CHAPTER 3

The Analysis Process of Wide Area Protection

The objective of research considered the protection problem in the loop model network also focus on the problem from contingency event and setting a not coordination of OC relay. So, the operating time of the protective devices needs to set properly with the operating of OC relays, which will protect the outage electricity in a wide area. However, these problems will be corrected by finding the method for the setting in the coordinating time interval and together with conditional in the contingency analysis. A DIgSILENT Power Factory software will be used in the paper for analyzing the system.

This research determines characteristics of area protection as follows: local area protection will protect device in each point that is in scope and capacity operation of protective device, which will set a protective device in each local area. This research determines a wide area protection (WAP) of protective device in each protection zone as shown in Figure 3.1.

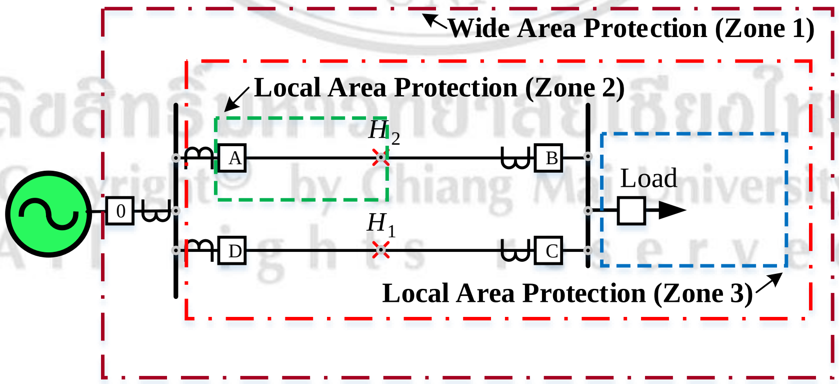


Figure 3.1 Determines characteristics of local area protection and wide area protection

3.1 The analysis process of WAP

The solution analysis process in order to prevent a power outage in wide areas caused by settings that are coordinated to clear the error. It also focuses on the issue of the rating system itself. In particular, the operating time of protective equipment must comply with current exceeds the relay emergency which caused a power outage in wide areas.

The analysis process presented a WAP as shown in Figure 3.2. The wide area protection for electrical distribution system was passed an analysis by two sections as follows the setting of OC relay and CA in conditional (N-1), which are detailed below as shown in step 8.

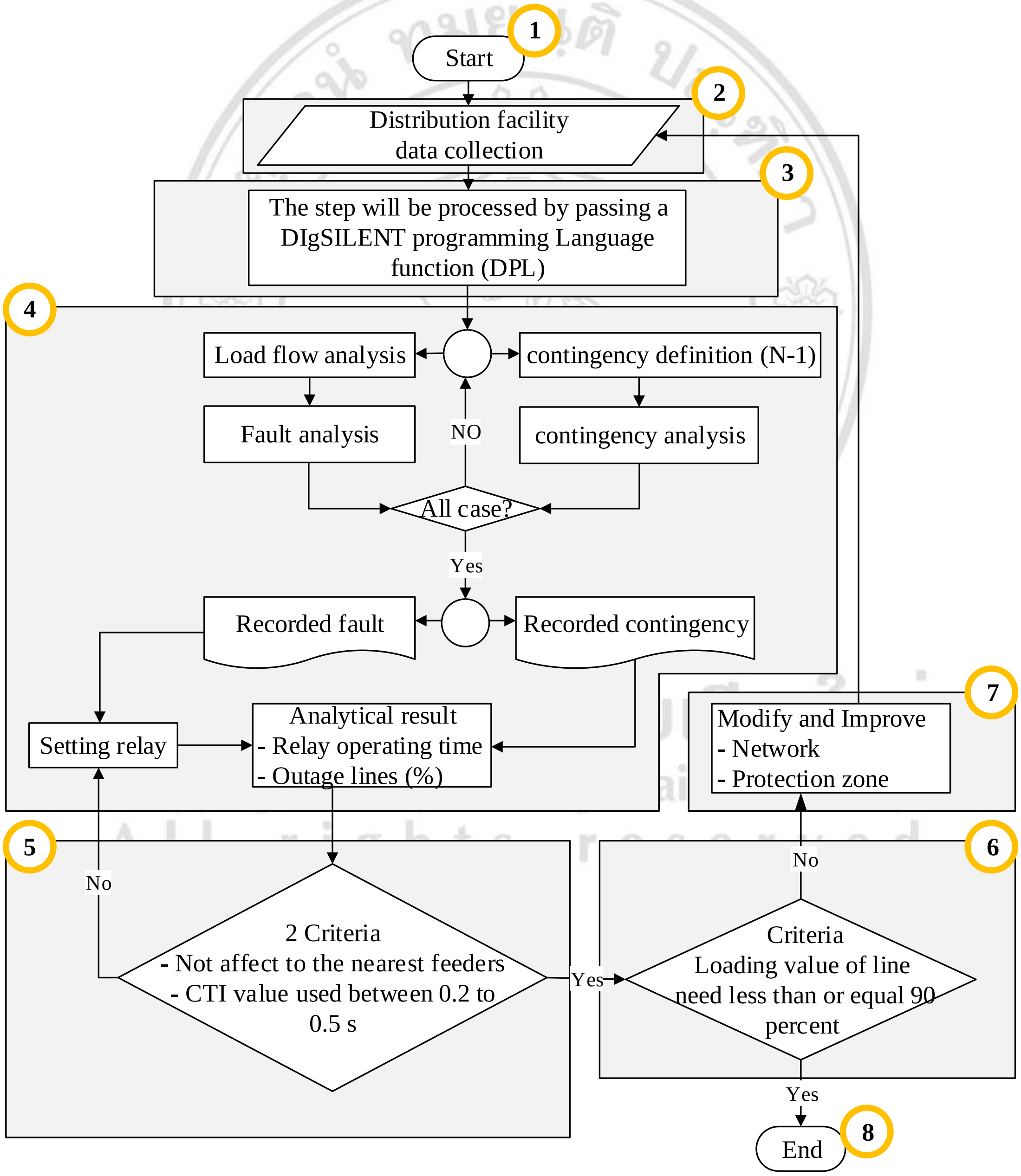


Figure 3.2 The analysis process of wide area protection for electrical distribution

Step 1: Start the process in the WAP for electrical distribution system was passed an analysis by two sections as follows the setting of OC relay and CA in conditional (N-1).

Step 2: The second step defines data collection of the system.

Step 3: The third step, the data is processed by passing a script of a DIgSILENT Programming Language (DPL) function.

Step 4: The fourth step, all case studies will be analyzed by DPL to study load flow and fault in the network, then record the result and set the relay setting. At this step, it also defined contingency definition (N-1), contingency analysis and record the contingency result. After that, the DPL will show the proper current setting and time dial value to the user.

Step 5: The fifth step, the model will be analyzed fault again under 2 criteria. After checking criteria, which are the fault will not affect to the nearest feeders and the CTI value used between 0.2 to 0.5 s.

Step 6: The sixth step will analyze the model by checking the overloading in the network that can support 90 percent of conductor capacity. If the overloading value is higher than 90% of conductor capacity the network will trip and the system will fail down.

Step 7: In this case, the model has to be modified by creating new feeder and improved the failure zone. Thus, the process will return to the second step and follow the instruction until finding the proper result in Step 8.

3.1.1 Start the process analysis in step 1

Start the process in the WAP for electrical distribution system was passed an analysis by two sections as follows the setting of OC relay and CA in conditional (N-1).

3.1.2 Data collection of the system in step 2

3.1.2.1 Data used in the analysis on the electrical system

The scope of study in this research consists three main power supplies as follows EDLgrid 1, EDLgrid 2, EDLgrid 3 that are connected with seven substations as follows Thanalang (1), Phonetong (2), Naxaythong (3), Sisaket (4), Sokpaluang (5), Thatluang (6), and Dongnasok (7) as shown in figure 4.1. The single line diagram shows the loop distribution system in medium voltage 22 kV as shown in Figure 3.3 and Figure 3.4 [1].

