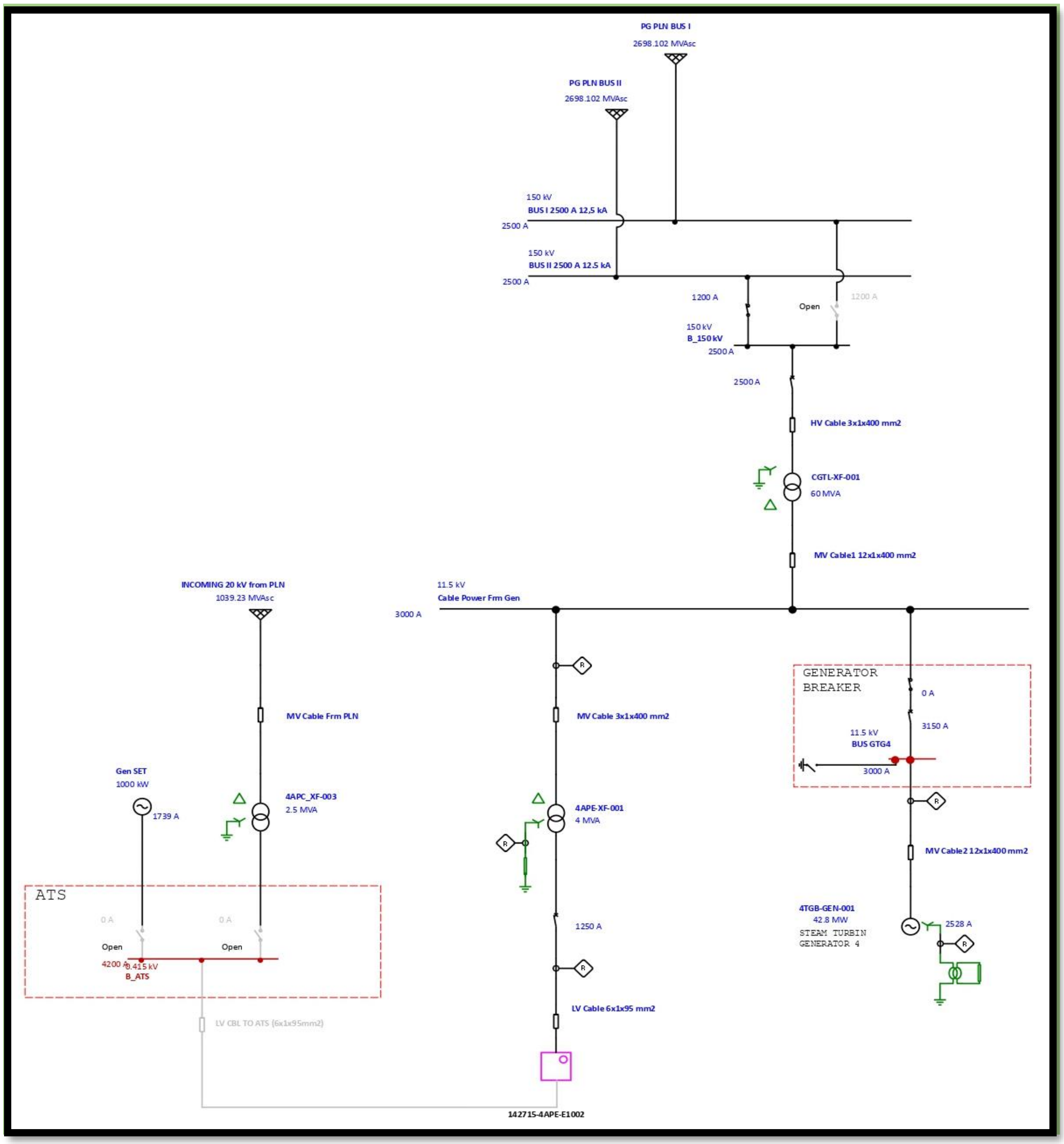


Figure 3. Single Line Diagram

The study database in ETAP 19.0.1 is modified according to the data collection as follows:

a. The desired power of the Steam Turbine Generator 1.0 (STG 1.0) is 14.39 MW and 6.22 Mvar.
b. STG 1.0 at 1.01 PU voltage and used as Mvar constant power control machine.

4.1. Initial Tunning

4.1.1 Load Flow

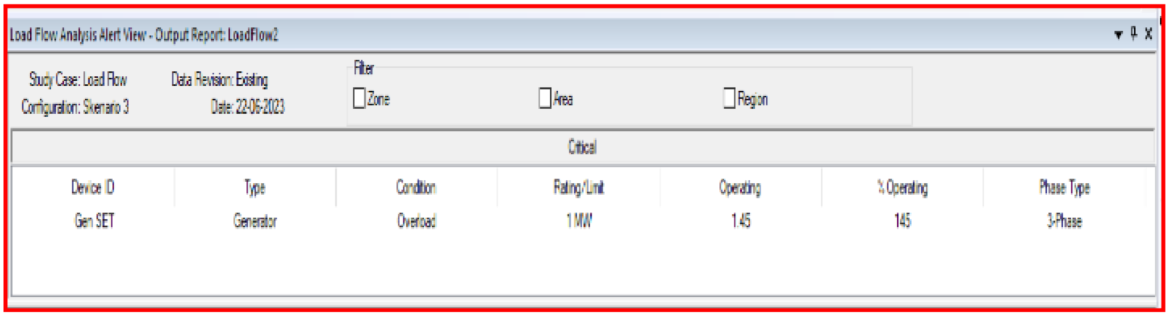
1. Scenario 1 where STG 1.0 is energized with self-use load according to current conditions.
2. Scenario 2 where STG 1.0 goes out and energized source from PLN 20 kV network.
3. Scenario 3 where STG 1.0 and PLN 20 kV outage and energized source from Diesel generator 1 MW.

