# CHAPTER 5

## Results Analysis and Discussion

### 5.1 Assessment of the existing power distribution systems up to 2013

From the data of existing networks and the results of load forecasting described in chapter 4, the peak load demand in 2011, 2012 and 2013 will be 268,659.37kW, 287,465.53kW and 333,460.01kW, respectively.

Use CYMDIST software to analyze load flow on the primary distribution networks of Vientiane capital in cases peak forecasted demands in 2013. Analysis results are shown in tables from 5.2.

### 5.2 Network elements

This research project has a situation that obtaining the specific detail, for CYMDIST, is very difficult. Because the project is located in the Vientiane capital and there are no complete data available for the Vientiane power distribution system and equipment even in distribution system. Therefore, the distribution transformers are not included in the simulation of the network. Also, some devices such as, fuses, re-closers, circuit breakers, switches, and etc are not included in the network simulation. Since the main point of the research is system's power loss and voltage drop in the MV level, the ignorance of the distribution transformers and protection devices do not have significant effect on the system simulation results.

For the feeders, as main factor causing power loss and voltage drop in the system, the zero sequence and negative sequence impedances and admittances and size of the conductors, used in CYMDIST, are collected for the system simulation. Table 5.1 shows bare conductors sizes used of the substations in the Vientiane capital electric network for overhead MV distribution lines. Similarly, contains specifications ($Z_1$ and B1 are positive sequence impedance and susceptance respectively, $Z_0$ and $B_0$ are zero sequence impedance and susceptance respectively).

Table 5.1 Conductors specifications used for overhead lines of the Substations in Vientiane capital.

| Equipment ID | Size ($mm^2$) | $Z_1$ (Ω/km) | | $Z_0$(Ω/km) | | B0 (uS/km) | B1 (uS/km) | Rating (Amps) |
|---|---|---|---|---|---|---|---|---|
| | | R1 (ohms/km) | X1 (ohms/km) | R0 (ohms/km) | X0 (ohms/km) | | | |
| ACSR | 25 | 1.138 | 0.4818 | 1.3158 | 1.9333 | 1.49 | 3.45 | 145 |
| ACSR | 35 | 1.11 | 0.4129 | 1.2582 | 1.6397 | 1.26 | 2.97 | 126 |
| ACSR | 50 | 0.556 | 0.3912 | 0.7042 | 1.6180 | 1.29 | 3.15 | 190 |
| ACSR | 70 | 0.5560 | 0.3912 | 0.7042 | 1.6180 | 1.29 | 3.15 | 190 |
| ACSR | 150 | 0.1830 | 0.3281 | 0.3312 | 1.5550 | 1.34 | 3.47 | 335 |
| ACSR | 185 | 0.1882 | 0.3068 | 0.3364 | 1.5336 | 1.38 | 3.74 | 535 |
| ACSR | 240 | 0.1343 | 0.3179 | 0.2825 | 1.5448 | 1.36 | 3.60 | 560 |
| PIC | 35 | 0.826 | 0.4199 | 0.9742 | 1.6467 | 1.25 | 2.91 | 149 |
| PIC | 50 | 0.7831 | 0.3851 | 0.9313 | 1.6119 | 1.26 | 3.00 | 186 |
| PIC | 70 | 0.443 | 0.3733 | 0.5912 | 1.6001 | 1.28 | 3.09 | 237 |
| PIC | 95 | 0.3834 | 0.2844 | 0.5316 | 1.7472 | 0.90 | 2.27 | 279 |
| PIC | 120 | 0.253 | 0.3553 | 0.4012 | 1.5822 | 1.30 | 3.25 | 321 |
| PIC | 150 | 0.206 | 0.3432 | 0.3542 | 1.5700 | 1.31 | 3.31 | 365 |
| PIC | 185 | 0.164 | 0.3361 | 0.3122 | 1.5629 | 1.33 | 3.38 | 429 |
| SAC | 25 | 1.20 | 0.4302 | 1.3482 | 1.6570 | 1.23 | 2.84 | 120 |
| SAC | 35 | 0.868 | 0.4199 | 1.0162 | 1.6467 | 1.25 | 2.91 | 151 |
| SAC | 50 | 0.641 | 0.4085 | 0.7892 | 1.6354 | 1.26 | 3.00 | 187 |
| SAC | 70 | 0.443 | 0.3733 | 0.5912 | 1.6001 | 1.28 | 3.09 | 231 |
| SAC | 95 | 0.32 | 0.3631 | 0.4682 | 1.5899 | 1.29 | 3.18 | 281 |
| SAC | 120 | 0.253 | 0.3553 | 0.4012 | 1.5822 | 1.30 | 3.25 | 324 |
| SAC | 150 | 0.206 | 0.3492 | 0.3542 | 1.5761 | 1.31 | 3.31 | 375 |
| SAC | 185 | 0.164 | 0.3361 | 0.3122 | 1.5629 | 1.33 | 3.38 | 433 |
| SAC | 240 | 0.125 | 0.327 | 0.2732 | 1.5538 | 1.34 | 3.48 | 525 |

## 5.3 Medium voltage of Vientiane Capital

The MV system in Vientiane capital is composed of MSS system and MSH system. The MSS system composed of MV single circuit feeders with radial form are strung from directly from 115 kV / 22 kV substations or 22 kV switching stations to power supply areas. The MSH system is a system of interconnections among 115 kV / 22kV substations or 22kV switching station mainly with 240 $mm^2$ x 2 circuits.

## 5.4 Loads

The Vientiane capital substations and its associated junction stations serve a total of 2,535 distribution transformers that are considered as spot loads for the network simulation (including some of the inactive distribution transformers). As was mentioned in the first section of this chapter, the loads are composed of seven types: residential loads, governmental loads, office loads, industrial loads, agriculture load, embassy loads and business loads as seen in Appendix B.

Phonthong substation is 115kV/22kV, has four transformers and 4x30 MVA of size. It have six feeders, the name of feeders were MSS5.1, MSS5.2, MSS5.3, MSS5.4, MSS5.5 and MSS5.6.

Naxaythong substation is 115kV/22kV, has two transformers and 2x30 MVA of size. It have four feeders, the name of feeders were MSS10.1, MSS10.2, MSS10.3, MSS10.4.

Tha Ngon substation is 115kV/22kV, has two transformers and 2x30 MVA of size. It have four feeders, the name of feeders were MSS8.1, MSS8.2, MSS8.3, MSS8.4.

Koksa-at substation is 115kV/22kV, has two transformers and 2x30 MVA of size. It have six feeders, the name of feeders were MSS9.1, MSS9.2, MSS9.3, MSS9.4, MSS9.5 and MSS9.6.

Thanaleng substation is 115kV/22kV, has four transformers and 4x30 MVA of size. It have seven feeders, the name of feeders were MSS6.1, MSS6.2, MSS6.4, MSS6.5, MSS6.6, MSS6.7 and MSS6.8.

Sokphalaung substation is 22kV/22kV, It have six feeders, the name of feeders were MSS1.1, MSS1.2, MSS1.3, MSS1.4, MSS1.5 and MSS1.6.

Sisakhet substation is 22kV/22kV, It have six feeders, the name of feeders were MSS2.1, MSS2.2, MSS2.3, MSS2.4, MSS2.5 and MSS2.6.

Thatlaung substation is 22kV/22kV, It have four feeders, the name of feeders were MSS3.1, MSS3.2, MSS3.3 and MSS3.4.

Dongnasok substation is 22kV/22kV, It have four feeders, the name of feeders were MSS4.1, MSS4.2, MSS4.3 and MSS4.4.

## 5.5 2013 base case

The total peak loads of MSS system were 333,460.01kW and the total length was 1,416 km in case with situation in Vientiane capital. The loads are set capacities transformer. From data load (table 4.6) considering load of year for input to software analysis shown in Table 5.2. The total losses are 9,460.60kW.

Table 5.2 The result of losses calculation of MSS system on 2013

| Name of substation | ID | Name of feeder | Total Load | | Total Losses | Length |
|---|---|---|---|---|---|---|
| | | | kW | PF % | kW | km |
| Phonethong | 1 | MSS 5.1 | 14,268.4 | 88 | 230.3 | 9.8 |
| | 2 | MSS 5.2 | 12,411.9 | 88 | 299.2 | 18.0 |
| | 3 | MSS 5.3 | 12,295.8 | 86 | 342.5 | 29.6 |
| | 4 | MSS 5.4 | 9,628.1 | 87 | 128.1 | 32.2 |
| | 5 | MSS 5.5 | 3,480.0 | 88 | 5.8 | 6.1 |
| | 6 | MSS 5.6 | 6,148.0 | 87 | 57.7 | 11.1 |

Table 5.2 The result of losses calculation of MSS system on 2013(Continued)

| Name of substation | ID | Name of feeder | Total Load | | Total Losses | Length |
|---|---|---|---|---|---|---|
| | | | kW | PF % | kW | km |
| Naxaythong | 7 | MSS10.1 | 1,044.0 | 88 | 2.3 | 18.3 |
| | 8 | MSS10.2 | 8,236.1 | 87 | 326.7 | 97.5 |
| | 9 | MSS10.3 | 7,716.6 | 86 | 1,191.9 | 200 |
| | 10 | MSS10.4 | 4,961.0 | 87 | 25.9 | 24.9 |
| Tha Ngon | 11 | MSS8.1 | 5,333.9 | 89 | 204.8 | 85.9 |
| | 12 | MSS8.2 | 6,852.9 | 88 | 187.3 | 23.5 |
| | 13 | MSS8.3 | 4,303.0 | 88 | 47.5 | 75.0 |
| | 14 | MSS8.4 | 221.0 | 87 | 0.2 | 7.9 |
| Koksa-at | 15 | MSS 9.1 | 6,737.0 | 87 | 128.1 | 26.0 |
| | 16 | MSS 9.2 | 5,590.9 | 87 | 372.3 | 59.4 |
| | 17 | MSS 9.3 | 14,996.5 | 84 | 2,099.9 | 205.8 |
| | 18 | MSS 9.4 | 9,279.9 | 87 | 218.9 | 5.1 |
| | 19 | MSS 9.5 | 3,969.0 | 87 | 16.8 | 1.1 |
| | 20 | MSS 9.6 | 6,148.0 | 87 | 24.0 | 20.3 |
| Thanaleng | 21 | MSS 6.1 | 7,887.9 | 88 | 222.8 | 14.2 |
| | 22 | MSS 6.2 | 812.0 | 88 | 1.2 | 4.9 |
| | 23 | MSS 6.4 | 7424.0 | 87 | 1.3 | 44.6 |
| | 24 | MSS 6.5 | 6,148.1 | 88 | 82.2 | 86.3 |
| | 25 | MSS 6.6 | 8,699.9 | 88 | 476 | 43.8 |
| | 26 | MSS 6.7 | 10,915.1 | 87 | 410.7 | 21.3 |
| | 27 | MSS 6.8 | 8,815.9 | 87 | 239.7 | 31.3 |
| Sokphalaung | 28 | MSS 1.1 | 5,683.9 | 87 | 18.1 | 5.0 |
| | 29 | MSS 1.2 | 7,540.0 | 87 | 51.7 | 11.0 |
| | 30 | MSS 1.3 | 4,872.0 | 87 | 19.2 | 10.8 |
| | 31 | MSS 1.4 | 1,771.0 | 87 | 0.7 | 1.9 |
| | 32 | MSS 1.5 | 7,076.0 | 88 | 38.0 | 12.9 |
| | 33 | MSS 1.6 | 6,727.9 | 88 | 15.8 | 6.7 |
| Sisakhet | 34 | MSS2.1 | 8,699.8 | 88 | 29.2 | 3.9 |
| | 35 | MSS2.2 | 7,496.9 | 87 | 18.1 | 3.8 |
| | 36 | MSS2.3 | 4,524.0 | 87 | 5.5 | 2.7 |
| | 37 | MSS2.4 | 1,624.0 | 88 | 0.2 | 0.3 |
| | 38 | MSS2.5 | 4,175.9 | 87 | 12.8 | 13.2 |
| | 39 | MSS2.6 | 9,280.0 | 87 | 53.1 | 10.7 |

Table 5.2 The result of losses calculation of MSS system on 2013(Continued)

| Name of substation | ID | Name of feeder | Total Load | | Total Losses | Length |
|---|---|---|---|---|---|---|
| | | | kW | PF % | kW | km |
| Thatlaung | 40 | MSS3.1 | 7,056.1 | 87 | 108.5 | 41.7 |
| | 41 | MSS3.2 | 6,031.9 | 88 | 20.2 | 6.2 |
| | 42 | MSS3.3 | 5,915.9 | 88 | 18.3 | 5.8 |
| | 43 | MSS3.4 | 5,733.0 | 87 | 37.2 | 8.7 |
| Dongnasok | 44 | MSS4.1 | 11,599.9 | 88 | 288.4 | 24.1 |
| | 45 | MSS4.2 | 20,532.8 | 87 | 1,288.4 | 26.0 |
| | 46 | MSS4.3 | 10,474.0 | 88 | 88.8 | 12.4 |
| | 47 | MSS4.4 | 2,320.0 | 87 | 4.8 | 4.4 |
| **Total** | | | **333,460.0** | | **9,460.6** | **1,416.1** |

## 5.6 2013 improved case

### 5.6.1 Load balancing

The load balancing analysis will determine which loads can be reconnected to different phases so as to minimize kW losses or balance the current or the load. It report s a series of individual changes to the network and the kW loss reduction with each change.

CYMDIST will run a voltage drop analysis for each change made. It then retains the change that reduces the losses the most or that balances the load or the current the best and repeats the whole process to find the subsequent change and so on. The process will continue until no change can further optimize the solution.

For example, if the load on a section were phase A is 40kVA, phase B is 48kVA and phase C is 62kVA, the average would be 150/3 =50 kVA. The unbalance factor would be 20% for phase A, 4% for phase B and 24% for phase C. the highest unbalance factor 24% is assigned to the section.

#### 5.6.1.1 Result of load balancing in feeder MSS3.1 of Thatlaung substation

The analysis load balancing can process feeders MSS3.1 of Thatlaung substation.

Table5.3 Parameters load balancing of Tatlaung substation

| **Objective:** | **Balance the load (KVA)** |
|---|---|
| Minimum load: | 1.00 KVA |
| Minimum unbalanced factor: | 10.00 % |
| Include 1-phase section(s): | Yes |
| Include 2-phase section(s): | Yes |
| Include 3-phase section(s): | Yes |
| Ignore the underground cable: | Yes |

Table 5.4 Recommended rephasing for location: feeder MSS3.1 (means applied by user)

| Section ID | Rephasing (KVA) | | | | Phase A KVA | Phase B KVA | Phase C KVA | Losses (KW) | Average KVA unbal. |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | | | | | | |
| S3_F1_290 | to B 8.38 | | to A 8.32 | Before | 2,709.02 | 2,692.12 | 2,709.33 | 108.51 | 0.28 % |
| | | | | After | 2,709.16 | 2,700.91 | 2,700.39 | 108.50 | 0.14 % |
| S3_F1_285 | to C 4.21 | | to B 4.19 | Before | 2,709.16 | 2,700.91 | 2,700.39 | 108.50 | 0.14 % |
| | | | | After | 2,704.75 | 2,705.41 | 2,700.31 | 108.50 | 0.08 % |

Table5.5 Feeder summary load balancing of Tatlaung substation

| | Capacity MVA | Phase A KVA | Phase B KVA | Phase C KVA | Losses KW | Average KVA unbal. |
|---|---|---|---|---|---|---|
| Before | 20.46 | 2,709.02 | 2,692.12 | 2,709.33 | 108.51 | 0.28 % |
| After | 20.46 | 2,704.75 | 2,705.41 | 2,700.31 | 108.50 | 0.08 % |
| **Savings losses** | | | | | **0.01** | |

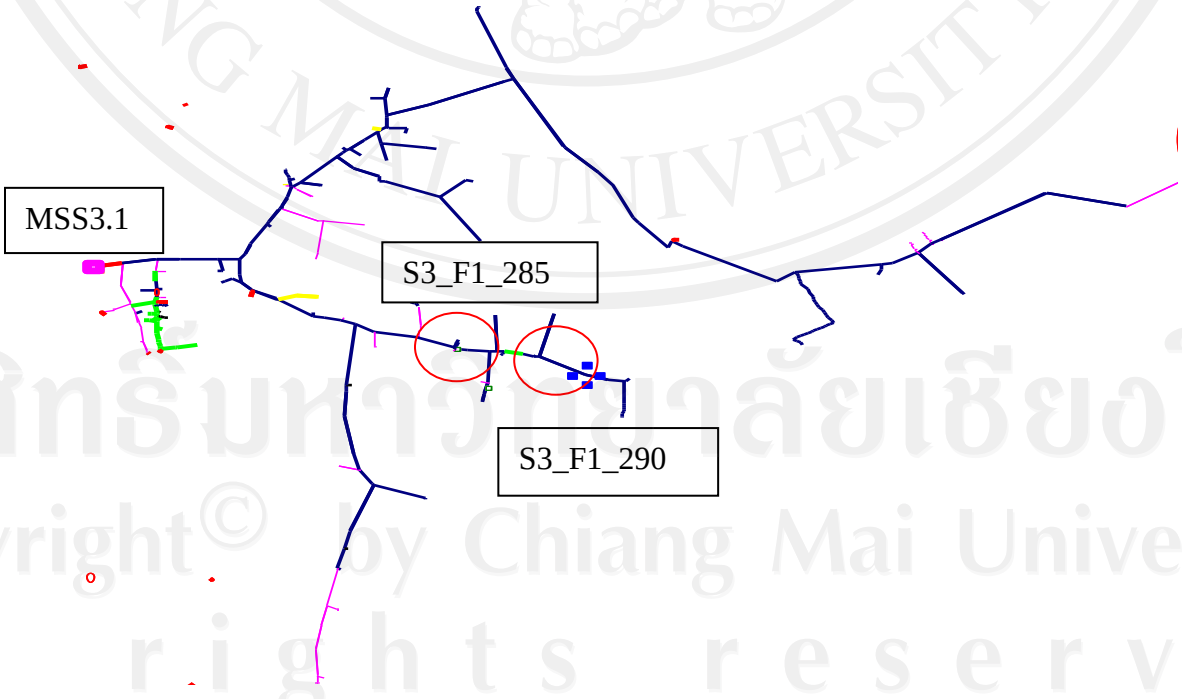


Figure 5.1 Location of single phase loads in feeder MSS3.1

### 5.6.1.2 Result of load balancing in Tha Ngon substation

♦ **Feeder MSS8.1**

Table 5.6 Recommended rephasing for location : feeder MSS8.1 (means applied by user)

| Section ID | Rephasing (KVA) | | | | Phase A | Phase B | Phase C | Losses | Average |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | | KVA | KVA | KVA | KW | KVA unbal. |
| S8_F1_34 | to B | | to A | Before | 2,000.28 | 1,991.96 | 2,000.76 | 204.76 | 0.19 % |
| | 3.47 | | 3.45 | After | 2,000.41 | 1,995.59 | 1,997.00 | 204.76 | 0.09 % |