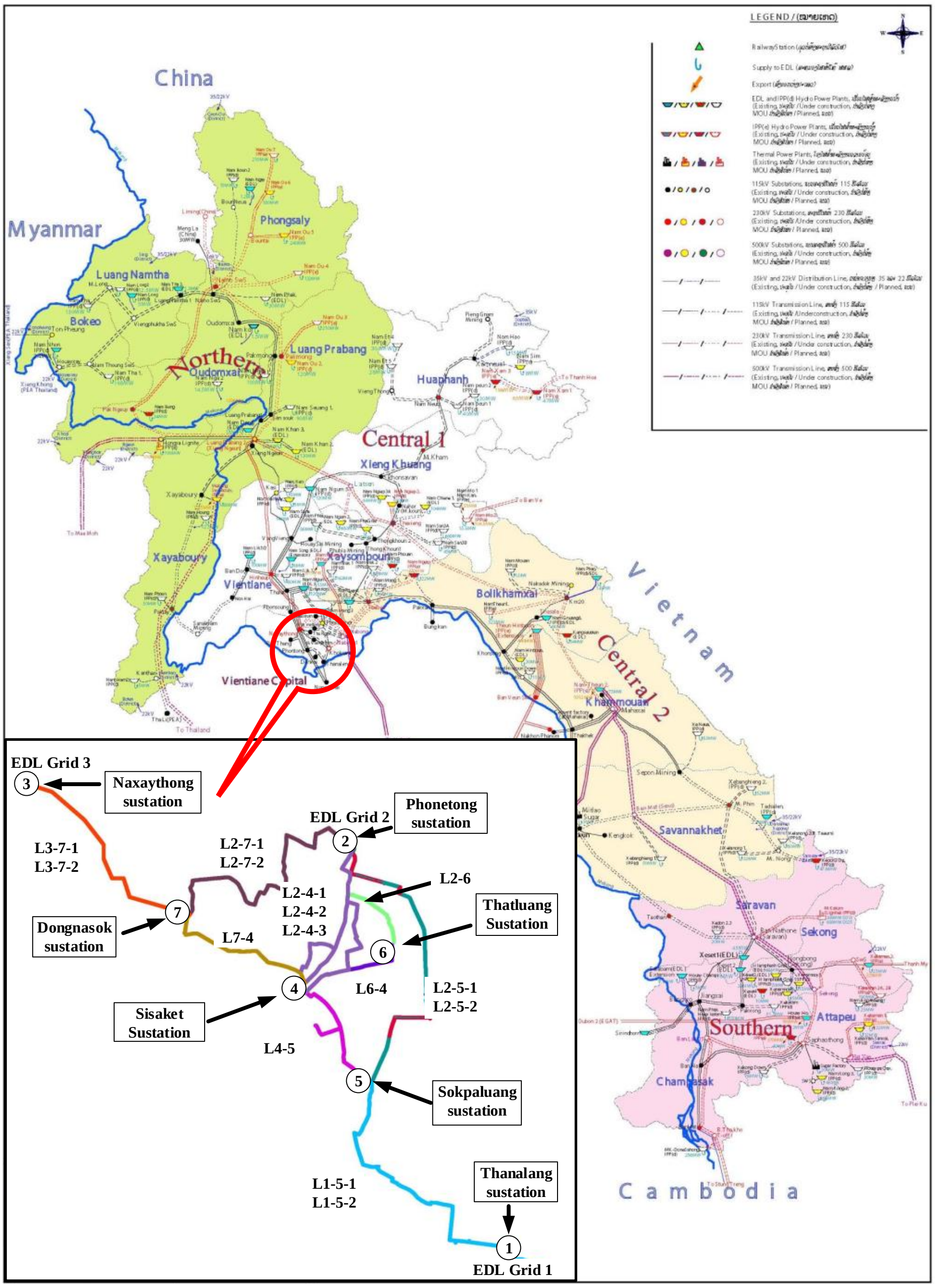


Figure 3.3 Location of the loop network in 22 kV distribution system of EDL

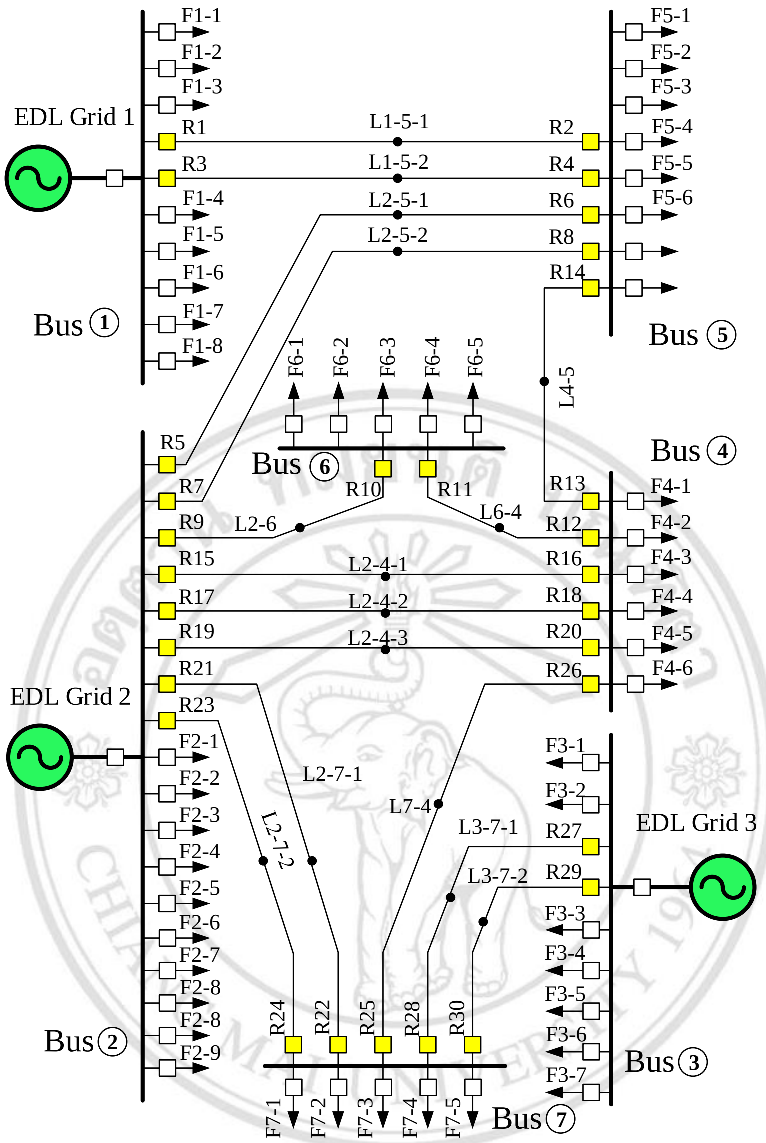


Figure 3.4 Single line diagram of the loop network in 22 kV distribution system

The structure of the circuit EDL grid is connected with substations (115/22 kV) as follows.

1) EDL gird 1 is connected in Thanalang (1) substation.

2) EDL gird 2 is connected in Phonetong (2) substation.

3) EDL gird 3 is connected in Naxaythong (3) substation and four substation the loop distribution system in medium voltage 22 kV as follows.

1) Sisaket substation (4).

2) Sokpaluang substation (5).

3) Thatluang substation (6).

4) Dongnasok substation (7).

3.1.2.2 General data of EDL grid 1

EDL grid 1 is connected with Thanalang substation, which consists power supplies of 115 kV transmission lines from Donekoy substation, Koksa Ad substation, Phonetong substation and connected to the Electricity Generating Authority of Thailand (EGAT) system at Nongkai. Thanalang substation is located at thamuang village, Hadxayfong district, and Vientiane capital city as shown in Table 3.1 and Figure 3.5.

Background of EDL grid connected with transmission lines.

1) Koksa Ad substation

- ❖ Length: 18.5 km
- ❖ Line type: ACSR 240 sq.mm
- ❖ Number of circuits: 1 circuit

2) Donekoy substation

- ❖ Length: 6.9 km
- ❖ Line type: ACSR 240 sq.mm
- ❖ Number of circuits: 1 circuit

3) Phonetong substation

- ❖ Length: 17.6 km
- ❖ Line type: ACSR 240 sq.mm
- ❖ Number of circuits: 1 circuit

4) The Electricity Generating Authority of Thailand (EGAT) system at Nongkai

- ❖ Length: 9.2 km
- ❖ Line type: ACSR 240 sq.mm
- ❖ Number of circuits: 1 circuit

5) Installed capacity of transformers in the substation

- ❖ Installed capacity: 90 MVA
- ❖ Number of units: 3 Unit
- ❖ Unit. 1, 2 and 3: 30 MVA

Table 3.1 Technical data of transformer of EDL grid 1

No.	Descriptions	Unit	T1	T2	T3
1	Rated Capacity	(MVA)	30	30	30
2	Rate Low Voltage	(kV)	22	22	22
3	Rate High Voltage	(kV)	115	115	115
4	Tap Voltage	(kV)	121	121	121
5	Tap Ratio		1.0522	1.0522	1.0522
6	System Voltage	(kV)	115	115	115
7	Winding		Y/Y	Y/Y	Y/Y

Figure 3.5 shows three transmission lines which are connected to the main transfer bus in the switch yard of Thanalang substation, which consists power supplies in 115 kV transmission lines. The transmission line 1 is connected to Donekoy substation. The transmission line 2 is connected to Koksa Ad substation. The transmission line 3 is connected to Phonetong substation and, the transmission line 4 is connected to EGAT system at Nongkai. The transformers change step down the voltage from 115 kV into 22 kV. It is connected to transfer bus 22 kV and consisted power supplies in 10 feeders.

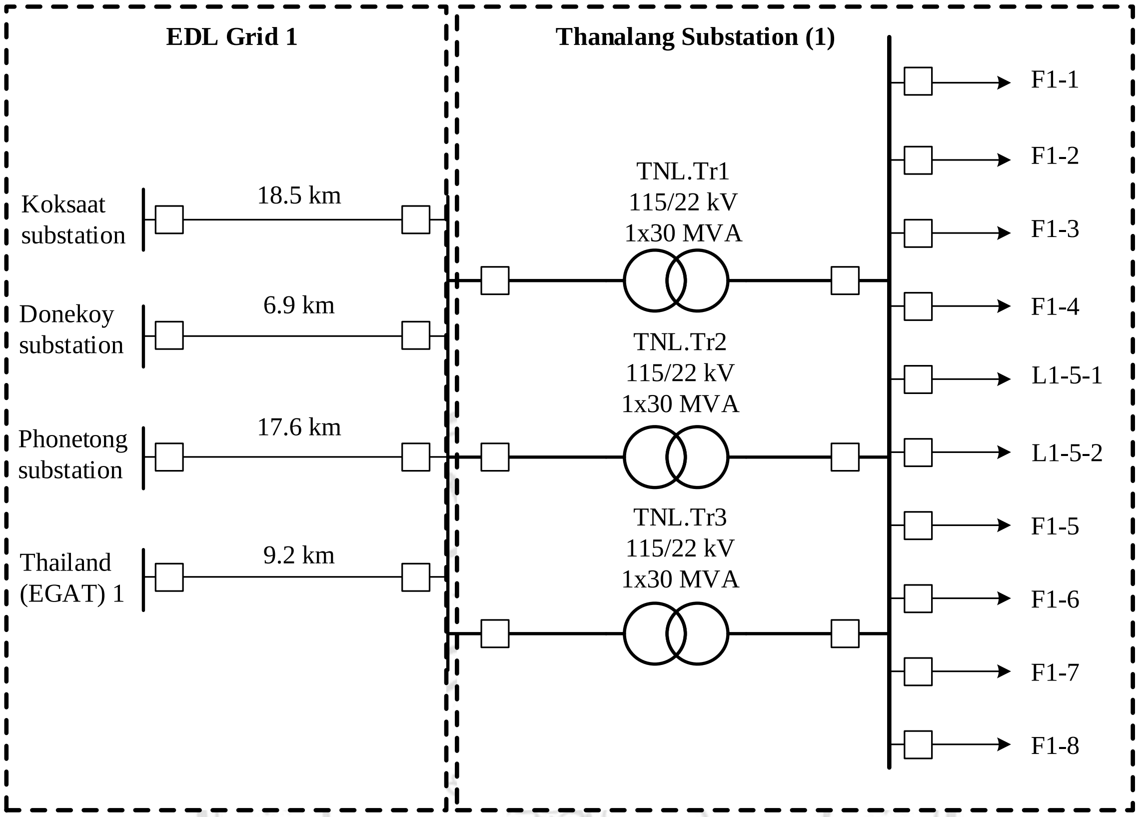


Figure 3.5 Single line diagram EDL grid 1 is connected with Thanalang substation

3.1.2.3 General data of EDL grid 2

EDL grid 2 is connected with Phonethong substation, which consists power supplies of 115 kV transmission lines from Pankthang substation, Thanalang substation, Donekoy substation, Nongviengkham substation, Naxaythong2 substation and connected to EGAT system at Nongkai, Phonethong substation is located at Phonethong village, Chanthabuly district, and Vientiane capital city as shown in Table 3.2 and Figure 3.6.

Background of EDL grid 2 connected with transmission lines.

1) Pakthang substation

- ❖ Length: 6.6 km
- ❖ Line type: ACSR 240 sq.mm
- ❖ Number of circuits: 1 circuit

2) Thanalang substation

- ❖ Length: 18 km
- ❖ Line type: ACSR 240 sq.mm
- ❖ Number of circuits: 1 circuit

3) Donekoy substation

- ❖ Length: 15.1 km
- ❖ Line type: ACSR 240 sq.mm
- ❖ Number of circuits: 1 circuit

4) Nongviengkham substation

- ❖ Length: 9.8 km
- ❖ Line type: ACSR 240 sq.mm
- ❖ Number of circuits: 1 circuit

5) Naxaythong2 substation

- ❖ Length: 13 km
- ❖ Line type: ACSR 240 sq.mm
- ❖ Number of circuits: 3 circuit

6) The Electricity Generating Authority of Thailand (EGAT) system at Nongkai

- ❖ Length: 26.7 km
- ❖ Line type: ACSR 240 sq.mm
- ❖ Number of circuits: 2 circuit

7) Installed capacity of transformers in the substation

- ❖ Installed capacity: 250 MVA
- ❖ Number of units: 4 Unit
- ❖ Unit. 1, 2, 3, 4, and 5: 50 MVA

Table 3.2 Technical data of transformer of EDL grid 2

No.	Descriptions	Unit	T1	T2	T3	T4
1	Rated Capacity	(MVA)	50	50	50	50
2	Rate Low Voltage	(kV)	22	22	22	22
3	Rate High Voltage	(kV)	115	115	115	115
4	Tap Voltage	(kV)	121	121	121	121
5	Tap Ratio		1.0522	1.0522	1.0522	1.0522
6	System Voltage	(kV)	115	115	115	115
7	Winding		Y/Y	Y/Y	Y/Y	Y/Y

Figure 3.6 shows three transmission lines which are connected to the main transfer bus in the switch yard of Phonethong substation, which consists power supplies in 115 kV transmission lines. The transmission line point 1 is connected to Pakthang substation. The transmission line point 2 is connected to Thanalang substation. The transmission line point 3 is connected to Donekoy substation. The transmission line 4 is connected to Nongviengkham substation. The transmission line point 5 is connected to Naxaythong2 substation. The transmission line point 6 is connected to the Electricity EGAT system at Nongkai. The transformers change step down the voltage from 115 kV into 22 kV. It is connected to transfer bus 22 kV and consisted power supplies in 16 feeders.