Scenario 1 has one STG 01 unit active with no changes to other equipment connections resulting in 12.3 MW of power flowing into the 150 kV grid and 2.10 MW of power going into the STG 1.0 self-use system.

Scenario 2 has one unit of generator STG 1.0 inactive and energising resources from the PLN 20 kV network without delivering power to the 150 kV grid and only supply to the STG 1.0 self-use system with a power of 1.44 MW on the LV system (0.415 kV).

Scenario 3 has one unit of generator STG 1.0 inactive and energises the resource from the Diesel Generator without delivering power to the 150 kV grid and only supplies to the STG 1.0 self-use system with a power of 1.45 MW on the LV network (0.415 kV).

Figure 4 and Table 1 showed from the simulation results there is an alert view before performing only in scenario 3 which occurs over operating the generator set by 145% of the 1 MW generator rating.


Load Flow Analysis Alert View - Output Report: LoadFlow2

Study Case: Load Flow
Configuration: Skenario 3
Data Revision: Existing
Date: 22-06-2023

Filter
☐ Zone ☐ Area ☐ Region

Critical

Device ID	Type	Condition	Rating/Limit	Operating	% Operating	Phase Type
Gen SET	Generator	Overload	1 MW	1.45	145	3-Phase

Figure 4. Alert View Load Flow

Table 1. Load Flow Condition initial Tunning

No.	Description	Active Power (MW)	Reactive Power (MVar)
1	**Scenario 1**		
	a. Busbar 11.5 kV Output Generator	14.4	6.22
	b. Busbar 150 kV ke Grid	12.3	5.12
	c. Busbar 11.5 kV Incoming Transformer 4 MVA	2.10	1.10
	d. Busbar 6.9 kV Outgoing Transformer 4 MVA	2.09	0.99

	e. Busbar 6.9 kV Incoming Transformer XF-01 2.5 MVA	0.85	0.43
	f. Busbar 0.415 kV Outgoing Transformer XF-01 2.5 MVA	0.85	0.40
	g. Busbar 6.9 kV Incoming Transformer XF-02 2.5 MVA	0.61	0.29
	h. Busbar 0.415 kV Outgoing Transformer XF-02 2.5 MVA	0.60	0.27
	i. Busbar 6.9 kV Motor 2FWA-P01A 315 kW	0.33	0.14
	j. Busbar 6.9 kV Motor 4HRCP-P01A 280 kW	0.30	0.13
	k. Busbar 0.415 kV SUS 1	0.85	0.40
	l. Busbar 0.415 kV SUS 2	0.60	0.27
2	**Scenario 2**		
	a. Busbar 0.415 kV Incoming ATS PLN 20 kV	1.44	0.67
	b. Busbar 0.415 kV SUS 1	1.44	0.66
	c. Busbar 0.415 kV SUS 2	0.59	0.27
3	**Scenario 3**		
	a. Busbar 0.415 kV Incoming ATS Genset 1 MW	1.45	0.67
	b. Busbar 0.415 kV SUS 1	1.45	0.67
	c. Busbar 0.415 kV SUS 2	0.60	0.27

4.1.2 Short Circuit

There are three scenarios (**Table 2 to 4)** in the simulation with several areas with fault types of line to ground (LG), double line to ground (LLG), and three phases (LLL) which include:

1. Area no. 1: A short circuit occurred at the 11.5kV bus bar.
2. Area no. 2: short circuit occurred at the 6.9kV switchgear MV bus bar.
3. Area no. 3: The short circuit occurred at the LV switchgear 0.415kV SUS 1 bus bar.
4. Area no. 4: The short circuit occurred at the LV switchgear 0.415kV SUS 2 bus bar.
5. Area no. 5: The short circuit occurred at the LV switchgear 0.415kV bus bar of the ATS unit.

Table 2. Fault Currents at Different Buses Considering LG Fault Condition Initial Tunning

No	Fault Bus	Voltage (kV)	Fault Current (kA)
1	**Scenario 1**		
	a. Busbar 11.5 kV Output Generator	11.5	0.011
	b. Busbar 6.9 kV Outgoing Transformer 4 MVA	6.9	0.008
	c. Busbar 0.415 kV SUS 1	0.415	32.53
	d. Busbar 0.415 kV SUS 2	0.415	34.37
2	**Scenario 2**		
	a. Busbar 0.415 kV Incoming ATS PLN	0.415	53.737
	b. Busbar 0.415 kV SUS 1	0.415	51.079
	c. Busbar 0.415 kV SUS 2	0.415	47.855
3	**Scenario 3**		
	a. Busbar 0.415 kV Incoming ATS Genset 1 MW	0.415	19.947
	b. Busbar 0.415 kV SUS 1	0.415	19.658
	c. Busbar 0.415 kV SUS 2	0.415	19.204

Table 3. Fault Currents at Different Buses Considering LLG Fault Condition initial Tunning

No	Fault Bus	Voltage (kV)	Fault Current (kA)
1	**Scenario 1**		

	a. Busbar 11.5 kV Output Generator	11.5	41.451
	b. Busbar 6.9 kV Outgoing Transformer 4 MVA	6.9	5.255
	c. Busbar 0.415 kV SUS 1	0.415	33.254
	d. Busbar 0.415 kV SUS 2	0.415	34.996
2	**Scenario 2**		
	a. Busbar 0.415 kV Incoming ATS PLN	0.415	53.976
	b. Busbar 0.415 kV SUS 1	0.415	51.977
	c. Busbar 0.415 kV SUS 2	0.415	49.395
3	**Scenario 3**		
	a. Busbar 0.415 kV Incoming ATS Genset 1 MW	0.415	20.494
	b. Busbar 0.415 kV SUS 1	0.415	20.165
	c. Busbar 0.415 kV SUS 2	0.415	19.654