Table 5.7 Feeder summary of load balancing in Tha Ngon substation

| | Capacity MVA | Phase A KVA | Phase B KVA | Phase C KVA | Losses KW | Average KVA unbal. |
|---|---|---|---|---|---|---|
| Before | 13.06 | 2,000.28 | 1,991.96 | 2,000.76 | 204.76 | 0.19 % |
| After | 13.06 | 2,000.41 | 1,995.59 | 1,997.00 | 204.76 | 0.09 % |
| **Savings losses** | | | | | **0** | |

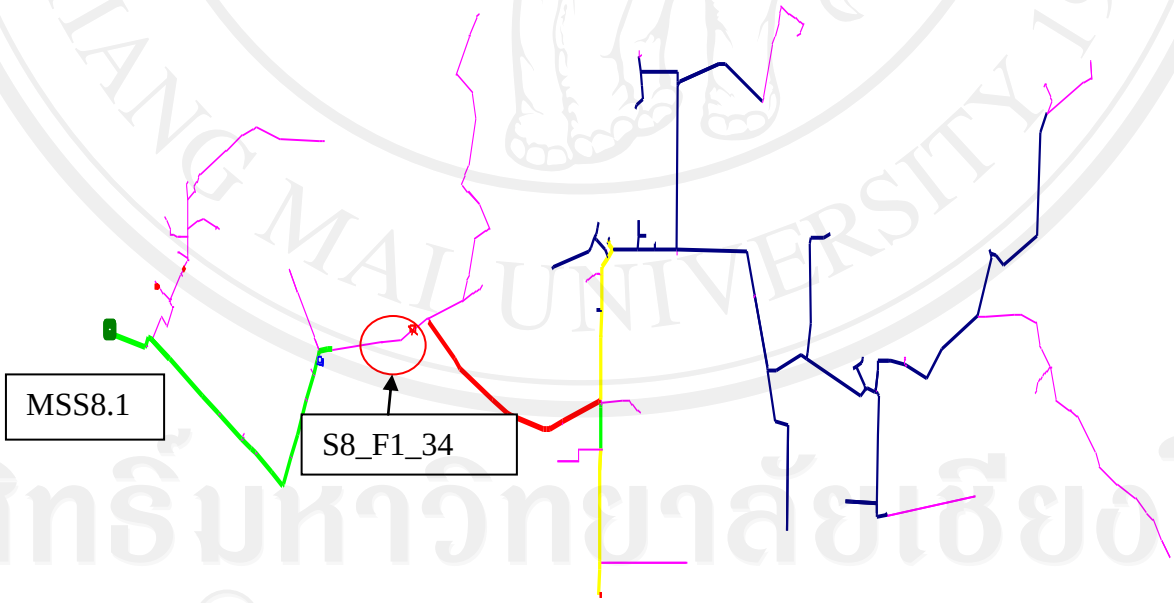


Figure 5.2 Location of single phase loads in feeder MSS8.1

♦ **Feeder MSS8.2**

Table 5.8 Recommended rephasing for location : feeder MSS8_2 ( means applied by user)

| Section ID | Rephasing (KVA) | | | | Phase A KVA | Phase B KVA | Phase C KVA | Losses KW | Average KVA unbal. |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | | | | | | |
| S8_F2_46 | to B 4.06 | | to A 4.06 | Before | 2,599.60 | 2,586.90 | 2,600.60 | 187.30 | 0.23 % |
| | | | | After | 2,599.90 | 2,591.30 | 2,596.00 | 187.29 | 0.11 % |
| S8_F2_288 | to B 4.06 | | No change | Before | 2,599.90 | 2,591.30 | 2,596.00 | 187.29 | 0.11 % |
| | | | | After | 2,595.30 | 2,596.20 | 2,595.60 | 187.29 | 0.01 % |

Table 5.9 Feeder summary of load balancing in feeder MSS8_2

| | Capacity MVA | Phase A KVA | Phase B KVA | Phase C KVA | Losses KW | Average KVA unbal. |
|---|---|---|---|---|---|---|
| Before | 13.06 | 2,599.67 | 2,586.95 | 2,600.68 | 187.30 | 0.23 % |
| After | 13.06 | 2,595.35 | 2,596.27 | 2,595.67 | 187.29 | 0.01 % |
| **Savings losses** | | | | | **0.01** | |

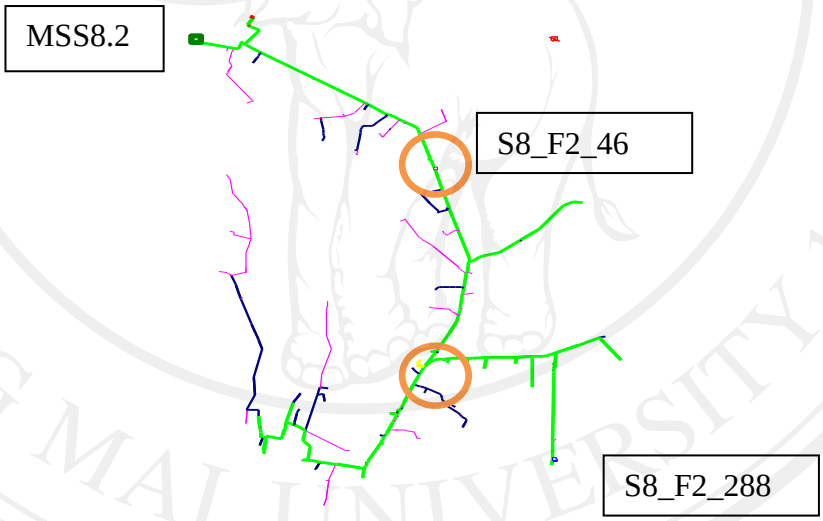


Figure 5.3 Location of single phase loads in feeder MSS8.2

♦ **Feeder MSS8.3**

Table 5.10 Recommended rephasing for location : feeder MSS8.3 ( means applied by user)

| Section ID | Rephasing (KVA) | | | | Phase A KVA | Phase B KVA | Phase C KVA | Losses KW | Average KVA unbal. |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | | | | | | |
| S8_F3_137 | to B 5.42 | | to A 5.42 | Before | 1,638.10 | 1,612.70 | 1,638.80 | 47.53 | 0.70 % |
| | | | | After | 1,638.40 | 1,618.50 | 1,632.80 | 47.53 | 0.47 % |
| S8_F3_205 | to B 4.66 | | No change | Before | 1,638.40 | 1,618.50 | 1,632.80 | 47.53 | 0.47 % |
| | | | | After | 1,633.60 | 1,623.20 | 1,632.90 | 47.53 | 0.27 % |
| S8_F3_249 | to B 4.76 | | No change | Before | 1,633.60 | 1,623.20 | 1,632.90 | 47.53 | 0.27 % |
| | | | | After | 1,628.70 | 1,628.20 | 1,632.80 | 47.53 | 0.12 % |

Table 5.11 Feeder summary of load balancing feeder MSS8.3

| | Capacity MVA | Phase A KVA | Phase B KVA | Phase C KVA | Losses KW | Average KVA unbal. |
|---|---|---|---|---|---|---|
| Before | 13.06 | 1,638.10 | 1,612.70 | 1,638.80 | 47.53 | 0.70 % |
| After | 13.06 | 1,628.70 | 1,628.20 | 1,632.80 | 47.53 | 0.12 % |
| **Savings losses** | | | | | 0 | |

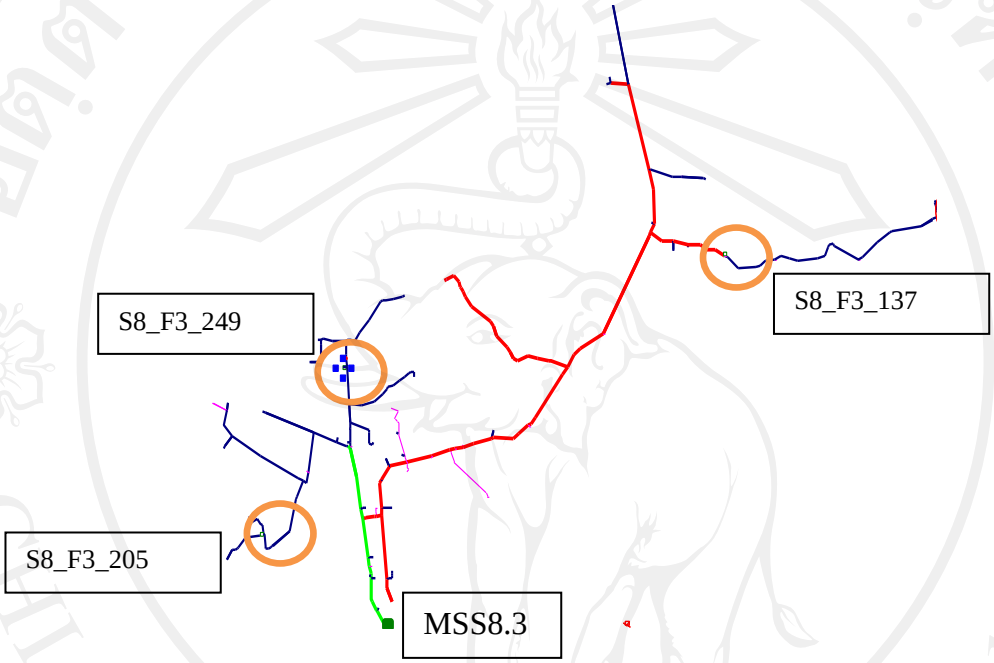


Figure 5.4 Location of single phase loads in feeder MSS8.3

### 5.6.1.3 Result of load balancing in Koksa-at substation

- **Feeder MSS9.1**

Table5.12 Recommended rephasing for location : feeder MSS9.1 (means applied by user)

| Section ID | Rephasing (KVA) | | | | Phase A KVA | Phase B KVA | Phase C KVA | Losses KW | Average KVA unbal. |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | | | | | | |
| S9_F1_33 | No change | | to B 12.80 | Before | 2,589.40 | 2,561.80 | 2,591.10 | 128.05 | 0.49 % |
| | | | | After | 2,590.20 | 2,575.50 | 2,576.60 | 128.05 | 0.24 % |

Table 5.13 Feeder summary of load balancing in feeder MSS9.1

| | Capacity MVA | Phase A KVA | Phase B KVA | Phase C KVA | Losses KW | Average KVA unbal. |
|---|---|---|---|---|---|---|
| Before | 13.06 | 2,589.40 | 2,561.80 | 2,591.10 | 128.05 | 0.49 % |
| After | 13.06 | 2,590.20 | 2,575.50 | 2,576.60 | 128.05 | 0.24 % |
| **Savings losses** | | | | | **0** | |

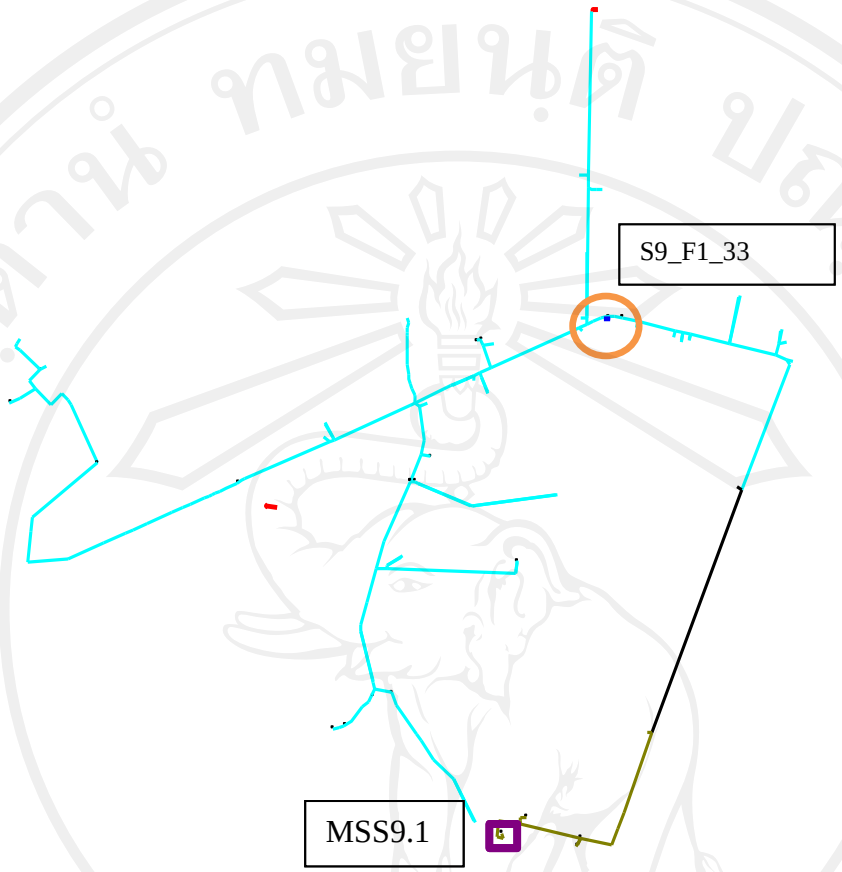


Figure 5.5 Location of single phase loads in feeder MSS9.1

♦**Feeder MSS9.2**

Table 5.14 Recommended rephasing for location : feeder MSS9.2 (means applied by user)

| Section ID | Rephasing (KVA) | | | | Phase A KVA | Phase B KVA | Phase C KVA | Losses KW | Average KVA unbal. |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | | | | | | |
| S9_F2_276 | No change | | to B 12.10 | Before | 2,158.10 | 2,094.40 | 2,173.60 | 299.90 | 1.48 % |
| | | | | After | 2,162.70 | 2,111.10 | 2,152.00 | 299.75 | 0.96 % |
| S9_F2_114 | to B 12.11 | | No change | Before | 2,162.70 | 2,111.10 | 2,152.00 | 299.75 | 0.96 % |
| | | | | After | 2,146.90 | 2,130.10 | 2,148.60 | 299.67 | 0.37 % |

Table 5.15 Feeder summary of load balancing in feeder MSS9.2

| | Capacity (MVA) | Phase A (KVA) | Phase B (KVA) | Phase C (KVA) | Losses (KW) | Average KVA unbal. |
|---|---|---|---|---|---|---|
| Before | 21.82 | 2,158.19 | 2,094.48 | 2,173.63 | 299.90 | 1.48 % |
| After | 21.82 | 2,146.98 | 2,130.10 | 2,148.63 | 299.67 | 0.37 % |
| **Savings losses** | | | | | **0.23** | |

♦**Feeder MSS9.3**

Table 5.16 Recommended rephasing for location : feeder MSS9_3 ( means applied by user)

| Section ID | Rephasing (KVA) | | | | Phase A | Phase B | Phase C | Losses | Average |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | | KVA | KVA | KVA | KW | KVA unbal. |
| S9_F3_308 | to B 8.5 5 | | No change | Before | 6,100.00 | 5,706.40 | 6,115.70 | 2,099.90 | 2.99 % |
| | | | | After | 6,104.00 | 5,748.00 | 6,060.30 | 2,095.40 | 2.49 % |
| S9_F3_526 | to B 8.5 5 | | No change | Before | 6,104.00 | 5,748.00 | 6,060.30 | 2,095.40 | 2.49 % |
| | | | | After | 6,099.70 | 5,794.30 | 6,010.40 | 2,091.80 | 1.94 % |
| S9_F3_297 | to B 8.5 2 | | No change | Before | 6,099.70 | 5,794.30 | 6,010.40 | 2,091.80 | 1.94 % |
| | | | | After | 6,091.10 | 5,844.80 | 5,963.00 | 2,089.30 | 1.39 % |
| S9_F3_102 | to B 4.1 5 | to C 4.1 6 | | Before | 6,091.10 | 5,844.80 | 5,963.00 | 2,089.30 | 1.39 % |
| | | | | After | 6,071.70 | 5,857.00 | 5,968.20 | 2,088.50 | 1.21 % |
| S9_F3_112 | to B 6.2 3 | | No change | Before | 6,071.70 | 5,857.00 | 5,968.20 | 2,088.50 | 1.21 % |
| | | | | After | 6,065.10 | 5,878.10 | 5,952.90 | 2,088.10 | 1.11 % |
| S9_F3_270 | to B 5.1 3 | | No change | Before | 6,065.10 | 5,878.10 | 5,952.90 | 2,088.10 | 1.11 % |
| | | | | After | 6,058.00 | 5,911.60 | 5,925.20 | 2,087.50 | 1.04 % |
| S9_F3_294 | to B 5.1 2 | | No change | Before | 6,058.00 | 5,911.60 | 5,925.20 | 2,087.50 | 1.04 % |
| | | | | After | 6,049.50 | 5,949.70 | 5,895.30 | 2,087.40 | 0.95 % |
| S9_F3_444 | to C 5.1 0 | | to B 0.16 | Before | 6,049.50 | 5,949.70 | 5,895.30 | 2,087.40 | 0.95 % |
| | | | | After | 6,005.90 | 5,990.40 | 5,896.30 | 2,086.50 | 0.76 % |

Table 5.17 Feeder summary of load balancing in feeder MSS9.3

| | Capacity MVA | Phase A KVA | Phase B KVA | Phase C KVA | Losses KW | Average KVA unbal. |
|---|---|---|---|---|---|---|
| Before | 21.82 | 6,100.00 | 5,706.40 | 6,115.70 | 2,099.90 | 2.99 % |
| After | 21.82 | 6,005.90 | 5,990.40 | 5,896.30 | 2,086.50 | 0.76 % |
| **Savings losses** | | | | | **13.4** | |

♦ **Feeder MSS9.4**

Table 5.18 Recommended rephasing for location : feeder MSS9_4 ( means applied by user)

| Section ID | Rephasing (KVA) | | | | Phase A | Phase B | Phase C | Losses | Average |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | | KVA | KVA | KVA | KW | KVA unbal. |
| S9_F4_20 | to B | | to A | Before | 3,591.40 | 3,478.80 | 3,596.30 | 218.80 | 1.44 % |
| | 13.32 | | 13.32 | After | 3,592.00 | 3,492.80 | 3,581.60 | 218.80 | 1.17 % |
| S9_F4_22 | to B | | No | Before | 3,592.00 | 3,492.80 | 3,581.60 | 218.80 | 1.17 % |
| | 13.32 | | change | After | 3,577.90 | 3,507.50 | 3,581.00 | 218.80 | 0.90 % |
| S9_F4_24 | to B | | to A | Before | 3,577.90 | 3,507.50 | 3,581.00 | 218.80 | 0.90 % |
| | 13.32 | | 13.32 | After | 3,578.50 | 3,521.50 | 3,566.30 | 218.80 | 0.64 % |

