Japan International Cooperation Agency

National Power Transmission Network Development Project in Myanmar (Power Network System Plan)

Site Investigation Report

May 2015

Tokyo Electric Power Company Inc.

The First Site Investigation Report

1. **Name of Experts, Belonging Organization and His Duty**

   Masaharu Yogo, TEPCO, Power System Planner

2. **Name of the Project**

   National Power Transmission Network Development Project in Myanmar

3. **Purpose of This Investigation**

   Myanmar government cited the development of 500 kV transmission lines and substations as a matter of priority and issued a request of their development by utilizing yen loan. According to the request, the Japanese Government informed Myanmar government of a new yen loan project as the donor policy on March 24, 2014 targeting "National Power Transmission Network Development Project Phase 1" in Myanmar. Furthermore, following the Phase 1, the rapid development of Phase 2 are also needed. In this survey, engaged member will carry out the supplementary investigation in cooperation with his counterpart, the Myanmar Electric Power Enterprise, in order to examine and recommend the appropriate power system plan for preparation of yean loan project by collecting and organizing the relevant information based on the current plans and implementation of the transmission lines and substation projects by Myanmar Government, power generation plans utilizing IPP and the support planning and implementation status of other donors.

4. **Methodology**

   The latest information regarding Myanmar's power system network plan was collected and reviewed. The necessary investigations were carried out for contributing to prepare the appraisal as yen loan projects relevant to the power network system plans in Myanmar in cooperation with the environmental expert and JICA staff (F/F mission and appraisal mission).

5. **Duration of the Project Survey**

   From January 16th 2015 to May 29th 2015 (scheduled)

   The first site investigation was from January 18th to 28th 2015.

6. **The First Site Investigation**

   In January 19th, 20th and 22nd, the information was collected based on the questionnaire attached in this report through the discussion with the Power Transmission Project Department of MEPE and DEP. In 26th January, the mission team carried out the site investigations at the candidate sites of Pharyargyi and Hlaingtayar to confirm their latest situations regarding the Phase 2 Project. The confirmed information is described as follows.

A. The Situations of Land Acquisitions

(1) Phayargyi Substation (Figure 1)

The location of the candidate site of 500 kV Phayargyi Substation had been moved to the outside of the military land by around 1 km in the south direction because the permission for its land usage had not been given by the military. The new site is a plane land without any hats or buildings, but with containing a wet land even in dry seasons. A distribution line of 11 kV that supplies the power to the military crossed over the southern part of the site from east to west. It is needed to be moved. (Its replacement cost is estimated around 2 or 3 million) The 500 kV switch yard will be installed in the north. The 230 kV switch yard will be installed in the south where 6 circuits of 230 kV transmission lines will be derived. The route of 500 kV transmission line between the original site of Pharyargyi and Hlaingtayar was not changed from the previous plan in 2014. The 500 kV transmission line between the new location and the original location is needed to be added. There are no buildings around this route.

(2) Hlaingtayar Substation (Figure 2)

The land for the new 500 kV Hlaingtayar Substation was owned by seven households. The six of them had been already paid for land provision, however, one of them would not enter into negotiations with MEPE and it seemed difficult to negotiate him. Lacking of his land would increase in the cost of substation because it requires compact facilities such as Gas Insulated Switchgears (GIS). Thus, the new additional land acquisition neighbor to the original land in the east direction was proposed and MEPE was expected to study its adequacy. The candidate site is a plain land with only a small hut utilized agricultural works. The 500 kV switch yard will be installed in the north and the 230 kV switch yard will be installed in the south.

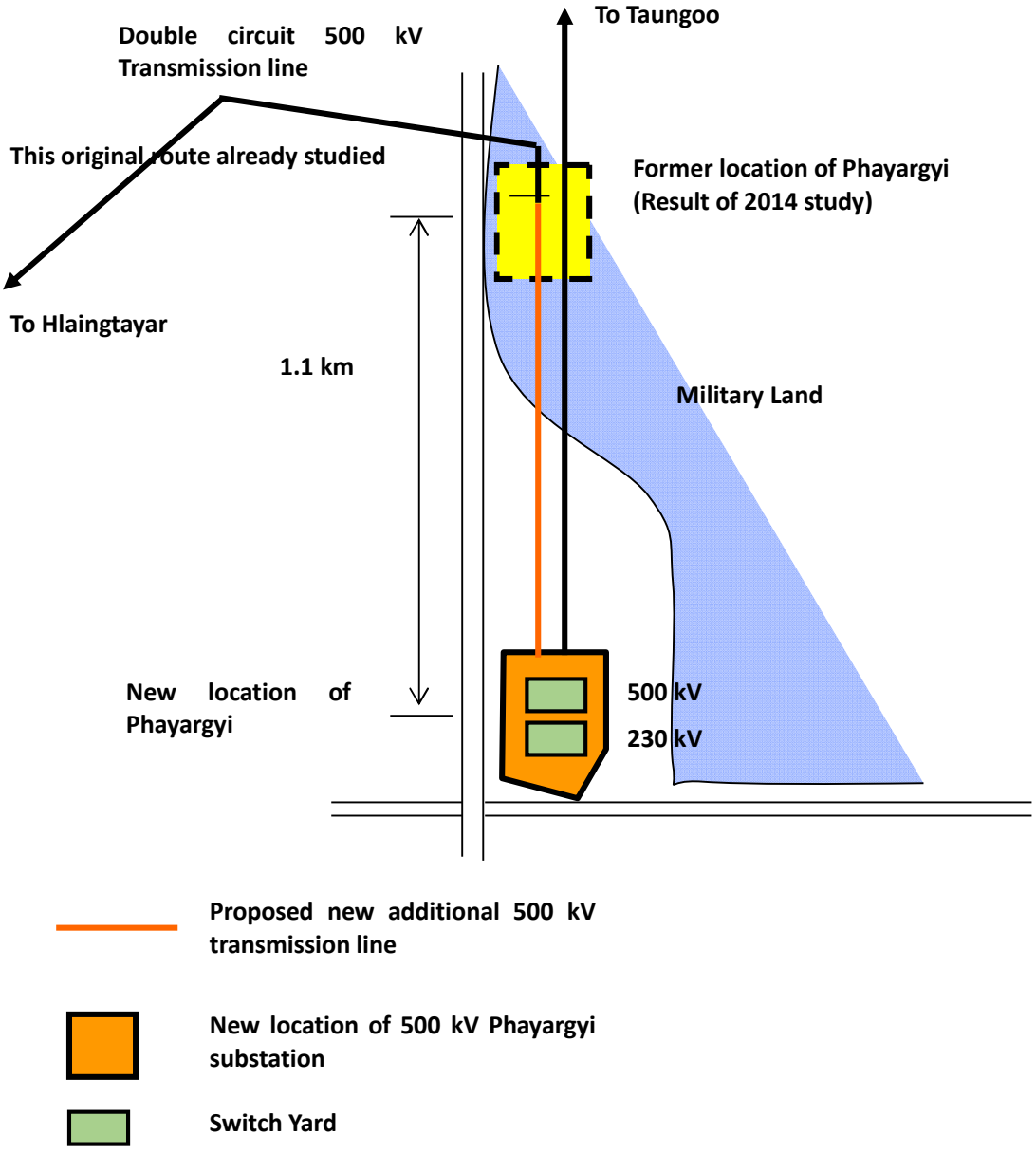


Figure 1 New Location of 500 kV Phayargyi Substation

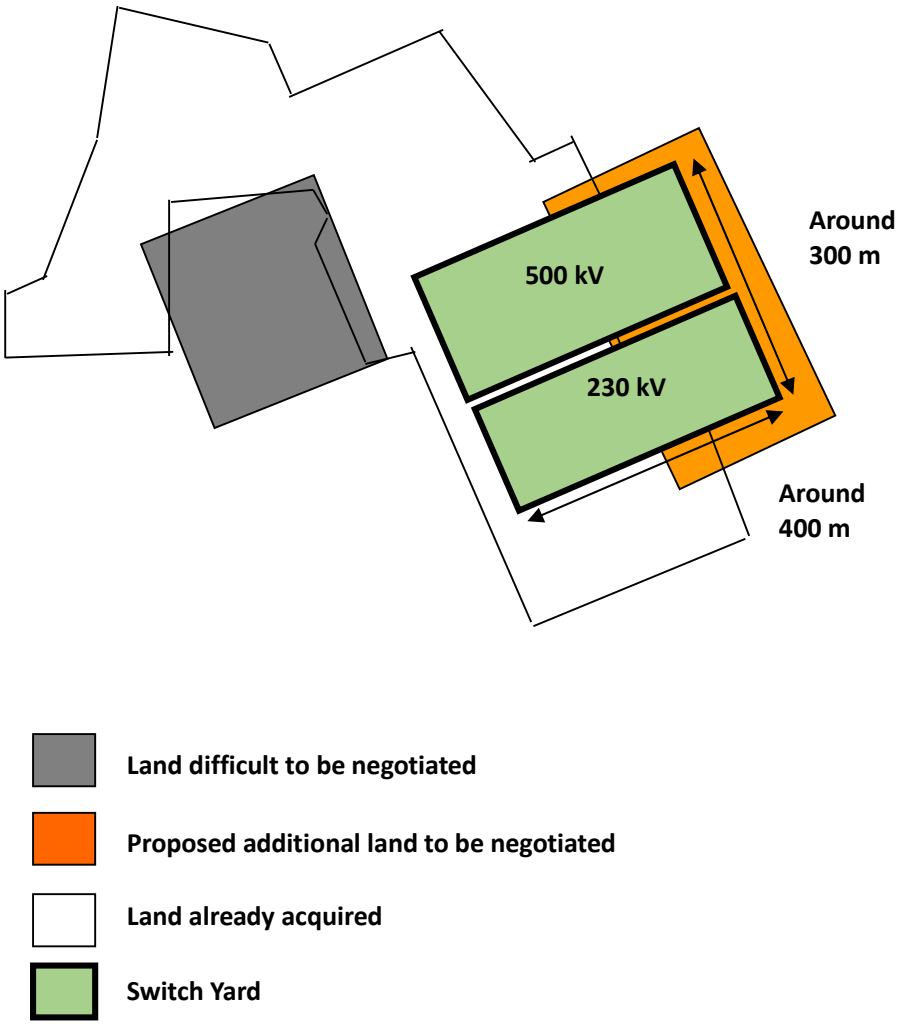


Figure 2 Land of Hlaingtaryar

B. Confirmation of the Latest Plans of Power Generation, Transmission Lines and Substation

(1) Power Demand Forecast and Power Generation Plan

The maximum electric power demand during the peak demand period of time (from March to May) in 2015 was forecasted as 1,500 MW for Yangon and 2,500 MW for the system of the whole country. From 2015, the yearly growing ratio of the maximum power demand is expected over 15%. DEP expressed an opinion that the latest demand forecast was the result of its study of the JICA Master Plan. The total generation capacity of Yangon city is currently 370 MW and expected to become 800 MW at the end of 2015.

(2) Plan of 230 kV Transmission Lines and Substations in Yangon

MEPE planned 230 kV transmission lines and substations in Yangon as shown in the following table.

Table 1 Project Plan for Yangon Division

No.	Name of Projects	Expected Fund
1.	230kV Ahlone-Thidar Transmission Line & Substation	China Exim Bank
2.	230 kV Tharkata-Kytekasan Transmission Line & Substation	ADB
3.	230 kV Tharkata -Thidar Transmission Line	
4.	230 kV Ahlone Dala Transmission Line & Substation	MEPE
5.	230 kV (Hlawga-Tharketa) In/Out Transmission Line & Sorth Oakkalar Substation	MEPE
6.	230 kV (Hlawga-Tharketa) In/Out Transmission Line & North Oakkalar Substation	MEPE
7.	230/66/11 kV, (2x125)MVA Bayintnaung Substation Extension	Deferred
8.	66 kV East Dagon- Shwe Pauk Kan Transmission Line	Deferred
9.	66 kV East Dagon-Wai Bar Gee Transmission Line	Deferred
10.	66 kV East Shwe Pauk Kan- North Oakkalar Transmission Line	Deferred
11.	66 kV East Dagon-Kon Padathar Transmission Line	Deferred
12.	66 kV East Dagon-East Dagon (1)(2) Transmission Line	Deferred
13.	66/33 kV, (30)MVA & 66/11 kV, (2x25)MVA Shwe Pauk Kan Substation	Deferred
14.	66/11 kV, (2x25)MVA North Oakkalar Substation	Deferred
15.	66/11 kV, (2x25)MVA Wai Bar Gee Substation	Deferred

The comments raised for the abovementioned list was as follows.

- All the projects were under discussion in the similar situation as "National Power Transmission Network Development Project Phase 2". However, MEPE hoped to complete all the project within two years. That was expected to be completed by the end of 2018.
- The 230 kV Ahlone-Dala transmission line listed in the number 4 probably to be carried out using its own funds of MEPE because the length of this transmission line was very short.
- Bayintnaung substation listed in 7 was expected to be completed in 2017 because this project contained just the expansion of substation.
- The projects of "Deferred" were still opened to the tenders.

The following comments were raised for the Project that were not listed in Table 1.

- The completion year was uncertain of 500 kV Phayargyi – Dawei transmission line because it depended on the plan of the Dawei power station.
- Shweli 3 was scheduled to be completed in 2020. There was an enterprise company that expressed an interest in the installation of 500 kV transmission line from Shweli 3 to Methila and said that he might implemented.
- The survey of the transmission line from Mawlamyine to Dawei has been asked to China Exim Bank. Dawei would have large power demand forecast due to its SEZ.
- The expected completion date of the transmission line between Taungoo and Pharyargyi would be informed as much as possible because its completion date seemed to be important information for JICA Project.

(3) Transmission Lines connected to New 500 kV Substations of Phase 2 Project just after Their Completion

There were no changes from the results of the study in 2014 of the transmission line connection to new 500 kV substations of Phase 2 Project. The followings were scheduled.。

Table 2 The Number of Circuits of Transmission Lines Connected to New 500 kV Substations at Their Initial Operation

500 kV substation	Bus voltage	Connected Transmission Line	Number of Circuits	Number of circuits at bus bars
Pharyargyi	500kV	500 kV Transmission Line to Taungoo	2	6
		500 kV Transmission Line to Dawei	2	
		500 kV Transmission Line to Hlaingtayar	2	
	230 kV	Line in-out to 230 kV Tharyargone - Kamarnat	4	6
		230 kV Transmission Line to East Dagon	2	
Hlaingtayar	500kV	500 kV Transmission Line to Ngayotekaung	2	4
		500 kV Transmission Line to Pharyargyi	2	
	230 kV	Line in-out to 230 kV Hlaingtayar-Ywama	4	6
		Line in-out to Myauntagar-230 kV Hlaingtayar	2	

(4) Main Specifications of Phase 2

The mission team had discussions with Power Transmission Project Department of MEPE regarding the main specifications of Phase 2 Project (Attached as reference of questionnaire) based on the previous study in 2014.

No main specifications had been changed except for pollution level of Insulators.