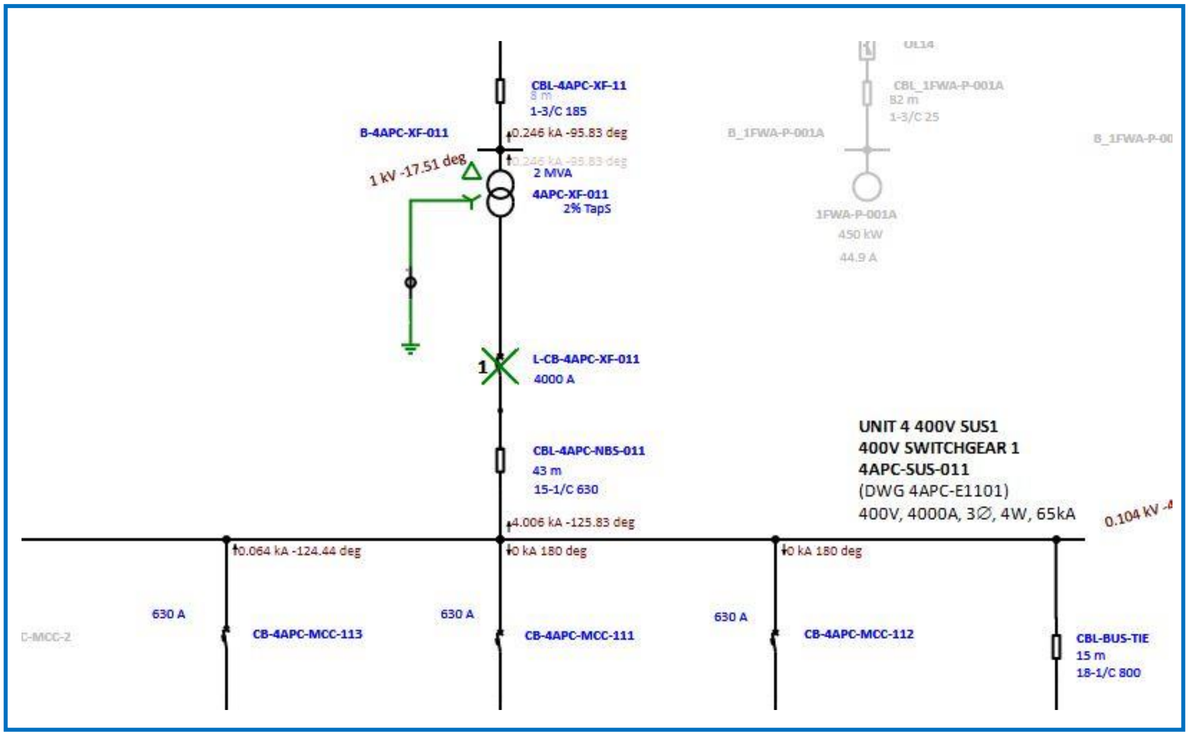
Table 4. Fault Currents at Different Buses Considering LLL Fault Condition initial Tunning

No	**Fault Bus**	**Voltage (kV)**	**Fault Current (kA)**
1	**Scenario 1**		
	a. Busbar 11.5 kV Output Generator	11.5	50.776
	b. Busbar 6.9 kV Outgoing Transformer 4 MVA	6.9	6.131
	c. Busbar 0.415 kV SUS 1	0.415	32.531
	d. Busbar 0.415 kV SUS 2	0.415	33.756
2	**Scenario 2**		
	a. Busbar 0.415 kV Incoming ATS PLN	0.415	49.909
	b. Busbar 0.415 kV SUS 1	0.415	48.724
	c. Busbar 0.415 kV SUS 2	0.415	46.925
3	**Scenario 3**		
	a. Busbar 0.415 kV Incoming ATS Genset 1 MW	0.415	19.368
	b. Busbar 0.415 kV SUS 1	0.415	19.329
	c. Busbar 0.415 kV SUS 2	0.415	19.112