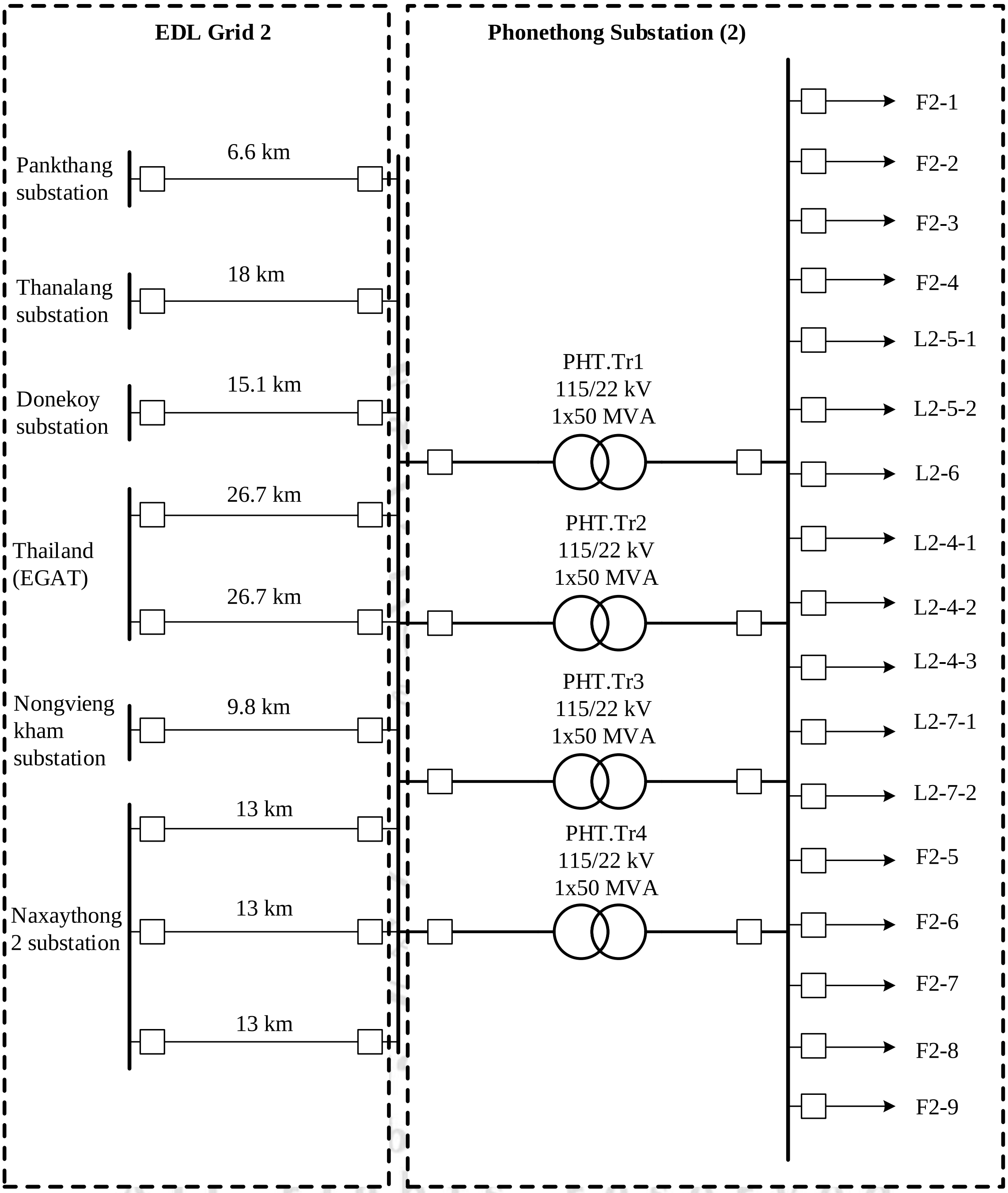


Figure 3.6 Single line diagram EDL grid 2 is connected with Phonethong substation

3.1.2.4 General data of EDL grid 3

EDL grid 3 is connected with Naxaythong substation, which consists power supplies of 115 kV transmission lines from Koksaat substation, Thangone substation, Phonethong substation, Naxaythong1 substation, Phonesoung substation and connected to NamNgum 1 hydropower plant. Naxaythong substation is located at the south Naxaythong village, Naxaythong district, and Vientiane capital city as shown in Table 3.3 and Figure 3.7.

Background of EDL grid 3 connected with transmission lines.

1) Koksaat substation

- ❖ Length: 20.6 km
- ❖ Line type: ACSR 240 sq.mm
- ❖ Number of circuits: 1 circuit

2) Thangone substation

- ❖ Length: 18.8 km
- ❖ Line type: ACSR 185 sq.mm
- ❖ Number of circuits: 1 circuit

3) Phonethong substation

- ❖ Length: 13 km
- ❖ Line type: ACSR 240 sq.mm
- ❖ Number of circuits: 3 circuit

4) Installed capacity of transformers in Naxaythong1 substation

- ❖ Rated Capacity: 200/200/60 MVA
- ❖ System Voltage: 230/115/22 kV
- ❖ Number transformer: 2

5) Phonesoung substation

- ❖ Length: 30 km
- ❖ Line type: ACSR 240 sq.mm

❖ Number of circuits: 1 circuit

6) NamNgum 1 hydropower plant

❖ Length: 61.1 km

❖ Line type: ACSR 240 sq.mm

❖ Number of circuits: 2 circuit

7) Installed capacity of transformers in the substation

❖ Installed capacity: 60 MVA

❖ Number of units: 2 Unit

❖ Unit. 1 and 2: 30 MVA

Table 3.3 Technical data of transformer of EDL grid 3

No.	Descriptions	Unit	T1	T2
1	Rated Capacity	(MVA)	50	50
2	Rate Low Voltage	(kV)	22	22
3	Rate High Voltage	(kV)	115	115
4	Tap Voltage	(kV)	121	121
5	Tap Ratio		1.0522	1.0522
6	System Voltage	(kV)	115	115
7	Winding		Y/Y	Y/Y

Figure 3.7 shows three transmission lines which are connected to the main transfer bus in the switch yard of Naxaythong substation, which consists power supplies in 115 kV transmission lines. The transmission line point 1 is connected to Koksaat substation. The transmission line point 2 is connected to Thangone substation. The transmission line point 3 is connected to Phonethong substation. The transmission line 4 is connected to Phonesoung substation. The 2 transformer unit of Naxaythong1 substation is connected to Naxaythong 2 substation. The transmission line point 5 is connected to NamNgum 1 hydropower plant. The transformers change step down the

voltage from 115 kV into 22 kV. It is connected to transfer bus 22 kV and consisted power supplies in 9 feeders.

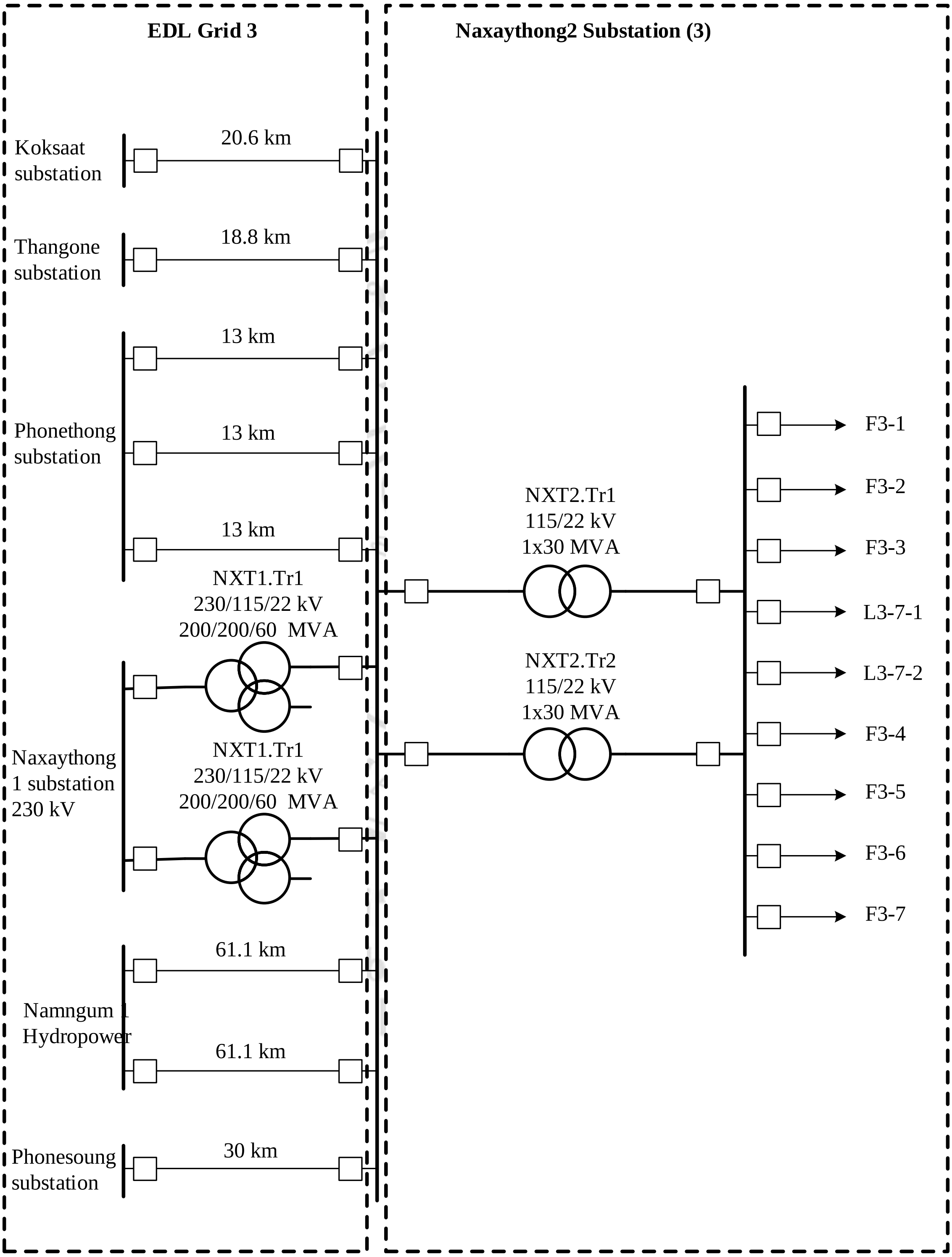


Figure 3.7 Single line diagram EDL grid 3 is connected with Naxaythong substation

3.1.2.5 General data of Sisaket substation

Sisaket substation is the switching station. It is a substation without transformers and operating only at a single voltage level which connects power supplies in 22 kV feeders. Sisaket substation is connected to feeders with Sokpaluang substation, Phonetong substation, and Dongnasok substation. Sisaket substation is located at Sisaket village, Xaysetha district, Vientiane capital city as shown in Figure 3.8.

Background of Sisaket substation connected with feeders.

1) Sokpaluang substation
   - Length: 3.3 km
   - Line type: SAC 240 sq.mm
   - Number of circuits: 1 circuit
2) Phonetong substation
   - Length: 4.4 km
   - Line type: SAC 240 sq.mm
   - Number of circuits: 3 circuit
3) Dongnasok substation
   - Length: 4.1 km
   - Line type: SAC 240 sq.mm
   - Number of circuits: 1 circuit

Figure 3.8 is shown five feeders which are connected to the main transfer bus in the switch yard of Sisaket substation which connects power supplies in 22 kV feeders. The feeders L4-5 connected from Thanalang substation. The feeders (L2-1-1, L2-1-2, and L2-4-3) connected from Phonethong substation. The feeder L4-5 connected from Dongnasok substation. It is connected to transfer bus 22 kV and consisted power supplies in 6 feeders.

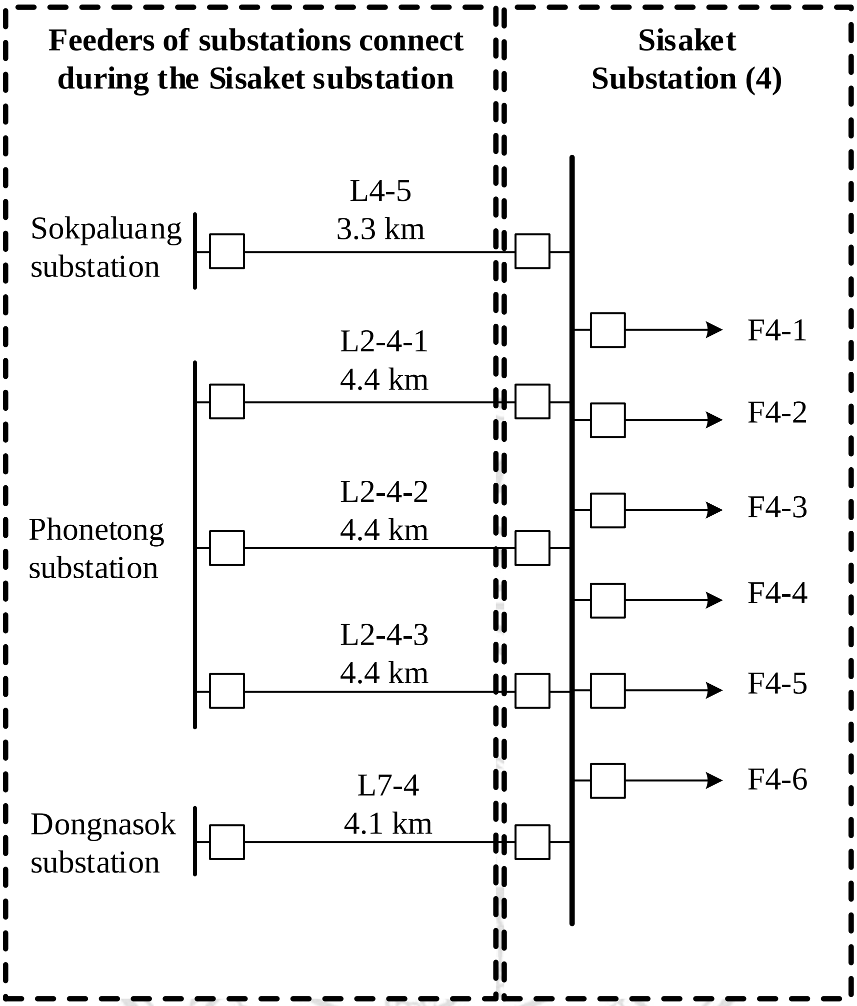


Figure 3.8 Single line diagram of Sisaket substation

3.1.2.6 General data of Sokpakluang substation

Sokpakluang substation is the switching station. It is a substation without transformers and operating only at a single voltage level which connects power supplies in 22 kV feeders. Sokpakluang substation is connected to feeders with Thanalang substation, Phonetong substation, and Sisket substation. Sokpakluang substation is located at Sokpakluang village, Chanthabuly district, Vientiane capital city as shown in Figure 3.9.