Table 5.19 Feeder summary of load balancing in feeder MSS9.4

| | Capacity MVA | Phase A KVA | Phase B KVA | Phase C KVA | Losses KW | Average KVA unbal. |
|---|---|---|---|---|---|---|
| Before | 14.61 | 3,591.40 | 3,478.80 | 3,596.30 | 218.86 | 1.44 % |
| After | 14.61 | 3,578.50 | 3,521.50 | 3,566.30 | 218.81 | 0.64 % |
| **Savings losses** | | | | | **0.05** | |

### 5.6.1.4 Result of load balancing in Naxaythong substation

♦ **Feeder MSS10.2**

Table 5.20 Recommended rephasing for location: feeder MSS10.2 ( means applied by user)

| Section ID | Rephasing (KVA) | | | | Phase A | Phase B | Phase C | Losses | Average |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | | KVA | KVA | KVA | KW | KVA unbal. |
| S10_2_159 | to B | | to A | Before | 3,166.10 | 3,130.00 | 3,170.50 | 326.74 | 0.54 % |
| | 7.56 | | 7.56 | After | 3,167.20 | 3,138.80 | 3,160.70 | 326.73 | 0.35 % |
| S10_2_446 | to B | | No | Before | 3,167.20 | 3,138.80 | 3,160.70 | 326.73 | 0.35 % |
| | 6.28 | | change | After | 3,159.40 | 3,147.50 | 3,159.60 | 326.71 | 0.17 % |
| S10_2_350 | to B | | to A | Before | 3,159.40 | 3,147.50 | 3,159.60 | 326.71 | 0.17 % |
| | 6.03 | | 5.54 | After | 3,159.90 | 3,154.40 | 3,152.20 | 326.71 | 0.09 % |

Table 5.21 Feeder summary load balancing in feeder MSS10.2

| | Capacity (MVA) | Phase A (KVA) | Phase B (KVA) | Phase C (KVA) | Losses (KW) | Average KVA unbal. |
|---|---|---|---|---|---|---|
| Before | 13.06 | 3,166.10 | 3,130.00 | 3,170.50 | 326.74 | 0.54 % |
| After | 13.06 | 3,159.90 | 3,154.40 | 3,152.20 | 326.71 | 0.09 % |
| Savings losses | | | | | 0.03 | |

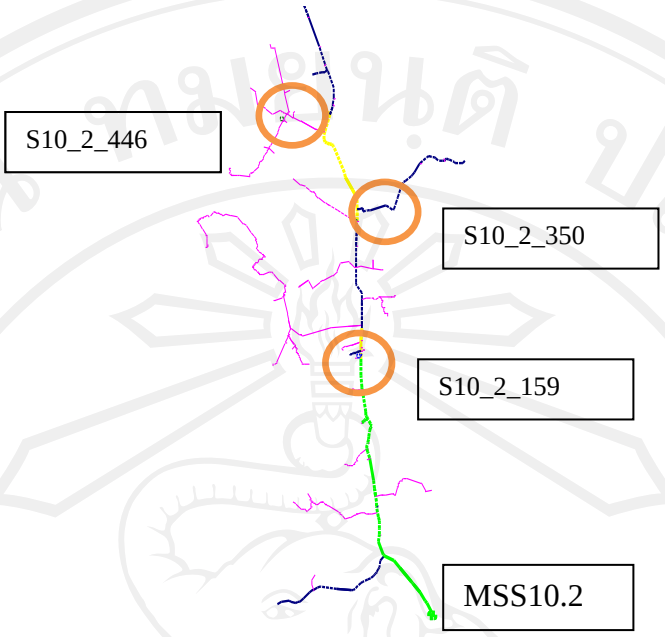


Figure 5.6 Location of single phase loads in feeder MSS10.2

♦ **Feeder MSS10.3**

Table 5.22 Recommended rephasing for location : feeder MSS10_3 ( means applied by user)

| Section ID | Rephasing (KVA) | | | | Phase A KVA | Phase B KVA | Phase C KVA | Losses KW | Average KVA unbal. |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | | | | | | |
| S10_3_566 | No change | | to B 9.86 | Before | 2,963.90 | 2,877.00 | 3,132.60 | 1,191.90 | 3.15 % |
| | | | | After | 3,001.30 | 2,892.40 | 3,071.50 | 1,187.00 | 2.14 % |
| S10_3_537 | No change | | to B 4.93 | Before | 3,001.30 | 2,892.40 | 3,071.30 | 1,187.00 | 2.14 % |
| | | | | After | 3,019.00 | 2,899.90 | 3,044.20 | 1,185.90 | 1.96 % |
| S10_3_632 | No change | | to B 4.92 | Before | 3,019.00 | 2,899.90 | 3,044.20 | 1,185.90 | 1.96 % |
| | | | | After | 3,037.30 | 2,907.40 | 3,017.50 | 1,185.40 | 1.79 % |
| S10_3_1236 | to B 4.92 | | No change | Before | 3,037.30 | 2,907.40 | 3,017.50 | 1,185.40 | 1.79 % |
| | | | | After | 3,027.30 | 2,930.80 | 3,002.20 | 1,184.40 | 1.25 % |
| S10_3_1017 | to B 4.11 | | No change | Before | 3,027.30 | 2,930.80 | 3,002.20 | 1,184.40 | 1.25 % |
| | | | | After | 3,019.20 | 2,950.90 | 2,989.60 | 1,184.00 | 0.80 % |
| S10_3_270 | to B 4.93 | | No change | Before | 3,019.20 | 2,950.90 | 2,989.60 | 1,184.00 | 0.80 % |
| | | | | After | 3,012.70 | 2,963.20 | 2,983.60 | 1,183.90 | 0.58 % |
| S10_3_296 | to B 4.93 | | No change | Before | 3,012.70 | 2,963.20 | 2,983.60 | 1,183.90 | 0.58 % |
| | | | | After | 3,005.90 | 2,976.70 | 2,976.90 | 1,183.90 | 0.43 % |
| S10_3_84 | to C 4.88 | | to B 4.87 | Before | 3,005.90 | 2,976.70 | 2,976.90 | 1,183.90 | 0.43 % |
| | | | | After | 3,000.60 | 2,984.00 | 2,974.90 | 1,184.00 | 0.31 % |

Table 5.23 Feeder summary of load balancing in feeder MSS 10.3

| | Capacity MVA | Phase A KVA | Phase B KVA | Phase C KVA | Losses KW | Average KVA unbal. |
|---|---|---|---|---|---|---|
| Before | 19.10 | 2,963.90 | 2,877.00 | 3,132.60 | 1,191.91 | 3.15 % |
| After | 19.10 | 3,000.60 | 2,984.00 | 2,974.90 | 1,184.00 | 0.31 % |
| **Savings losses** | | | | | **7.91** | |

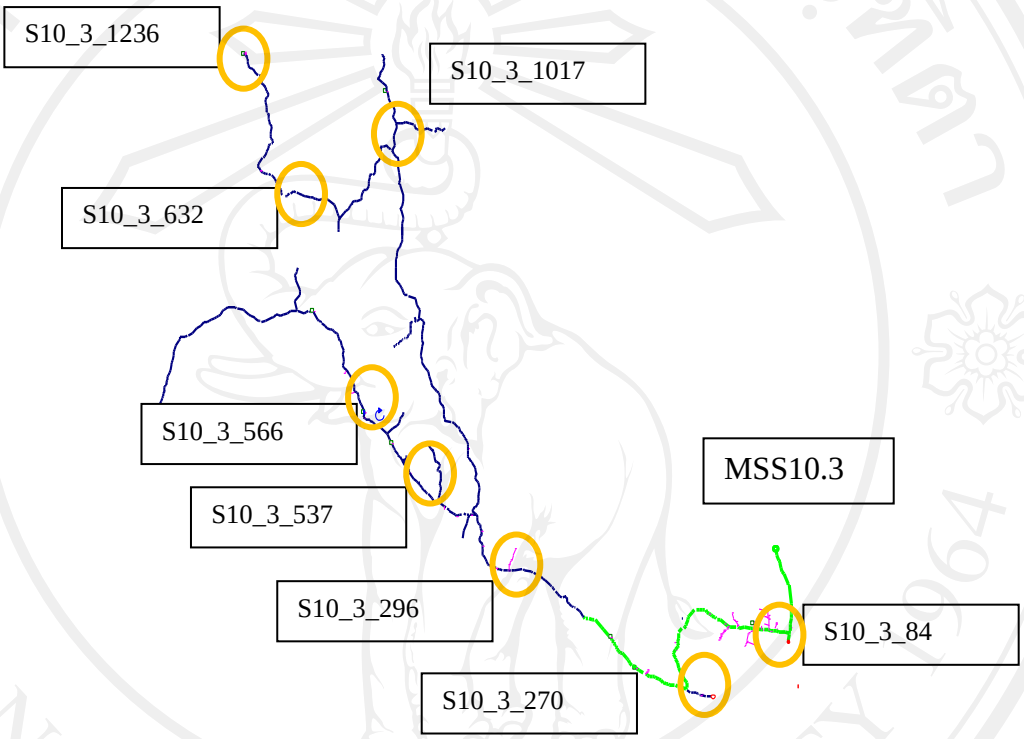


Figure 5.7 Location of single phase loads in feeder MSS10.3

### 5.6.1.5 Summarize of load balancing in distribution system of Vientiane capital

The load balancing in CYMDIST program had calculated ten feeders. There are MSS3.1, MSS8.1, MSS8.3, MSS9.1 MSS9.2, MSS9.3 MSS9.4, MSS10.2 and MSS10.3. The results in above could summarize as seen table…

Table 5.24 Summarize load balancing of distribution system

| Name of feeder | Capacity size (single phase) | Unit | Losses | | Loss reduction | Average kVA unbalance | |
|---|---|---|---|---|---|---|---|
| | | | Before | After | | Before | After |
| | kVA | | kW | kW | kW | % | % |
| MSS3.1 | 30 | 2 | 108.51 | 108.50 | 0.01 | 0.28 | 0.08 |
| MSS8.1 | 30 | 1 | 204.76 | 204.76 | - | 0.19 | 0.09 |
| MSS8.2 | 30 | 2 | 187.30 | 187.29 | 0.01 | 0.23 | 0.01 |
| MSS8.3 | 30 | 3 | 47.53 | 47.53 | - | 0.70 | 0.12 |
| MSS9.1 | 30 | 1 | 128.05 | 128.05 | - | 0.49 | 0.24 |
| MSS9.2 | 30 | 2 | 299.90 | 299.67 | 0.23 | 1.48 | 0.37 |
| MSS9.3 | 30 | 8 | 2,099.95 | 2,086.55 | 13.40 | 2.99 | 0.76 |
| MSS9.4 | 30 | 3 | 218.86 | 218.81 | 0.05 | 1.44 | 0.64 |
| MSS10.2 | 30 | 3 | 326.74 | 326.71 | 0.03 | 0.54 | 0.09 |
| MSS10.3 | 30 | 8 | 1,191.91 | 1,184.00 | 7.91 | 3.15 | 0.31 |
| **Losses reduction** | | | | | **21.64** | | |

### 5.6.2 Optimal capacitor placement

The following data is required for the capacitor placement.

- Capacitor bank unit size (set 50 kVAR, 100kVAR and 200kVAR per phase).

- Loading conditions (3 step loading levels: light, normal and heavy load or peak load).CYMDIST is capable of calculating the appropriate amount of capacitor according to the loading level is shown in table 5.4. The loading level is determined by the required for the light load period, it can calculate the amount of capacitor for normal load and heavy load period as on-off switchable capacitor. In addition to the loading level setting, it must be determined how long each of 3 step loading level continues in a year. Desired power factor is also required.

- Process of capacitor placement by program, feeder loading on CYMDIST and select an objective function such as factor correction, loss reduction, and voltage rise, etc. capacitor bank selection so that program can choose the bank applied in the system. The setting of loading conditions so that program can indicate how much the fixed capacitor or switched capacitor required is shown in table 5.25

Table 5.25 Loading condition

| Name of feeders | Light load | | | Normal load | | | Peak load | | |
|---|---|---|---|---|---|---|---|---|---|
| | Loading [%] | Desired power factor [%] | Time at loading [% of Year] | Loading [%] | Desired power factor [%] | Time at loading [% of Year] | Loading [%] | Desired power factor [%] | Time at loading [% of Year] |
| MSS 5.1 | 33 | 98 | 40 | 49 | 98 | 42 | 80 | 98 | 18 |
| MSS 5.2 | 42 | 98 | 26 | 56 | 98 | 52 | 75 | 98 | 22 |
| MSS 5.3 | 20 | 98 | 35 | 45 | 98 | 44 | 75 | 98 | 21 |
| MSS 5.4 | 27 | 98 | 32 | 45 | 98 | 44 | 75 | 98 | 21 |
| MSS 5.5 | 19 | 98 | 33 | 30 | 98 | 45 | 61 | 98 | 22 |
| MSS 5.6 | 20 | 98 | 38 | 60 | 98 | 41 | 80 | 98 | 21 |
| MSS10.1 | 51 | 98 | 21 | 60 | 98 | 54 | 79 | 98 | 25 |
| MSS10.2 | 51 | 98 | 21 | 60 | 98 | 54 | 79 | 98 | 25 |
| MSS10.3 | 51 | 98 | 21 | 60 | 98 | 54 | 79 | 98 | 25 |
| MSS10.4 | 51 | 98 | 21 | 60 | 98 | 54 | 79 | 98 | 25 |
| MSS8.1 | 45 | 98 | 37 | 60 | 98 | 41 | 75 | 98 | 22 |
| MSS8.2 | 42 | 98 | 24 | 77 | 98 | 59 | 85 | 98 | 17 |
| MSS8.3 | 39 | 98 | 36 | 50 | 98 | 47 | 78 | 98 | 17 |
| MSS8.4 | 11 | 98 | 11 | 20 | 98 | 66 | 53 | 98 | 23 |
| MSS 9.1 | 20 | 98 | 39 | 41 | 98 | 41 | 81 | 98 | 20 |
| MSS 9.2 | 28 | 98 | 29 | 46 | 98 | 51 | 78 | 98 | 20 |
| MSS 9.3 | 40 | 98 | 19 | 60 | 98 | 57 | 80 | 98 | 24 |
| MSS 9.4 | 30 | 98 | 25 | 49 | 98 | 54 | 70 | 98 | 21 |
| MSS 9.5 | 32 | 98 | 38 | 49 | 98 | 44 | 70 | 98 | 18 |
| MSS 9.6 | 32 | 98 | 33 | 64 | 98 | 49 | 85 | 98 | 18 |
| MSS 6.1 | 20 | 98 | 22 | 44 | 98 | 57 | 74 | 98 | 21 |
| MSS 6.2 | 18 | 98 | 26 | 20 | 98 | 54 | 35 | 98 | 20 |
| MSS 6.4 | 39 | 98 | 29 | 53 | 98 | 50 | 70 | 98 | 21 |
| MSS 6.5 | 23 | 98 | 37 | 49 | 98 | 43 | 70 | 98 | 20 |
| MSS 6.6 | 23 | 98 | 29 | 47 | 98 | 50 | 72 | 98 | 21 |
| MSS 6.7 | 38 | 98 | 31 | 63 | 98 | 45 | 75 | 98 | 24 |
| MSS 6.8 | 39 | 98 | 32 | 66 | 98 | 42 | 78 | 98 | 26 |
| MSS 1.1 | 35 | 98 | 27 | 54 | 98 | 57 | 78 | 98 | 16 |
| MSS 1.2 | 32 | 98 | 24 | 67 | 98 | 56 | 85 | 98 | 20 |
| MSS 1.3 | 36 | 98 | 31 | 62 | 98 | 51 | 82 | 98 | 18 |
| MSS 1.4 | 45 | 98 | 16 | 70 | 98 | 65 | 86 | 98 | 19 |
| MSS 1.5 | 49 | 98 | 26 | 68 | 98 | 51 | 80 | 98 | 23 |
| MSS 1.6 | 50 | 98 | 16 | 69 | 98 | 61 | 86 | 98 | 23 |
| MSS2.1 | 32 | 98 | 34 | 65 | 98 | 44 | 77 | 98 | 22 |
| MSS2.2 | 20 | 98 | 28 | 50 | 98 | 56 | 83 | 98 | 16 |
| MSS2.3 | 46 | 98 | 31 | 51 | 98 | 54 | 82 | 98 | 15 |
| MSS2.4 | 57 | 98 | 48 | 71 | 98 | 33 | 86 | 98 | 19 |
| MSS2.5 | 30 | 98 | 26 | 56 | 98 | 57 | 83 | 98 | 17 |
| MSS2.6 | 30 | 98 | 35 | 50 | 98 | 42 | 70 | 98 | 23 |
| MSS3.1 | 36 | 98 | 17 | 77 | 98 | 72 | 82 | 98 | 11 |
| MSS3.2 | 35 | 98 | 14 | 67 | 98 | 66 | 79 | 98 | 20 |
| MSS3.3 | 35 | 98 | 33 | 63 | 98 | 41 | 76 | 98 | 26 |
| MSS3.4 | 41 | 98 | 27 | 61 | 98 | 54 | 75 | 98 | 19 |
| MSS4.1 | 43 | 98 | 30 | 60 | 98 | 43 | 70 | 98 | 27 |
| MSS4.2 | 56 | 98 | 22 | 69 | 98 | 53 | 75 | 98 | 25 |
| MSS4.3 | 22 | 98 | 18 | 60 | 98 | 48 | 70 | 98 | 34 |
| MSS4.4 | 25 | 98 | 15 | 40 | 98 | 67 | 50 | 98 | 18 |