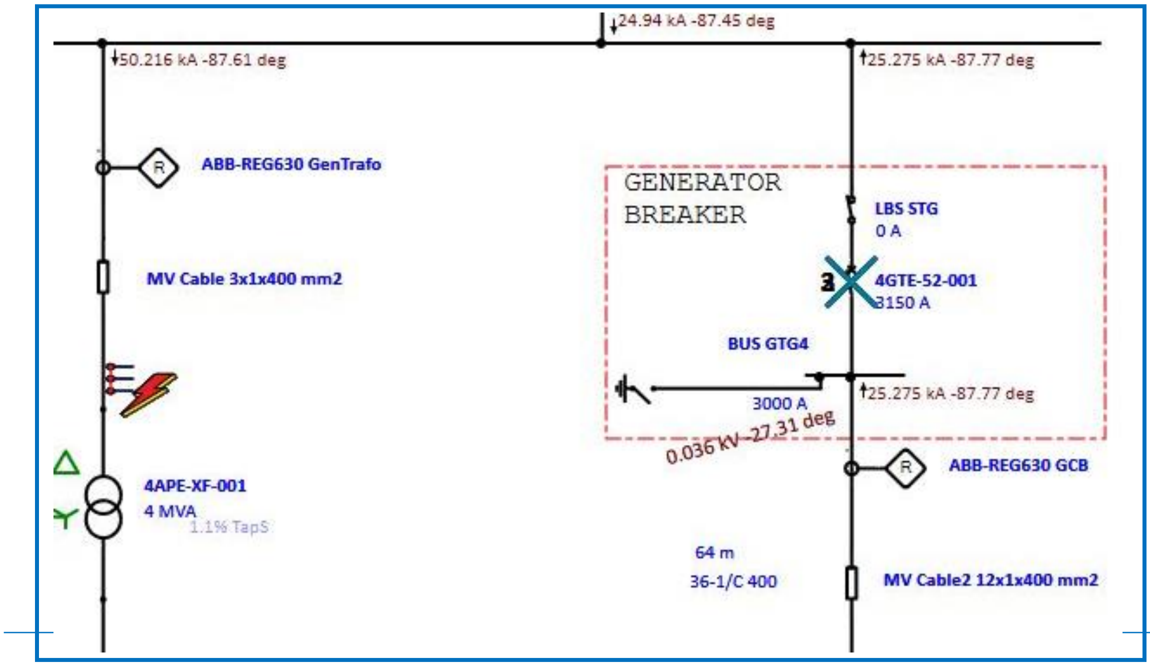
4.1.3 Coordinating Relay

This simulation is carried out to ensure the protection system on the existing equipment is correct by considering several relays M-3425 as generator protection, M-3311 as protection on incoming transformer 4 MVA and the characteristics of all relays shown in **Figure 5**. From the relay coordination curve before tunning in the 4 MVA transformer area using beck with electric relay.

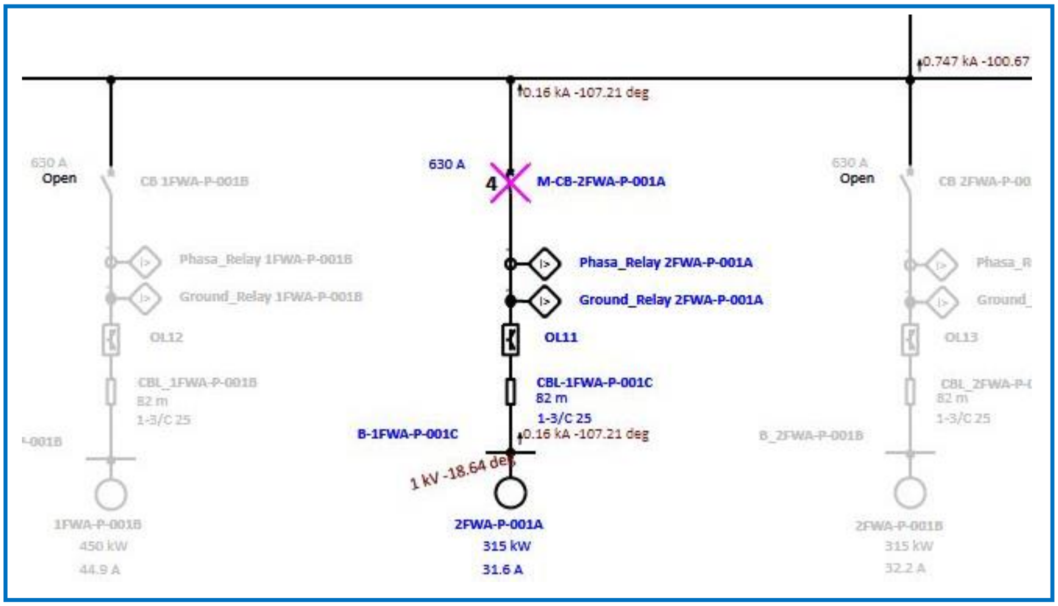
If the LLL, LG and LLG fault currents occur in the 4 MVA transformer based on the actual case as the cause of the blackout system, the TRIP relay sequence operates as shown in the **Figure 6**, starting the trip from the CB outgoing transformer 2.5 MVA unit 1 first then continuing as shown below.


UL14
CBL-4APC-XF-11
8 m
1-3/C 185
CBL_1FWA-P-001A
82 m
1-3/C 25
B-4APC-XF-011
0.246 kA -95.83 deg
B_1FWA-P-001A
B_1FWA-P-00
1 kV -17.51 deg
0.246 kA -95.83 deg
2 MVA
4APC-XF-011
2% TapS
1FWA-P-001A
450 kW
44.9 A
1
L-CB-4APC-XF-011
4000 A
UNIT 4 400V SUS1
400V SWITCHGEAR 1
4APC-SUS-011
(DWG 4APC-E1101)
400V, 4000A, 3∅, 4W, 65kA
CBL-4APC-NBS-011
43 m
15-1/C 630
4.006 kA -125.83 deg
0.104 kV
0.064 kA -124.44 deg
0 kA 180 deg
0 kA 180 deg
630 A
630 A
630 A
C-MCC-2
CB-4APC-MCC-113
CB-4APC-MCC-111
CB-4APC-MCC-112
CBL-BUS-TIE
15 m
18-1/C 800

(a)


24.94 kA -87.45 deg
50.216 kA -87.61 deg
25.275 kA -87.77 deg
R
ABB-REG630 GenTrafo
GENERATOR
BREAKER
LBS STG
0 A
MV Cable 3x1x400 mm2
3
4GTE-52-001
3150 A
BUS GTG4
3000 A
25.275 kA -87.77 deg
0.036 kV -27.31 deg
R
ABB-REG630 GCB
4APE-XF-001
4 MVA
1.1% TapS
64 m
36-1/C 400
MV Cable2 12x1x400 mm2

(b)



(c)

Figure 5. (a)-(c) Characteristics performer of 4 MVA Phase-Phase Transformer Initial Tunning

1X = 1st operate relay
2X = 2nd operate relay
3X = 3rd operate relay
4X = 4th operate relay