Background of Sokpakluang substation connected with feeders.

1) Thanalang substation

❖ Length: 15.9 km

- ❖ Line type: SAC 240 sq.mm
- ❖ Number of circuits: 2 circuit

2) Phonetong substation

- ❖ Length: 7.8 km
- ❖ Line type: SAC 240 sq.mm
- ❖ Number of circuits: 2 circuit

3) Sisaket substation

- ❖ Length: 3.3 km
- ❖ Line type: SAC 240 sq.mm
- ❖ Number of circuits: 1 circuit

Figure 3.9 is shown five feeders which are connected to the main transfer bus in the switch yard of Sokpakluang substation which connects power supplies in 22 kV feeders. The feeders (L1-5-1, L1-5-2) connected from Thanalang substation. The feeders (L2-5-1, L2-5-2) connected from Phonethong substation. The feeder L4-5 connected from Sisaket substation. It is connected to transfer bus 22 kV and consisted power supplies in 6 feeders.

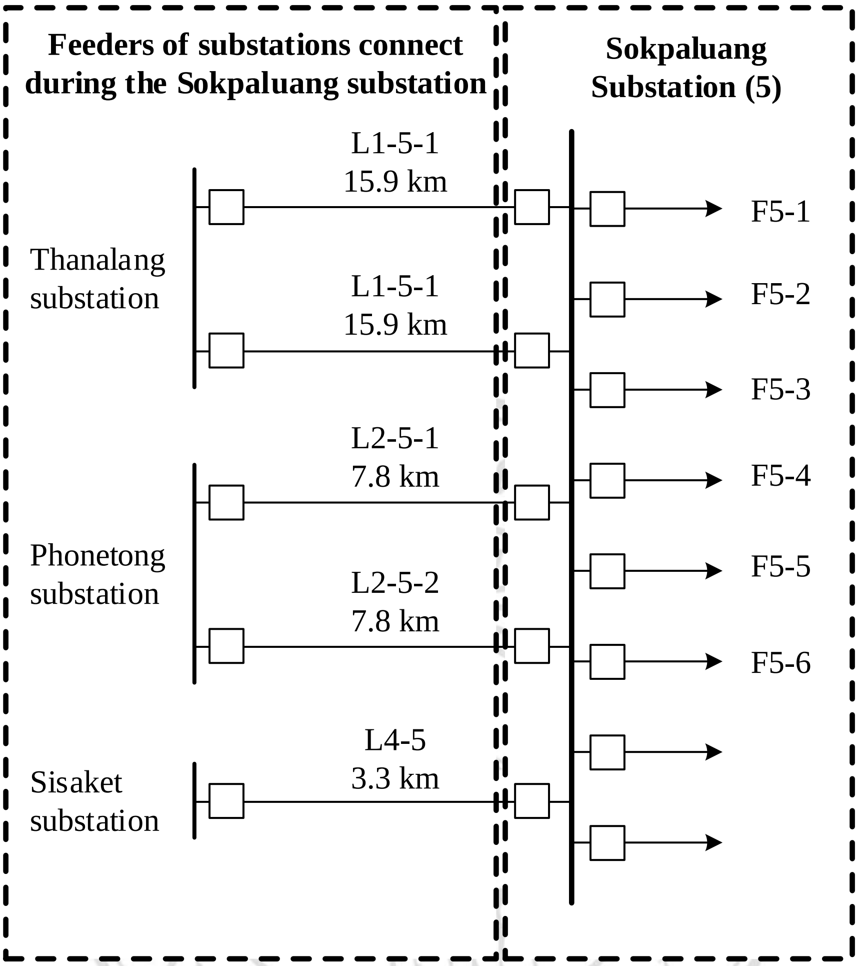


Figure 3.9 Single line diagram of Sokpakluang substation

3.1.2.7 General data of Thatluang substation

Thatluang substation is the switching station. It is a substation without transformers and operating only at a single voltage level which connects power supplies in 22 kV feeders. Thatluang substation is connected to feeders with Phonetong substation, and Sisaket substation. Sisaket substation is located at north Thatluang village, Xaysetha district, Vientiane capital city as shown in Figure 3.10.

Background of Thatluang substation connected with feeders.

1) Phonetong substation

- ❖ Length: 4.0 km
- ❖ Line type: SAC 240 sq.mm

- ❖ Number of circuits: 1 circuit

2) Sisaket substation

- ❖ Length: 3.0 km
- ❖ Line type: SAC 240 sq.mm
- ❖ Number of circuits: 1 circuit

Figure 3.10 is shown five feeders which are connected to the main transfer bus in the switch yard of Sisaket substation which connects power supplies in 22 kV feeders. The feeders L2-6 connected from Phonethong substation. The feeders L6-4 connected from Sisaket substation. It is connected to transfer bus 22 kV and consisted power supplies in 5 feeders.

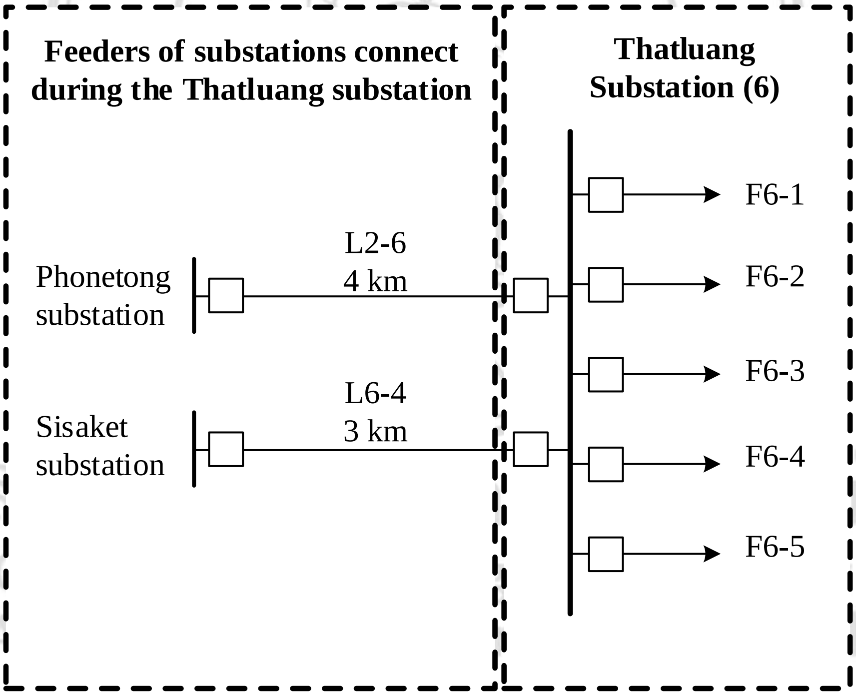


Figure 3.10 Single line diagram of Thatluang substation

3.1.2.8 General data of Dongnasok substation

Dongnasok substation is the switching station. It is a substation without transformers and operating only at a single voltage level which connects power supplies in 22 kV feeders. Dongnasok substation is connected to feeders with Naxaythong 2 substation, Sisaket substation and Phonethong substation. Dongnasok substation is located at the north Dongnasok village, Sisattanak District, Vientiane capital city as shown in Figure 3.11.

Background of Dongnasok substation connected with feeders.

1) Naxaythong2 substation
    - ❖ Length: 12.2 km
    - ❖ Line type: SAC 240 sq.mm
    - ❖ Number of circuits: 2 circuit
2) Sisaket substation
    - ❖ Length: 4.1 km
    - ❖ Line type: SAC 240 sq.mm
    - ❖ Number of circuits: 1 circuit
3) Phonethong substation
    - ❖ Length: 5.5 km
    - ❖ Line type: SAC 240 sq.mm
    - ❖ Number of circuits: 2 circuit

Figure 3.11 is shown five feeders which are connected to the main transfer bus in the switch yard of Dongnasok substation which connects power supplies in 22 kV feeders. The feeders (L3-7-1, L3-7-2) connected from Naxaythong2 substation. The feeders L7-4 connected from Sisaket substation. The feeders (L2-7-1, L2-7-2) connected from Phonethong substation. It is connected to transfer bus 22 kV and consisted power supplies in 5 feeders.

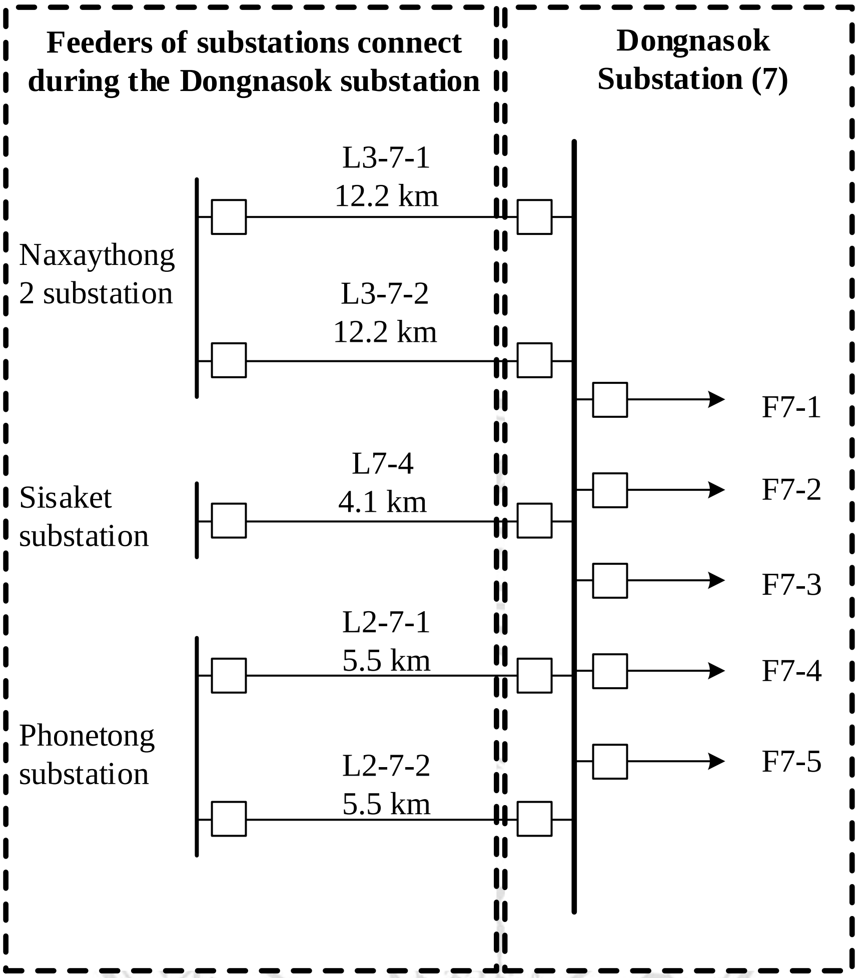


Figure 3.11 Single line diagram of Dongnasok substation

3.1.2.9 Data of Substation in the loop network in 22 kV

The existing of the system data in this research focuses on Vientiane Capital area, which consists as shown in following:

1) Data in Table 3.4 show size of line, length, and impedance of line that connect with seven substations.