### 5.6.2.1 Capacitor bank at 50 kVAR per phase

Table 5.26 Summarize result from program of capacitor bank 50kVAR

| Name of substation | ID | Name of feeder | Total Loss Before | Capacitor placement | | | |
|---|---|---|---|---|---|---|---|
| | | | | Loss | Fixed | Switch | Savings Loss |
| | | | kW | kW | Unit | Unit | kW |
| Phonethong | 1 | MSS 5.1 | 230.30 | 188.70 | 12 | 14 | 41.50 |
| | 2 | MSS 5.2 | 299.20 | 244.00 | 13 | 8 | 55.20 |
| | 3 | MSS 5.3 | 342.50 | 264.50 | 6 | 18 | 78.00 |
| | 4 | MSS 5.4 | 128.10 | 105.70 | 7 | 11 | 22.40 |
| | 5 | MSS 5.5 | 5.80 | 5.30 | 1 | 3 | 0.40 |
| | 6 | MSS 5.6 | 57.70 | 45.90 | 3 | 9 | 11.80 |
| Naxaythong | 7 | MSS10.1 | 2.30 | 2.10 | 1 | | 0.30 |
| | 8 | MSS10.2 | 326.70 | 259.10 | 11 | 5 | 67.70 |
| | 9 | MSS10.3 | 1,191.90 | 838.10 | 8 | 7 | 353.80 |
| | 10 | MSS10.4 | 25.90 | 20.70 | 7 | 2 | 5.20 |
| Tha Ngon | 11 | MSS8.1 | 204.80 | 168.00 | 5 | 3 | 36.80 |
| | 12 | MSS8.2 | 187.30 | 149.80 | 7 | 6 | 37.50 |
| | 13 | MSS8.3 | 47.50 | 39.20 | 3 | 4 | 8.30 |
| | 14 | MSS8.4 | 0.20 | 0.20 | - | - | - |
| Koksa-at | 15 | MSS 9.1 | 128.05 | 101.20 | 3 | 10 | 26.90 |
| | 16 | MSS 9.2 | 372.26 | 288.00 | 2 | 8 | 11.90 |
| | 17 | MSS 9.3 | 2099.88 | 1,506.90 | 12 | 19 | 593.10 |
| | 18 | MSS 9.4 | 218.87 | 1.00 | 7 | 9 | 0.20 |
| | 19 | MSS 9.5 | 16.75 | 4.60 | 4 | 6 | 4.90 |
| | 20 | MSS 9.6 | 24.04 | 19.30 | 5 | 7 | 4.80 |
| Thanaleng | 21 | MSS 6.1 | 222.80 | 184.40 | 3 | 10 | 38.40 |
| | 22 | MSS 6.2 | 1.20 | 1.20 | - | - | - |
| | 23 | MSS 6.4 | 1.30 | 1.00 | - | 1 | 0.20 |
| | 24 | MSS 6.5 | 82.20 | 67.40 | 3 | 6 | 14.80 |
| | 25 | MSS 6.6 | 476.00 | 402.00 | 4 | 9 | 73.90 |
| | 26 | MSS 6.7 | 410.70 | 333.00 | 11 | 9 | 77.70 |
| | 27 | MSS 6.8 | 239.70 | 187.60 | 9 | 8 | 52.10 |
| Sokphalaung | 28 | MSS 1.1 | 18.10 | 14.20 | 5 | 6 | 3.80 |
| | 29 | MSS 1.2 | 51.70 | 40.60 | 6 | 10 | 11.10 |
| | 30 | MSS 1.3 | 19.20 | 15.10 | 5 | 5 | 4.10 |
| | 31 | MSS 1.4 | 0.70 | 0.60 | 2 | 1 | 0.10 |
| | 32 | MSS 1.5 | 38.00 | 31.30 | 9 | 4 | 6.70 |
| | 33 | MSS 1.6 | 15.80 | 12.80 | 9 | 4 | 3.00 |

Table 5.26 Summarize result from program of capacitor bank 50kVAR(Continued)

| Name of substation | ID | Name of feeder | Total Loss Before | Capacitor placement | | | |
|---|---|---|---|---|---|---|---|
| | | | | Loss | Fixed | Switch | Savings Loss |
| | | | kW | kW | Unit | Unit | kW |
| Sisakhet | 34 | MSS2.1 | 29.20 | 23.80 | 7 | 8 | 5.40 |
| | 35 | MSS2.2 | 18.10 | 14.40 | 4 | 11 | 3.70 |
| | 36 | MSS2.3 | 5.50 | 4.40 | 5 | 4 | 1.10 |
| | 37 | MSS2.4 | 0.20 | 0.10 | 2 | 1 | 0.10 |
| | 38 | MSS2.5 | 12.80 | 10.10 | 3 | 5 | 2.60 |
| | 39 | MSS2.6 | 53.10 | 42.80 | 7 | 9 | 10.30 |
| Thatlaung | 40 | MSS3.1 | 108.50 | 86.00 | 6 | 8 | 22.50 |
| | 41 | MSS3.2 | 20.20 | 16.60 | 5 | 6 | 3.60 |
| | 42 | MSS3.3 | 18.30 | 15.10 | 5 | 5 | 3.20 |
| | 43 | MSS3.4 | 37.20 | 30.10 | 6 | 4 | 7.10 |
| Dongnasok | 44 | MSS4.1 | 288.40 | 239.10 | 12 | 6 | 49.30 |
| | 45 | MSS4.2 | 1,288.40 | 1,026.80 | 32 | 7 | 261.60 |
| | 46 | MSS4.3 | 88.80 | 73.20 | 6 | 10 | 15.60 |
| | 47 | MSS4.4 | 4.80 | 4.20 | 1 | 1 | 0.60 |
| **Total** | | | **9,460.60** | **7,130.20** | **284** | **307** | **2,033.10** |

Table 5.26 can be summarized as following: the fixed capacitors bank installed 284 units, 300 kVAR per unit and 5.5 USD/ kVAR. The switched capacitors bank installed 307 units, 300 kVAR per unit and 10 USD/ kVAR. Total loss is 9,460.60 kW before installing capacitors bank and 7,130.20 kW after installing capacitors bank. It decreases 2,033.10 kW.

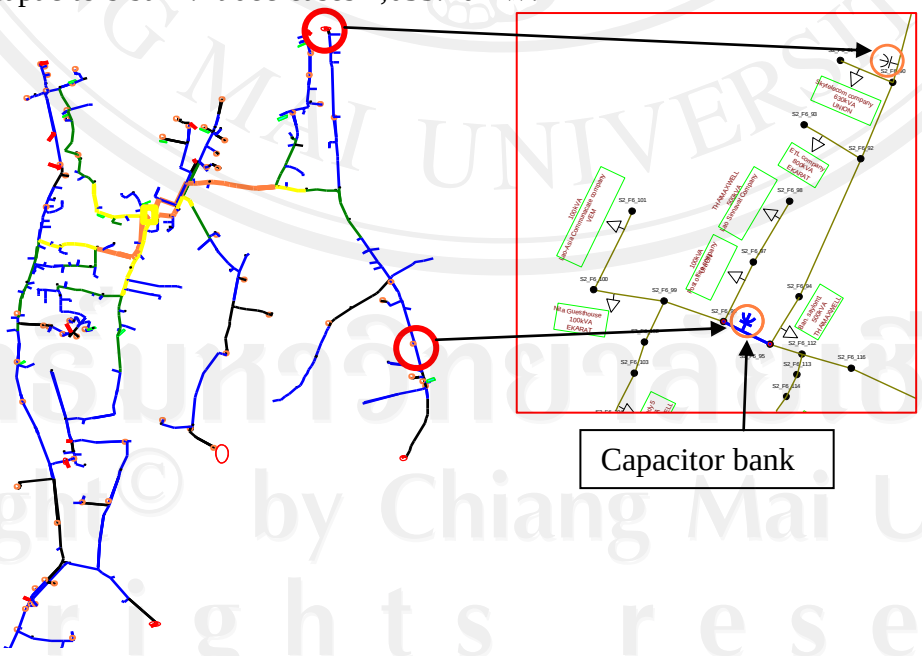


Figure 5.8 Location of capacitor bank of Sokpalaung substration

### 5.6.2.2 Capacitor bank at 100 kVAR per phase

Table 5.27 Summarize result from program of capacitor bank 100kVAR

| Name of substation | ID | Name of feeder | Total Loss | Capacitor placement | | | |
|---|---|---|---|---|---|---|---|
| | | | Before | Loss | Fixed | Switch | Savings Loss |
| | | | kW | kW | Unit | Unit | kW |
| Phonethong | 1 | MSS 5.1 | 230.30 | 188.80 | 6 | 7 | 41.50 |
| | 2 | MSS 5.2 | 299.20 | 245.90 | 6 | 4 | 53.40 |
| | 3 | MSS 5.3 | 342.50 | 264.10 | 3 | 9 | 78.40 |
| | 4 | MSS 5.4 | 128.10 | 105.50 | 3 | 6 | 22.60 |
| | 5 | MSS 5.5 | 5.80 | 5.30 | - | 2 | 0.40 |
| | 6 | MSS 5.6 | 57.70 | 45.90 | 1 | 5 | 11.80 |
| Naxaythong | 7 | MSS10.1 | 2.30 | 2.30 | - | - | - |
| | 8 | MSS10.2 | 326.70 | 258.90 | 5 | 3 | 67.90 |
| | 9 | MSS10.3 | 1,191.90 | 850.80 | 4 | 3 | 341.10 |
| | 10 | MSS10.4 | 25.90 | 21.00 | 3 | 1 | 4.90 |
| Tha Ngon | 11 | MSS8.1 | 204.80 | 168.20 | 2 | 2 | 36.60 |
| | 12 | MSS8.2 | 187.30 | 151.40 | 3 | 3 | 35.90 |
| | 13 | MSS8.3 | 47.50 | 40.10 | 1 | 2 | 7.40 |
| | 14 | MSS8.4 | 0.20 | 0.20 | - | - | - |
| Koksa-at | 15 | MSS 9.1 | 128.10 | 102.70 | 1 | 4 | 25.30 |
| | 16 | MSS 9.2 | 372.30 | 287.50 | 1 | 4 | 84.80 |
| | 17 | MSS 9.3 | 2,099.90 | 1,506.90 | 6 | 7 | 593.00 |
| | 18 | MSS 9.4 | 218.90 | 181.30 | 3 | 5 | 37.60 |
| | 19 | MSS 9.5 | 16.80 | 14.30 | 2 | 2 | 2.40 |
| | 20 | MSS 9.6 | 24.00 | 19.60 | 2 | 4 | 4.40 |
| Thanaleng | 21 | MSS 6.1 | 222.80 | 186.60 | 1 | 5 | 36.20 |
| | 22 | MSS 6.2 | 1.20 | 1.20 | - | - | - |
| | 23 | MSS 6.4 | 1.30 | 1.30 | - | - | - |
| | 24 | MSS 6.5 | 82.20 | 68.10 | 1 | 3 | 14.20 |
| | 25 | MSS 6.6 | 476.00 | 406.80 | 2 | 4 | 69.20 |
| | 26 | MSS 6.7 | 410.70 | 332.80 | 5 | 5 | 77.90 |
| | 27 | MSS 6.8 | 239.70 | 189.50 | 4 | 4 | 50.20 |
| Sokphalaung | 28 | MSS 1.1 | 18.10 | 14.40 | 2 | 3 | 3.70 |
| | 29 | MSS 1.2 | 51.70 | 40.70 | 3 | 5 | 11.00 |
| | 30 | MSS 1.3 | 19.20 | 15.50 | 2 | 2 | 3.70 |
| | 31 | MSS 1.4 | 0.70 | 0.60 | 1 | | 0.10 |
| | 32 | MSS 1.5 | 38.00 | 31.70 | 4 | 2 | 6.30 |
| | 33 | MSS 1.6 | 15.80 | 13.00 | 4 | 2 | 2.80 |

Table 5.27 Summarize result from program of capacitor bank 100kVAR (Continued)

| Name of substation | ID | Name of feeder | Total Loss Before | Capacitor placement | | | |
|---|---|---|---|---|---|---|---|
| | | | | Loss | Fixed | Switch | Savings Loss |
| | | | kW | kW | Unit | Unit | kW |
| Sisakhet | 34 | MSS2.1 | 29.20 | 24.00 | 3 | 4 | 5.20 |
| | 35 | MSS2.2 | 18.10 | 14.50 | 2 | 5 | 3.60 |
| | 36 | MSS2.3 | 5.50 | 4.50 | 2 | 2 | 1.00 |
| | 37 | MSS2.4 | 0.20 | 0.10 | 1 | - | 0.00 |
| | 38 | MSS2.5 | 12.80 | 10.10 | 1 | 3 | 2.60 |
| | 39 | MSS2.6 | 53.10 | 42.80 | 3 | 5 | 10.20 |
| Thatlaung | 40 | MSS3.1 | 108.50 | 86.30 | 3 | 4 | 22.20 |
| | 41 | MSS3.2 | 20.20 | 16.80 | 2 | 3 | 3.40 |
| | 42 | MSS3.3 | 18.30 | 15.10 | 2 | 3 | 3.20 |
| | 43 | MSS3.4 | 37.20 | 30.10 | 3 | 2 | 7.10 |
| Dongnasok | 44 | MSS4.1 | 288.40 | 239.00 | 6 | 3 | 49.40 |
| | 45 | MSS4.2 | 1,288.40 | 1,030.10 | 16 | 3 | 258.30 |
| | 46 | MSS4.3 | 88.80 | 73.10 | 3 | 5 | 15.60 |
| | 47 | MSS4.4 | 4.80 | 4.20 | - | 1 | 0.60 |
| **Total** | | | **9,460.60** | **7,353.50** | **128** | **151** | **2,107.10** |

Table 5.27 can be summarized as following: the fixed capacitors bank installed 128 units, 300 kVAR per unit and 5.5 USD/ kVAR. The switched capacitors bank installed 151 units, 300 kVAR per unit and 10 USD/ kVAR. Total loss is 9,460.60 kW before installing capacitors bank and 7,353.50 kW after installing capacitors bank. It decreases 2,107.10 kW

### 5.6.2.3 Capacitor bank at 200 kVAR per phase

Table 5.28 Summarize result from program of capacitor bank 200kVAR

| Name of substation | ID | Name of feeder | Total Loss Before | Capacitor placement | | | |
|---|---|---|---|---|---|---|---|
| | | | | Loss | Fixed | Switch | Savings Loss |
| | | | kW | kW | Unit | Unit | kW |
| Phonethong | 1 | MSS 5.1 | 230.30 | 190.40 | 3 | 3 | 39.80 |
| | 2 | MSS 5.2 | 299.20 | 246.50 | 3 | 2 | 52.70 |
| | 3 | MSS 5.3 | 342.50 | 264.10 | 1 | 5 | 78.40 |
| | 4 | MSS 5.4 | 128.10 | 107.60 | 1 | 3 | 20.50 |
| | 5 | MSS 5.5 | 5.80 | 5.40 | - | 1 | 0.40 |
| | 6 | MSS 5.6 | 57.70 | 46.10 | - | 3 | 11.60 |
| Naxaythong | 7 | MSS10.1 | 2.30 | 2.30 | - | - | - |
| | 8 | MSS10.2 | 326.70 | 270.70 | 2 | 1 | 56.00 |
| | 9 | MSS10.3 | 1,191.90 | 881.40 | 2 | 1 | 310.60 |
| | 10 | MSS10.4 | 25.90 | 21.00 | 1 | 1 | 4.90 |

Table 5.28 Summarize result from program of capacitor bank 200kVAR (Continued)

| Name of substation | ID | Name of feeder | Total Loss | Capacitor placement | | | |
|---|---|---|---|---|---|---|---|
| | | | Before | Loss | Fixed | Switch | Savings Loss |
| | | | kW | kW | Unit | Unit | kW |
| Tha Ngon | 11 | MSS8.1 | 204.80 | 168.10 | 1 | 1 | 36.70 |
| | 12 | MSS8.2 | 187.30 | 151.70 | 1 | 2 | 35.60 |
| | 13 | MSS8.3 | 47.50 | 42.50 | - | 1 | 5.00 |
| | 14 | MSS8.4 | 0.20 | 0.20 | - | - | - |
| Koksa-at | 15 | MSS 9.1 | 128.10 | 102.80 | - | 3 | 25.30 |
| | 16 | MSS 9.2 | 372.30 | 297.20 | - | 2 | 75.10 |
| | 17 | MSS 9.3 | 2,099.90 | 1,509.10 | 3 | 4 | 590.70 |
| | 18 | MSS 9.4 | 218.90 | 188.60 | 1 | 2 | 30.30 |
| | 19 | MSS 9.5 | 16.80 | 14.30 | 1 | 1 | 2.40 |
| | 20 | MSS 9.6 | 24.00 | 19.90 | 1 | 2 | 4.20 |
| Thanaleng | 21 | MSS 6.1 | 222.80 | 186.60 | | 3 | 36.20 |
| | 22 | MSS 6.2 | 1.20 | 1.20 | - | - | - |
| | 23 | MSS 6.4 | 1.30 | 1.30 | - | - | - |
| | 24 | MSS 6.5 | 82.20 | 68.10 | | 2 | 14.10 |
| | 25 | MSS 6.6 | 476.00 | 408.00 | 1 | 2 | 68.00 |
| | 26 | MSS 6.7 | 410.70 | 333.00 | 2 | 3 | 77.70 |
| | 27 | MSS 6.8 | 239.70 | 189.70 | 2 | 2 | 50.00 |
| Sokphalaung | 28 | MSS 1.1 | 18.10 | 14.80 | 1 | | 3.20 |
| | 29 | MSS 1.2 | 51.70 | 40.80 | 1 | 3 | 10.90 |
| | 30 | MSS 1.3 | 19.20 | 15.80 | 1 | 1 | 3.50 |
| | 31 | MSS 1.4 | 0.70 | 0.70 | - | - | - |
| | 32 | MSS 1.5 | 38.00 | 31.70 | 2 | 1 | 6.30 |
| | 33 | MSS 1.6 | 15.80 | 13.10 | 2 | 1 | 2.70 |
| Sisakhet | 34 | MSS2.1 | 29.20 | 24.50 | 1 | 2 | 4.70 |
| | 35 | MSS2.2 | 18.10 | 14.90 | 1 | 2 | 3.20 |
| | 36 | MSS2.3 | 5.50 | 4.50 | 1 | 1 | 1.00 |
| | 37 | MSS2.4 | 0.20 | 0.10 | - | - | - |
| | 38 | MSS2.5 | 12.80 | 10.20 | - | 2 | 2.60 |
| | 39 | MSS2.6 | 53.10 | 42.90 | 1 | 3 | 10.10 |
| Thatlaung | 40 | MSS3.1 | 108.50 | 88.50 | 1 | 2 | 20.00 |
| | 41 | MSS3.2 | 20.20 | 17.30 | 1 | 1 | 2.90 |
| | 42 | MSS3.3 | 18.30 | 15.60 | 1 | 1 | 2.70 |
| | 43 | MSS3.4 | 37.20 | 31.10 | 1 | 1 | 6.10 |
| Dongnasok | 44 | MSS4.1 | 288.40 | 242.80 | 3 | 1 | 45.60 |
| | 45 | MSS4.2 | 1,288.40 | 1,038.60 | 8 | 1 | 249.80 |
| | 46 | MSS4.3 | 88.80 | 73.10 | 1 | 3 | 15.70 |
| | 47 | MSS4.4 | 4.80 | 4.80 | - | - | - |
| **Total** | | | **9,460.60** | **7,443.40** | **53** | **76** | **2,017.20** |

Table 5.28 can be summarized as following: the fixed capacitors bank installed 53 units, 300 kVAR per unit and 5.5 USD/ kVAR. The switched capacitors bank installed 76 units, 300 kVAR per unit and 10 USD/ kVAR. Total loss is 9,460.60 kW before installing capacitors bank and 7,443.40 kW after installing capacitors bank. It decreases 2,017.20 kW.