- MEPE hoped to apply the heavy pollution level to the route around 4 to 5 km before reaching 500 kV Hlaingtayar substation. On the other hand, the light pollution level was recommended to be applied for the whole of the transmission line routes by JICA team side based on the site survey in the 2014 previous study and this study. The applied pollution levels should be discussed with MEPE during the detailed design stage.
- MEPE raised a comment that they hoped to know the O&M methodology for Oil Forced Cooling System to maintain its better insulation. (Some know-hows are considered such as Dessolved Gas Analysis and Reduce Oil Circulator Speed)

(5) Prioritized Projects of Transmission Lines and Substations Except for the System from 500 kV Taugoo − Hlaingtayar

MEPE identified the study of the plan of the transmission lines from the hydropower stations located in the north of Meiktila substation as the prioritized projects.

(6) Institutional Structure for O&M

Currently, there are fourteen Transmission Line Offices with 137 staffs per office on the average. One office maintains 700 – 800 km of lines by 30-40 persons. Safety trainings are

held by Administration Office.

C. Power Flow Analysis for the 500 kV System of Phase 2 and 230 kV System in around Yangon

(1) 500kV and 230kV System in around Yangon

Figure 3 shows the plan of the 500 kV and 230 kV power network system in around Yangon around 2020 after Phase 2 500 kV Project will be completed based on the information from MEPE.

The 230 kV system of Yangon will be divided into east and west, where eastern system will have Hlawga, East Dagon, Thaketa and Thanlyin and western system will have Hlaingtayar, Ywama, Bayintnaun and Ahlone. There will be no direct interconnection of 230 kV between them.

Two 500 MVA transformers of 500/230 kV will be installed in Phayargyi and Hlaingtayar respectively.

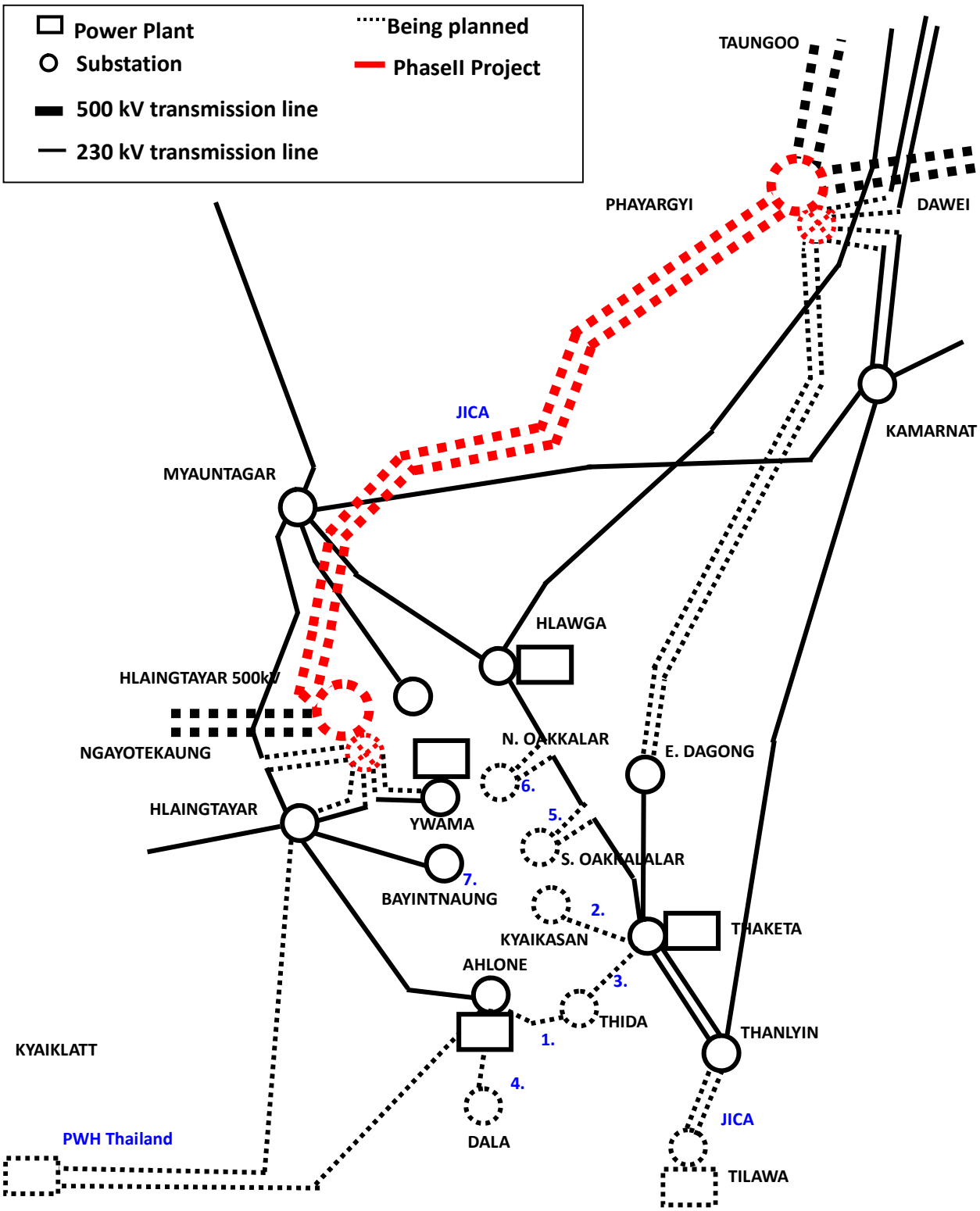


Figure 3 500 kV and 230 kV System in around Yangon around 2020

(2) Load Forecast for 230 kV Substati ons in Yangon in 2020

The maximum power demand of Yangon in 2020 was set out as 2,869 MW from the result of JICA Master Plan Study. The insufficient energy will be taken from the outside of this area at Myauntagar, Payargyi and Kamarnat substations and the amount of its required energy will be determined only by the power demand supply balance in Yangon. The power generation plan outside of Yangon was used as the plan obtained in the study in 2014. Loads of 230 kV substations in Yangon were set out as follows.

- There are two ways of power supply from 230 kV substations, one is by 66 kV and another is 33 kV. Thus, the amount of loads of 230 kV substations has to be divided into loads of 66 kV system and 33 kV system. The maximum power demand in 2014 was 917 MW in Yangon. Around 40% (372 MW) was allocated to 66 kV system and around 60% (545 MW) was allocated to 33 kV system based on the current power supply information.
- The growing ratio of the maximum power demand in Yangon was assumed 20% per year for the first 5 years and 10% for the next 5 years and the growing ration of the maximum power demand of 33 kV system was assumed only 4% because the loads of 33 kV system were planned to be gradually switched to 66 kV based on the information obtained from YESB last year. This maximum power demand can be depicted as shown in Figure 7 that lies at the middle point between the high case and the low case in 2020 estimated in JICA Master Plan. The high case maximum power demand of JICA Master Plan was applied as the maximum power demand of this study for 2020.

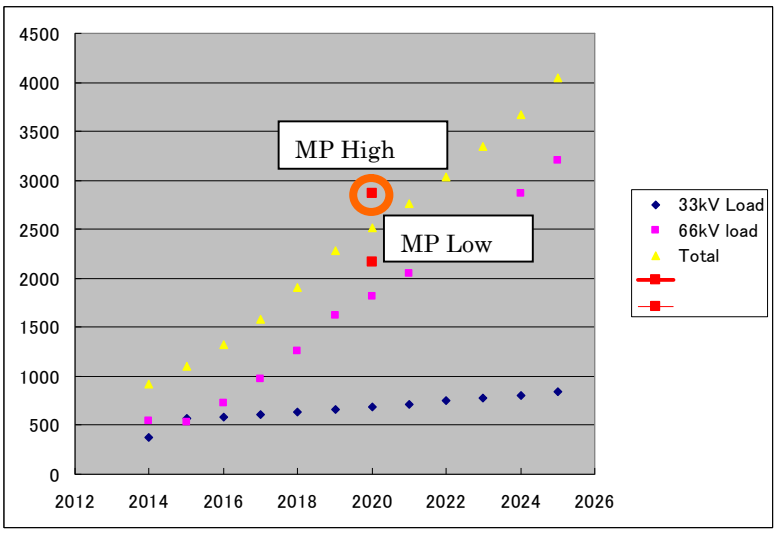


Figure 4 Maximum Power Demand Forecast in Yangon

- The ratio of the allocated load of 66 kV system was 72.5 % and 33kV system was 27.5%. Using those ratios, the maximum power demand of 66 kV system was calculated as around 2,081 MW and 33 kV was around 788 MW for 2020 based on the high case demand of JICA Master Plan, 2,869 MW in 2020.
- The capacities of the facilities of 230 kV substations in Yangon in 2020 were estimated as shown in the following table. The information about the expansion of Ahlone, Thakheta, Thanlyin and Iwama was obtained at the end of 2014. It was found out that the 66 kV system could have around 2,200 MW and the 33 kV system around 1,300 MW according to the following table assuming 90% as the power factor of transformers and 80% as the power supply ability ratio to the capacities of the transformers and generators.

Table 3 Capacities of Facilities at 230/66 kV Substations

230/66 kV Substation	66 kV Power Supply Facilities	Existing Capacities	Estimated Capacities After Expansion
Ahlone	66 kV Gen.	194 MW	
	230/66 kV Trans.	2 x 100 MVA	3 x 100 MVA
Bayintnaung	230/66 kV Trans.	100 MVA	2 x 125 MVA
Hlawga	230/66 kV Trans.	60 MVA	
Thakheta	66 kV Gen.	84 MW	
	230/66 kV Trans.	2 x 100 MVA	3 x 100 MVA
Iwama	66 kV Gen.	50 MW	
	230/66 kV Trans.	-	2 x 125 MVA
East Dagong	230/66 kV Trans.	-	2 x 125 MVA
South Okkalapa	230/66 kV Trans.	-	2 x 125 MVA
Kyaikkasan	230/66 kV Trans.	-	2 x 125 MVA
Thida	230/6 6kV Trans.	-	2 x 125 MVA
Tilawa	66 kV Gen.		50 MW
	230/66 kV Trans.	-	2 x 100 MVA

Table 4 Capacities of Facilities at 230/33 kV Substations

230/33 kV Substation	33 kV Power Supply Facilities	Existing Capacities	Estimated Capacities After Expansion
Ahlone	66/33 kV Trans.	60 MVA	
	33 kV Gen.	100 MVA	
Hlaingtharyar	230/33 kV Trans.	2 x 100 MVA	
Hlawga	230/33 kV Trans.	3 x 100MVA	
	33 kV Gen.	210 MVA	
Thanlyin	230/33 kV Trans.	100 MVA	2 x 100 MVA
Wartayar	230/33 kV Trans.	100 MVA	
Thakheta	230/33 kV Trans.	100 MVA	
	33 kV Gen.	50 MVA	
Iwama	33 kV Gen.	36 MVA	
West University	230/33 kV Trans.	2 x 100 MVA	

- The maximum load of around 2,081 MW for 66 kV system and the maximum load of around 788 MW for 33 kV system were assumed to be supplied from 230 kV substations in proportion to their power supply capacities. The estimated loads of 230 kV substations were listed as Table 4.

Table 5 Maximum Power Demand Forecast for 230 kV Substations in 2020

66 kV	Load (MW)	33 kV	Load (MW)
Ahlone	391	Ahlone	84
Bayintnaung	189	Hlaingtharyar	99
Hlawga	45	Hlawga	263
Thakheta	298	Thanlyin	99
Iwama	231	Wartayar	49
East Dagong	189	Thakheta1	38
South Okkalapa	189	Thakheta2	38
Kyaikkasan	189	Iwama	20
Thida	189	West University	99
Tilawa	168	Total	788
Total	2,081		

(3) The Result of Power Flow Calculation of the 500 kV and 230 kV System in around Yangon around 2020 (Base Case)

Figure 5 shows the result of power flow calculation for the base case of 500 kV and 230 kV system in around Yangon around 2020 with modeling the original plan by MEPE.

The power flows in the interval of 230 kV transmission lines such as Myauntagar –Hlawga and Hlaingtayar-Ahlone - Thida - Thakheta largely exceed their capacities causing overloaded situations. Thus, some countermeasures will be required.

The following two types of conductors are mainly used for 230 kV transmission lines in Myanmar.

- Twin bundle conductors of 605 MCM, its capacity is 288 MVA/cct
- Single conductor of 795 MCM and its capacity is 164 MVA/cct

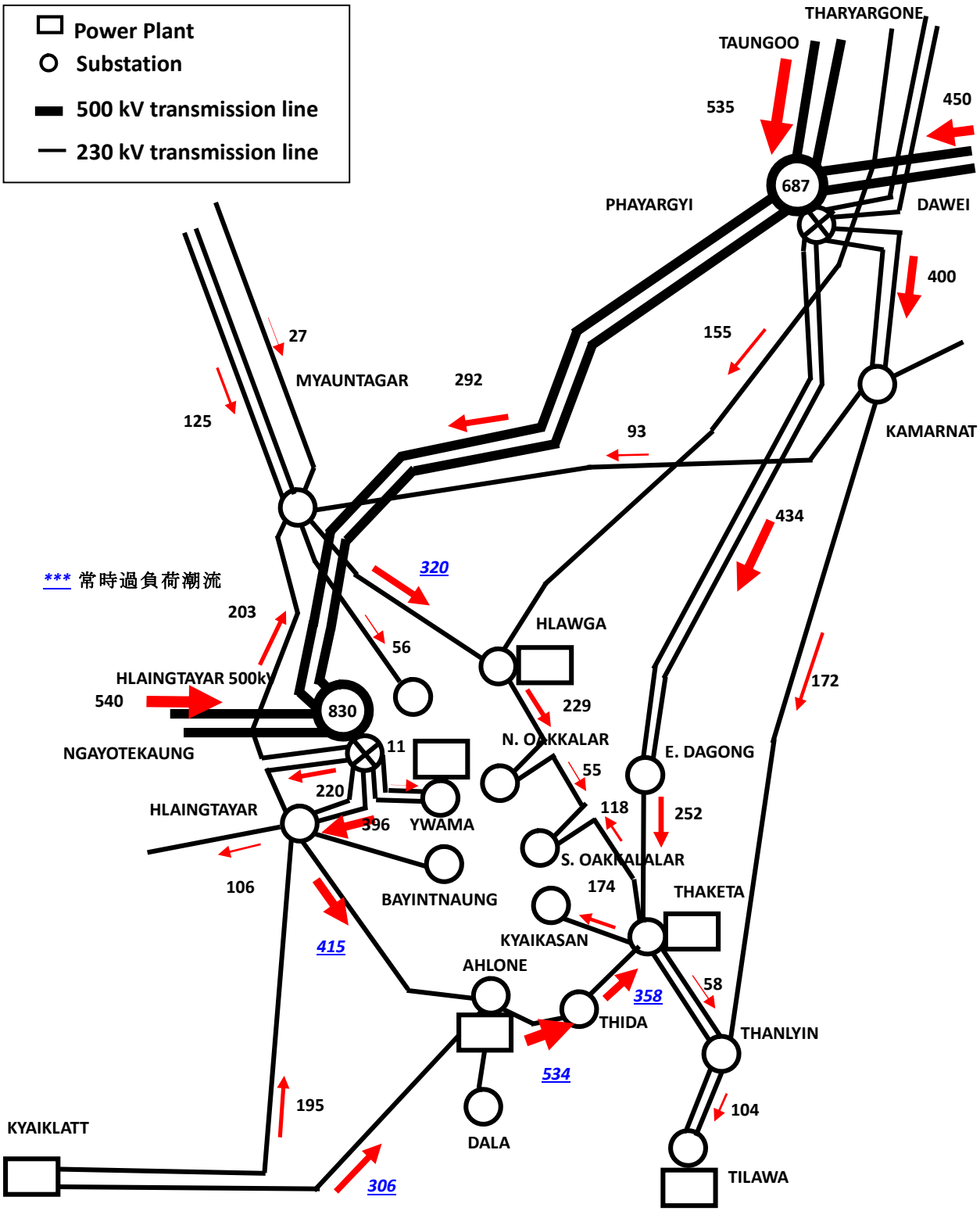
The single of 795 MCM is used for Tharyargone - Hlawga that has a smaller capacity and the twin bundles of 605 MCM is mainly used for other interval.