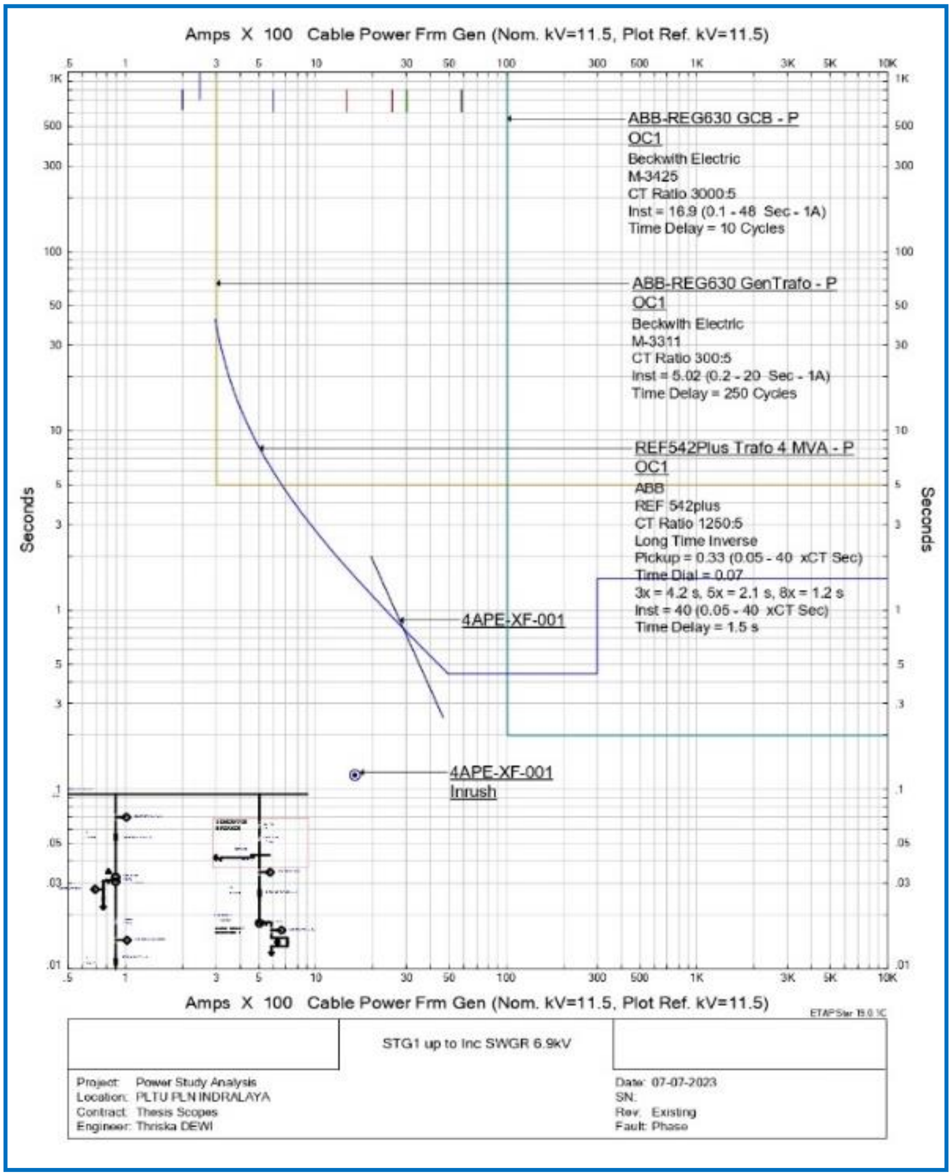


Figure 6. Transformer Coordinated Relay System 4 MVA initial tunning

4.2. Actual Tunning

4.2.1. Load Flow

Actual tunning in order to perform specifically in scenario 3 which previously generated alerts, in scenario 3 there has been one unit of STG 1.0 inactive and energizing the power source comes from the Caterpillar Diesel Generator without delivering power to the 150 kV grid and only supplying to the STG 1.0 self-use system from the previous power of 1.45 MW to 0.91 MW in the LV switchgear system (0.415 kV).

Table 5. Load Flow Condition Actual Tunning

No	Description	Active Power (MW)	Reactive Power (MVar)
1	**Scenario 1**		
	a. Busbar 11.5 kV Output Generator	14.4	6.22
	b. Busbar 150 kV ke Grid	12.3	5.12
	c. Busbar 11.5 kV Incoming Transformer 4 MVA	2.10	1.10
	d. Busbar 6.9 kV Outgoing Transformer 4 MVA	2.09	0.99
	e. Busbar 6.9 kV Incoming Transformer XF-01 2.5 MVA	0.85	0.43
	f. Busbar 0.415 kV Outgoing Transformer XF-01 2.5 MVA	0.85	0.40
	g. Busbar 6.9 kV Incoming Transformer XF-02 2.5 MVA	0.61	0.29
	h. Busbar 0.415 kV Outgoing Transformer XF-02 2.5 MVA	0.60	0.27
	i. Busbar 6.9 kV Motor 2FWA-P01A 315 kW	0.33	0.14
	j. Busbar 6.9 kV Motor 4HRCP-P01A 280 kW	0.30	0.13
	k. Busbar 0.415 kV SUS 1	0.85	0.40
	l. Busbar 0.415 kV SUS 2	0.60	0.27
2	**Scenario 2**		
	a. Busbar 0.415 kV Incoming ATS PLN	1.44	0.67
	b. Busbar 0.415 kV SUS 1	1.44	0.66
	c. Busbar 0.415 kV SUS 2	0.59	0.27
3	**Scenario 3**		
	a. Busbar 0.415 kV Incoming ATS Genset 1 MW	0.91	0.41
	b. Busbar 0.415 kV SUS 1	0.91	0.41
	c. Busbar 0.415 kV SUS 2	0.36	0.15

4.2.2. Short Circuit

Short circuit in each area is simulated with several types of interference, including 3 phases (LLL), line to ground (LG) and line to line to ground (LLG) carried out in each scenario showed on **Table 6 to 8**.