#### 5.6.2.4 Summarizing of capacitor placement in distribution system of Vientiane capital

The capacitor placement in CYMDIST program had calculated three value of capacitor bank. There are set capacitor bank 50 kVAR, 100 kVAR and 200kVAR per phase. The results in above could summarize as seen table 5.29.

Table 5.29 Summarize installation capacitor bank at 50 kVAR, 100kVAR and 200 kVAR per phase in distribution system.

| Name of substation | Total Loss | Capacitor bank at 50 kVAR/phase | | | Capacitor bank at 100 kVAR/phase | | | Capacitor bank at200 kVAR/phase | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Before | Fixed | Switch | Savings Loss | Fixed | Switch | Savings Loss | Fixed | Switch | Savings Loss |
| | kW | Unit | Unit | kW | Unit | Unit | kW | Unit | Unit | kW |
| Phonethong | 1063.60 | 42 | 63 | 209.30 | 19 | 33 | 208.10 | 8 | 17 | 203.40 |
| Naxaythong | 1546.80 | 27 | 14 | 427.00 | 12 | 7 | 413.90 | 5 | 3 | 371.50 |
| Tha Ngon | 439.80 | 15 | 13 | 82.60 | 6 | 7 | 79.90 | 2 | 4 | 77.30 |
| Koksa-at | 2860.00 | 33 | 59 | 641.80 | 15 | 26 | 747.50 | 6 | 14 | 728.00 |
| Thanaleng | 1433.90 | 30 | 43 | 257.10 | 13 | 21 | 247.70 | 5 | 12 | 246.00 |
| Sokphalaung | 143.50 | 36 | 30 | 28.80 | 16 | 14 | 27.60 | 7 | 6 | 26.60 |
| Sisakhet | 118.90 | 28 | 38 | 23.20 | 12 | 19 | 22.60 | 4 | 10 | 21.60 |
| Thatlaung | 184.20 | 22 | 23 | 36.40 | 10 | 12 | 35.90 | 4 | 5 | 31.70 |
| Dongnasok | 1670.40 | 51 | 24 | 327.10 | 25 | 12 | 323.90 | 12 | 5 | 311.10 |
| **Total** | **9,461.10** | **284** | **307** | **2,033.30** | **128** | **151** | **2,107.10** | **53** | **76** | **2,017.20** |

### 5.6.3 Switching optimization

#### 5.6.3.1 Sokphalaung substation Switching Optimization Report

Sokphalaung substation have six feeders, the name of feeders are MSS1.1, MSS1.2, MSS1.3 MSS1.4, MSS1.5 MSS1.6 shown as figure 5.9

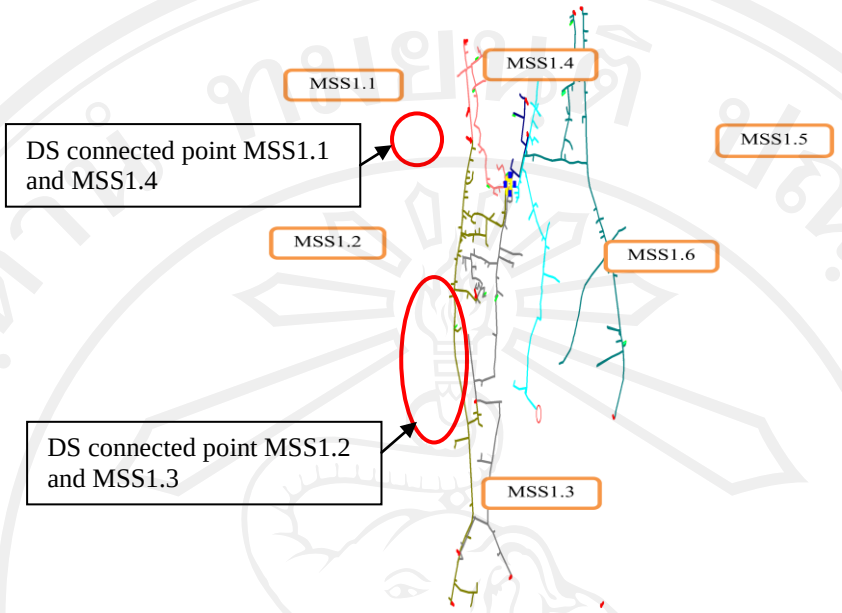


Figure 5.9 Location of DS connected point feeders of Sokpalaung substration

Table 5.30 Switching operations of Sokphalaung substation

| Section Id | Action | Switch Id | Load transferred | | | Losses |
|---|---|---|---|---|---|---|
| | | | From | To | kW | kW |
| S1_F2_92 | Open | S1_F2_92 | | | | 143.50 |
| S1_F2_98 | Close | S1_F2_98 | MSS1_2 | MSS1_3 | 616.00 | 139.40 |
| S1_F2_52 | Open | S1_F2_52 | | | | 137.40 |
| S1_F2_61 | Close | S1_F2_61 | MSS1_2 | MSS1_3 | 276.00 | 137.40 |
| S1_F2_24 | Open | S1_F2_24 | | | | 136.00 |
| S1_F2_148 | Close | S1_F2_148 | MSS1_2 | MSS1_2 | 3,591.00 | 136.00 |

Table 5.31 Network summary of Sokphalaung substation

| Feeder Id | Capacity | Initial load | Final load | Initial losses | Final losses | Initial length | Final length |
|---|---|---|---|---|---|---|---|
| | MVA | MVA | MVA | kW | kW | km | km |
| MSS1_1 | 14.20 | 6.50 | 6.50 | 18.10 | 18.10 | 5.00 | 5.00 |
| MSS1_2 | 14.60 | 8.70 | 7.60 | 51.70 | 37.10 | 11.00 | 10.10 |
| MSS1_3 | 14.60 | 5.60 | 6.60 | 19.20 | 26.30 | 10.80 | 11.70 |
| MSS1_4 | 20.50 | 2.00 | 2.00 | 0.70 | 0.70 | 1.90 | 1.90 |
| MSS1_5 | 14.60 | 8.00 | 8.00 | 38.00 | 38.00 | 12.90 | 12.90 |
| MSS1_6 | 14.60 | 7.60 | 7.60 | 15.80 | 15.80 | 6.70 | 6.70 |

Table 5.32 System losses of Sokphalaung substation

| Initial Losses | Final losses | Savings losses | | |
|---|---|---|---|---|
| kW | kW | kW | % | USD/year |
| 143.48 | 135.99 | 7.49 | 5.22 | 0 |

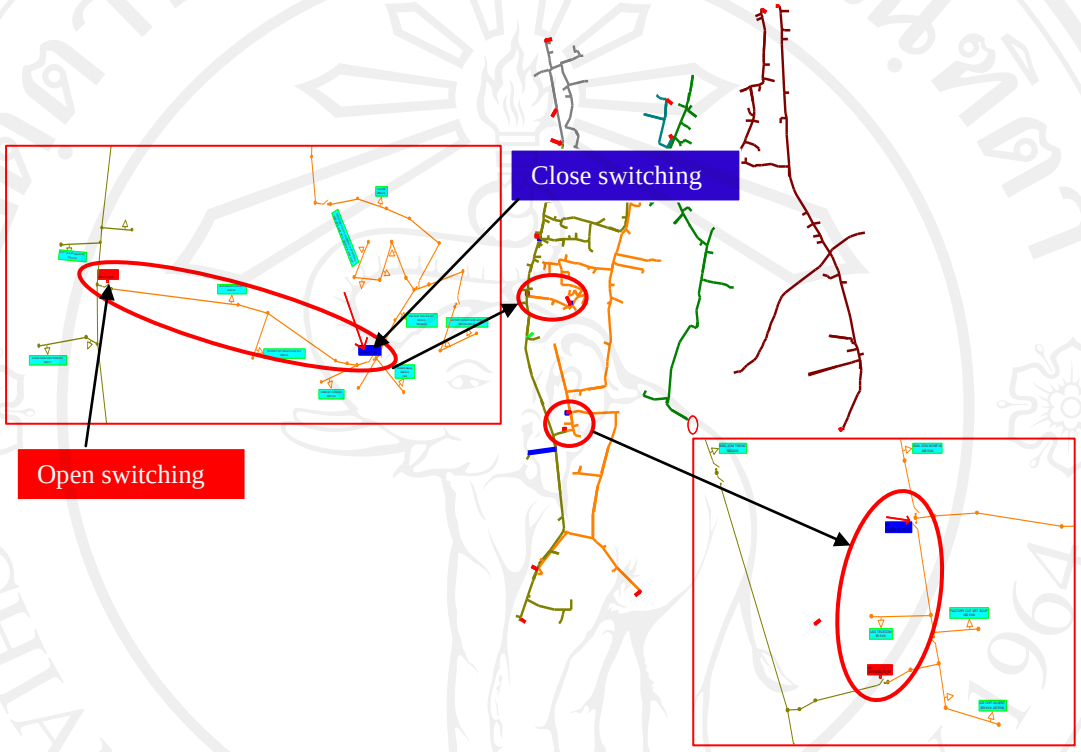


Figure 5.10 Location of DS connected point feeders of Sokpalaung substration

**5.6.3.2 Sisakhet substation Switching Optimization Report**

Sisakhet substation have six feeders, the name of feeders are MSS2.1, MSS2.2, MSS2.3 MSS2.4, MSS2.5 MSS2.6 shown as figure 5.11

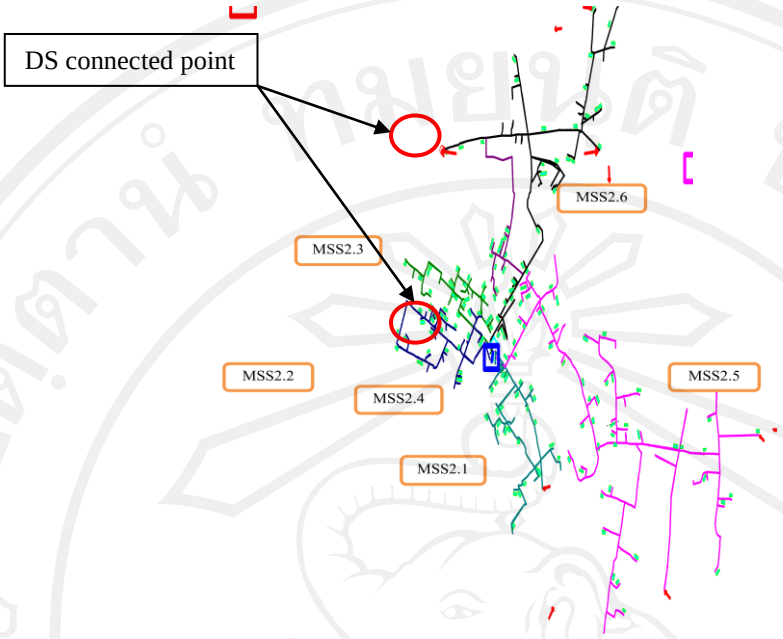


Figure 5.11 Location of DS connected point feeders of Sisakhet substation

Table 5.33 a. Switching operations of Sisakhet substation

| Section Id | Action | Switch Id |
|---|---|---|
| S2_F2_29 | Close | S2_F2_29 |
| S2_F2_76 | Close | S2_F2_76 |
| S2_F3_38 | Open | S2_F3_38 |
| S2_F2_73 -1 | Open | S2_F2_73-1 |

b. Network summary of Sisakhet substation

| Feeder Id | Capacity | Initial load | Final load | Initial losses | Final losses | Initial length | Final length |
|---|---|---|---|---|---|---|---|
| | MVA | MVA | MVA | kW | kW | km | km |
| MSS2_2 | 14.60 | 8.60 | 8.90 | 18.10 | 18.80 | 3.80 | 4.00 |
| MSS2_3 | 14.60 | 5.20 | 4.90 | 5.50 | 4.80 | 2.70 | 2.60 |

c. System losses of Sisakhet substation

| Initial losses | Final losses | Savings losses | | |
|---|---|---|---|---|
| kW | kW | kW | % | USD/year |
| 23.64 | 23.59 | 0.05 | 0.21 | 0 |

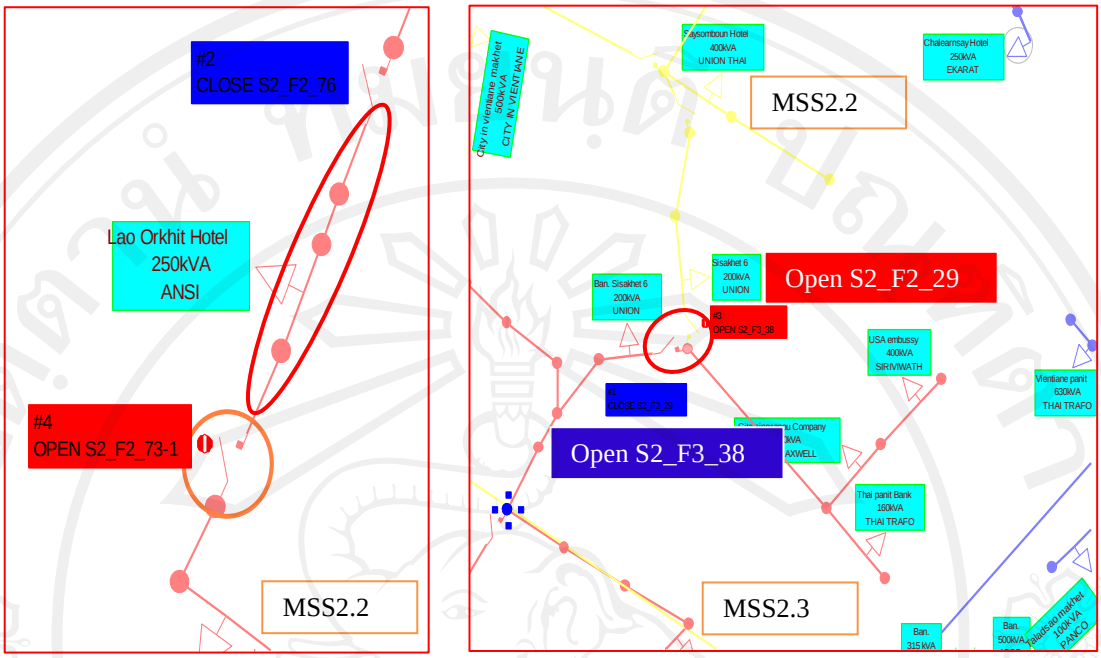


Figure 5.12 Location of open and close DS connected point feeders of Sisakhet substation

### 5.6.3.3 Thatlaung substation switching optimization report

Thatlaung substation have four feeders, the name of feeders are MSS3.1, MSS3.2, MSS3.3 and MSS3.4, shown as figure 5.13.

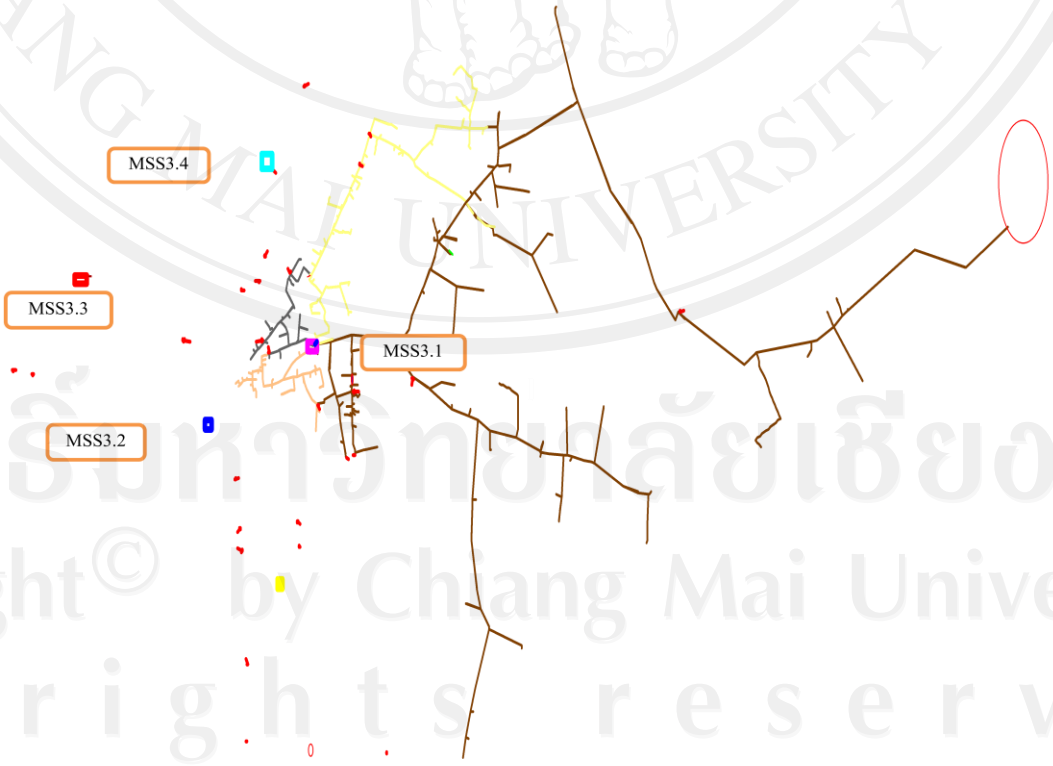


Figure 5.13 Location of DS connected point feeders of Thatlaung substation

Table 5.34 a. Switching operations of Thatlaung substation

| Section Id | Action | Switch Id |
|---|---|---|
| S3_F1_68 | Close | S3_F1_68 |
| S3_F4_139 | Close | S3_F4_139 |
| S3_F4_160 | Close | S3_F4_160 |
| S3_F3_75 | Close | S3_F3_75 |
| S3_F1_136 | Open | S3_F1_136 |
| S3_F1_20 | Open | S3_F1_20 |
| S3_F1_108 | Open | S3_F1_108 |
| S3_F2_52 | Open | S3_F2_52 |

b. Network summary of Thatlaung substation

| Feeder | Capacity | Initial load | | Final load | | Initial losses | Final losses | Initial length | Final length |
|---|---|---|---|---|---|---|---|---|---|
| Id | kVA | kVA | % | kVA | | kW | kW | km | km |
| MSS3.1 | 20,459.90 | 8,110.50 | 39.64 | 7,116.10 | 34.78 | 108.50 | 75.24 | 62.12 | 38.72 |
| MSS3.2 | 14,614.20 | 6,853.20 | 46.89 | 5,866.20 | 40.14 | 20.15 | 14.21 | 6.17 | 5.75 |
| MSS3.3 | 14,614.20 | 6,721.40 | 45.99 | 7,705.20 | 52.72 | 18.32 | 22.37 | 5.79 | 6.21 |
| MSS3.4 | 14,614.20 | 6,589.70 | 45.09 | 7,578.80 | 51.86 | 37.16 | 59.49 | 16.32 | 39.70 |

c. System losses of Thatlaung substation

| Initial losses | Final losses | Savings losses | | |
|---|---|---|---|---|
| kW | kW | kW | % | USD/year |
| 184.13 | 171.31 | 12.82 | 6.96 | 0 |