The power generators in around Yangon area were set out as shown in Table 5. The numerical values of power outputs from Thaketa, Ahlone, Ywama and Hlawga were used that were also used in the previous study.

Table 5 Power Outputs of Generators in around Yangon Area in Base Case

Power Stations	In service	Out of service
Tilawa	50 MW	0 MW
Thakheta	92.2 MW	0 MW
Ahlone	278.4 MW	0 MW
Ywama	223.5 MW	0 MW
Hlawga	104.7 MW	51.1 MW
TWH Thailand	500 MW	0 MW
Ngayotekaung	540 MW	0 MW
Dawei	450 MW	0 MW

This case can be considered as the case with large power outputs of generators in around Yangon area.



Blue colored figures indicates over loaded power flow (MW)
Myauntagar – Hlaingtayar, Myauntagar –Hlawga, Hlawga- N. OAKKALAR, Phayargyi – East Dagon etc. Over Loaded

Figure 5 Power Flow of Base Case in 2020

(4) Option of 230 kV Interconnection between East and West in Yangon around 2020

An option of the installation of the 230 kV transmission lines connecting the east and west in Yangon (they may be installed with underground cables due to their locations in a city area) is studied as a countermeasure against overloaded situations in Base Case.

The result of the calculation is shown in the following figure. Blue colored lines indicate newly installed transmission lines. There are no overloaded 230 kV transmission lines in normal operation. This option assumes the installation of a single circuit between 230 kV Hlaingtayar and Bayintnaung and double circuits between Ywama and South Okkalar.

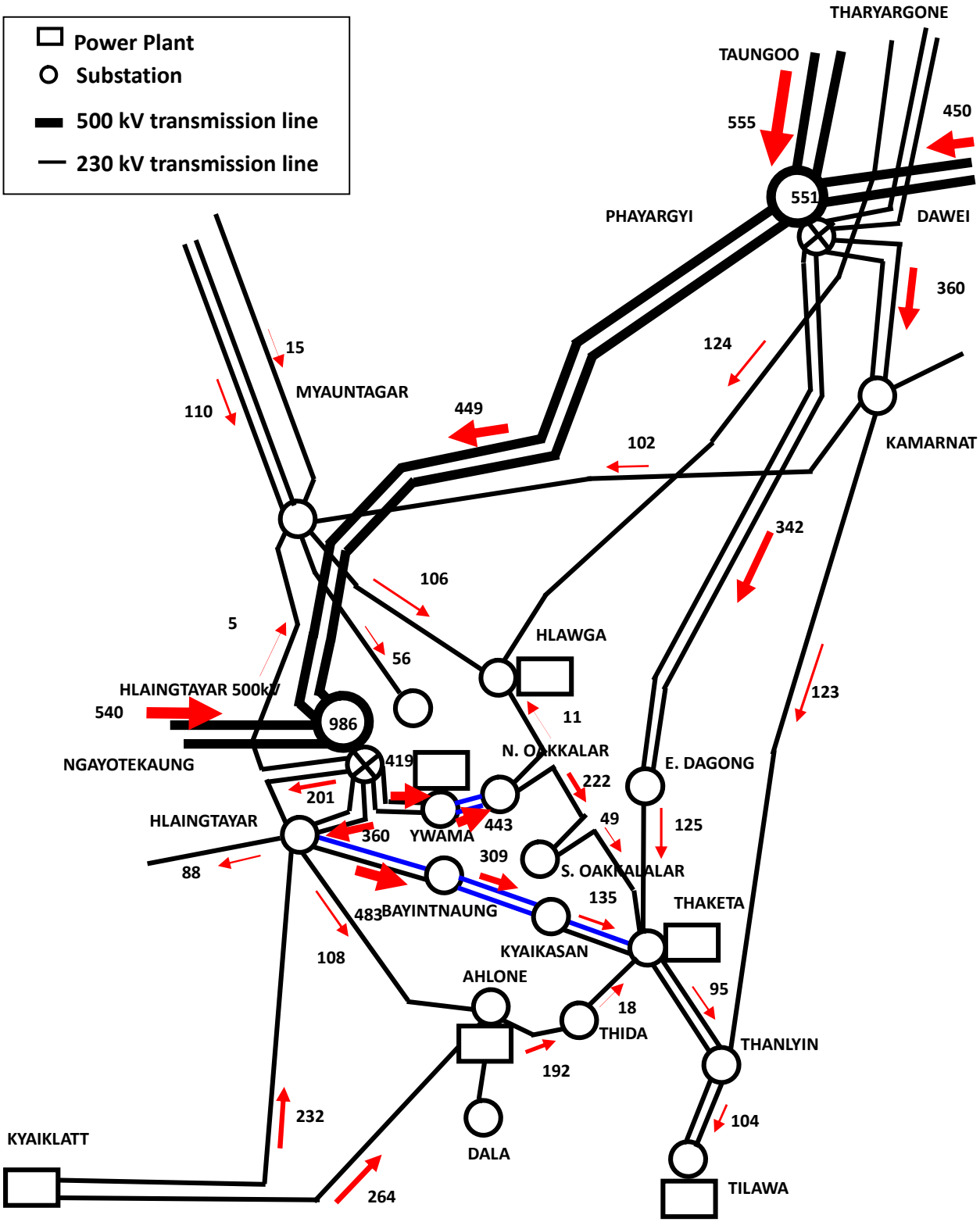


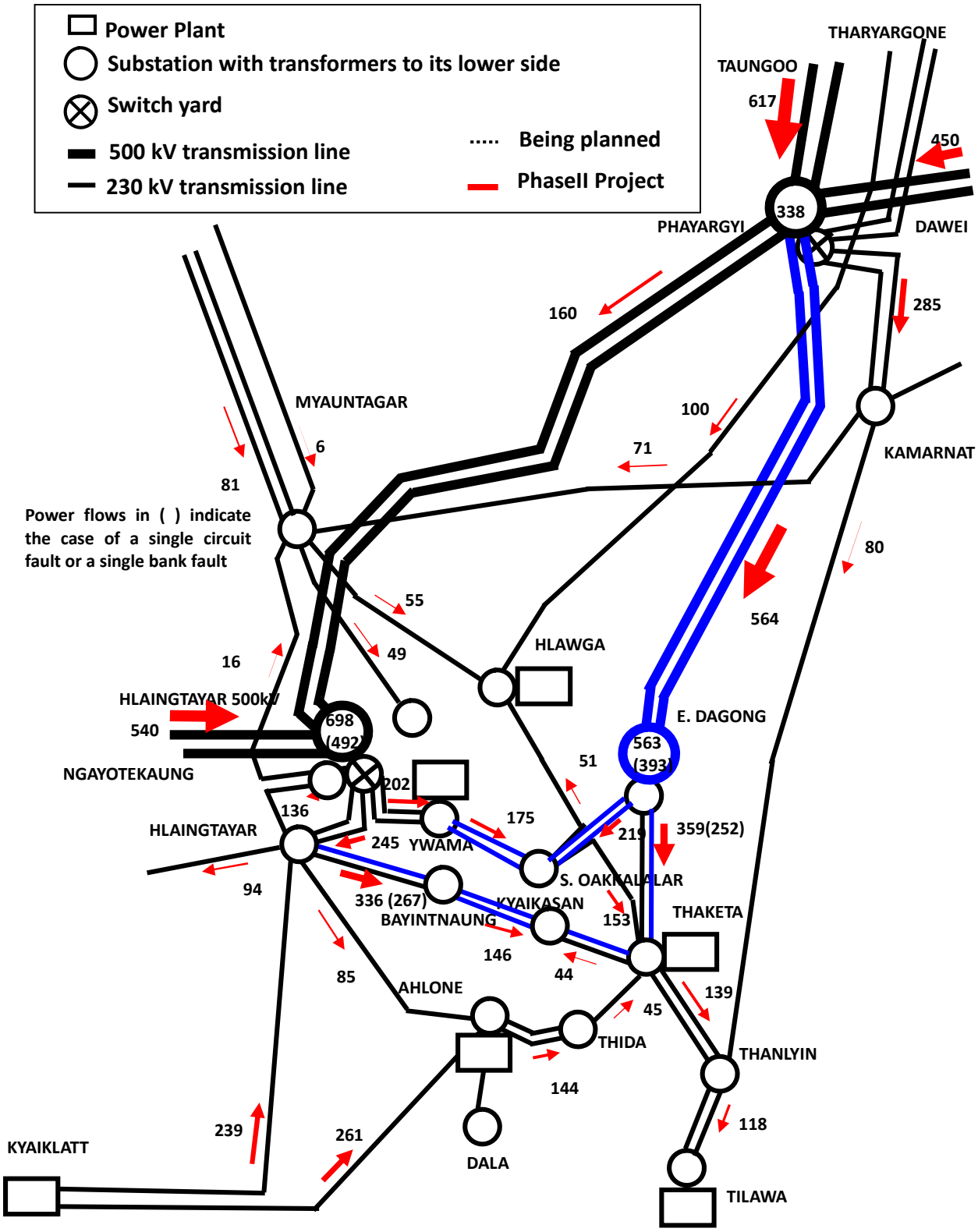
Figure 6 Power Flow in the 230 kV System with East-West Interconnection

(5) Option of the Future System Configuration of Fulfilling N-1 Criteria

The options of the installation of the 230 kV Interconnection between east and west does not caused overloaded situations in normal operation; however, the overloads are caused by dropping a single circuit of 230 kV or a 500 kV transformer.

An option of the installation of both the 230 kV Interconnection between east and west in Yangon and the eastern 500 kV substation around Yangon does not cause overloaded situations even when a 230 kV single circuit is dropped. The loads of 500 kV transformers can be within 120 % of their capacity even when one of their banks is dropped in this option.

Those cases are the cases with large power outputs of generation in around Yangon. The severe cases should be studied such as the cases with lower power outputs of generators in Yangon.



( ): power flow in case of dropping a single circuit fault or a transformer

Figure 7 Power Flow in the Future System Fulfilling N-1 Criteria

(6) Cases without Phase 2 Project

The power flow was calculated in case of not implementing Phase 2 Project for the case with the 230 kV east – west interconnections (the case of relatively large power outputs of generators in around Yangon). Ngayotekaung and Dawei thermal power stations were assumed to be still connected to 500 kV transmission lines because they were independent from Phase 2 Project.

This case assumed that Phase 1 and the transmission line from Meikhtila to Pharyargyi through Taungoo were implemented.

From the result of the power flow analysis, the power flows at Tharyargone - Hlawga and East Dagone-Thaketa exceeded the capacities of their lines apart from Hlaingtayar - Ahlon and Kyaiklat-Ahlon if Phase 2 was not implemented.

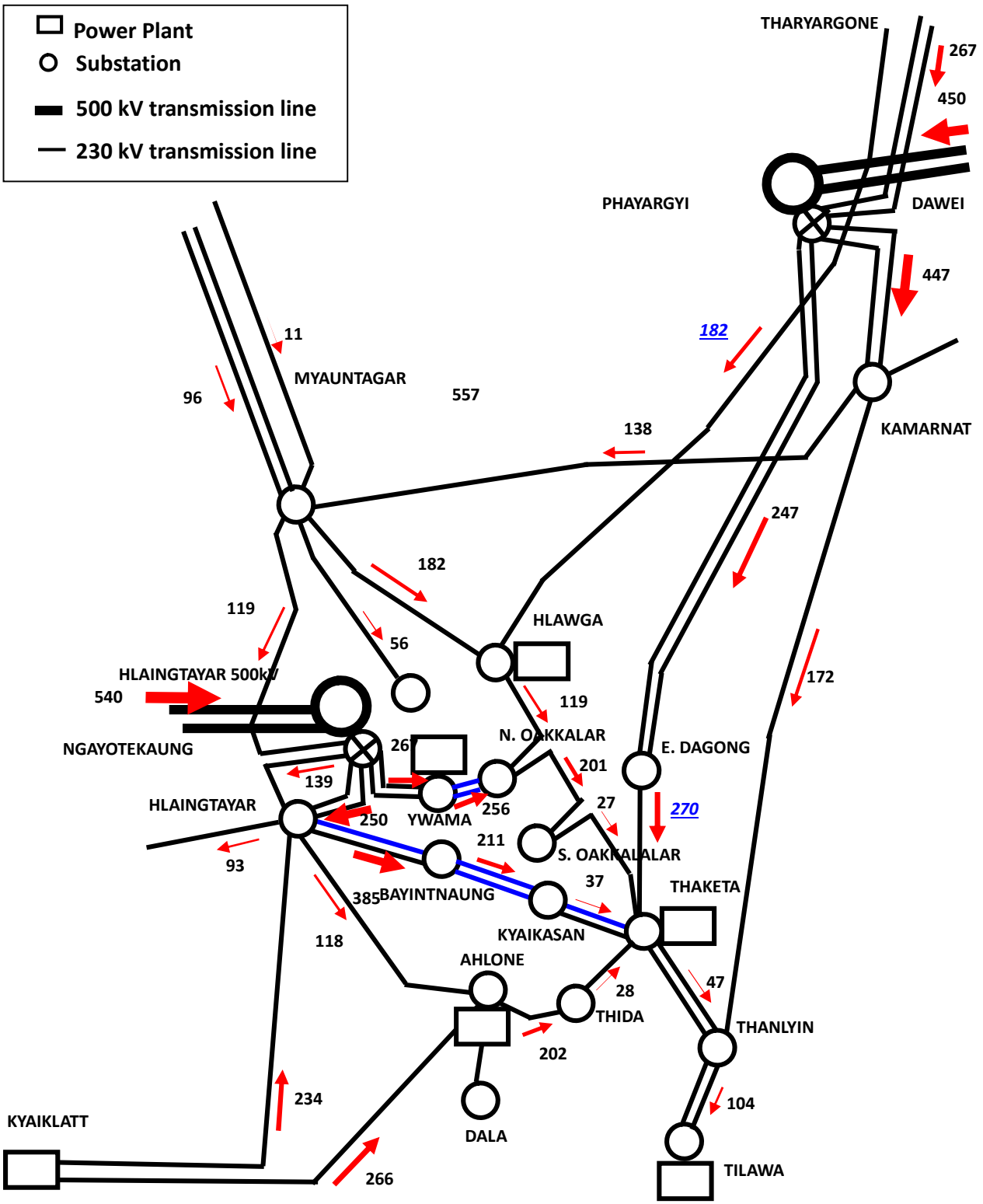


Figure 8 Power Flow in Case of Not Implementing Phase 2 Project for B the case with the 230 kV east – west interconnections in 2020

(7) Power Flow in Case of Lower Power Outputs from Thermal Power Stations in 2020 (Power output from Ngayotekaug in the west is zero)

The power flow would be increased from the northern area where a lot of hydropower stations will be located to Yangon in case of the lower power outputs from the thermal power stations in Yangon. The power flow was calculated for the both cases with and without Phase 2 setting out no power outputs from Ngayotekaug power station located in the west of Yangon. The power outputs were set out as follows.