2) Data in Table 3.5 show the type, capacity, c-bank, and connects installation that connect with seven substations.

3) Data in Table 3.6 show lines, connection point of relay, and protection devices of substations.

4) Data in Table 3.7 show power flow load in the feeders, which consists active power, reactive power, and current flow value.

Table 3.4 The existing data of lines that connect with seven substations

No.	Feeder	Substation		Size	Length/ Circuits	Impedance	
		From	To	Sq.mm	km/ccts	R (Ohm)	X (Ohm)
1	L1-5-1	Thanalang	Sokpaluang	240	15.9	1.993606	5.198397
2	L1-5-2	Thanalang	Sokpaluang	240	15.9	1.993606	5.198397
3	L2-5-1	Phonethong	Sokpaluang	240	7.8	0.979956	2.550157
4	L2-5-2	Phonethong	Sokpaluang	240	7.8	0.979956	2.550157
5	L2-6	Phonethong	Thatluang	240	4.0	0.5015363	1.307773
6	L6-4	Thatluang	Sisaket	240	3.0	0.3761522	0.9808296
7	L4-5	Sisaket	Sokpaluang	240	3.3	0.4137675	1.078912
8	L2-4-1	Phonethong	Sisaket	240	4.4	0.2355048	0.8153951
9	L2-4-2	Phonethong	Sisaket	240	4.4	0.2355048	0.8153951
10	L2-4-3	Phonethong	Sisaket	240	4.4	0.2355048	0.8153951
11	L2-7-1	Phonethong	Dongnasok	240	5.5	0.6896123	1.798187
12	L2-7-2	Phonethong	Dongnasok	240	5.5	0.6896123	1.798187
13	L7-4	Dongnasok	Sisaket	240	4.1	0.5140747	1.340467
14	L3-7-1	Naxaythong	Dongnasok	240	12.2	1.529685	3.988707
15	L3-7-2	Naxaythong	Dongnasok	240	12.2	1.529685	3.988707

Table 3.5 The existing data into seven substations

No.	Type of Substation		Capacity installation	C-Bank (MVar) 22kV	Voltage (kV)
	Distribution substation	Switching station	115/22kV (MVA)		
1	Thanalang	-	3 x 30 = 90	12 x 2.5 = 30	115/22kV

Table 3.5 The existing data into seven substations (Continued)

No.	Type of Substation		Capacity installation	C-Bank (MVar)	Voltage (kV)
	Distribution substation	Switching station	115/22kV (MVA)	22kV	
2	Phonethong	-	5 x 50 = 250	8 x 9 = 72	115/22kV
3	Naxaythong	-	2 x 30 = 60	8 x 2.5 = 20	115/22kV
4	-	Sisaket	-	-	22kV
5	-	Sokpaluang	-	6 x 2.4 = 14.4	22kV
6	-	thatluang	-	-	22kV
7	-	Dongnasok	-	3 x 2.4 = 7.2	22kV

Table 3.6 Data of lines, connection point relay, and protection devices

No.	Lines	Relay	Substations		Current Transformer (CT)
		Name	From	To	
1	L1-5-1	R1	Thanalang	Sokpaluang	800/1A
		R2	Sokpaluang	Thanalang	800/1A
2	L1-5-2	R3	Thanalang	Sokpaluang	800/1A
		R4	Sokpaluang	Thanalang	800/1A
3	L2-5-1	R5	Phonethong	Sokpaluang	800/5A
		R6	Sokpaluang	Phonethong	800/5A
4	L2-5-2	R7	Phonethong	Sokpaluang	800/5A
		R8	Sokpaluang	Phonethong	800/5A
5	L2-6	R9	Phonethong	Thatluang	800/5A
		R10	Thatluang	Phonethong	800/5A
6	L6-4	R11	Thatluang	Sisaket	600/5A
		R12	Sisaket	Thatluang	600/5A

Table 3.6 Data of lines, connection point relay, and protection devices (Continued)

No.	Lines	Relay	Substations		Current Transformer (CT)
		Name	From	To	
7	L4-5	R13	Sisaket	Sokpaluang	600/5A
		R14	Sokpaluang	Sisaket	600/5A
8	L2-4-1	R15	Phonethong	Sisaket	800/5A
		R16	Sisaket	Phonethong	800/5A
9	L2-4-2	R17	Phonethong	Sisaket	800/5A
		R18	Sisaket	Phonethong	800/5A
10	L2-4-3	R19	Phonethong	Sisaket	800/5A
		R20	Sisaket	Phonethong	800/5A
11	L2-7-1	R21	Phonethong	Dongnasok	800/5A
		R22	Dongnasok	Phonethong	800/5A
12	L2-7-2	R23	Phonethong	Dongnasok	800/5A
		R24	Dongnasok	Phonethong	800/5A
13	L7-4	R25	Dongnasok	Sisaket	600/5A
		R26	Sisaket	Dongnasok	600/5A
14	L3-7-1	R27	Naxaythong	Dongnasok	800/1A
		R28	Dongnasok	Naxaythong	800/1A
15	L3-7-2	R29	Naxaythong	Dongnasok	800/1A
		R30	Dongnasok	Naxaythong	800/1A

Table 3.7 The existing data of power flow load in the feeders

No.	Substations	Feeders	Load		Current
			P (MW)	Q (Mvar)	I (kA)
1	Thanalang	F1-1	-	-	-

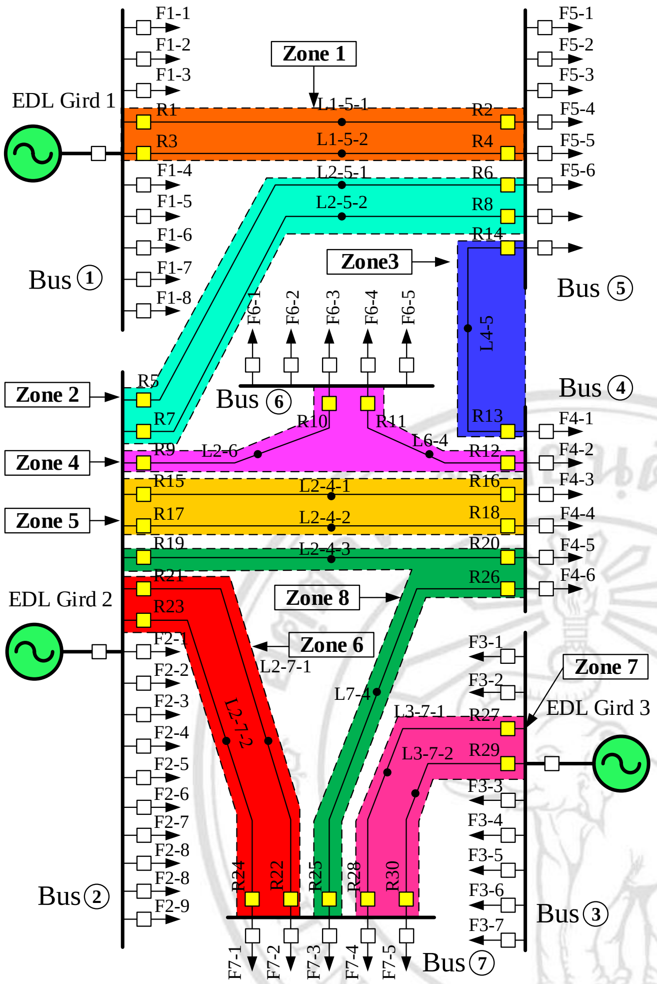
Table 3.7 The existing data of power flow load in the feeders (Continued)

No.	Substations	Feeders	Load		Current
			P (MW)	Q (Mvar)	I (kA)
2	Thanalang	F1-2	1.5	0.6	0.044
3		F1-3	9.5	3.4	0.273
4		F1-4	8.2	3.2	0.238
7		F1-5	6.0	2.4	0.174
8		F1-6	8.7	4.0	0.258
9		F1-7	8.5	4.1	0.255
10		F1-8	-	-	-
11	Phonethong	F2-1	6.2	2.6	0.182
12		F2-2	5.9	2.3	0.171
13		F2-3	2.5	0.9	0.072
14		F2-4	1.1	0.4	0.032
23		F2-5	9.6	3.8	0.279
24		F2-6	6.2	2.0	0.176
25		F2-7	5.7	2.1	0.164
26		F2-8	5.9	2.5	0.173
27		F2-9	-	-	-
28	Naxaythong	F3-1	0.9	0.3	0.025
29		F3-2	7.4	3.8	0.224
30		F3-3	-	-	-
33		F3-4	6.4	2.3	0.183
34		F3-5	-	-	-
35		F3-6	0.5	0.2	0.013
36		F3-7	-	-	-
37	Sisaket	F4-1	5.9	2.3	0.175

Table 3.7 The existing data of power flow load in the feeders (Continued)

No.	Substations	Feeders	Load		Current
			P (MW)	Q (Mvar)	I (kA)
38	Sisaket	F4-2	10.5	4.8	0.318
39		F4-3	9.5	4.6	0.291
40		F4-4	2.6	0.9	0.076
41		F4-5	6.8	2.5	0.200
42		F4-6	5.2	2.1	0.154
43	Sokpaluang	F5-1	3.7	1.5	0.111
44		F5-2	6.3	2.9	0.194
45		F5-3	6.4	3.1	0.198
46		F5-4	5.4	2.0	0.161
47		F5-5	3.5	1.3	0.103
48		F5-6	4.9	1.9	0.147
49	Thatluang	F6-1	2.4	0.5	0.068
50		F6-2	4.9	1.0	0.139
51		F6-3	5.1	1.0	0.144
52		F6-4	3.6	0.7	0.102
53		F6-5	2.8	0	0.078
54	Dongnasok	F7-1	9.0	1.8	0.254
55		F7-2	7.2	2.4	0.210
56		F7-3	4.1	1.5	0.121
57		F7-4	1.0	0.4	0.030
58		F7-5	6.0	2.2	0.176

The single line diagram of the network system connects the 22kV loop network in the figure. For defining the protection zone, this is based on the parallel networks as shown in Figure 3.12, because it is suitable for the N-1 security of the network.



Protection Zone		
No	Backup OC relay	Primary OC relay
Zone1	R1	R4
	R3	R2
Zone2	R5	R8
	R7	R6
Zone3	R13	R14
Zone4	R9	R11
	R10	R12
Zone5	R15	R18
	R17	R16
Zone6	R21	R24
	R23	R22
Zone7	R27	R30
	R29	R28
Zone8	R19	R26
	R25	R20

Figure 3.12 Single line diagram of defining protection zone in the seven substations

After, single line diagram of defining protection zone in the seven substations. It will be created the modeling with DIgSILENT PowerFactory as shown in Figure 3.13, which will the date of studied in this research.

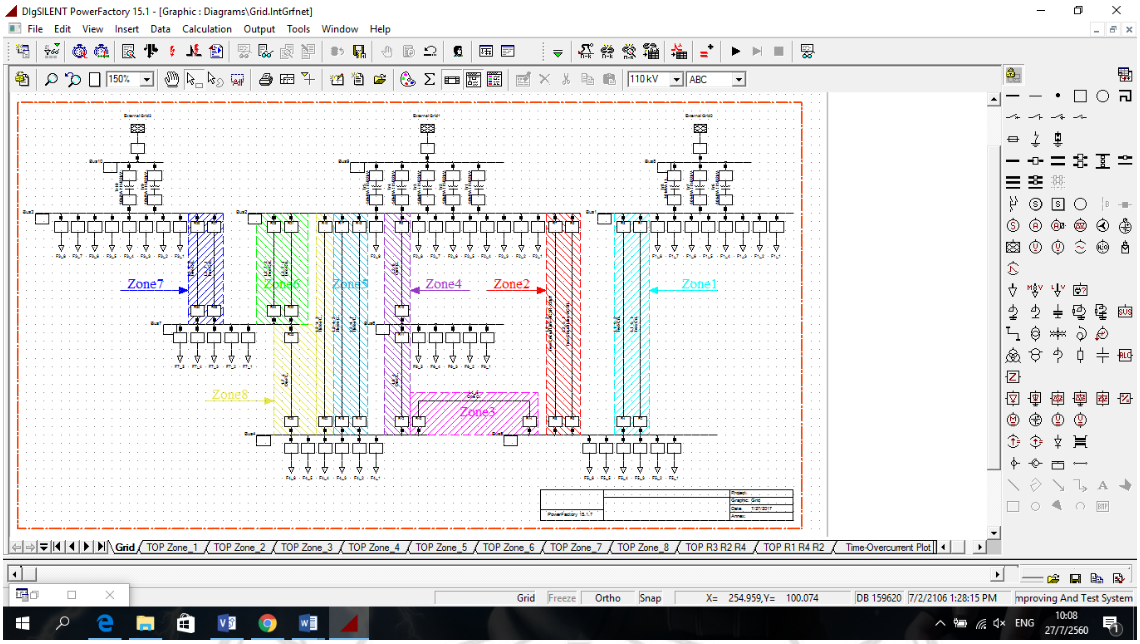


Figure 3.13 The modeling with DIgSILENT PowerFactory

3.1.3 The system is analyzed by passing a script of DPL in step 3

The data are processed by passing a script of DPL function.