### 5.6.3.4 Dongnasok substation switching optimization report

Dongnasok substation have four feeders, the name of feeders are MSS4.1, MSS4.2, MSS4.3 and MSS4.4, shown as figure 5.14

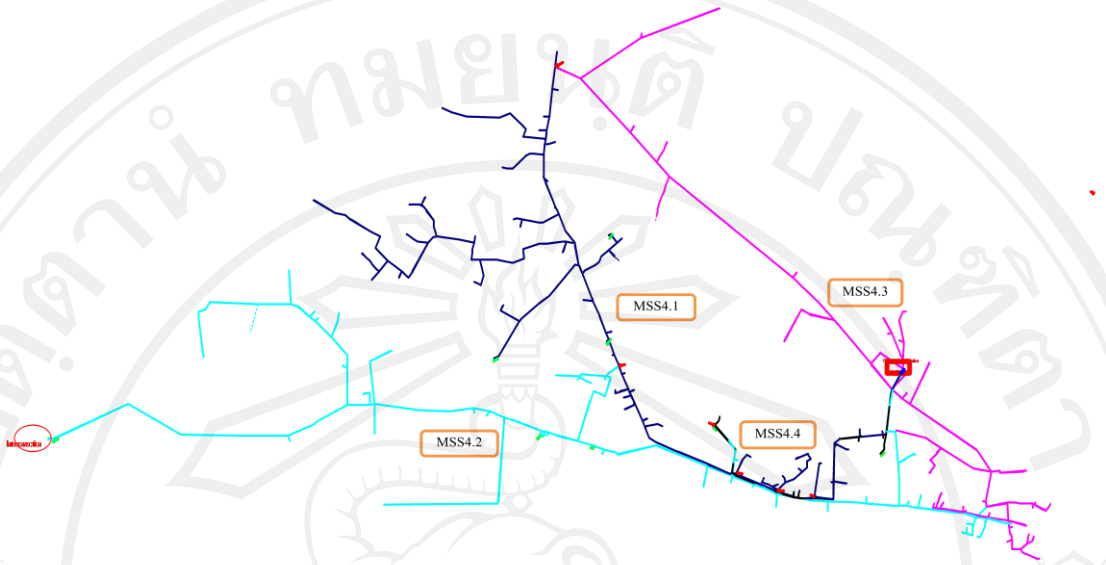


Figure 5.14 Location of DS connected point feeders of Dongnasok substation

Table 5.35 a. Switching operations of Dongnasok substation

| Section Id | Action | Switch Id | Load Transferred | | | Losses |
|---|---|---|---|---|---|---|
| | | | From | To | kW | kW |
| S4_F2_21 | Open | S4_F2_21 | | | | 1,670.10 |
| S4_F2_46 | Close | S4_F2_46 | MSS4_2 | MSS4_3 | 2,251.00 | 1,518.70 |
| S4_F2_61 | Open | S4_F2_61 | | | | 1,483.20 |
| S4_F2_66 | Close | S4_F2_66 | MSS4_2 | MSS4_4 | 311.00 | 1,483.20 |
| S4_F1_22 | Open | S4_F1_22 | | | | 1,480.10 |
| S4_F1_25 | Close | S4_F1_25 | MSS4_1 | MSS4_4 | 139.00 | 1,480.10 |
| S4_F1_30 | Open | S4_F1_30 | | | | 1,445.50 |
| S4_F4_35 | Close | S4_F4_35 | MSS4_1 | MSS4_4 | 1,531.00 | 1,445.50 |
| S4_F1_52 | Open | S4_F1_52 | | | | 1,437.90 |
| S4_F4_34 | Close | S4_F4_34 | MSS4_1 | MSS4_4 | 362.00 | 1,437.90 |
| S4_F3_30 | Open | S4_F3_30 | | | | 1,435.10 |
| S4_F2_45 | Close | S4_F2_45 | MSS4_3 | MSS4_3 | 1,998.00 | 1,435.10 |

b. Network summary of Dongnasok substation

| Feeder Id | Capacity | Initial load | Final load | Initial losses | Final losses | Initial length | Final length |
|---|---|---|---|---|---|---|---|
| | MVA | MVA | MVA | kW | kW | km | km |
| MSS4_1 | 14.60 | 13.20 | 10.80 | 288.30 | 224.60 | 24.30 | 22.40 |
| MSS4_2 | 7.30 | 23.60 | 20.40 | 1,288.20 | 1,049.70 | 26.50 | 24.30 |
| MSS4_3 | 14.60 | 11.90 | 14.50 | 88.80 | 135.70 | 19.70 | 21.30 |
| MSS4_4 | 14.60 | 2.70 | 5.30 | 4.80 | 24.20 | 4.50 | 7.00 |

c. System losses of Dongnasok substation

| Initial losses | Final losses | Savings losses | | |
|---|---|---|---|---|
| kW | kW | kW | % | USD/year |
| 1,670.11 | 1,435.15 | 234.96 | 14.07 | 0 |

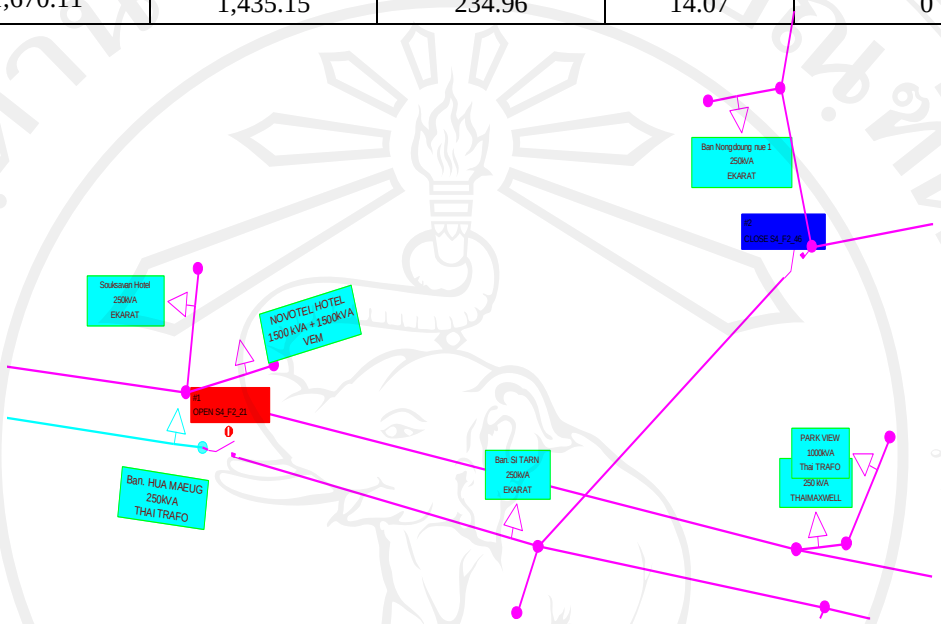


Figure 5.15 Location of open and close DS connected point feeders of Dongnasok substation

### 5.6.3.5 Phonthong substation switching optimization report

Phonthong substation have six feeders, the name of feeders are MSS5.1, MSS5.2, MSS5.3, MSS5.4, MSS5.5 and MSS5.6, shown as figure 5.16.

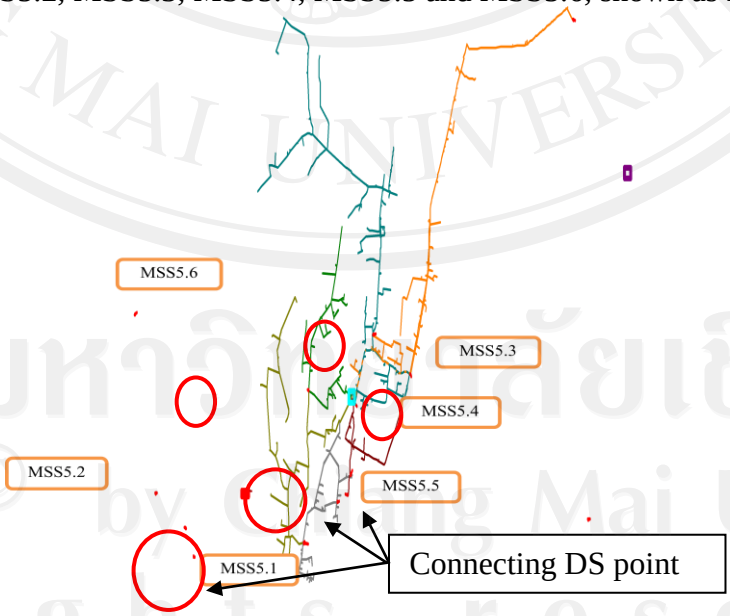


Figure 5.16 Location of DS connected point feeders of Phonthong substation

Table 5.36 a. Switching operations of Phonthong substation

| Section Id | Action | Switch Id | Load transferred | | | Losses |
|---|---|---|---|---|---|---|
| | | | From | To | kW | kW |
| S5_F1_10 | Open | S5_F1_10 | | | | 698.40 |
| S5_F1_1000 | Close | S5_F1_1000 | MSS5_1 | MSS5_5 | 3,354.00 | 665.60 |
| S5_F3_277 | Open | S5_F3_277 | | | | 646.50 |
| S5_F3_301 | Close | S5_F3_301 | MSS5_3 | MSS5_4 | 1,826.00 | 646.50 |
| S5_F4_250 | Open | S5_F4_250 | | | | 620.80 |
| S5_F5_2 | Close | S5_F5_2 | MSS5_4 | MSS5_5 | 2,155.00 | 620.80 |
| S5_F2_61 | Open | S5_F2_61 | | | | 612.70 |
| S5_F2_66 | Close | S5_F2_66 | MSS5_2 | MSS5_1 | 1,050.00 | 612.70 |
| S5_F5_54 | Open | S5_F5_54 | | | | 611.40 |
| S5_F4_280 | Close | S5_F4_280 | MSS5_5 | MSS5_5 | 266.00 | 611.40 |

b. Network summary of Phonthong substation

| Feeder Id | Capacity | Initial load | Final load | Initial losses | Final losses | Initial length | Final length |
|---|---|---|---|---|---|---|---|
| | MVA | MVA | MVA | kW | kW | km | km |
| MSS5_1 | 13.10 | 12.50 | 9.90 | 137.40 | 113.90 | 9.90 | 8.10 |
| MSS5_2 | 21.80 | 9.60 | 8.40 | 139.10 | 101.70 | 18.00 | 16.40 |
| MSS5_3 | 13.10 | 12.30 | 10.20 | 251.00 | 202.10 | 26.80 | 23.60 |
| MSS5_4 | 13.10 | 8.30 | 7.90 | 73.60 | 73.20 | 31.40 | 28.60 |
| MSS5_5 | 14.00 | 5.30 | 11.60 | 11.40 | 34.70 | 6.80 | 16.30 |
| MSS5_6 | 21.80 | 8.60 | 8.60 | 85.90 | 85.90 | 11.10 | 11.10 |

c. System losses of Phonthong substation

| Initial losses | Final losses | Savings losses | | |
|---|---|---|---|---|
| kW | kW | kW | % | USD/year |
| 698.35 | 611.43 | 86.93 | 12.45 | 0 |

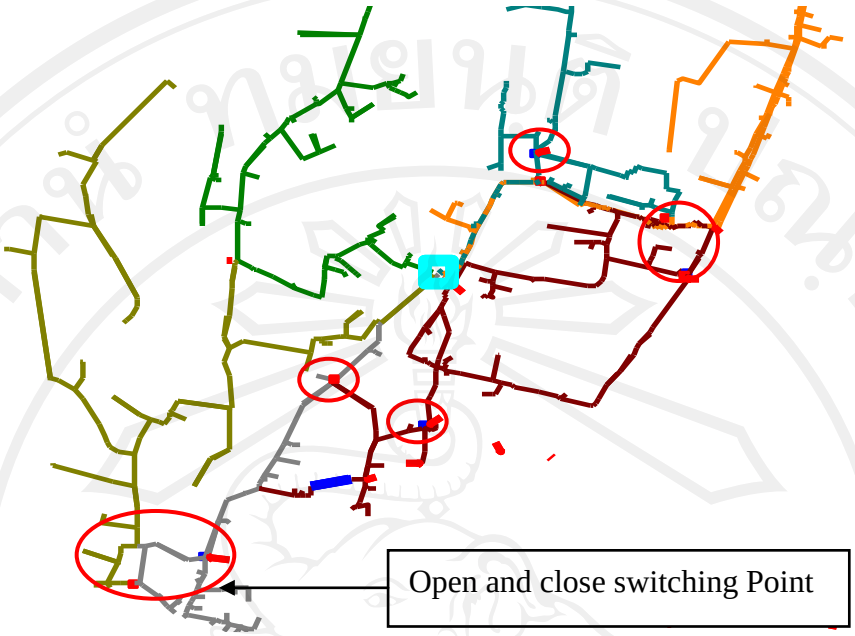


Figure 5.17 Location of open and close DS connected point feeders of Phonthong substation

### 5.6.3.6 ThaNgon substation switching optimization report

ThaNgon substation have four feeders, the name of feeders are MSS8.1, MSS8.2, MSS8.3 and MSS8.4, shown as figure

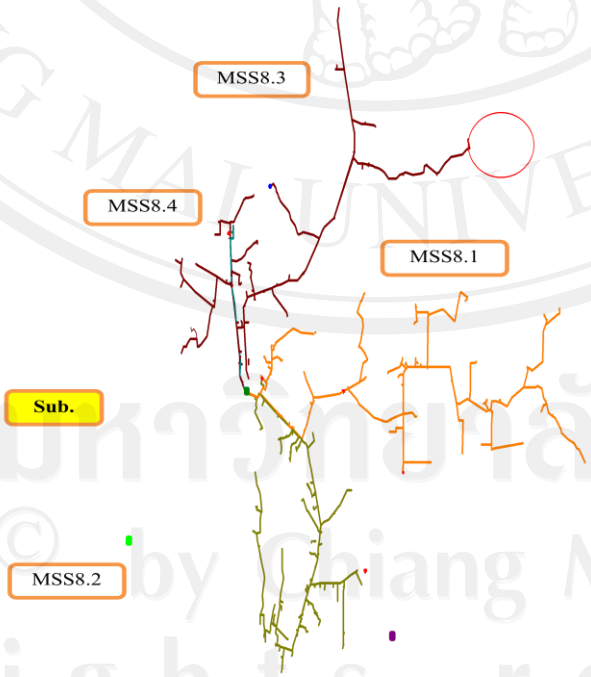


Figure 5.18 Location of DS connected point feeders of ThaNgon substation

Table 5.37 a. Switching operations of ThaNgon substation

| Section Id | Action | Switch Id | Load transferred | | | Losses |
|---|---|---|---|---|---|---|
| | | | From | To | kW | kW |
| S8_F3_222 | Open | S8_F3_222 | | | | 439.80 |
| S8_F4_16 | Close | S8_F4_16 | MSS8_3 | MSS8_4 | 830 | 432.50 |

b. Network summary of ThaNgon substation

| Feeder Id | Capacity | Initial load | Final load | Initial losses | Final losses | Initial length | Final length |
|---|---|---|---|---|---|---|---|
| | MVA | MVA | MVA | kW | kW | km | km |
| MSS8_1 | 13.10 | 6.00 | 6.00 | 204.80 | 204.80 | 86.10 | 86.10 |
| MSS8_2 | 13.10 | 7.80 | 7.80 | 187.30 | 187.30 | 66.30 | 66.30 |
| MSS8_3 | 13.10 | 4.90 | 3.90 | 47.50 | 35.80 | 75.10 | 64.40 |
| MSS8_4 | 20.80 | 0.30 | 1.20 | 0.20 | 4.70 | 7.90 | 18.60 |

c. System losses of ThaNgon substation

| Initial losses | Final losses | Savings losses | | |
|---|---|---|---|---|
| kW | kW | kW | % | USD/year |
| 439.77 | 432.50 | 7.27 | 1.65 | 0 |

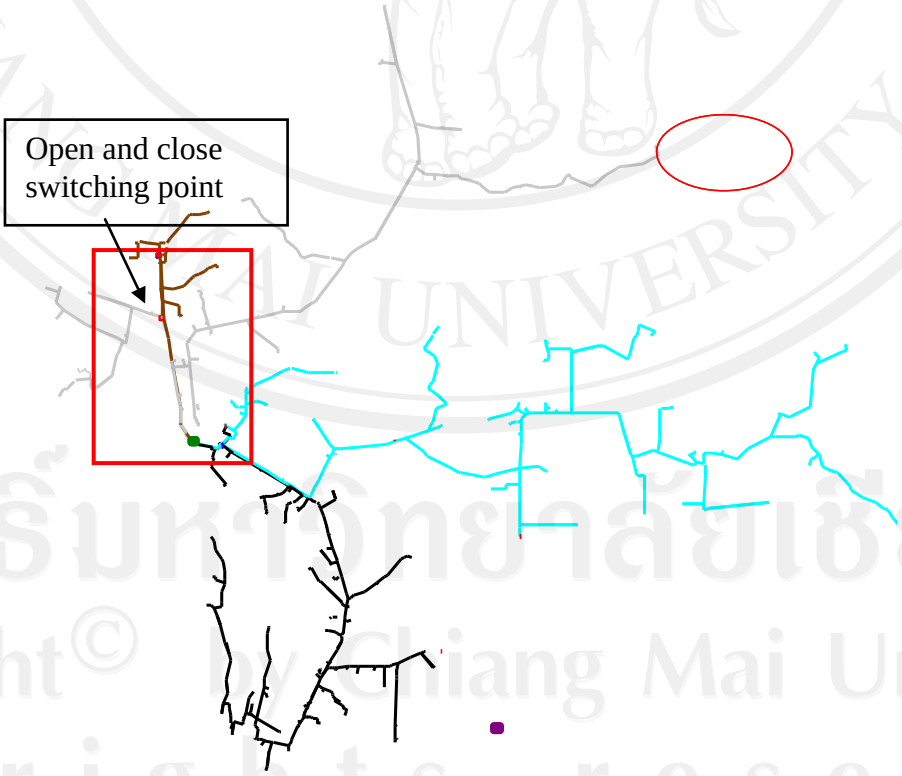


Figure 5.19 Location of open and close DS connected point feeders of ThaNgon substation