Table 6 Power Outputs of Generators in around Yagon in Case of Lower Power Outputs from Thermal Power Stations in 2020 (Power output from Ngayotekaug in the west is zero)

Power Station	Power Outputs	Stopped Power Outputs
Tilawa	50 MW	0 MW
Thakheta	92.2 MW	0 MW
Ahlone	278.4 MW	0 MW
Ywama	223.5 MW	0 MW
Hlawga	104.7 MW	51.1 MW
TWH Thailand	500 MW	0 MW
Ngayotekaung	0 MW	540 MW
Dawei	450 MW	0 MW

Figure 10 shows the power flow with Phase 2 in this generation pattern.

In the similar manner to the base case, the power flows between Hlaingtayar - Ahlon and Kyaiklat – Ahlon exceed their capacity of transmission lines. There are some intervals of 230 kV transmission lines that have the over loading power flow in case of a fault of a circuit around Hlawga, East Dagon and Ahlone.

Without Phase 2, the power flow calculation was not converged. This means that the power transmission is not possible at the maximum power demand without Phase 2. Its calculation was converged when the maximum power demand was decreased.The power flow became not to exceed the capacities of the transmission lines when the power demand of Yangon was decreased by around 28%. The Figure 11 shows the results of the power flow calculation for this case.

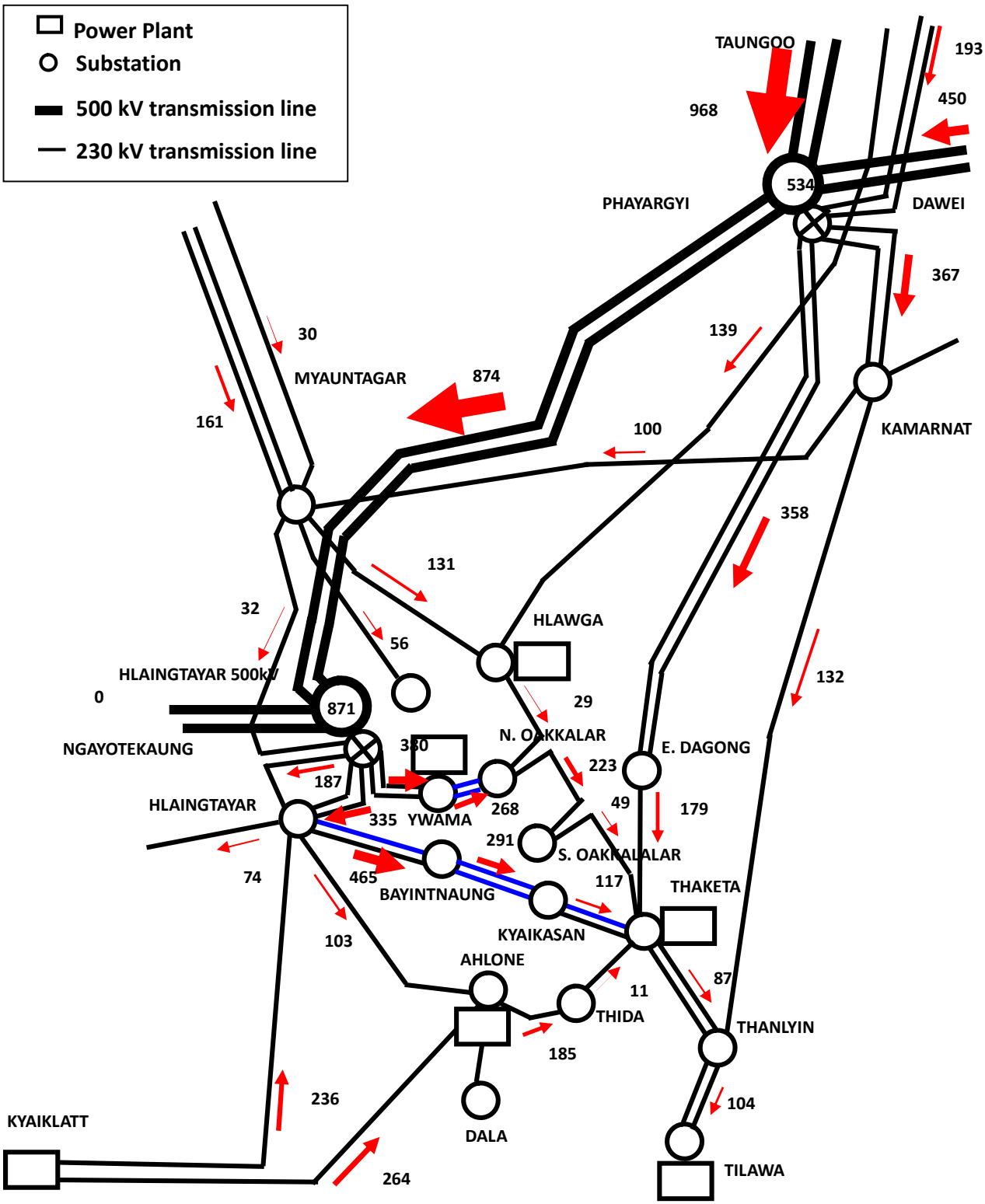


Figure 9 Case of Lower Power Outputs from Thermal Power Stations in 2020 (Power output from Ngayotekaug in the west is zero)

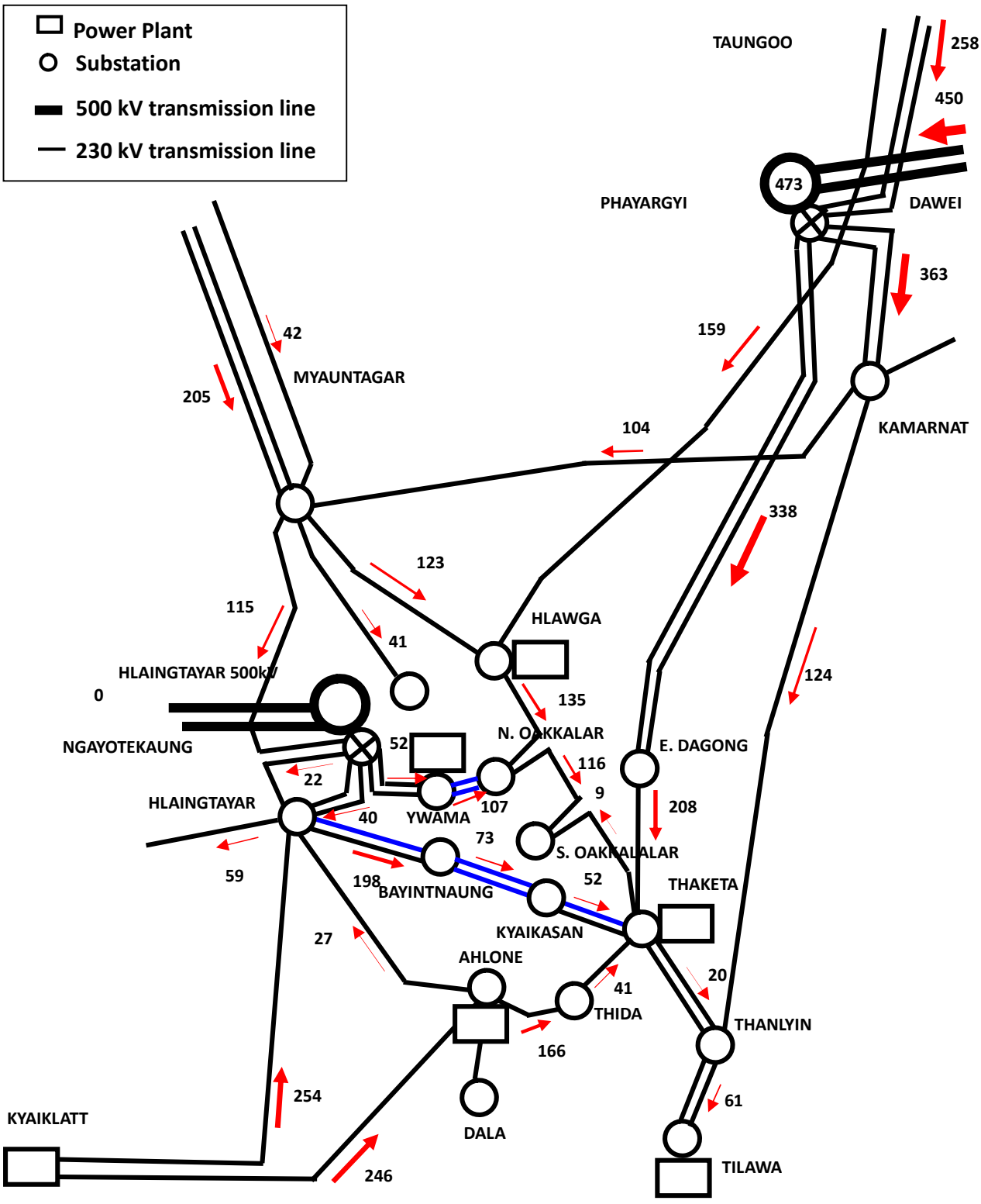


Figure 10 Case of Lower Power Outputs from Thermal Power Stations in 2020 (Power output from Ngayotekaug in the west is zero) without Phase 2 Decreasing Power Demand of Yangon by 28%

(8) The Future 500 kV and 230 kV System Configuration in Yangon

When the maximum power demand of Yangon will reach 4,000 MW from 2,869 MW that is the maximum power demand of Yangon in 2020, it is considered that more four substation at least will be required even in consideration with the expansion of the existing substations. The installation of the east-west interconnections and the east 500 kV substation are both considered as the effective countermeasures against overloaded conditions. An option of the future 500 kV and 230 kV system in Yangon is shown in the following figure.

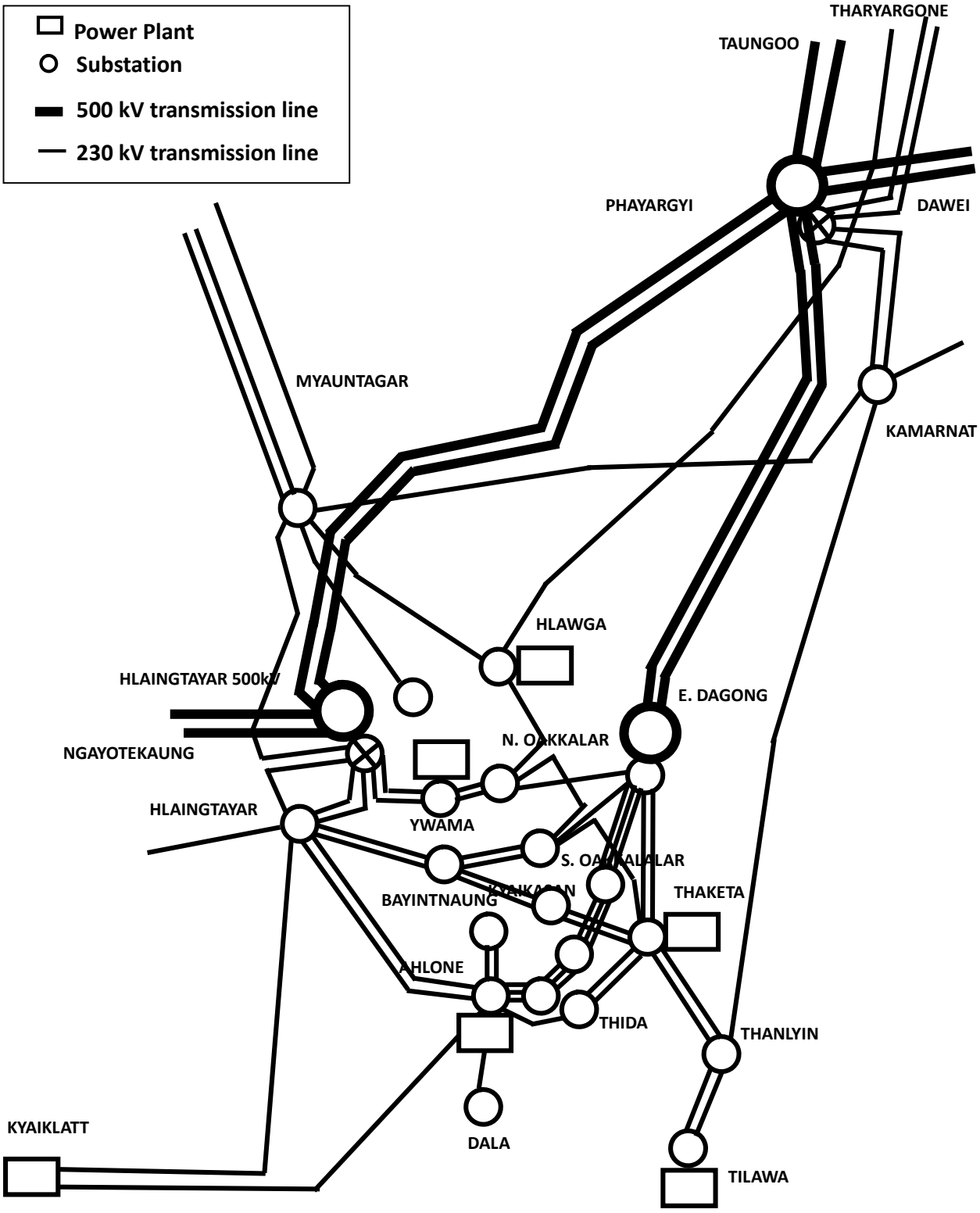


Figure 11 Option of the Future 500 kV and 230 kV System in Yangon

(9) Recommendations for Future Power System Configuration

The followings can be raised as the candidates of recommendations for future power system configuration.

- Implementation of 500 kV and 230 kV transmission lines and substations planned by MEPE including Phase 2 Project on schedule
- Installation of 230 kV transmission lines connecting the east and the west in Yangon through Ywama-S.Oakkalar and Bayintnaung-Kyaikasan and doubling circuits of Hlaigntayar-Bayintnaung and Thaketa-Kyaikasan up to around 2020. It will contribute to secure the power supply to the substations planed by MEPE responding to the rapid growing of power flow from the west to the east in Yangon.
- Installation of the new 500 kV substation in the eastern part of Yangon in around East Dagon to supply power from the east. In order to prepare this, the transmission line from Pharyargi to East Dagon is considered to be constructed as 500 kV design lines.

Abovementioned recommendations would be required even for the situations where power outputs from generators in around Yangon are relatively large. However, the detailed studies will be required including the fault current analysis regarding the bulk power system in Yangon because the system power flow can be changed in accordance with the power generation plans and their operation.

- In future, some 230 kV substations will be required apart from the current plan. Those substations will be connected to east and west in Yangon respectively.

<Appendix 1>

Questionnaire for the Counterparts during the First Site Survey

Questionnaire (Power System Plan)

JICA 500 kV Phase 2

2015/01/19

M. YOGO, TEPCO

JICA Mission

Purpose of this Study

To carry out the supplementary survey to prepare the JICA appraisal mission of 500 kV Phase II Project by examining and recommending the adequate system plan through reviews of the latest information.