3.1.3.1 Part of the analysis tools to write DPL Script

DPL stands for programming language is the language written in DIgSILENT, it uses the command to run a command in a program automatically, the function of DPL language quite similar to C ++ language. The structure of the program as shown in Figure 3.14 [14].

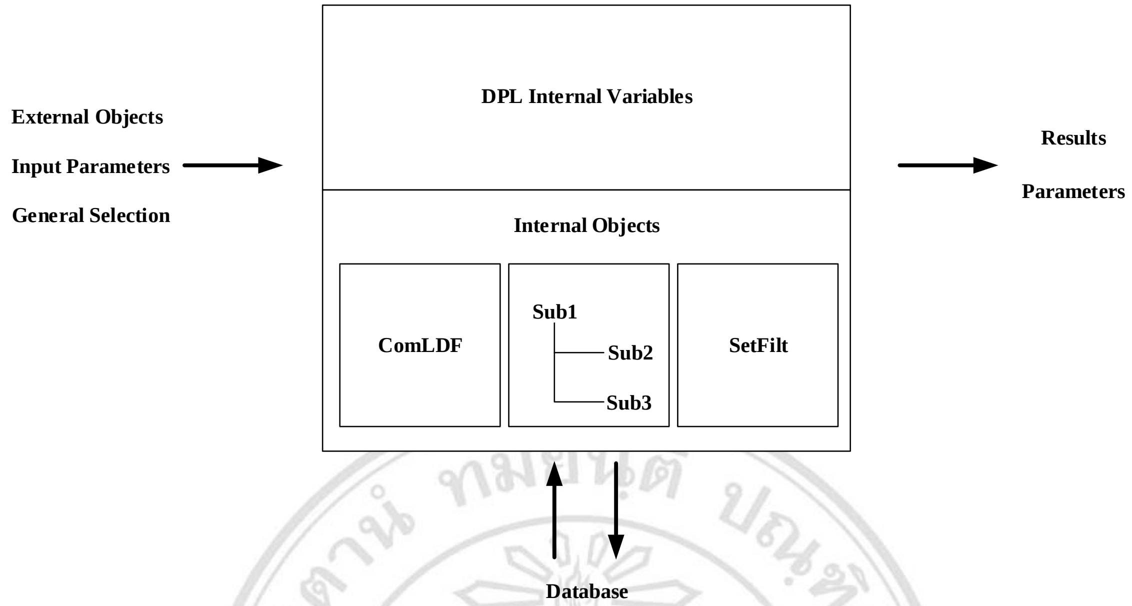


Figure 3.14 The structure of the DPL

1) Input Parameter is the section users can enter values for the variables.

2) DPL Internal Variables are command setting that can create a functional in mathematical calculations, loops, conditions, loops, and command.

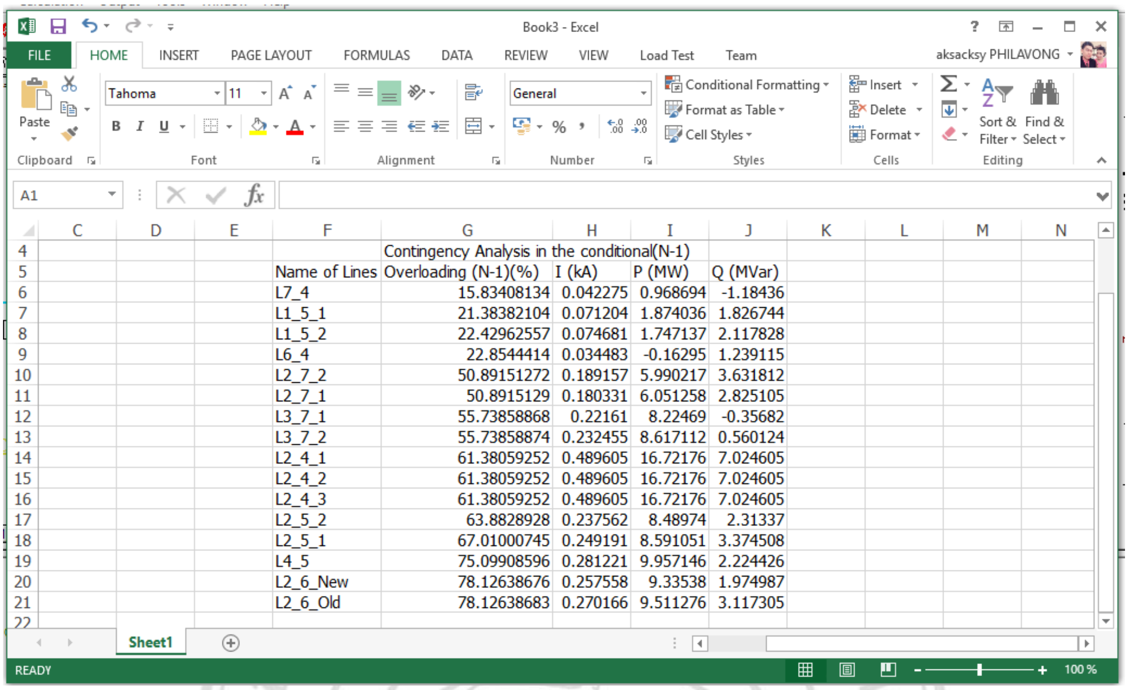
3) Internal Objects is as a specific set of commands, programs, and tools, such as automated DIgSILENT PowerFactory command to calculate power flow and short circuit current calculations, commands, etc.

4) Results Parameter will shows display on the DIgSILENT PowerFactory itself.

5) The database is an exchange of information between the databases of other programs such as Microsoft Excel, etc.

3.1.3.2 Part of the information display

From the structure of the Database in that part of the DPL language can display all analysis results into Microsoft Excel's Worksheet automatically, so the result of the analysis was the issue, so it can display both the window display of a program Microsoft Excel and DIgSILENT PowerFactory as shown in Figure 3.15 and Figure 3.16.



Name of Lines	Overloading (N-1)(%)	I (kA)	P (MW)	Q (MVar)
L7_4	15.83408134	0.042275	0.968694	-1.18436
L1_5_1	21.38382104	0.071204	1.874036	1.826744
L1_5_2	22.42962557	0.074681	1.747137	2.117828
L6_4	22.8544414	0.034483	-0.16295	1.239115
L2_7_2	50.89151272	0.189157	5.990217	3.631812
L2_7_1	50.8915129	0.180331	6.051258	2.825105
L3_7_1	55.73858868	0.22161	8.22469	-0.35682
L3_7_2	55.73858874	0.232455	8.617112	0.560124
L2_4_1	61.38059252	0.489605	16.72176	7.024605
L2_4_2	61.38059252	0.489605	16.72176	7.024605
L2_4_3	61.38059252	0.489605	16.72176	7.024605
L2_5_2	63.8828928	0.237562	8.48974	2.31337
L2_5_1	67.01000745	0.249191	8.591051	3.374508
L4_5	75.09908596	0.281221	9.957146	2.224426
L2_6_New	78.12638676	0.257558	9.33538	1.974987
L2_6_Old	78.12638683	0.270166	9.511276	3.117305

Figure 3.15 Contingency analysis in the conditional (N-1) export in Microsoft Excel

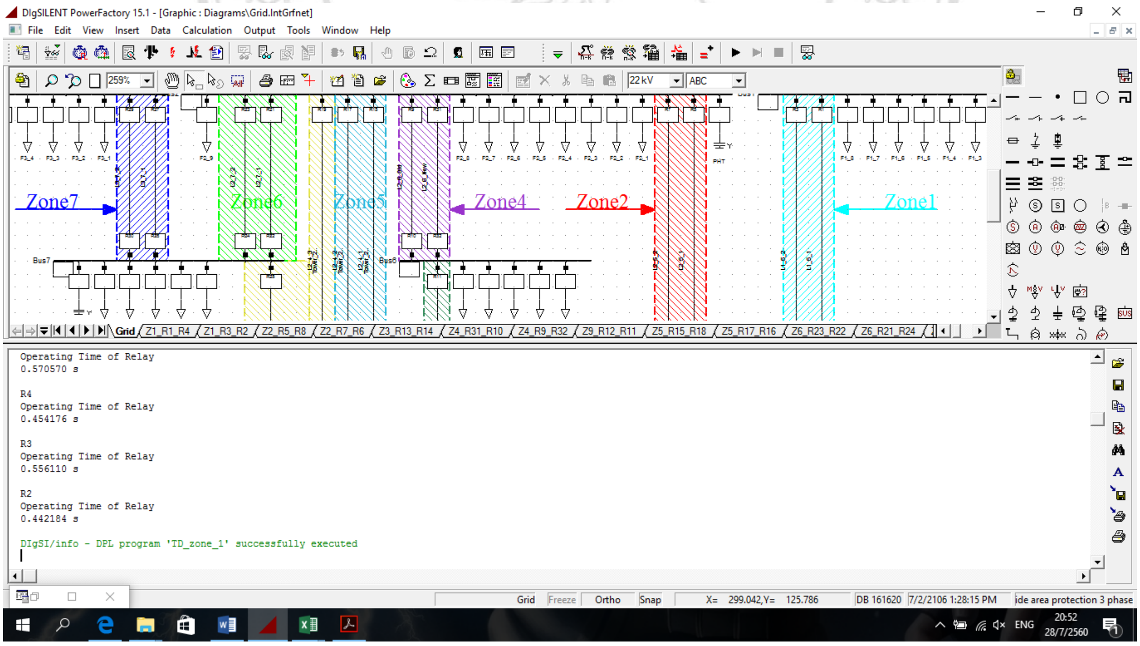


Figure 3.16 Operating time, which show in Window result of program

3.1.4 The processing analysis in step 4

All case studies will be analyzed by DPL to study load flow and fault in the network, then record the result and set the relay setting. At this step, it also defined contingency definition (N-1), CA and record the contingency result. After that, the DPL will show the proper current setting and TD value to the user Program text of DPL function in Figure 3.17, Figure 3.18, Figure 3.19, and Figure 3.20.