### 5.6.3.7 Khoksa-at substation switching optimization Report

Khoksa-at substation have six feeders, the name of feeders are MSS9.1, MSS9.2, MSS9.3, MSS9.4, MSS9.5 and MSS9.6, shown as figure

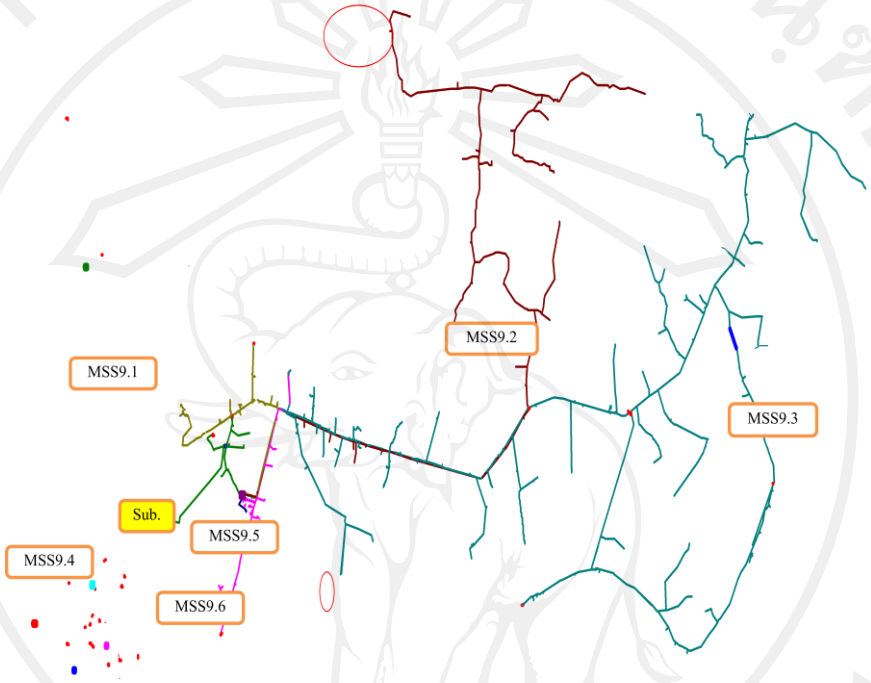


Figure 5.20 Location of DS connected point feeders of Khoksa-at substation

Table 5.38 a. Switching operations of Khoksa-at substation

| Section Id | Action | Switch Id | Load transferred | | | Losses |
|---|---|---|---|---|---|---|
| | | | From | To | kW | kW |
| S9_F1_74 | Open | S9_F1_74 | | | | 2,772.50 |
| S9_F4_A | Close | S9_F4_A | MSS9_1 | MSS9_4 | 949 | 2,760.20 |

b. Network summary of Khoksa-at substation

| Feeder Id | Capacity | Initial load | Final load | Initial losses | Final losses | Initial length | Final length |
|---|---|---|---|---|---|---|---|
| | MVA | MVA | kVA | kW | kW | km | km |
| MSS9_1 | 13.10 | 7.70 | 6.60 | 128.00 | 83.40 | 28.86 | 21.40 |
| MSS9_2 | 21.80 | 6.40 | 6.40 | 299.60 | 299.60 | 90.63 | 90.60 |
| MSS9_3 | 21.80 | 17.90 | 17.90 | 2,085.30 | 2,085.30 | 212.42 | 212.40 |
| MSS9_4 | 14.60 | 10.70 | 11.80 | 218.80 | 251.10 | 13.28 | 20.70 |
| MSS9_5 | 14.60 | 6.10 | 6.10 | 16.80 | 16.80 | 1.13 | 1.10 |
| MSS9_6 | 21.80 | 7.10 | 7.10 | 24.00 | 24.00 | 23.34 | 23.30 |

c. System losses of Khoksa-at substation

| Initial losses | Final losses | Savings losses | | |
|---|---|---|---|---|
| kW | kW | kW | % | USD/year |
| 2,772.50 | 2,760.18 | 12.31 | 0.44 | 0 |

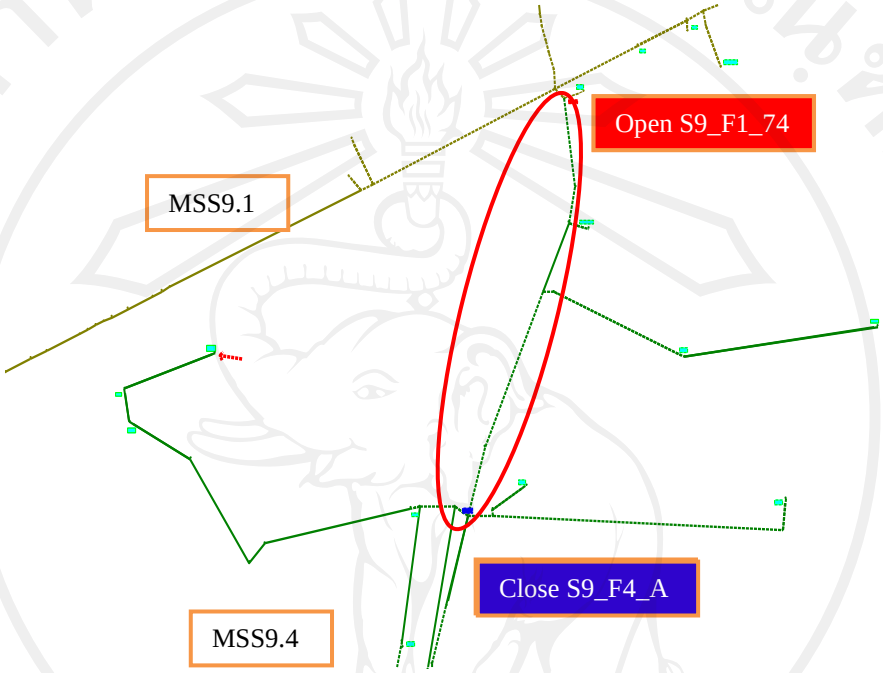


Figure 5.21 Location of open and close DS connected point feeders of Khoksa-at substation

### 5.6.3.8 Switching optimization report all feeders

The switching optimization with utilizing the interconnection could mitigate the feeders' peak losses; however, some of the heavily loaded sections were still remained. Some feeders in all substations are connection by DS as seen below.

Table 5.39 a. Switching operations of switching optimization report all feeders

| Section Id | Action | Switch Id | Load Transferred | | | Losses |
|---|---|---|---|---|---|---|
| | | | From | To | kW | kW |
| S9_F3_300 | Open | S9_F3_300 | | | | 8,728.80 |
| S6_F5_265 | Close | S6_F5_265 | MSS9_3 | MSS6_5 | 1,862.00 | 7,801.10 |
| S6_F6_150 | Open | S6_F6_150 | | | | 7,529.40 |
| S6_F6_226 | Close | S6_F6_226 | MSS6_6 | MSS1_2 | 3,405.00 | 7,529.40 |
| S6_F7_99 | Open | S6_F7_99 | | | | 7,358.30 |
| S6_F7_141 | Close | S6_F7_141 | MSS6_7 | MSS1_5 | 3,330.00 | 7,358.30 |

Table 5.39 a. Switching operations of switching optimization report all feeders (Continued)

| Section Id | Action | Switch Id | Load Transferred | | | Losses |
|---|---|---|---|---|---|---|
| | | | From | To | kW | kW |
| S6_F8_193 | Open | S6_F8_193 | | | | 7,272.10 |
| S1_F3_125 | Close | S1_F3_125 | MSS6_8 | MSS1_3 | 2,441.00 | 7,272.10 |
| S3_F1_257 | Open | S3_F1_257 | | | | 7,253.40 |
| S6_F4_30 | Close | S6_F4_30 | MSS3_1 | MSS6_4 | 879.00 | 7,253.40 |
| S3_F4_160 | Open | S3_F4_160 | | | | 7,242.70 |
| S9_F6_91 | Close | S9_F6_91 | MSS3_4 | MSS9_6 | 766.00 | 7,242.70 |
| S8_F1_227 | Open | S8_F1_227 | | | | 7,234.80 |
| S8_F1_240 | Close | S8_F1_240 | MSS8_1 | MSS9_1 | 132.00 | 7,234.80 |
| S6_F1_12 | Open | S6_F1_12 | | | | 7,232.60 |
| S6_F1_13 | Close | S6_F1_13 | MSS6_1 | MSS6_6 | 372.00 | 7,232.60 |
| S1_F5_39 | Open | S1_F5_39 | | | | 7,229.70 |
| S1_F5_57 | Close | S1_F5_57 | MSS1_5 | MSS2_5 | 1,213.00 | 7,229.70 |
| S3_F1_107 | Open | S3_F1_107 | | | | 7,230.20 |
| S3_F1_108 | Close | S3_F1_108 | MSS3_1 | MSS3_4 | 461.00 | 7,230.20 |
| S6_F8_10 | Open | S6_F8_10 | | | | 7,229.90 |
| F6_F6_A | Close | F6_F6_A | MSS6_8 | MSS6_6 | 385.00 | 7,229.90 |
| S6_F8_261 | Open | S6_F8_261 | | | | 7,229.50 |

b. Network summary of switching optimization report all feeders

| Feeder Id | Capacity | Initial load | Final load | Initial losses | Final losses | Initial length | Final length |
|---|---|---|---|---|---|---|---|
| | MVA | MVA | MVA | kW | kW | km | km |
| MSS1_1 | 14.20 | 6.50 | 6.50 | 18.10 | 18.10 | 5.00 | 5.00 |
| MSS1_2 | 14.60 | 7.60 | 11.50 | 37.10 | 147.40 | 10.10 | 26.80 |
| MSS1_3 | 14.60 | 6.60 | 9.30 | 26.30 | 78.60 | 11.70 | 19.90 |
| MSS1_4 | 20.50 | 2.00 | 2.00 | 0.70 | 0.70 | 1.90 | 1.90 |
| MSS1_5 | 14.60 | 8.00 | 10.80 | 38.00 | 107.10 | 12.90 | 17.80 |
| MSS1_6 | 14.60 | 7.60 | 7.60 | 15.80 | 15.80 | 6.70 | 6.70 |
| MSS10_1 | 20.50 | 1.20 | 1.20 | 2.30 | 2.30 | 18.30 | 18.30 |
| MSS10_2 | 13.10 | 9.50 | 9.50 | 326.70 | 326.70 | 97.60 | 97.60 |
| MSS10_3 | 19.10 | 9.00 | 9.00 | 1,183.70 | 1,183.70 | 200.60 | 200.60 |
| MSS10_4 | 13.10 | 5.70 | 5.70 | 25.90 | 25.90 | 24.90 | 24.90 |
| MSS2_1 | 14.20 | 9.90 | 9.90 | 29.20 | 29.20 | 3.90 | 3.90 |
| MSS2_2 | 14.60 | 8.90 | 8.90 | 18.80 | 18.80 | 4.00 | 4.00 |
| MSS2_3 | 14.60 | 4.90 | 4.90 | 4.80 | 4.80 | 2.60 | 2.60 |

b. Network summary of switching optimization report all feeders(Continued)

| Feeder Id | Capacity | Initial load | Final load | Initial losses | Final losses | Initial length | Final length |
|---|---|---|---|---|---|---|---|
| | MVA | MVA | MVA | kW | kW | km | km |
| MSS2_4 | 14.60 | 1.80 | 1.80 | 0.20 | 0.20 | 0.30 | 0.30 |
| MSS2_5 | 14.20 | 4.80 | 6.20 | 12.80 | 26.30 | 13.20 | 14.40 |
| MSS2_6 | 14.20 | 10.70 | 10.70 | 53.10 | 53.10 | 10.70 | 10.70 |
| MSS3_1 | 20.50 | 7.10 | 5.50 | 75.20 | 38.60 | 38.70 | 25.90 |
| MSS3_2 | 14.60 | 5.90 | 5.90 | 14.20 | 14.20 | 5.70 | 5.70 |
| MSS3_3 | 14.60 | 7.70 | 7.70 | 22.40 | 22.40 | 6.20 | 6.20 |
| MSS3_4 | 14.60 | 7.60 | 7.20 | 59.50 | 48.70 | 39.70 | 22.80 |
| MSS4_1 | 14.60 | 10.80 | 10.80 | 224.60 | 224.60 | 22.40 | 22.40 |
| MSS4_2 | 7.30 | 20.40 | 20.40 | 1,049.70 | 1,049.70 | 24.30 | 24.30 |
| MSS4_3 | 14.60 | 14.50 | 14.50 | 135.70 | 135.70 | 21.30 | 21.30 |
| MSS4_4 | 14.60 | 5.30 | 5.30 | 25.10 | 25.10 | 7.00 | 7.00 |
| MSS5_1 | 13.10 | 9.90 | 9.90 | 113.90 | 113.90 | 8.10 | 8.10 |
| MSS5_2 | 21.80 | 8.40 | 8.40 | 101.70 | 101.7 | 16.40 | 16.40 |
| MSS5_3 | 13.10 | 10.20 | 10.20 | 202.10 | 202.10 | 23.60 | 23.60 |
| MSS5_4 | 13.10 | 7.90 | 7.90 | 73.20 | 73.20 | 28.60 | 28.60 |
| MSS5_5 | 14.00 | 11.60 | 11.60 | 34.70 | 34.70 | 16.30 | 16.30 |
| MSS5_6 | 21.80 | 8.60 | 8.60 | 85.90 | 85.90 | 11.10 | 11.10 |
| MSS6_1 | 20.80 | 9.00 | 8.50 | 222.80 | 219.00 | 15.20 | 14.20 |
| MSS6_2 | 20.80 | 0.90 | 0.90 | 1.20 | 1.20 | 4.90 | 4.90 |
| MSS6_4 | 20.80 | 0.80 | 1.80 | 1.30 | 9.50 | 16.70 | 26.40 |
| MSS6_5 | 20.80 | 7.00 | 9.20 | 82.20 | 241.40 | 41.00 | 95.40 |
| MSS6_6 | 20.80 | 9.90 | 6.40 | 476.00 | 97.50 | 43.50 | 28.20 |
| MSS6_7 | 20.80 | 12.50 | 8.40 | 410.70 | 160.60 | 21.40 | 16.00 |
| MSS6_8 | 20.80 | 10.10 | 6.70 | 239.70 | 92.10 | 31.30 | 21.80 |
| MSS8_1 | 13.10 | 6.00 | 5.80 | 204.80 | 192.30 | 86.10 | 79.20 |
| MSS8_2 | 13.10 | 7.80 | 7.80 | 187.30 | 187.30 | 66.30 | 66.30 |
| MSS8_3 | 13.10 | 3.90 | 3.90 | 35.80 | 35.80 | 64.40 | 64.40 |
| MSS8_4 | 20.80 | 1.20 | 1.20 | 4.70 | 4.70 | 18.60 | 18.60 |
| MSS9_1 | 13.10 | 6.60 | 6.70 | 83.40 | 87.90 | 21.40 | 28.30 |
| MSS9_2 | 21.80 | 6.60 | 6.60 | 390.80 | 390.80 | 101.50 | 101.50 |
| MSS9_3 | 21.80 | 17.90 | 14.00 | 2,085.20 | 998.40 | 212.80 | 158.40 |
| MSS9_4 | 14.60 | 11.80 | 11.80 | 251.10 | 251.10 | 20.70 | 20.70 |
| MSS9_5 | 14.60 | 6.10 | 6.10 | 16.80 | 16.80 | 1.10 | 1.10 |
| MSS9_6 | 21.80 | 7.10 | 8.00 | 24.00 | 34.30 | 23.30 | 43.40 |

C. System losses of switching optimization report all feeders

| Initial losses | Final losses | Savings losses | | |
|---|---|---|---|---|
| kW | kW | kW | % | USD/year |
| 8,728.76 | 7,229.46 | 1,499.29 | 17.18 | 0 |

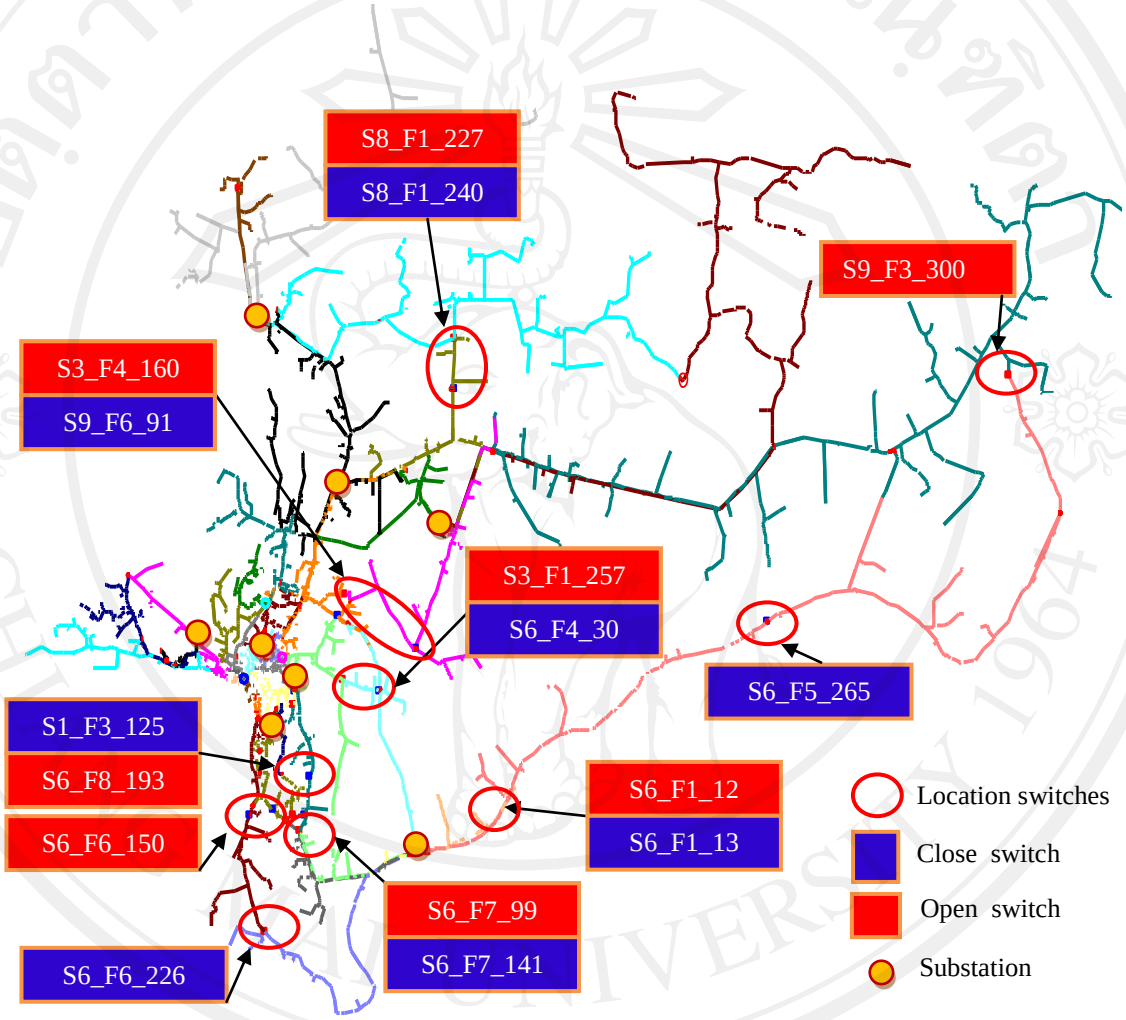


Figure 5.22 Location of open and close DS connected point feeders of Khoksa-at substation

### 5.6.3.9 Summarize of switching optimization in distribution system of Vientiane capital

The switching optimization in CYMDIST program had calculated. The results in above could summarize as seen table 5.40. The result consist 17 case can reduced losses are 1,861.10 kW or 59.14%. The total DS are 66 sets; there were installed DS 33 sets and existing 33 sets.