Questionnaire (Power System Plan)

1. The latest nationwide power demand forecast (Maximum power as MW) (also the latest power demand forecast in Yangon)
2. The latest power generation plan and its on-going projects including their expected donors (also the latest power generation plan in around Yangon)
3. The latest bulk power transmission line/substation plan and its on-going projects including their expected donors (also the latest 230 kV power transmission line/substation plan in around Yangon))
4. The prioritized projects except for 500 kV Phase II
5. Current situations and their main specifications of 500 kV Phase II
6. Any significant changes in the route of 500 kV Hpharyargyi - Hlainghtaryar transmission line from the Previous Study?
7. Are there any significant changes in the location of 500 kV Hpharyargyi and Hlainghtaryar substations from the Previous Study?
8. Are there any significant changes in the main specifications of 500 kV transmission line from the Previous Study?
9. Are there any significant changes in the main specifications of 500 kV Hpharyargyi and Hlainghtaryar substations from the Previous Study?
10. Expected institutional arrangement for O&M
11. Current progress and main specifications of Meikhtila-Taungoo –Pharyargyi 500 kV transmission lines

- JICA 500 kV Phase II Project means “500 kV Phatyargyi and Hleigntayar substation and their connecting 500 kV transmission line”.
- Previous Study means “JICA Expert for Strengthening of Implementation Capacity for Transmission Line and Substation, 2014”.

<Reference>

Main Specifications of the Phase II Project

500 kV Hpharyargyi - Hlainghtaryar transmission line

- Conductor: Drake four (4) bundles
- Pollution level "Light"
- Insulators made in Japan
- Clearances are same as 500 kV Meikhtila – Taungoo Transmission line

500 kV Hpharyargyi substation and 500 kV Hlainghtaryar substation

- Number of Feeders, Transformers and Reactors

	Hpayargyi	Hlaingtharyar
Number of 500 kV Line feeders	6 Taungoo: 2, Hlaingtharyar: 2, Dawei: 2 (Final 8)	4 Hpayargyi: 2, West Yangon: 2 (Final 8)
Number of 230 kV Line feeders	6 Tharyargone: 2, Kamarnat: 2, Dagon East: 2 (Final 12)	6 Myaungtagar: 1, Ywama: 2, Hlaingtharyar: 3 (Final 12)
Number of 500/230/11 kV Transformer banks	2 (Final 4)	2 (Final 4)
Reserved transformer (Single Phase)	1	1
Reactor (100 MVA)	2 (Final 4)	2 (Final 4)

- Specifications of the 500/230/11 kV Transformers

Type	Outdoor type single phase Auto transformer
Capacity	500/3MVA/500/3MVA/75/3MVA
Shipping Mass	Less than 60t (Actual limit weight should be studied in the Detailed Design stage, Site-assembly type would be recommended.)
%Impedance	12.5% (P-S)
Tap	±50 kV 21 tap
Cooling system	OFAF (Oil Forced Air Forced)

- Specification of the 500 kV Reactor

Type	Outdoor type single phase
Capacity	100/3MVA
Cooling system	ONAN (Oil Natural Air Natural)
Shipping Mass	Less than 60t(Actual limit weight should be studied in the Detailed Design stage)
Connected	Bus bar

- Telecommunication

Media	Object	Notes
OPGW	PCM current differential relay for transmission line protection	
	SCADA for National Control Center	
	High speed communication line in MEPE	For Intranet, VoIP
PLC	SCADA for National Control Center	For Backup
	Internal telephone line in MEPE	

- Circuit Breaker

500 kV H-GIS50 kA	50 kA
220 kV Gas Circuit Breaker	40 kA

- Protection relay system

500 kV Line	Main	Digital PCM current differential relay with high speed multi-phase re-closing relay system
	Back-up	Distance Relay (2-4 stage)
230 kV line	Main	Digital PCM current differential relay with high speed re-closing relay system
	Back-up	Distance Relay (2-4 stage)
500 kV and 230 kV bus		Current differential relay
Transformer	Main	Ratio Differential Relay, OCR, OCGR (Neutral Protection)
	Back-up	Distance Relay (2-4 stage)
500 kV Reactor		Ratio Differential Relay, OCR, OCGR (Neutral Protection)

- The selection of seismic design standards applied to the 500 kV transmission system in Myanmar should be discussed in the detailed design stage.
- SCS (Substation Control System) of each substation will be connected to the National Control Center (NCC) for the supervision and monitoring done by

The Second Site Investigation Report

1. Name of Experts, Belonging Organization and His Duty

Masaharu Yogo, TEPCO, Power System Planner

2. Name of the Project

National Power Transmission Network Development Project in Myanmar

3. Purpose of this Investigation

Myanmar government cited the development of 500 kV transmission lines and substations as a matter of priority and issued a request of their development by utilizing yen loan. According to the request, the Japanese Government informed Myanmar government of a new yen loan project as the donor policy on March 24, 2014 targeting "National Power Transmission Network Development Project Phase 1" in Myanmar. Furthermore, following the Phase 1, the rapid development of Phase 2 are also needed. In this survey, engaged member will carry out the supplementary investigation in cooperation with his counterpart, the Myanmar Electric Power Enterprise, in order to examine and recommend the appropriate power system plan for preparation of yean loan project by collecting and organizing the relevant information based on the current plans and implementation of the transmission lines and substation projects by Myanmar Government, power generation plans utilizing IPP and the support planning and implementation status of other donors.

4. Methodology

The latest information regarding Myanmar's power system network plan was collected and reviewed. The necessary investigations were carried out for contributing to prepare the appraisal as yen loan projects relevant to the power network system plans in Myanmar in cooperation with the environmental expert and JICA staff (F/F mission and appraisal mission).

5. Duration of the Project Survey

From January 16th 2015 to May 29th 2015 (scheduled)

The first site investigation was from January 18th to 28th 2015.

The second site investigation was from March 16th to 21st 2015

6. Contents of the Second Site Survey

The cost of the transmission lines was discussed with MEPE Engineer and the expert explained the draft plan of power network system plan. The confirmed information is described as follows.

7. Power System Plan

The team explained the 230 kV system plan in Yangon by using the attached material (Power System Analysis for 230 kV System in Yangon) to MEPE Executive Engineer on 2015/3/18. He mentioned that the plan would be explained to DM and MEPE.

(1) The Revision of the List of the Plan of 230 kV System in Yangon

MEPE revised the list of the plan of 230 kV system in Yangon that was obtained during the first site investigation.

- 230 kV (Hlawga-Tharketa) In/Out Transmission Line & North Oakkalar Substation was canceled.
- Projects of 66 kV were deleted from the list and only the 230 kV projects were described.

(2) Reviewing ADB's Report (by Fichtner)

The ADB's report "ADB - TA 8342 MYA Preparing the Power Transmission and Distribution Improvement Project" (Fichtner, Feb.2015) has been reviewed unofficially by the mission team (not through MEPE).

The demand forecast of ADB's Report was a little bit lower than that of JICA Master Plan as follows.

- The maximum demand for the whole system in ADB's Report
  Year 2020: 3,728 MW, Year 2030：7,498 MW

- The maximum demand for the whole system in JICA Master Plan
  Year 2020: High Case 4,531 MW, Low Case 3,862 MW
  Year 2030: High Case 14,542 MW, Low Case 9,100 MW

The following projects in around Yangon were recommended in the ADB's report.
Thida - Thaketa TL、Thaketa SS (extension)、Thaketa - Kyaikasan、Kyaikasan SS (new)、South Oakkalarpa SS (new)、West University SS (new)

The 230/33kV West University Substation, that is listed above, was not informed in Table 1. However, this substation would have an effect on the Phase 2 Project because the ADB report described this substation was to be installed at the same location of 500 kV Hlaingtayar substation of Phase 2. JICA mission team had a discussion with MEPE regarding this substation.

(3) 230/33kV West University Substation

MEPE informed that The 230/33 kV West University Substation was planned to be

installed at the same land as the candidate site of the 500 kV Hlaingtayar Substation and the bus bars of 230/33 kV West University Substation would be expanded and connected to the 500 kV Hlaingtyar substation. Its implementation schedule was not yet decided.

(4) 230 kV Transmission Lines connected to 500 kV Pharyargyi and Hlaingtayar Substations of Phase 2 Project just after Their Completion

Current status of the progress of 230 kV transmission line connection to 500 kV substations were collected.

- 500 kV Phatryargyi Substation

In 2019, the 500 kV Pharyargyi substation will be connected to the newly constructed 230 kV transmission line between Tharyargone - Kamarnat where 500 kV Pharyargyi substation is located in the middle of the line. The transmission line between Pharyargyi and East Dagon was not yet decided, however, it would take normally only three years from its plan to its operation in MEPE.

- 500 kV Hlaingtyar Substation

As mentioned later, 230/33 kV West University substation will be constructed in the same location as 500 kV Hlaingtayar Substation by ADB. 230/33 kV West University substation will collect the existing transmission line from Mayungtagar - 230 kV Hleingtayar. 500 kV Hlaingtayar Substation will be installed as the expanded substation of 230/33 kV West University.

(5) The Connection of 500 kV Hlaingtayar Substation to 230/33kV West University Substation

Points to note regarding the connection of the 230/33 kV West University Substation and the 500 kV Hlaingtayar Substation are as follows.

(The design of both projects should be coordinated regarding the methodology of the expansion of 230/33 kV West University Substation to 500 kV Hlaingtayar substation at the detailed design stage.)

- The layout of the facilities of the foregoing ADB 230 kV West Univrsity substation should be necessarily incorporated with the future layout of Phase 2 500 kV Hlaingtayar Substation.
- It is necessary to study the treatment of the protection relays and supervisory control system of the foregoing ADB 230 k West University Substation when Phase 2 500 kV Hlaingtayar substation will be installed. Generally, it is not enough for connection of bus bars not only by the connection of bus bars itself. It also requires for changing the connection of the information-telecommunication system utilized for supervisory control system in the substation. (such as the selection of the locations of control rooms for both

old and new substations or the selection of the protection scheme against bus fault)

In case of difficulties, an option can be considered that connects new and old buses by installation of the circuit breakers between them to ensure their independent operation as shown in the following figure.

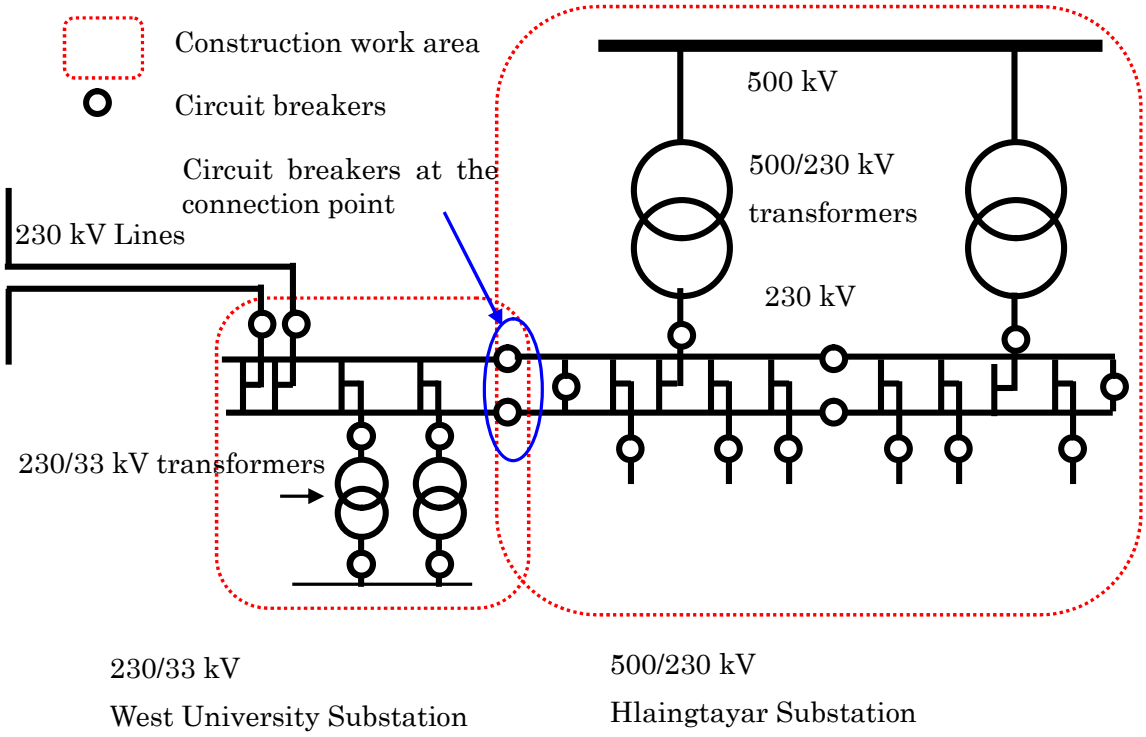


Figure 1 Covering areas of 230/33 kV West University Substation and 500/230 kV Hlaingtayar Substation

(6) Revision of the List of the Projects of 230 kV System in Yangon

The list of the projects of 230 kV system in Yangon was revised based on the information obtained during the second site investigation mentioned above.

Table 1 Project Plan for Yangon Division

No.	Name of Projects	Expected Fund
1.	230kV Ahlone-Thidar Transmission Line & Substation	China Exim Bank
2.	230 kV Tharkata-Kyaikasan Transmission Line & Substation	ADB
3.	230 kV Tharkata -Thidar Transmission Line	ADB
4.	230 kV Ahlone Dala Transmission Line & Substation	MEPE
5.	230 kV (Hlawga-Tharketa) In/Out Transmission Line & South Oakkalar Substation	MEPE
6.	230/66/11 kV, (2x125)MVA Bayintnaung Substation Extension	Deferred
7.	230/33 kV, (2x100)MVA West University Substation	Deferred

（The number of circuits between Ahlone - Thidar was assumed two and Thidar - Thaketa single in this study according to the ADB's Report "TA 8342 MYA Preparing the Power

Transmission and Distribution Improvement Project" by Fichtner".)

The following two types of conductors are mainly used for 230 kV transmission lines in Myanmar.

- Twin bundle conductors of 605 MCM, its capacity is 288 MVA/cct
- Single conductor of 795 MCM and its capacity is 164 MVA/cct

The single of 795 MCM is used for Tharyargone - Hlawga that has a smaller capacity and the twin bundles of 605 MCM is mainly used for other interval.

The ADB's Report that was mentioned in the previous section described the application of ACCC (Aluminum Conductor Composite Core) for the interval of Thida - Thaketa. This conductor can be used at high temperature with large capacity of 1,576 A (628 MVA) per circuit. Thus, only this interval was assumed to be equipped with this conductor.

(However, the ADB's report also mentioned that this conductor should not be applied for other intervals because it would produce huge losses when the power flow reached closed to its capacity.)

8. Power System Analysis

The power system analysis was carried out again based on the system described in the report of the first site investigation and revised based on the information obtained during the second site investigation.

(1) 500kV and 230kV System in around Yangon

Figure 3 shows the plan of 500 kV and 230 kV system in around Yangon around 2020 by MEME when the 500 kV system of Phase 2 will be completed based on the information from MEPE.