Table 6. Fault Currents at Different Buses Considering LG Fault Condition Actual Tunning

No	Fault Bus	Voltage (kV)	Fault Current (kA)
1	**Scenario 1**		
	a. Busbar 11.5 kV Output Generator	11.5	0.011
	b. Busbar 6.9 kV Outgoing Transformer 4 MVA	6.9	0.008
	c. Busbar 0.415 kV SUS 1	0.415	32.53
	d. Busbar 0.415 kV SUS 2	0.415	34.37
	Scenario 2		
	a. Busbar 0.415 kV Incoming ATS PLN	0.415	53.737
	b. Busbar 0.415 kV SUS 1	0.415	51.079
	c. Busbar 0.415 kV SUS 2	0.415	47.855
3	**Scenario 3**		
	a. Busbar 0.415 kV Incoming ATS Genset 1 MW	0.415	17.115
	b. Busbar 0.415 kV SUS 1	0.415	16.864
	c. Busbar 0.415 kV SUS 2	0.415	16.504

Table 7. Fault Currents at Different Buses Considering LLG Fault Condition Actual Tunning

No	Fault Bus	Voltage (kV)	Fault Current (kA)
1	**Scenario 1**		
	a. Busbar 11.5 kV Output Generator	11.5	41.451
	b. Busbar 6.9 kV Outgoing Transformer 4 MVA	6.9	5.255
	c. Busbar 0.415 kV SUS 1	0.415	33.254
	d. Busbar 0.415 kV SUS 2	0.415	34.996
2	**Scenario 2**		
	a. Busbar 0.415 kV Incoming ATS PLN	0.415	53.976
	b. Busbar 0.415 kV SUS 1	0.415	51.977
	c. Busbar 0.415 kV SUS 2	0.415	49.395
3	**Scenario 3**		
	a. Busbar 0.415 kV Incoming ATS Genset 1 MW	0.415	17.250
	b. Busbar 0.415 kV SUS 1	0.415	16.936
	c. Busbar 0.415 kV SUS 2	0.415	16.616

Table 8. Fault Currents at Different Buses Considering LLL Fault Condition Actual Tunning

No	Fault Bus	Voltage (kV)	Fault Current (kA)
1	**Scenario 1**		
	a. Busbar 11.5 kV Output Generator	11.5	50.776
	b. Busbar 6.9 kV Outgoing Transformer 4 MVA	6.9	6.131
	c. Busbar 0.415 kV SUS 1	0.415	32.531
	d. Busbar 0.415 kV SUS 2	0.415	33.756
2	**Scenario 2**		
	a. Busbar 0.415 kV Incoming ATS PLN	0.415	49.909
	b. Busbar 0.415 kV SUS 1	0.415	48.724
	c. Busbar 0.415 kV SUS 2	0.415	46.925
3	**Scenario 3**		
	a. Busbar 0.415 kV Incoming ATS Genset 1 MW	0.415	15.582
	b. Busbar 0.415 kV SUS 1	0.415	15.504
	c. Busbar 0.415 kV SUS 2	0.415	15.330

4.2.3. Coordinating Relay

Coordinating Relay used to protect area during fault simulation is only carried out on the 4 MVA transformer as in the actual case which causes a system blackout that are illustrated on **Figure 7**.

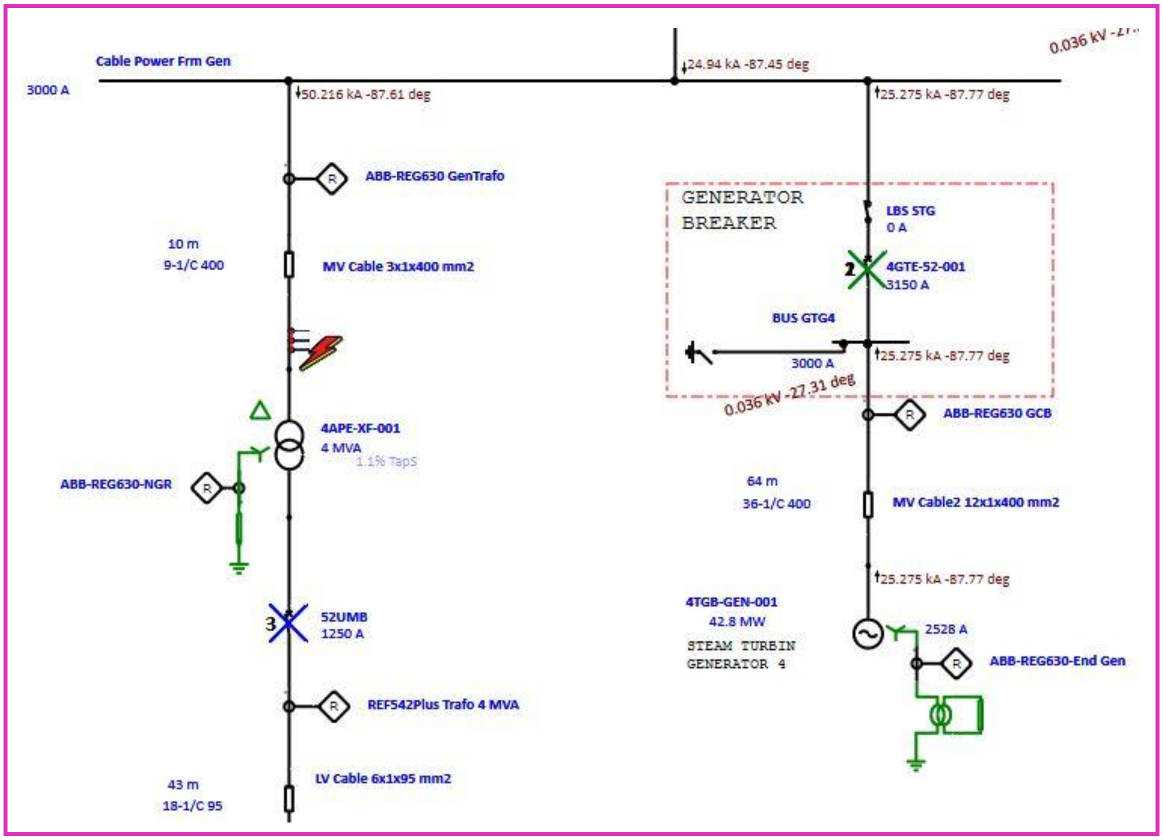


Figure 7. Transformer Coordinated Relay System 4MVA for actual Tunning

The following is the sequence of circuit breaker (CB) trips that occur when a disturbance simulation is carried out starting from the CB Generator TRIP.