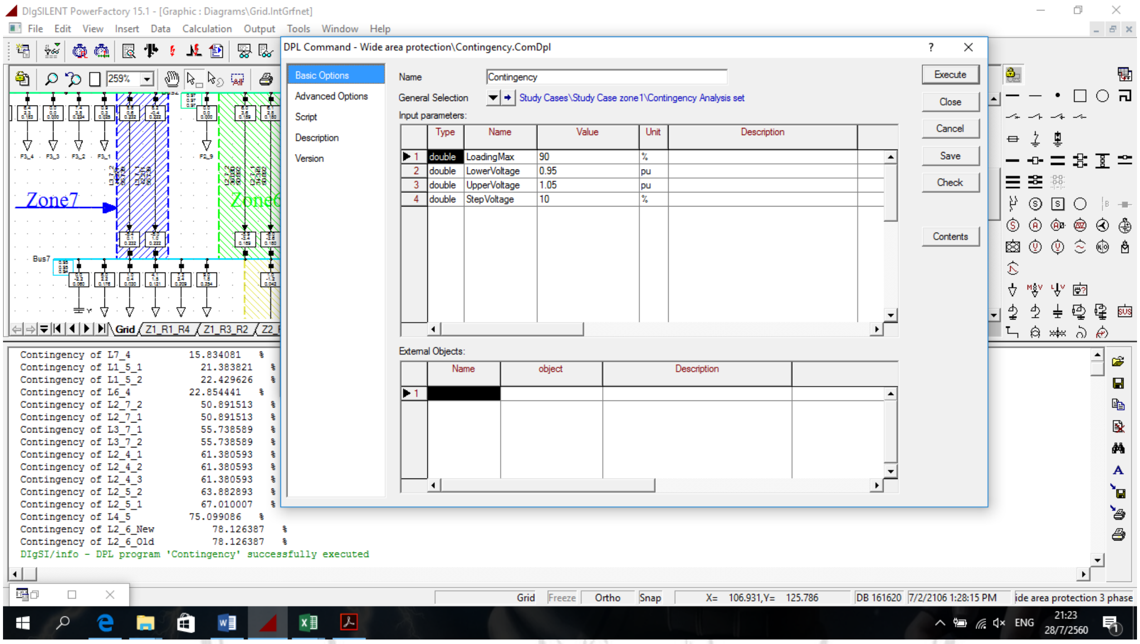


Figure 3.17 DPL command of CA in conditional (N-1)

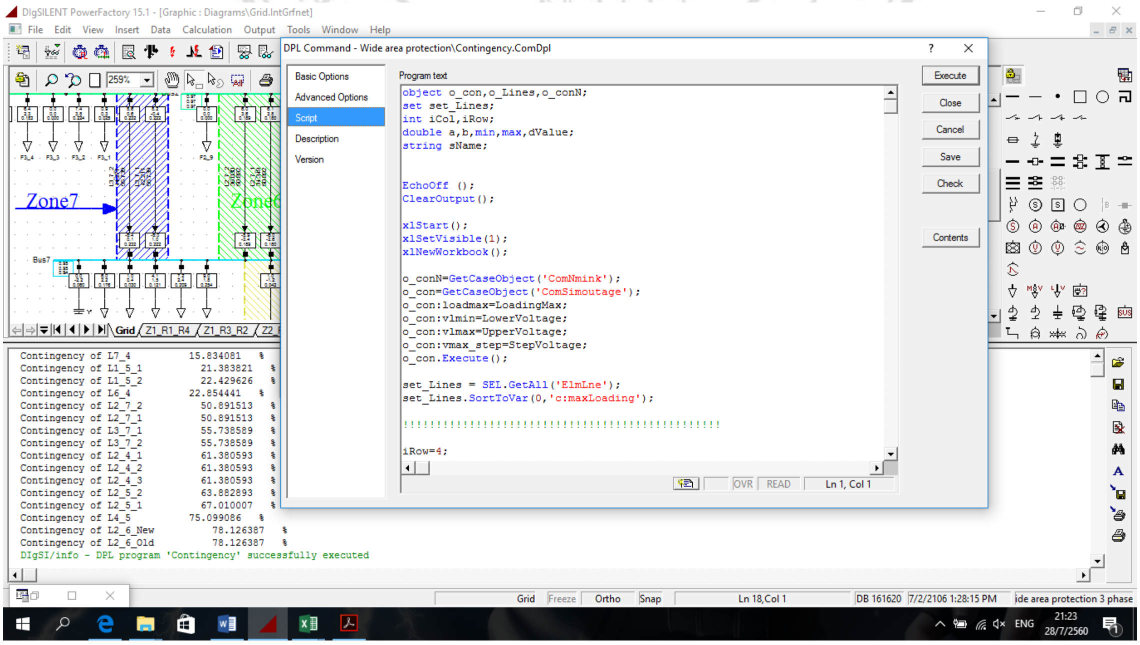


Figure 3.18 Program text of CA by DPL function

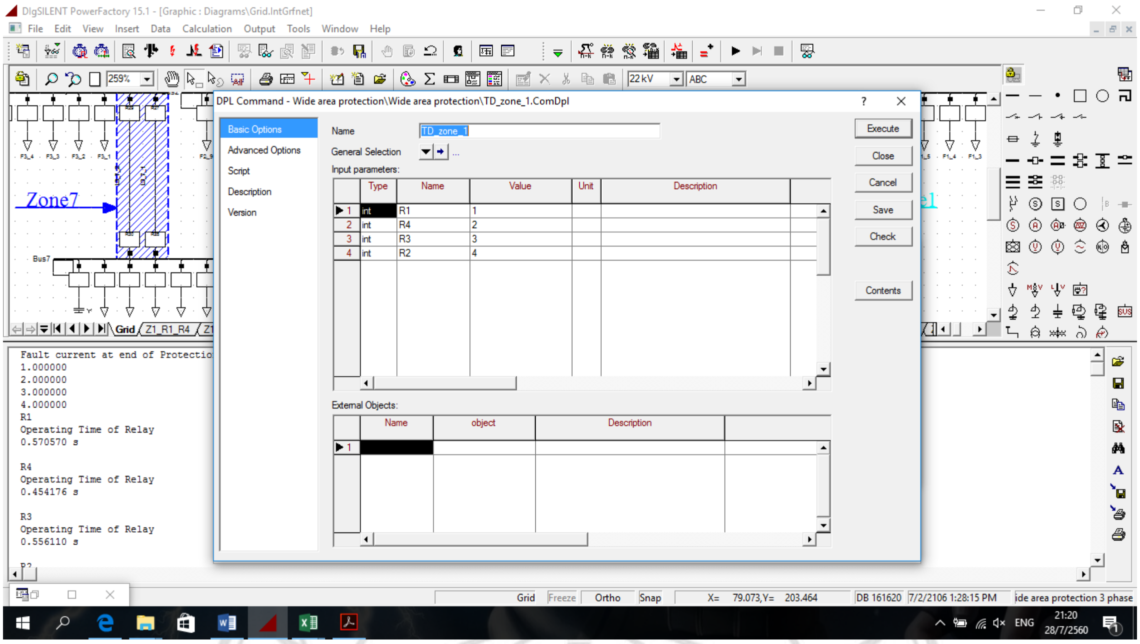


Figure 3.19 DPL command of setting OC relay

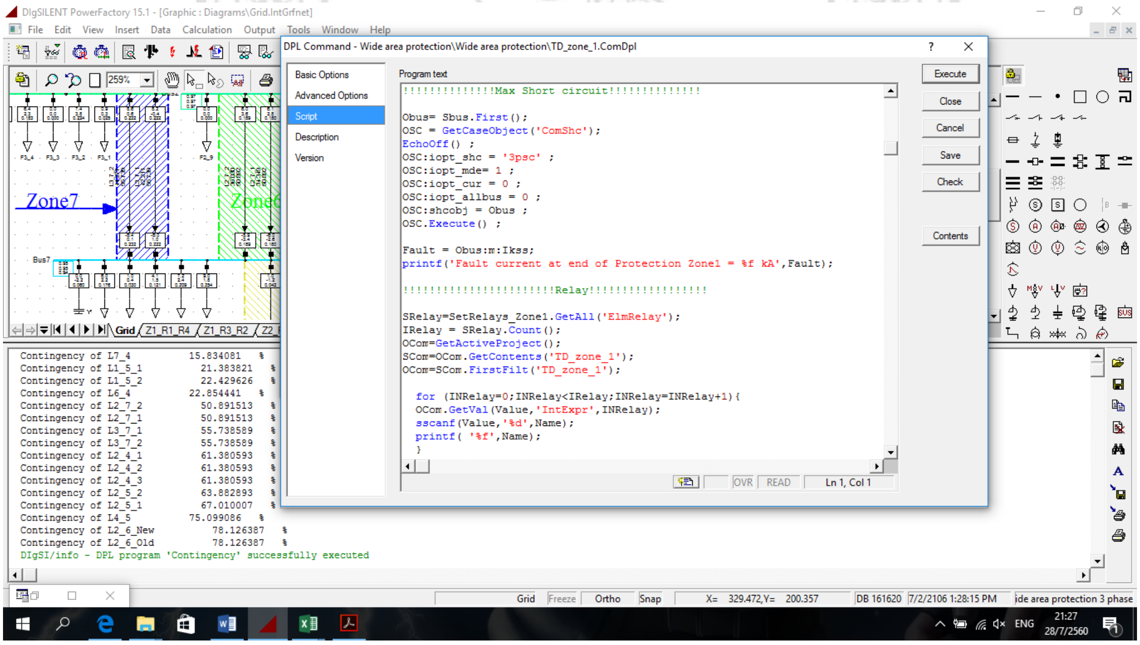


Figure 3.20 Setting OC relay by program text

3.1.5 The model will be analyzed fault again under 2 criteria in step 5

The WAP can protect by many the methods. This case study analyzes the system problem by setting the proper OC relay together with conditional the CA in the abnormal network (N-1). The network will support the outage problem with a wide area in the future if it has occurrence, event such as the overloading problem and the fault occurrence in the network.

3.1.5.1 The contingency analysis

The model will be checked the overloading value in the network that can support 90 percent of conductor capacity. If the overloading value is higher than 90% of conductor capacity the network will trip and the system will fail down.

The analysis result in Figure 3.12 shows the load flow and CA in conditional (N-1) the networks in Table 3.8.

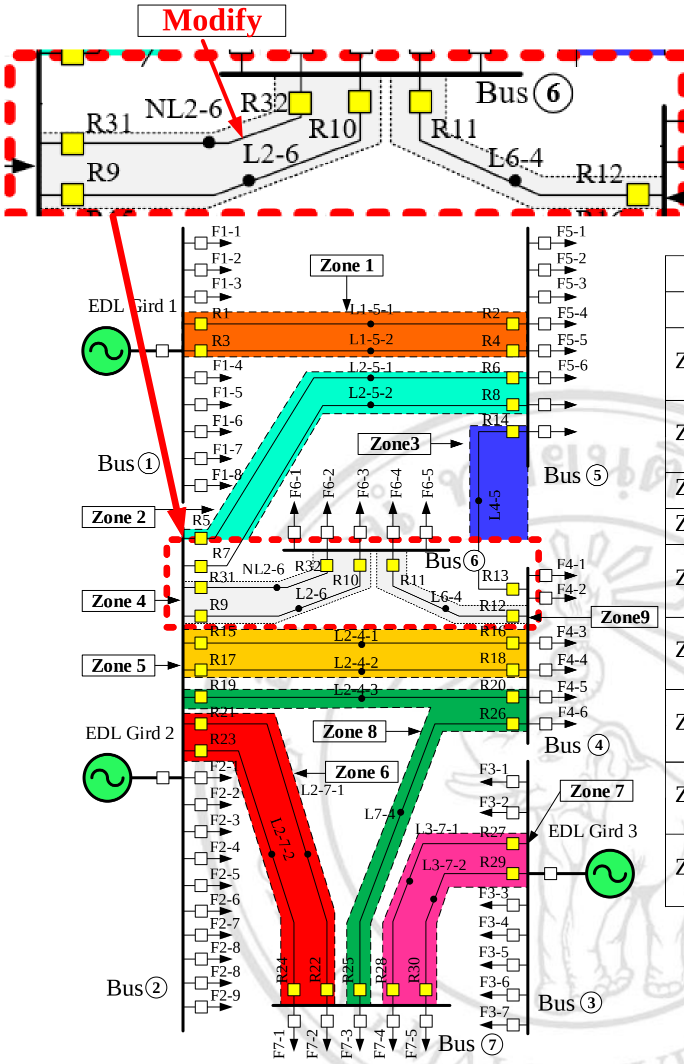
Table 3.8 Result analysis before improvement the system

Networks No	Load flow			Contingency Analysis Condition [%]	
	P [MW]	Q [MVAR]	I [kA]	Normal Load	Overloading [N-1]
L1-5-1	1.947779	1.848663	0.073047	13.91378	21.39162
L1-5-2	1.821554	2.149041	0.076615	14.59334	22.43781
L2-5-1	8.749882	3.440262	0.253838	48.35018	67.0068
L2-5-2	8.647043	2.359335	0.241993	46.09388	64.61646
L4-5	9.500603	2.088256	0.268505	51.14387	73.02277
L2-6	14.60112	3.799829	0.407224	77.56651	101.3466
L6-4	-4.44865	-0.09396	0.123315	23.48863	103.3527
L2-4-1	17.87925	7.479876	0.523182	49.82685	66.22072
L2-4-2	17.87925	7.479876	0.523182	49.82685	66.22072
L2-7-1	6.215479	2.869343	0.184859	35.21131	52.18937
L2-7-2	6.156457	3.696549	0.193907	36.93471	52.18937
L3-7-1	8.289597	-0.33075	0.223336	42.54025	56.18056
L3-7-2	8.681845	0.594659	0.234266	44.62205	56.18056
L2-4-3	17.87925	7.479876	0.523182	49.82685	66.22072

Table 3.8 Result analysis before improvement the system (Continued)

Networks No	Load flow			Contingency Analysis Condition [%]	
	P [MW]	Q [MVAR]	I [kA]	Normal Load	Overloading [N-1]
L7-4	1.414203	-1.05995	0.048856	9.305954	19.21956

The analysis results of the networks in Table 3.8 show the overloading problem in conditional (N-1) that are more than 90 %. The overloading feeders consist L2-6 and L6-4 that are equal to 101.34% and 103.35 % respectively. These networks will not support the outage problem with a wide area in the future if it has an event occurrence such as the overloading problem and the fault occurrence in the network. Therefore, the model built line thesis can be upgraded the new feeder NL2-6 for carrying out the complete relay coordination for substation in Figure 3.19.