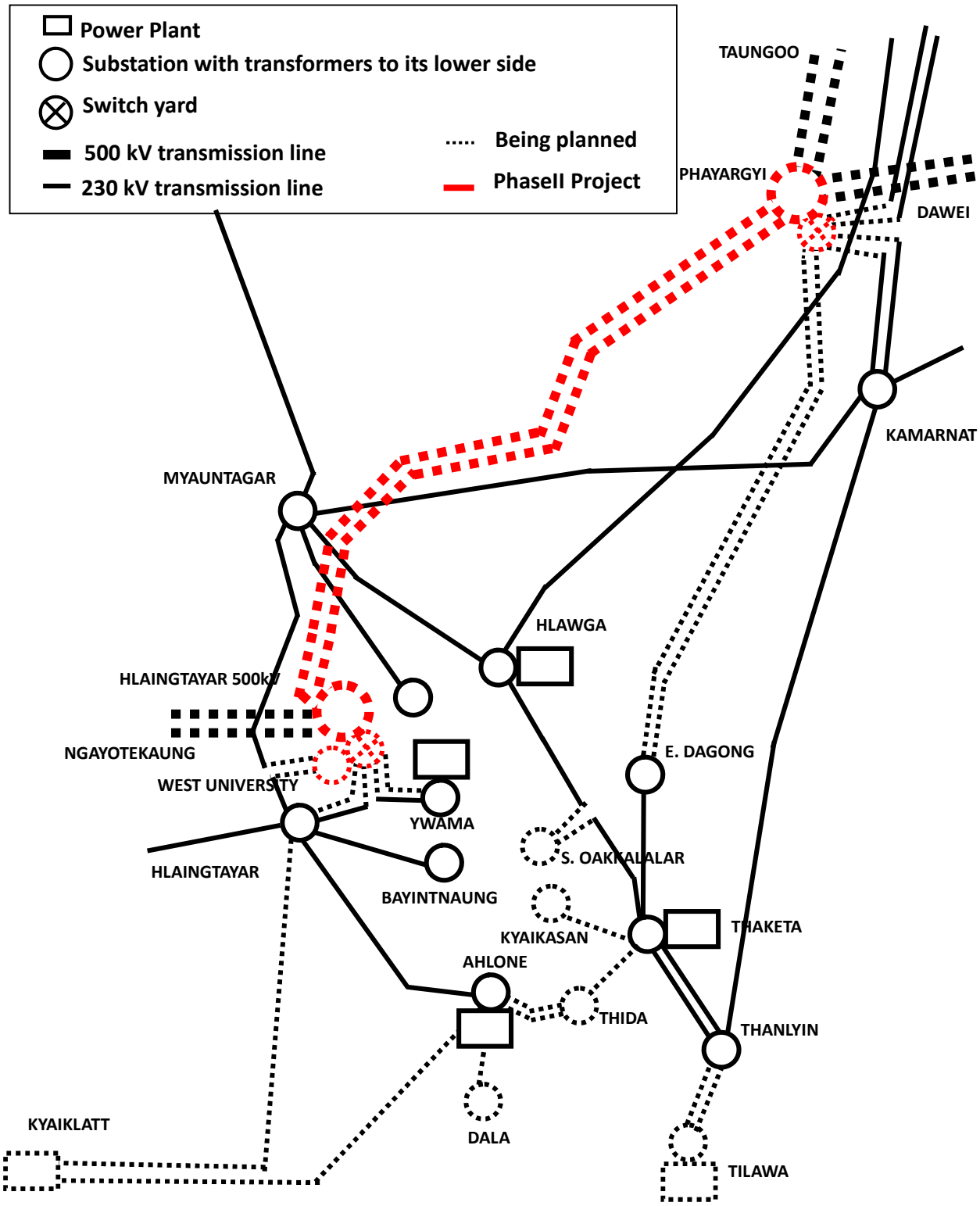


Figure 3 500 kV and 230 kV System in around Yangon around 2020

(2) Load Forecast for 230 kV Substations in Yangon in 2020

The maximum power demand of Yangon in 2020 was set out as 2,869 MW from the result

of JICA Master Plan Study.

The maximum power demand of 66 kV system was assumed as around 2,081 MW and 33 kV was around 788 MW for 2020.

The capacities of the facilities of 230 kV substations in Yangon in 2020 were estimated as shown in the following table.

Table 2 Capacities of Facilities at 230/66 kV Substations

230/66 kV Substation	66 kV Power Supply Facilities	Existing Capacities	Estimated Capacities After Expansion
Ahlone	66 kV Gen.	194 MW	
	230/66 kV Trans.	2 x 100 MVA	3 x 100 MVA
Bayintnaung	230/66 kV Trans.	100 MVA	2 x 125 MVA
Hlawga	230/66 kV Trans.	60 MVA	
Thakheta	66 kV Gen.	84 MW	
	230/66 kV Trans.	2 x 100 MVA	3 x 100 MVA
Iwama	66 kV Gen.	50 MW	
	230/66 kV Trans.	-	2 x 125 MVA
East Dagong	230/66 kV Trans.	-	2 x 125 MVA
South Okkalapa	230/66 kV Trans.	-	2 x 125 MVA
Kyaikkasan	230/66 kV Trans.	-	2 x 125 MVA
Thida	230/6 6kV Trans.	-	2 x 125 MVA
Tilawa	66 kV Gen.		50 MW
	230/66 kV Trans.	-	2 x 100 MVA

Table 3 Capacities of Facilities at 230/33 kV Substations

230/33 kV Substation	33 kV Power Supply Facilities	Existing Capacities	Estimated Capacities After Expansion
Ahlone	66/33 kV Trans.	60 MVA	
	33 kV Gen.	100 MVA	
Hlaingtharyar	230/33 kV Trans.	2 x 100 MVA	
Hlawga	230/33 kV Trans.	3 x 100MVA	
	33 kV Gen.	210 MVA	
Thanlyin	230/33 kV Trans.	100 MVA	2 x 100 MVA
Wartayar	230/33 kV Trans.	100 MVA	
Thakheta	230/33 kV Trans.	100 MVA	
	33 kV Gen.	50 MVA	
Iwama	33 kV Gen.	36 MVA	
West University	230/33 kV Trans.	2 x 100 MVA	

The estimated loads of 230 kV substations were listed as follows.

Table 3 Maximum Power Demand Forecast for 230 kV Substations in 2020

66 kV	Load (MW)	33 kV	Load (MW)
Ahlone	**391**	**Ahlone**	**84**
Bayintnaung	**189**	**Hlaingtharyar**	**99**
Hlawga	**45**	**Hlawga**	**263**
Thakheta	**298**	**Thanlyin**	**99**
Iwama	**231**	**Wartayar**	**49**
East Dagong	**189**	**Thakheta1**	**38**
South Okkalapa	**189**	**Thakheta2**	**38**
Kyaikkasan	**189**	**Iwama**	**20**
Thida	**189**	**West University**	**99**
Tilawa	**168**	**合計**	**788**
合計	**2,081**		

The power generators in around Yangon area were set out as shown in the following table. The numerical values of power outputs from Thaketa, Ahlone, Ywama and Hlawga were used that were also used in the previous study.

Table 4 Power Outputs of Generators in around Yangon Area in Base Case

Power Stations	In service	Out of service
Tilawa	50 MW	0 MW
Thakheta	92.2 MW	0MW
Ahlone	278.4 MW	0MW
Ywama	223.5 MW	0MW
Hlawga	104.7 MW	51.1 MW
TWH Thailand	500 MW	0MW
Ngayotekaung	540 MW	0MW
Dawei	450 MW	0MW

This case can be considered as the case with large power outputs of generators in around Yangon area.

(3) The Results of Power Flow Analysis for the 500 kV and 230 kV System in around Yangon around 2020 (Base Case)

Figure 4 shows the results of power flow calculation of the 500 kV and 230 kV system in

around Yangon around 2020 (base case) with modeling the original plan by MEPE.

The power flow at the intervals of Hlaingtayar – Ahlon and Kyaiklat-Ahlone exceed the capacity of their transmission lines. Some intervals of the 230 kV transmission lines become overloaded around Hlawga, East Dagon and Ahlone when the single circuit is dropped.

The overload of an intervals caused by dropping a single circuit would make circuit breakers opened through working of protection relays and it is feared that other intervals are also dropped out in a cascading manner causing a large black out.

For example, the power flow of Ahlone – Thida becomes 477 MW when its single circuit is dropped causing overloading at this interval and making its circuit breakers opened. This causes the other overloaded transmission lines. Figure 5 shows the power flow in this situation.

Some intervals of the transmission lines such as Myaungtagar – Hlawga – Thaketa、Phayargyi – East Dagon – Thaketa become overloaded. At that time, protection relays work and make their circuit breakers opened causing multiple circuits dropped. In this case, large power shortage can be expected. The similar situations is considered for the overloaded intervals.

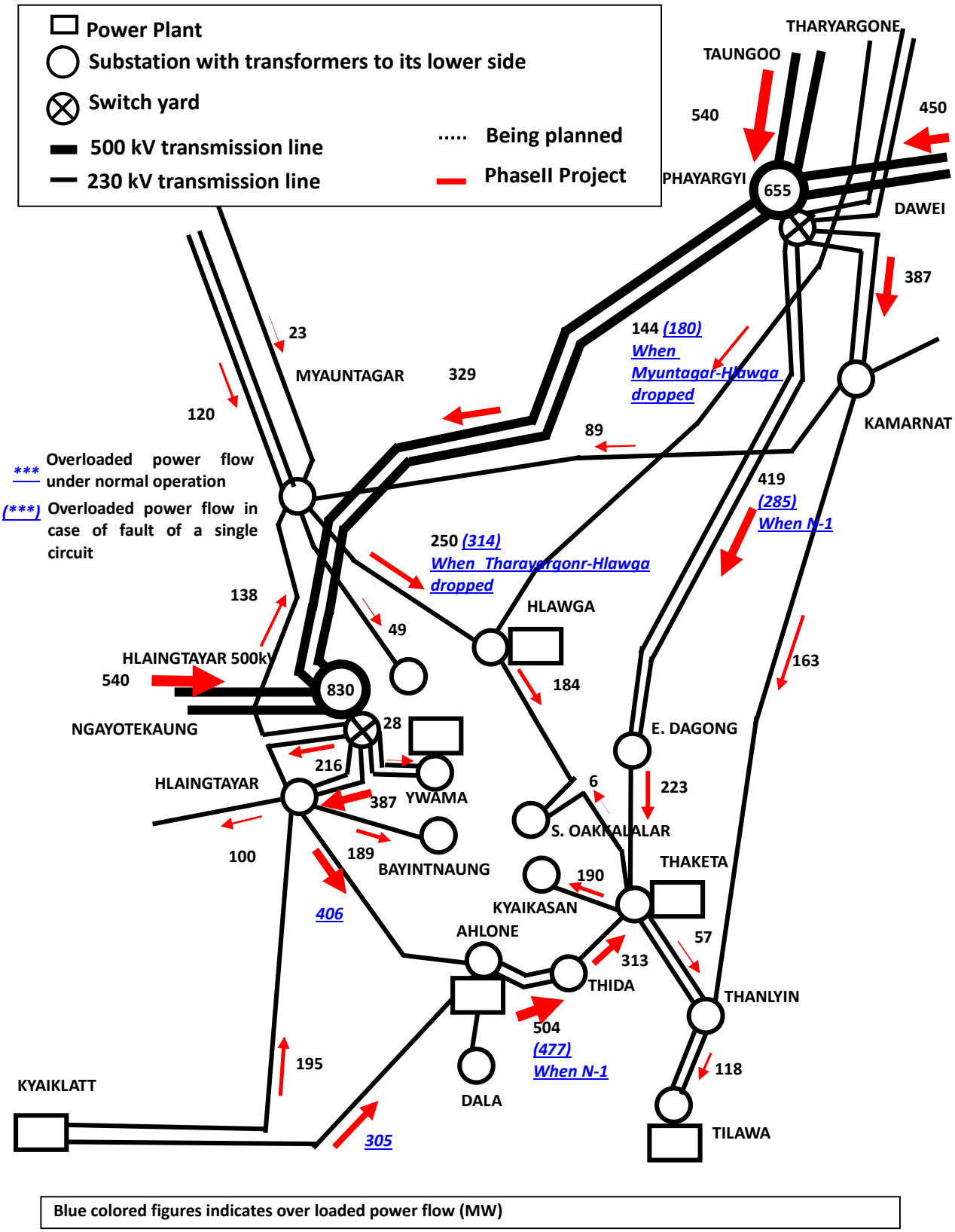


Figure 4 Power Flow for Base Case in 2020

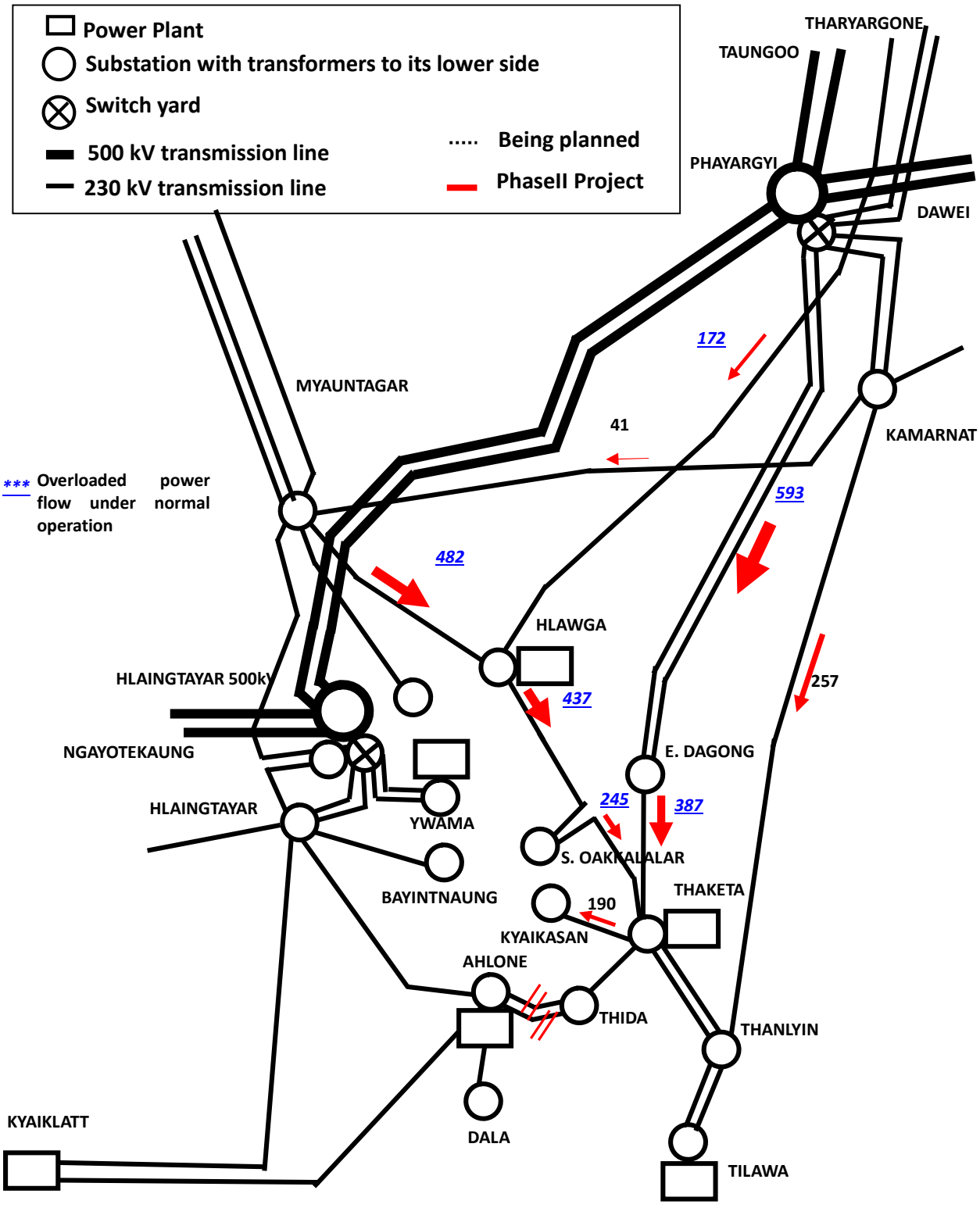


Figure 5 Power Flow in Case of a Fault between Ahlone and Thida for Base Case in 2020

(4) Option of 230 kV Interconnection between East and West in Yangon around 2020

An option of the installation of the 230 kV transmission lines connecting the east and west in Yangon (they may be installed with underground cables due to their locations in a city area) is studied as a countermeasure against overloaded situations in Base Case.