1X = 1st operate relay
2X = 2nd operate relay
3X = 3rd operate relay

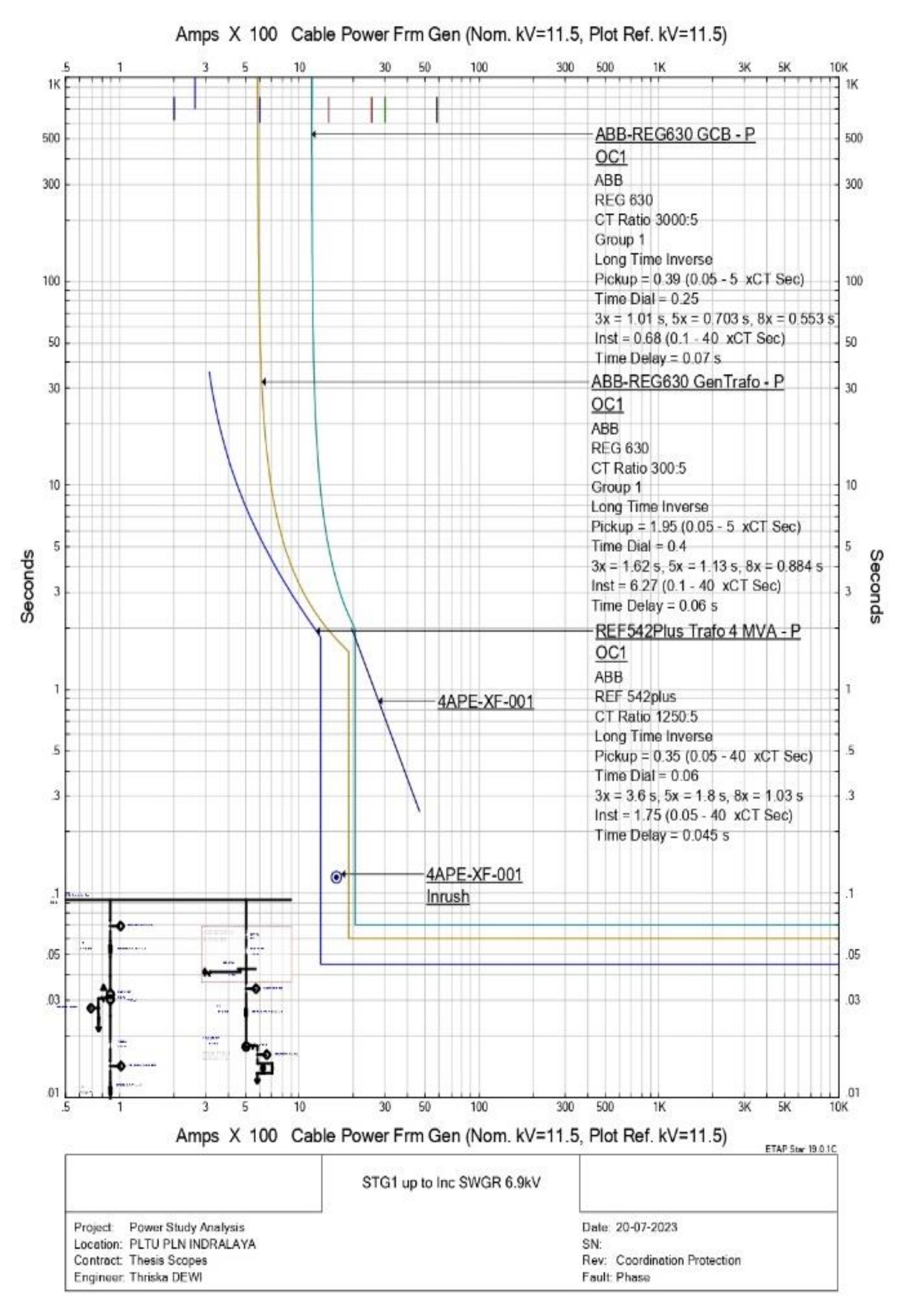


Figure 8. Characteristics performing of 4MVA Phase-Phase Transformer for actual Tunning

In **Figure 8** from the coordination relay to actual tunning, we obtained the protection relay setting in the area of the 4 MVA transformer and 11.5 kV generator, it is replaced using ABB relay type REG630 which has a choice of over current performing.

5. CONCLUSION

Power system analysis for STG 1.0 using ETAP, there are three results:

1. Load flow analysis in the third scenario by removing some loads by 63% so that the power source backup (Diesel generator) from 1.45 MW to 0.91 MW from SUS 1 & 2.
2. Short-circuit analysis in all scenarios in each fault area are still lower than short-circuit withstand current rating < 65 kA in LV switchgear, < 25 kA in MV switchgear and < 54 kA in GCB.
3. Relay coordinating analysis in the first scenario, in order to reach the protection against interference, it is necessary to replace the solid state relay (Beckwith Electric) with a multifunction relay (ABB) which has a curve selection function from IDMT (inverse definite minimum time), namely Long Time Inverse.