Protection Zone		
No	Backup OC relay	Primary OC relay
Zone1	R1	R4
	R3	R2
Zone2	R5	R8
	R7	R6
Zone3	R13	R14
Zone9	R12	R11
Zone4	R9	R32
	R31	R10
Zone5	R15	R18
	R17	R16
Zone6	R21	R24
	R23	R22
Zone7	R27	R30
	R29	R28
Zone8	R19	R26
	R25	R20

Figure 3.19 New single line diagram, after improvement of the distribution system

The single line diagram of defining protection zone in the seven substations. It will be created the modeling with DIgSILENT PowerFactory as shown in Figure 3.19.

After the network was improved in Figure 3.19 again, which shows the load flow and overloading in the conditional (N-1) in the feeder L2-6, NL2-6, and L6-4 in Table 3.9.

Table 3.9 Result analysis after improvement the system

Networks No	Load flow			Contingency Analysis Condition [%]	
	P [MW]	Q [MVAR]	I [kA]	Normal Load	Overloading [N-1]
L1-5-1	1.874036	1.826744	0.071204	13.56259	21.38382
L1-5-2	1.747137	2.117828	0.074681	14.22493	22.42963
L2-5-1	8.591051	3.374508	0.249191	47.46498	67.01001
L2-5-2	8.48974	2.31337	0.237562	45.24998	63.88289
L4-5	9.957146	2.224426	0.281221	53.5659	75.09909
L2-6	9.33538	1.974987	0.257558	49.05866	78.12639
NL2-6	9.511276	3.117305	0.270166	51.46012	78.12639
L6-4	-0.16295	1.239115	0.034483	6.568158	22.85444
L2-4-1	16.72176	7.024605	0.489605	46.62905	61.38059
L2-4-2	16.72176	7.024605	0.489605	46.62905	61.38059
L2-7-1	6.051258	2.825105	0.180331	34.3488	50.89151
L2-7-2	5.990217	3.631812	0.189157	36.02997	50.89151
L3-7-1	8.22469	-0.35682	0.22161	42.21141	55.73859
L3-7-2	8.617112	0.560124	0.232455	44.27711	55.73859
L2-4-3	16.72176	7.024605	0.489605	46.62905	61.38059
L7-4	0.968694	-1.18436	0.042275	8.052336	15.83408

The analysis results of the networks in Table 3.9 show the overloading problem in conditional (N-1) that are less than 90 %. Therefore, the process will set new coordinate value of overcurrent relay.

3.1.5.2 The coordination of overcurrent relay

The model will be analyzed fault again under 2 criteria, after checking criteria, which are the fault will not affect to the nearest feeders and the coordination range of CTI used between 0.2 and 0.5 s.

The coordinating OC relay is one of all method for protecting the outage electricity problem. Especially, the fault occurrence in the distribution system. The protection device must fast operate to clear the fault for avoiding damage to the network. The coordination procedure of OC relays is analyzed by the DPL function in DIgSILENT software for setting appropriately of the OC relay in Figure 3.21.

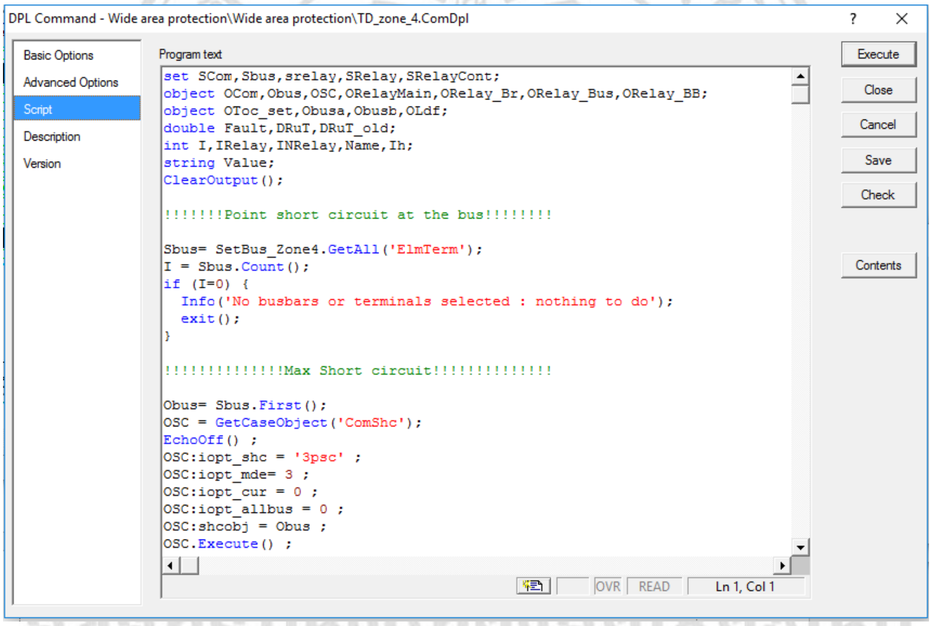


Figure 3.21 DPL command of the coordination overcurrent relay

❖ Example of setting relay

The protection zone 4 which consists OC relay as follows R31, R10, R9, and R32 that will operate the operating time of relays respectively. If the feeder L2-6 and NL2-6 occur on the fault current in protection zone 4. The results of the coordination of R31, R10, R9, and R32 are shown in Figure 3.22 and Figure 3.23.

Rated current 90 percent of the line is equal 472.5 A. Which Rated current max of line Space Aerial Cable (SAC) 240 Sq.mm is equal 525 A. OC relay R31, R10, R9, and R32 operate at overload current to reaching predestined value that is equal current approximately 472.5 pri.A in Figure 3.22 and Figure 3.23.

Figure 3.22 shows the coordination of OC relay at the protection zone 4 that occur on the fault at network L2-6, which operate as follows:

1) The backup OC relay R31 operates at the fault current to reaching predestined value that is equal approximately 5880.766 pri. A. The current settings of I pick-up (I_{CS}) and Time dial (*Tpset*) are equal to 2.5 sec. A and 3.00 respectively. The operation time (t) of the OC relay R31 is equal 0.696s.

2) The primary OC relay R10 operates on the fault current reaching predestined value that is equal approximately 13449.118 pri. A current settings of I pick-up (I_{CS}) and Time dial (*Tpset*) are equal to 2.5 sec.A and 2.08 respectively. The operation time (t) of the OC relay R10 is equal 0.434s. Therefore, the CTI of R31 with R10 is equal 0.262s from setting values. The coordination range of CTI used between 0.2 to 0.5 s, which depends on the degree of reliability system.

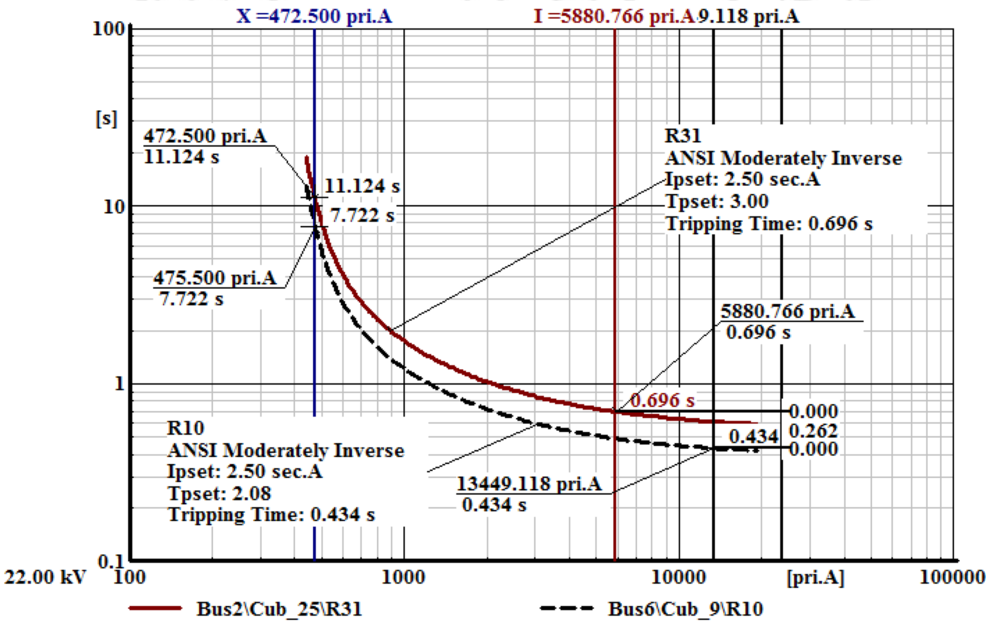


Figure 3.22 The coordination of OC relay R31 and R10

Figure 3.23 shows the coordination of OC relay at the protection zone 4 that occur on the fault at network NL2-6, which operate as follows:

1) The backup OC relay R9 operates at the fault current to reaching predestined value that is equal approximately 6168.633 pri. A. The current settings of I pick-up (I_{CS}) and Time dial (*Tpset*) are equal to 2.5 sec. A and 3.00 respectively. The operation time (t) of the OC relay R9 is equal 0.689s.

2) The primary OC relay R32 operates on the fault current reaching predestined value that is equal approximately 13731.109 pri. A current settings of I pick-up (I_{CS}) and Time dial (*Tpset*) are equal to 2.5 sec.A and 2.03 respectively. The operation time (t) of the OC relay R32 is equal 0.423s. Therefore, the CTI of R9 with R32 is equal 0.266s from setting values. The coordination range of CTI used between 0.2 to 0.5 s which depends on the degree of reliability system.

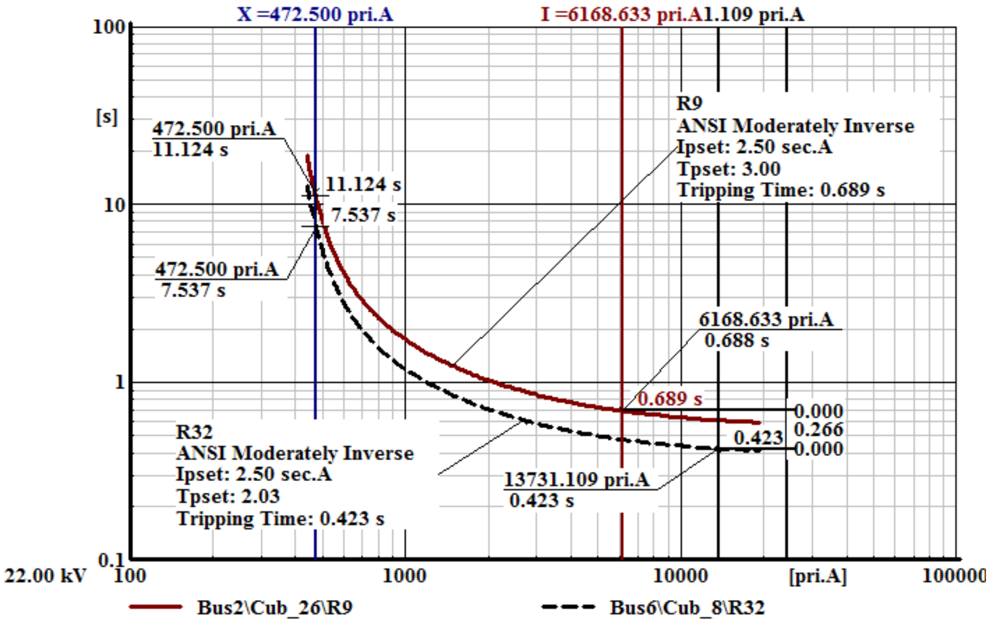


Figure 3.23 The coordination of OC relay R9 and R32

3.1.6 The checking system in step 6, 7, and 8

The model will be checked the overloading value in the network that can support 90 percent of conductor capacity. If the overloading value is higher than 90% [1] of conductor capacity the network will trip and the system will fail down, which has to be modified by created new feeder and improved the failure zone in step 7. Thus, the process will return to the second step and follow the instruction until finding the proper result in step 8.