This option assumes the installation of a single circuit between 230 kV Hlaingtayar and Bayintnaung and double circuits between Ywama and South Okkalar

The result of the calculation is shown in the following figure. Blue colored lines indicate newly installed transmission lines. There are no overloaded 230 kV transmission lines in normal operation. However, some intervals become still overloaded such as Hlaingtayar-Iwama and 230 kV Hlaingtayara-Bayintnaung after dropping a circuit of their lines. The overloaded situation still remains when a single circuit is dropped.

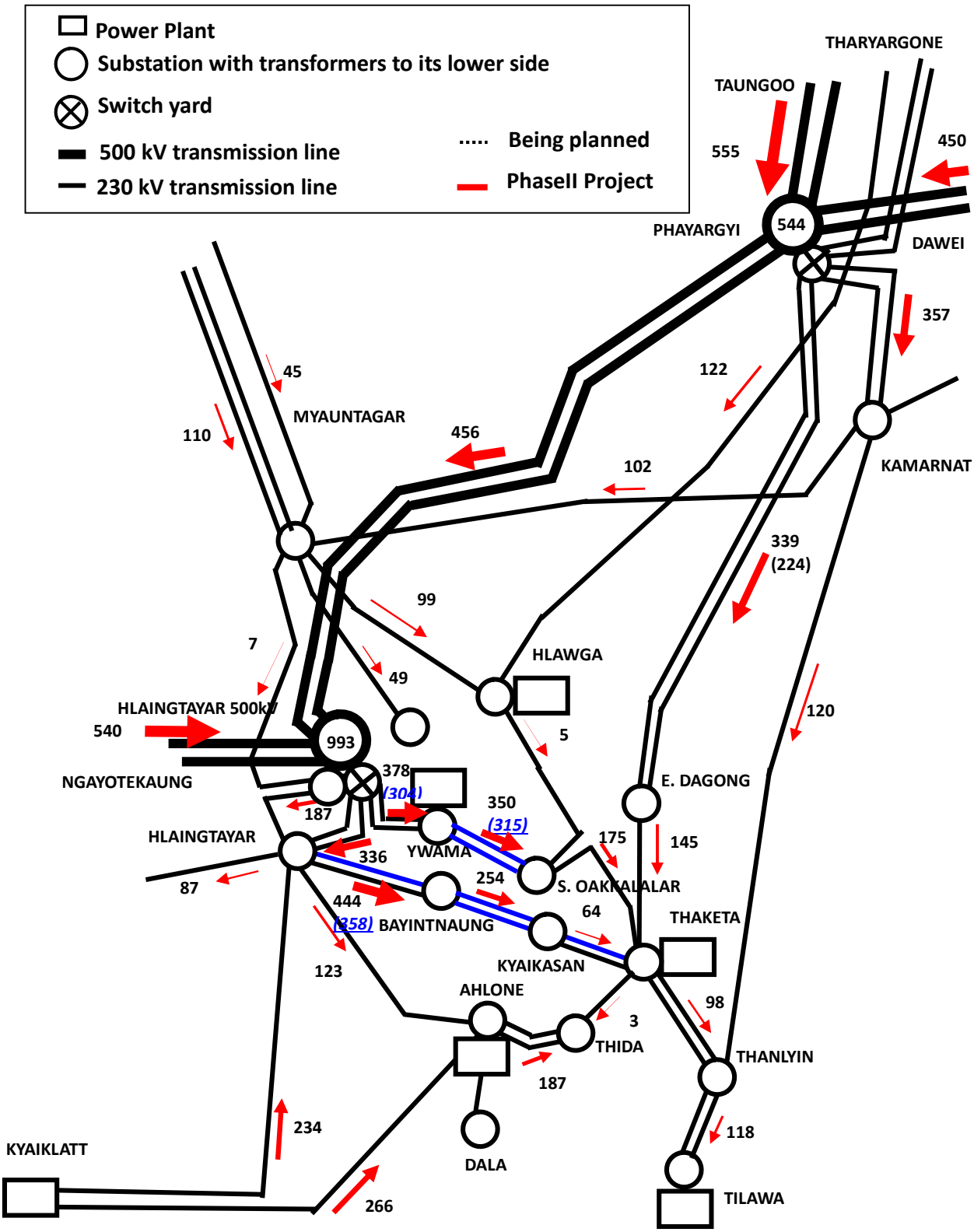


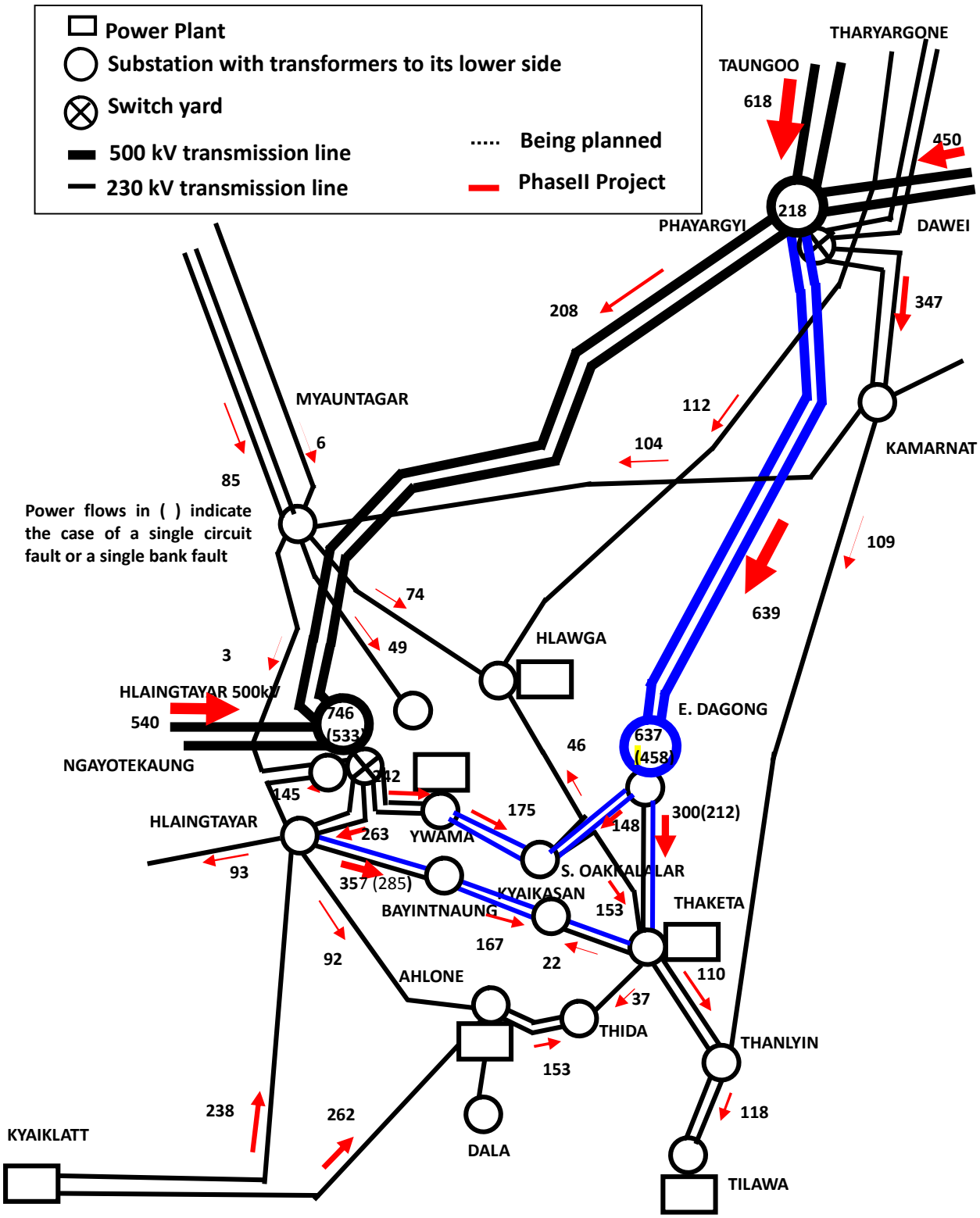
Figure 6 Power Flow in the 230 kV System with East-West Interconnection

(5) Option of the Future System Configuration of Fulfilling N-1 Criteria

An option of the installation of both the 230 kV Interconnection between east and west in Yangon and the eastern 500 kV substation around Yangon as an countermeasure against overloaded conditions caused by dropping a single circuit of transmission lines as show in the following figure.

This option does not cause overloaded situations even when a 230 kV single circuit is dropped except for the lines from Kyaikalat power station. The loads of 500 kV transformers can be within 120 % of their capacity even when one of their banks is dropped in this option.

Thus, it is recommended that the installation of a new 500 kV substation in the east of Yangon or an equivalent power source to supply the power both from the east and the west of Yangon in addition to the 230 kV interconnection in future.



( ): power flow in case of dropping a single circuit fault or a transformer

Figure 7 Power Flow in the Future System Fulfilling N-1 Criteria (East-West Interconnection and East 500 kV substation)

(6) Cases without Phase 2 Project

The power flow was calculated in case of not implementing Phase 2 Project for Base Case. Ngayotekaung and Dawei thermal power stations were assumed to be still connected to 500 kV transmission lines because they were independent from Phase 2 Project.

From the result of the power flow analysis, the power flows at Tharyargone - Hlawga and East Dagone-Thaketa exceeded the capacities of their lines apart from Hlaingtayar - Ahlon and Kyaiklat-Ahlon if Phase 2 was not implemented.

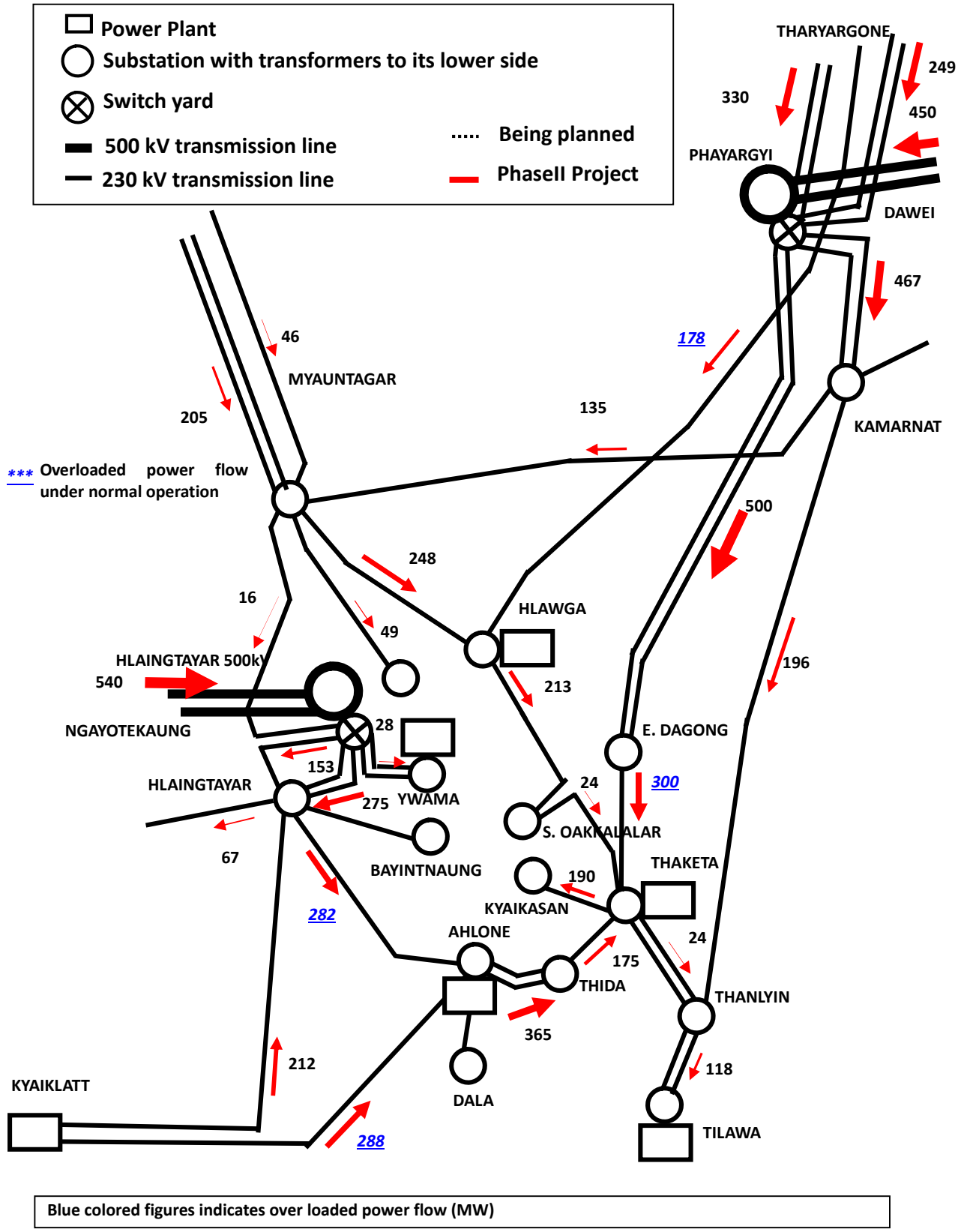


Figure 8 Power Flow in Case of Not Implementing Phase 2 Project for Base Case 2020

(7) Effects on Loss Reduction of Transmission Lines by Phase 2 Project

The implementation of Phase 2 Project can reduce the loss of transmission lines. The loss of the 500 kV and 230 kV system in Myanmar in 2020 was calculated as shown in the following table.

Table 6 Difference of Transmission System Loss between Before and After Phase 2

Case	Myanmar 500 kV and 230 kV Transmission System Loss
Before Implementation	204.4 MW
After Implementation	179.9 MW
Difference (Effect on Loss Reduction)	24.5 MW
Annual Loss Reduction	64,386 MWh
Conversion for reduction of CO2 emission	45,933 tCO2/Year

Annual loss reduction of the system and its conversion for CO2 emission are estimated as 64,386 MWh and 45,933 tCO2/year respectively by using the loss reduction of transmission lines at the maximum power demand assuming its annual loss factor 0.3.