REFERENCES

[1] Ery Fuji Risnawati and Nurissaidah Ulinnuha, "Optimasi Pembagian Beban Pada Turbin Gas Blok 1 Dan Blok 3 Pltgu Pt. Pjb Up Gresik Menggunakan Metode Iterasi Lambda Berdasarkan Base Point And Participation Factors," *Publikasi Ilmiah Matematika*, vol. 5, no. 2, pp. 83–94, 2020, doi: org/10.29080/algebra.v1i2.10.

[2] Xue Zhang, Dong Sheng Wang, Fuchun Jiang, Tao Lin, and Hao Xiang, "An Optimal Regulation Method for Parallel Water-Intake Pump Group of Drinking Water Treatment Process," *IEEE Access*, vol. 8, pp. 82797–82803, 2020, doi: 10.1109/ACCESS.2020.2991895.

[3] Haleonar Mycson Karusitio Silaban and Abdul Ghofur, "Analisa Performa Turbin Gas Tipe CW251 B11 pada Sistem Pembangkit Listrik Tenaga Gas Sektor Pembangkitan Bali," *JTAM Rotary*, vol. 2, no. 2, pp. 161–170, 2020, doi: org/10.20527/jtam_rotary.v2i2.2412.

[4] E. K. Arakelyan, A. V. Andryushin, G. A. Pikina, S. V. Mezin, and A. A. Kosoy, "The choice of the optimal energy-saving technology redundant power steam turbines during the passage of the daily schedules of power consumption gaps," in *Procedia Computer Science*, Elsevier B.V., 2019, pp. 69–74. doi: 10.1016/j.procs.2019.08.013.

[5] Manish Parihar and M.K Bhaskar, "Review of Power System Blackout, International Journal of Research and Innovation in Applied Science (IJRIAS)," 2018. doi: org/10.51584/IJRIAS.

[6] J. William D. Stevenson, *Analisis Sistem Tenaga Listrik*. Jakarta: Erlangga, 1996.

[7] Caesar Wiratama, "Cara Kerja Turbin Uap." [Online]. Available: https://www.aeroengineering.co.id/ 2021/05//cara-kerja-turbin-uap/

[8] "Studi Analisis Sistem Tenaga Listrik." [Online]. Available: https://www.omazaki.co.id/studi-analisis-sistem-tenaga-listrik/

[9] "Pengertian Software." [Online]. Available: https://www.sekawanmedia.co.id/blog/pengertian-software

[10] Dewa Putra Iwana, “Memahami Software: Data & Instruksi Terprogram Dalam Komputer.” [Online]. Available: https://www.sekawanmedia.co.id/blog/pengertian-software
[11] Muhammad Fauzan Gusti Triyanto, “Sekilas Tentang Software ETAP Berserta Tollbarnya.” [Online]. Available: https://www.anakteknik.co.id/fauzan_triyanto02/articles/sekilas-tentang-software-etap-beserta-tollbarnya
[12] Heru Dibyo Laksono and Aditya Putra Pratama, “Perancangan dan Analisa Sistem Kendali Frekuensi Sistem Tenaga Listrik dengan Metode Penempatan Kutub,” *Teknologi Informasi & Pendidikan*, vol. 10, no. 2, pp. 37–48, 2017, doi: org/10.24036/tip.v10i2.30.
[13] Fivia Eliza and Dwiprima Elvanny Myori, “Trainer Pada Pembelajaran Dasar Dan Pengukuran Listrik,” *Teknologi Informasi & Pendidikan*, vol. 10, no. 1, pp. 12–22, 2017, doi: org/10.24036/tip.v10i1.40.
[14] Muhammad Anwar and Zulwisli, “Pengujian Kinerja Pembangkit Listrik Tenaga Surya Untuk Menggerakkan Pompa Air,” *Teknologi Informasi & Pendidikan*, vol. 10, no. 3, pp. 44–47, 2017, doi: org/10.24036/tip.v10i3.16.
[15] Miftahul Fikri and Dwi Anggaini., “Metode Newton Raphson Untuk Analisis Aliran Daya Jaringan Distribusi 12,66 kV,” *Ilmiah Sutet*, vol. 8, no. 2, pp. 114–121, 2018, [Online]. Available: https://jurnal.itpln.ac.id/sutet/article/view/226
[16] Agusthiaus S.Sampeallo, Nursalim, and Patrisius J. Fischer, “Analisa Jaringan Hubung Singkat Pada Pemakaian Sendiri PLTU Bolok PT. SMSE (IPP) Unit 3 dan dan 4 Menggunakan Software ETAP 12.6.0,” *Jurnal Media Elektro*, vol. VIII, no. 1, pp. 76–85, doi: org/10.35508/jme.v8i1.1442.
[17] Yulisman, “Analisis Arus Gangguan Hubung Singkat Sistem Tenaga Listrik Dengan Aplikasi Matlab,” *Jurnal Rang Teknik*, vol. 1, no. 1, pp. 113–121, 2018, doi: org/10.31869/rtj.v1i1.598.
[18] Rahman Dashti, Salahedin Hassani, and Hamid Reza Shaker, *2018 5th International Conference on Electrical and Electronics Engineering (ICEEE 2018) : May 3-5, 2018, Istanbul, Turkey*. 2018. doi: org/10.1109/ICEEE2.2018.8391343.
[19] Amine Zeggai Irecom and Farid Benhamida, *Proceedings of Algerian Large Electrical Network Conference : CAGRE'2019 : Algiers, Algeria, 26-28 February 2019*. 2019. doi: org/10.1109/CAGRE.2019.8713172.
[20] Sugiyano, *Metode Penelitian Kuantitatif Kualitatif dan R&D*. Bandung: Alfabeta, 2021.