Table 5.40 Summarize installation switched in distribution system.

| | Name of substations | Name of feeders | Switching optimization | | | | |
|---|---|---|---|---|---|---|---|
| | | | Initial losses | Final losses | Savings losses | | DS |
| | | | kW | kW | kW | % | sets |
| Case1 | Sokphalaung | 2,3 | 143.50 | 136.00 | 7.50 | 5.22 | 6 |
| Case2 | Sisakhet | 2,3 | 23.60 | 23.60 | 0.10 | 0.21 | 4 |
| Case3 | Thatlaung | 1,2,3,4 | 184.10 | 171.30 | 12.80 | 6.96 | 8 |
| Case4 | Dongnasok | 1,2,3,4 | 1,670.10 | 1,435.20 | 235.00 | 14.07 | 12 |
| Case5 | Phonthong | 1,2,3,4,5 | 698.40 | 611.40 | 86.90 | 12.45 | 10 |
| Case6 | Tha Ngon | 3,4 | 439.80 | 432.50 | 7.30 | 1.65 | 2 |
| Case7 | Koksa-at | 1,4 | 2,772.50 | 2,760.20 | 12.30 | 0.44 | 2 |
| Case8 | Koksa-at | 3 | 8,728.80 | 7,801.10 | 927.70 | 10.63 | 2 |
| | Thanaleng | 5 | | | | | |
| Case9 | Thanaleng | 6 | 7,801.10 | 7,529.40 | 271.70 | 3.48 | 2 |
| | Sokphalaung | 2 | | | | | |
| Case10 | Thanaleng | 7 | 7,529.40 | 7,358.30 | 171.10 | 2.27 | 2 |
| | Sokphalaung | 5 | | | | | |
| Case11 | Thanaleng | 8 | 7,358.30 | 7,272.10 | 86.20 | 1.17 | 2 |
| | Sokphalaung | 3 | | | | | |
| Case11 | Thatlaung | 1 | 7,272.10 | 7,253.40 | 18.70 | 0.26 | 2 |
| | Thanaleng | 4 | | | | | |
| Case12 | Thatlaung | 4 | 7,253.40 | 7,242.70 | 10.70 | 0.15 | 2 |
| | Koksa-at | 6 | | | | | |
| Case13 | Tha Ngon | 1 | 7,242.70 | 7,234.80 | 7.90 | 0.11 | 2 |
| | Koksa-at | 1 | | | | | |
| Case14 | Thanaleng | 1,6 | 7,234.80 | 7,232.60 | 2.20 | 0.03 | 2 |
| Case15 | Sokphalaung | 1 | 7,232.60 | 7,230.20 | 2.40 | 0.03 | 2 |
| | Sisakhet | 5 | | | | | |
| Case16 | Thanaleng | 6,8 | 7,230.20 | 7,229.90 | 0.30 | 0.00 | 2 |
| Case17 | Sokphalaung | 3,5 | 7,229.90 | 7,229.50 | 0.40 | 0.01 | 2 |
| **Total savings losses** | | | **88,045.30** | **86,184.20** | **1,861.10** | **59.14** | **66** |

### 5.6.4 Assumptions in the calculations

#### 5.6.4.1 Tariff

EDL has specification the new electricity tariff adjustment from 3/2012 to 12/2017 as seen in Appendix C. The cost of low voltage could average power tariff are 726 kip/kWH or 0.09 USD. Exchange Rate on (12$^{th}$ October 2012, Bank of the Lao P.D.R) US 1 $ = 7,980.00 Kip) as seen in Appendix E.

#### 5.6.4.2 Depreciation

According to stipulation of Ministry of Finance the assets of power sector have a high depreciation; the period of depreciation is normally from 5 to 13 years. For fixed assets newly put into operation, the depreciation rate of power network is 10% .

#### 5.6.4.3 Operation and Maintenance Cost (O&M)

Equal to 3% of total investment cost.

#### 5.6.4.4 Discount rate

Based on the technical economic norms given, the discount rate of investment projects in energy sector is usually 10%.

#### 5.6.4.5 Economic life of equipments

According to stipulation of Ministry of Finance the assets of power sector and technical economic norms of Ministry of energy and mines, the economic life of equipments and material is normally 25 years.

### 5.6.5 Analysis results

#### 5.6.5.1 Improving of financial analysis in the cases

Based on the forecasted demand, technical results calculated in the chapter 5, estimated investment costs, and above assumptions, the case are analyzed; the results are tabulated in table 5.41 to 5.47.

##### 5.6.5.1.1 Summarizing economic of load balancing in distribution system

Table 5.41 Summarize saving cost of load balancing in distribution system

| Case | Savings losses | | Cost | Savings cost | Investment |
|---|---|---|---|---|---|
| | kW | MWH | USD/kWH | USD | USD |
| MSS3.1 | 0.01 | 0.09 | 0.09 | 7.80 | 0 |
| MSS8.1 | - | - | 0.09 | - | - |
| MSS8.2 | 0.01 | 0.09 | 0.09 | 7.80 | 0 |
| MSS8.3 | - | - | 0.09 | - | - |
| MSS9.1 | - | - | 0.09 | - | - |
| MSS9.2 | 0.23 | 2.01 | 0.09 | 181.33 | 0 |
| MSS9.3 | 13.40 | 117.38 | 0.09 | 10,564.56 | 0 |
| MSS9.4 | 0.05 | 0.44 | 0.09 | 39.43 | 0 |
| MSS10.2 | 0.03 | 0.26 | 0.09 | 23.65 | 0 |
| MSS10.3 | 7.91 | 69.29 | 0.09 | 6,236.24 | 0 |
| **Total** | **21.64** | **189.57** | **0.09** | **17,060.98** | **0** |

### 5 .6.5.2 Economic parameters for capacitor placement

The cost of fixed and switched capacitors, energy price, discount rate and inflation rate are taken from the data collection. From now to 2013, reactive power consumption cost and demand cost are still set to zero, so they are set to zero. These parameters are shown in table 5.2.

Table 5.42 Economic parameter for optimal capacitor placement

| | |
|---|---|
| Energy price (USD/kWh) | 0.09 |
| Reactive energy price (USD/kVARh) | 0 |
| Demand cost (USD/kW) | 0 |
| Discount rate % | 10 |
| Evaluation period (years) | 5 |
| Fixed capacitor price (USD/kVAR) | 10 |
| Switched capacitor price (USD/kVAR) | 15 |
| Maintenance cost for fixed capacitor (USD/kVAR/year) | 0.06 |
| Maintenance cost for Switched capacitor (USD/kVAR/year) | 0.09 |

Table 5.43 Summarize savings cost of capacitor bank 50kVAR

| Name of substation | Capacitor bank at 50 kVAR/phase | | | | | | |
|---|---|---|---|---|---|---|---|
| | Fixed | | Switch | | Savings Loss | | Savings cost |
| | kVAR | Investment USD | kVAR | Investment USD | kW | MWH | USD |
| Phonethong | 6,300 | 63,000 | 9,450 | 141,750 | 209.30 | 1,833.50 | 165,012 |
| Naxaythong | 4,050 | 40,500 | 2,100 | 31,500 | 4270 | 3,740.50 | 336,647 |
| Tha Ngon | 2,250 | 22,500 | 1,950 | 29,250 | 82.60 | 723.60 | 65,122 |
| Koksa-at | 4,950 | 49,500 | 8,850 | 132,750 | 641.80 | 5,622.20 | 505,995 |
| Thanaleng | 4,500 | 45,000 | 6,450 | 96,750 | 257.10 | 2,252.20 | 202,698 |
| Sokphalaung | 5,400 | 54,000 | 4,500 | 67,500 | 28.80 | 252.30 | 22,706 |
| Sisakhet | 4,200 | 42,000 | 5,700 | 85,500 | 23.20 | 203.20 | 18,291 |
| Thatlaung | 3,300 | 33,000 | 3,450 | 51,750 | 36.40 | 318.90 | 28,698 |
| Dongnasok | 7,650 | 76,500 | 3,600 | 54,000 | 327.10 | 2,865.40 | 257,886 |
| **Total** | **42,600** | **426,000** | **46,050** | **690,750** | **2,033.30** | **17,811.70** | **1,603,054** |

Table 5.44 Summarize savings cost of capacitor bank 100kVAR

| Name of substation | Capacitor bank at 100 kVAR/phase | | | | | | |
|---|---|---|---|---|---|---|---|
| | Fixed | | Switch | | Savings Loss | | Savings cost |
| | kVAR | Investment USD | kVAR | Investment USD | kW | MWH | USD |
| Phonethong | 5,700 | 57,000 | 9,900 | 148,500 | 208.10 | 1,823.00 | 164,066 |
| Naxaythong | 3,600 | 36,000 | 2,100 | 31,500 | 413.90 | 3,625.80 | 326,319 |
| Tha Ngon | 1,800 | 18,000 | 2,100 | 31,500 | 79.90 | 699.90 | 62,993 |
| Koksa-at | 4,500 | 45,000 | 7,800 | 117,000 | 747.50 | 6,548.10 | 589,329 |
| Thanaleng | 3,900 | 39,000 | 6,300 | 94,500 | 247.70 | 2,169.90 | 195,287 |
| Sokphalaung | 4,800 | 48,000 | 4,200 | 63,000 | 27.60 | 241.80 | 21,760 |
| Sisakhet | 3,600 | 36,000 | 5,700 | 85,500 | 22.60 | 198.00 | 17,818 |
| Thatlaung | 3,000 | 30,000 | 3,600 | 54,000 | 35.90 | 314.50 | 28,304 |
| Dongnasok | 7,500 | 75,000 | 3,600 | 54,000 | 323.90 | 2,837.40 | 255,363 |
| **Total** | **38,400** | **384,000** | **45,300** | **679,500** | **2,107.10** | **18,458.20** | **1,661,238** |

Table 5.45 Summarize savings cost of capacitor bank 200kVAR

| Name of substation | Capacitor bank at 200 kVAR/phase | | | | | | |
|---|---|---|---|---|---|---|---|
| | Fixed | | Switch | | Savings Loss | | Savings cost |
| | kVAR | Investment USD | kVAR | Investment USD | kW | MWH | USD |
| Phonethong | 4,800 | 48,000 | 10,200 | 153,000 | 203.40 | 1,781.80 | 160,361 |
| Naxaythong | 3,000 | 30,000 | 1,800 | 27,000 | 371.50 | 3,254.30 | 292,891 |
| Tha Ngon | 1,200 | 12,000 | 2,400 | 36,000 | 77.30 | 677.10 | 60,943 |
| Koksa-at | 3,600 | 36,000 | 8,400 | 126,000 | 728.00 | 6,377.30 | 573,955 |
| Thanaleng | 3,000 | 30,000 | 7,200 | 108,000 | 246.00 | 2,155.00 | 193,946 |
| Sokphalaung | 4,200 | 42,000 | 3,600 | 54,000 | 26.60 | 233.00 | 20,971 |
| Sisakhet | 2,400 | 24,000 | 6,000 | 90,000 | 21.60 | 189.20 | 17,029 |
| Thatlaung | 2,400 | 24,000 | 3,000 | 45,000 | 31.70 | 277.70 | 24,992 |
| Dongnasok | 7,200 | 72,000 | 3,000 | 45,000 | 311.10 | 2,725.20 | 245,271 |
| **Total** | **31,800** | **318,000** | **45,600** | **684,000** | **2,017.20** | **17,670.70** | **1,590,360** |

Based on the results of the forecasted demand, technical analyses, estimated investment costs, reference data and assumptions; table 5.43 to 5.46 summarizes the results of financial analyses for installation capacitor banks 50kVAR, 100kVAR and 200 kVAR. The results of detailed analyses are given in appendix D. In this table, the IRR are high, because the investments are lower profit, there for IRR >10% and Sisakhet case NPV, IRR and Payback period are minus, because investment more than profit. In three cases, the results of installed capacitor banks at 50kVAR, 100kVAR and 200 kVAR case are feasible with NPV>0, and IRR>10%. However,

the NPV of capacitor banks at 100 kVAR case is higher than 50kVAR and 200 kVAR. The investment cost of installed capacitor banks at 100kVAR is lower than investment cost of 50kVAR, 100kVAR. As a result, payback period capacitor bank at 100kVAR is 0.72 year and the best choice as seen in Appendix D.

Table 5.46 Results of financial analyses of capacitor placement

| Name of substation | Capacitor bank at 50 kVAR/phase | | | Capacitor bank at 100 kVAR/phase | | | Capacitor bank at 200 kVAR/phase | | |
|---|---|---|---|---|---|---|---|---|---|
| | NPV | IRR | Payback period | NPV | IRR | Payback period | NPV | IRR | Payback period |
| | $x10^6$ USD | % | year | $x10^6$ USD | % | year | $x10^6$ USD | % | year |
| Phonethong | 0.41 | 75% | 1.46 | 0.40 | 74% | 1.47 | 0.39 | 74% | 1.47 |
| Naxaythong | 1.20 | 467% | 0.23 | 1.16 | 483% | 0.22 | 1.05 | 514% | 0.21 |
| Tha Ngon | 0.19 | 123% | 0.90 | 0.19 | 124% | 0.89 | 0.18 | 124% | 0.89 |
| Koksa-at | 1.72 | 277% | 0.40 | 2.06 | 363% | 0.30 | 2.00 | 354% | 0.31 |
| Thanaleng | 0.62 | 141% | 0.79 | 0.60 | 144% | 0.77 | 0.59 | 138% | 0.81 |
| Sokphalaung | 0.00 | 11% | 10.78 | 0.01 | 12% | 10.07 | 0.03 | 15% | 8.65 |
| Sisakhet | (0.07) | -15% | - | (0.06) | -14% | - | (0.06) | -13% | - |
| Thatlaung | 0.02 | 18% | 3.75 | 0.02 | 18% | 3.76 | 0.02 | 22% | 3.49 |
| Dongnasok | 0.84 | 196% | 0.57 | 0.83 | 197% | 0.57 | 0.80 | 208% | 0.53 |
| **Total** | **4.89** | **141%** | **0.79** | **5.16** | **154%** | **0.72** | **4.96** | **157%** | **0.71** |

### 5.6.5.3 Results of financial analyses of switching optimization

Table 5.47 summarizes the results of financial analyses for switching optimization. The results of detailed analyses are high profit. The disconnecting switch installed 33 sets. Table 4.7 is shown DS costs 6,000 USD/set. Therefore, the investment cost for DS are 198,000.0 USD. This case can reduce losses are 1,861.10 kW, 16,303,236 kWH and savings cost is 1,467,291 USD. For NPV > 10% and payback period is 0.14 year.

Table 5.47 Results of financial analyses of switching optimization

| | Existing DS | Installation DS | Investment | Savings losses | | |
|---|---|---|---|---|---|---|
| | set | set | USD | kW | MWH | USD |
| Case1 | 3 | 3 | 18,000 | 7.50 | 65.70 | 5,913 |
| Case2 | 2 | 2 | 12,000 | 0.10 | 0.90 | 79 |
| Case3 | 4 | 4 | 24,000 | 12.80 | 112.10 | 10,092 |
| Case4 | 6 | 6 | 36,000 | 235.00 | 2,058.60 | 185,274 |
| Case5 | 5 | 5 | 30,000 | 86.90 | 761.20 | 68,512 |
| Case6 | 1 | 1 | 6,000 | 7.30 | 63.90 | 5,755 |
| Case7 | 1 | 1 | 6,000 | 12.30 | 107.70 | 9,697 |
| Case8 | 1 | 1 | 6,000 | 927.70 | 8,126.70 | 731,399 |
| Case9 | 1 | 1 | 6,000 | 271.70 | 2,380.10 | 214,208 |
| Case10 | 1 | 1 | 6,000 | 171.10 | 1,498.80 | 134,895 |
| Case11 | 1 | 1 | 6,000 | 86.20 | 755.10 | 67,960 |
| Case11 | 1 | 1 | 6,000 | 18.70 | 163.80 | 14,743 |
| Case12 | 1 | 1 | 6,000 | 10.70 | 93.70 | 8,436 |
| Case13 | 1 | 1 | 6,000 | 7.90 | 69.20 | 6,228 |
| Case14 | 1 | 1 | 6,000 | 2.20 | 19.30 | 1,734 |
| Case15 | 1 | 1 | 6,000 | 2.40 | 21.00 | 1,892 |
| Case16 | 1 | 1 | 6,000 | 0.30 | 2.60 | 237 |
| Case17 | 1 | 1 | 6,000 | 0.40 | 3.50 | 315 |
| **Total** | **33** | **33** | **198,000** | **1,861.10** | **16,303.2** | **1,467,291** |