- 0.7134 tCO2/MWh* is used as CO2 emission factor

  *) Averaged Grid Emission Factor of China/Myanmar listed in "List of Grid Emission Factor" posted on the Web site of Institute for Global Environmental Strategies in Japan

  http://pub.iges.or.jp/modules/envirolib/view.php?docid=2136

- Loss factor is often estimated by the following formula. Assuming Load Factor of 0.48 gives a Loss Factor of 0.3.

  Loss Factor = k x Loss Factor +(1-k) x Loss Factor^2 (where k is often used as 0.3 for transmission system and 0.2 for distribution system)

(8) Power Flow in Case of Lower Power Outputs from Thermal Power Stations in 2020 (Power output from Ngayotekaug in the west is zero)

The power flow would be increased from the northern area where a lot of hydropower stations will be located to Yangon in case of the lower power outputs from the thermal power stations in Yangon. The power flow was calculated for the both cases with and without Phase 2 setting out no power outputs from Ngayotekaug power station located in the west of Yangon. The power outputs were set out as follows.

Table 7 Power Outputs of Generators in around Yagon in Case of Lower Power Outputs from Thermal Power Stations in 2020 (Power output from Ngayotekaug in the west is zero)

Power Stations	In service	Out of service
Tilawa	50 MW	0 MW
Thakheta	92.2 MW	0 MW
Ahlone	278.4 MW	0 MW
Ywama	223.5 MW	0 MW
Hlawga	104.7 MW	51.1 MW
TWH Thailand	500 MW	0 MW
Ngayotekaung	0 MW	540 MW
Dawei	450 MW	0 MW

Figure 9 shows the power flow with Phase 2 in this generation pattern.

In the similar manner to the base case, the power flows between Hlaingtayar - Ahlon and Kyaiklat – Ahlon exceed their capacity of transmission lines. There are some intervals of 230 kV transmission lines that have the over loading power flow in case of a fault of a circuit around Hlawga, East Dagon and Ahlone.

Without Phase 2, the power flow calculation was not converged. This means that the power transmission is not possible at the maximum power demand without Phase 2. Its calculation was converged when the maximum power demand was decreased.The power flow became not to exceed the capacities of the transmission lines when the power demand of Yangon was decreased by around 28%. The Figure 10 shows the results of the power flow calculation for this case.

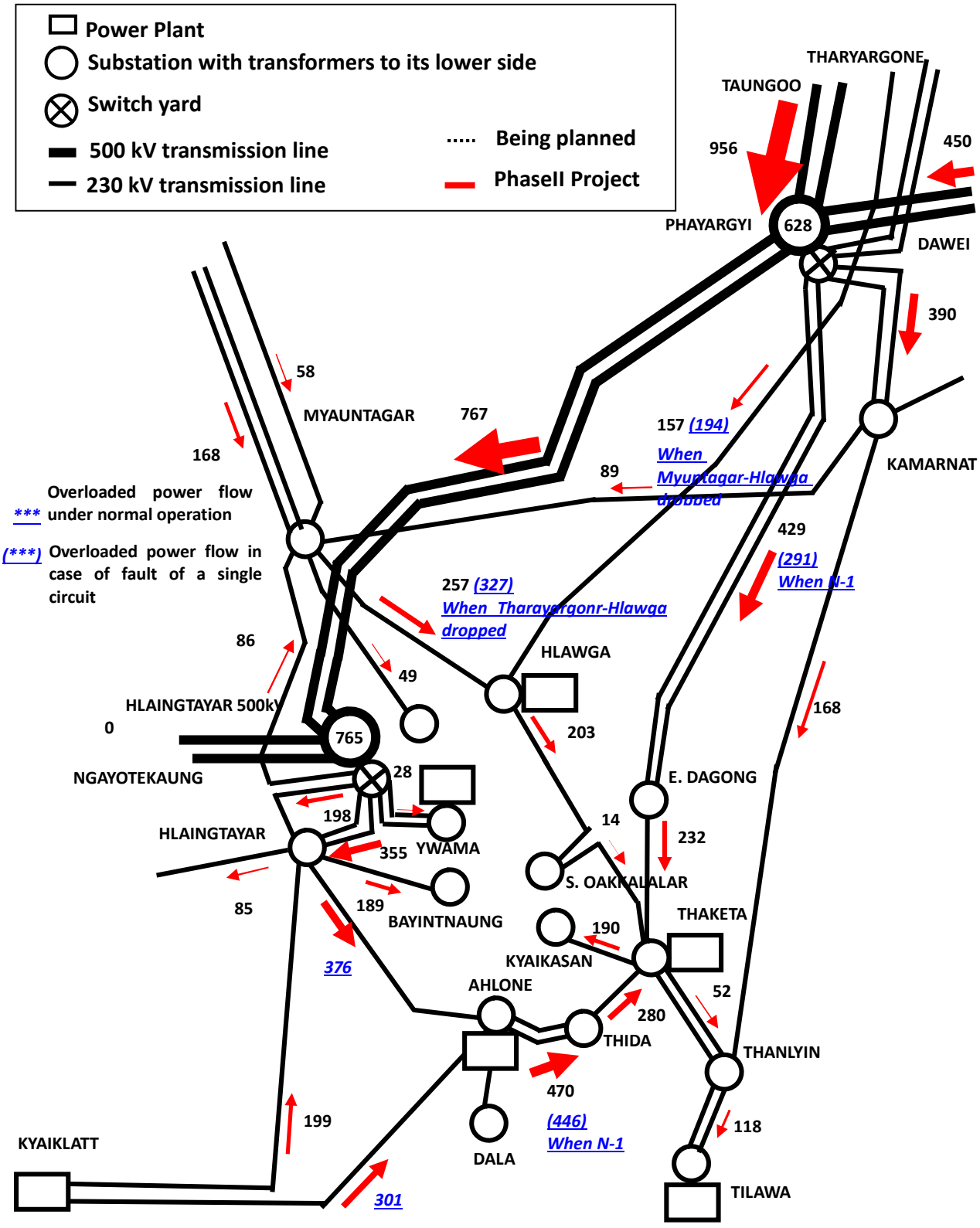


Figure 9 Case of Lower Power Outputs from Thermal Power Stations in 2020 (Power output from Ngayotekaug in the west is zero)

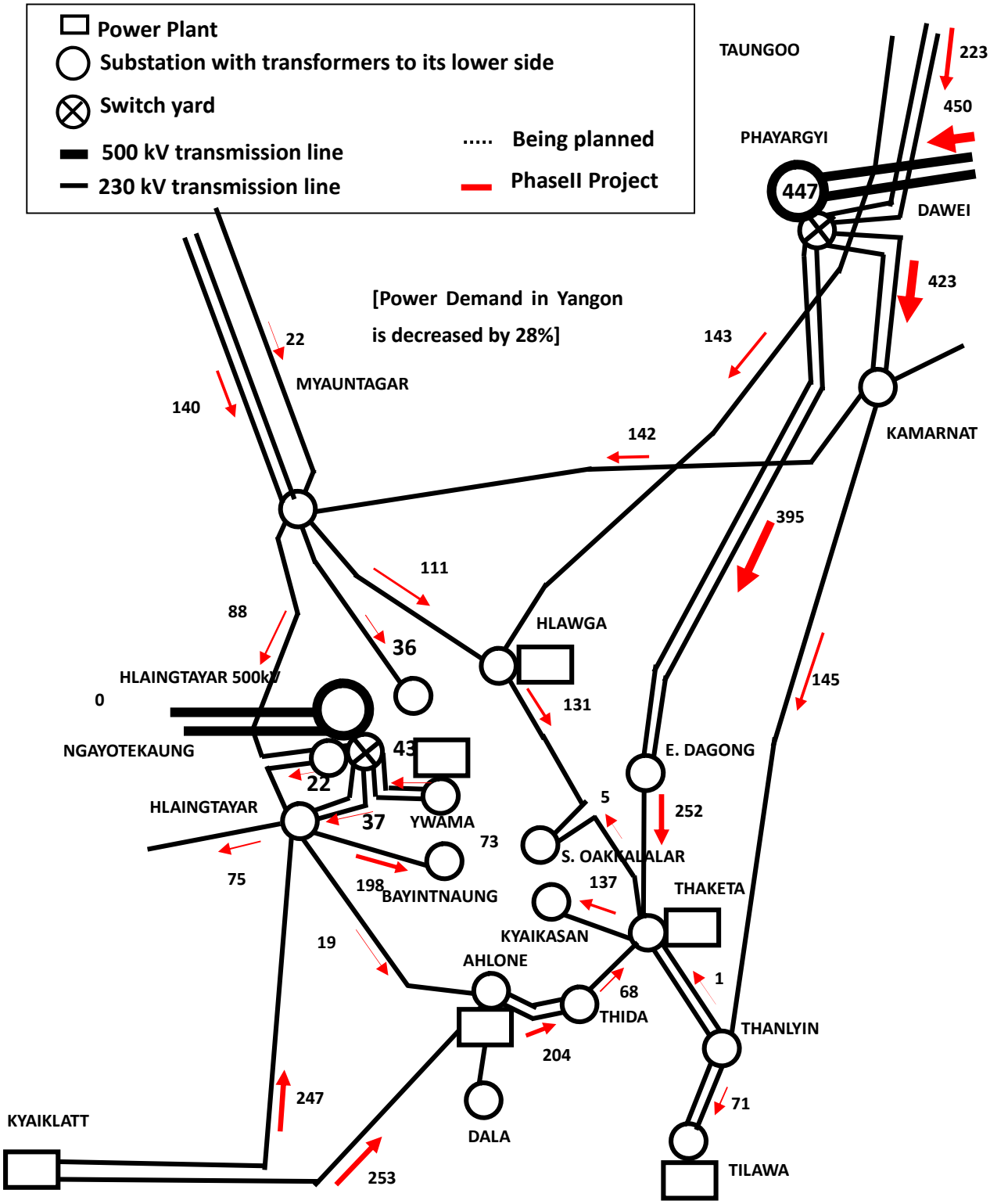


Figure 10 Case of Lower Power Outputs from Thermal Power Stations in 2020 (Power output from Ngayotekaug in the west is zero) without Phase 2 and decreasing power demand of Yangon by 28%

(9) Option of the Future 500 kV and 230 kV system in Yangon

When the maximum power demand of Yangon will reach 4,000 MW from 2,869 MW that is the maximum power demand of Yangon in 2020, it is considered that more four substation at least will be required even in consideration with the expansion of the existing substations. The installation of the east-west interconnections and the east 500 kV substation are both considered as the effective countermeasures against overloaded conditions. An option of the future 500 kV and 230 kV system in Yangon is shown in the following figure.

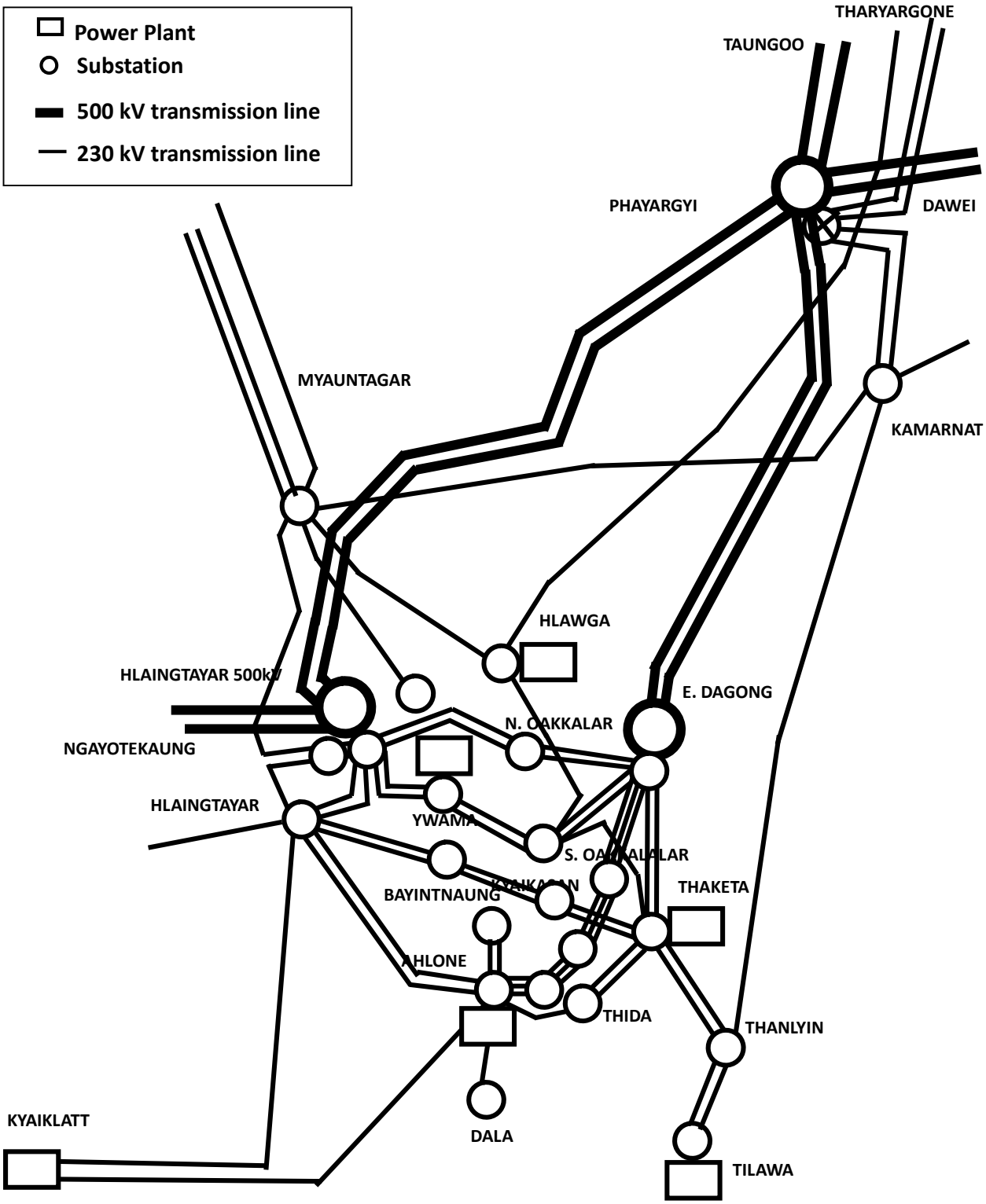


Figure 11 Option of the Future 500 kV and 230 kV System in Yangon

(10) Recommendations for Power System Configuration

The followings can be raised as the candidates of recommendations for future power system configuration.

- Implementation of 500 kV and 230 kV transmission lines and substations planned by MEPE including Phase 2 Project on schedule
- Installation of 230 kV transmission lines connecting the east and the west in Yangon through Ywama-S.Oakkalar and Bayintnaung-Kyaikasan and doubling circuits of Hlaigntayar-Bayintnaung and Thaketa-Kyaikasan up to around 2020. It will contribute to secure the power supply to the substations planed by MEPE responding to the rapid growing of power flow from the west to the east in Yangon.
- Installation of the new 500 kV substation in the eastern part of Yangon in around East Dagon to supply power from the east. In order to prepare this, the transmission line from Pharyargi to East Dagon is considered to be constructed as 500 kV design lines. is installed.
- More 230 kV substations apart from the current planned ones will be required in Yangon city.
- Abovementioned recommendations would be required even for the situations where power outputs from generators in around Yangon are relatively large. However, the detailed studies will be required including the fault current analysis regarding the bulk power system in Yangon because the system power flow can be changed in accordance with the power generation plans and their operation.