The Republic of the Union of Myanmar
Ministry of Electricity and Energy

Preparatory Survey on National Power Transmission Network Development Project Phase III

Final Report
Pre-release Version
Separate - Volume

(Preliminary Data Collection Survey on Power Grid Expansion towards Mawlamyaing)

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Japan International Cooperation Agency (JICA)

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1. Data Collection on System Configuration

1.1. Outline of the survey

A preliminary data collection survey was conducted on the expansion of the power grid from the area around Yangon to Mawlamyaing.

Mawlamyaing is a city located about 300 km southwest of Yangon. There are plans for an industrial park in the vicinity, and an industrial park and LNG-fired power plant are planned for the Dawei district (Kanbouk) in the south. In addition, an interconnected transmission line from Thailand is planned for Myawaddy, on the border with Thailand northeast of Mawlamyaing.

There is only one 230 kV transmission line from Kamarnat to Mawlamyaing, near Pharyargyi, which does not meet the N-1 criteria. The 230 kV Mawlamyaing-Myawaddy two-line transmission line has recently been constructed.

1.2. Current status and plans for system configuration

1.2.1. Current Status of Grid Structure

The existing 230 kV transmission lines and substations from Kamarnat to Mawlamyaing are summarized in Table 1.2-1.

Table 1.2-1 Overview of existing 230 kV transmission lines and substations from Kamarnat to Mawlamyaing

230 kV Transmission Lines				
No.	Name of Transmission Line	Conductor Size	Distance (Miles)	Number of Towers
1	230 kV Kamarnat - Sittaung	605 MCM	36.60	136
2	230 kV Sittaung - Thaton	605 MCM	60.25	266
3	230 kV Thaton - Mawlamyaing	605 MCM	49.77	233

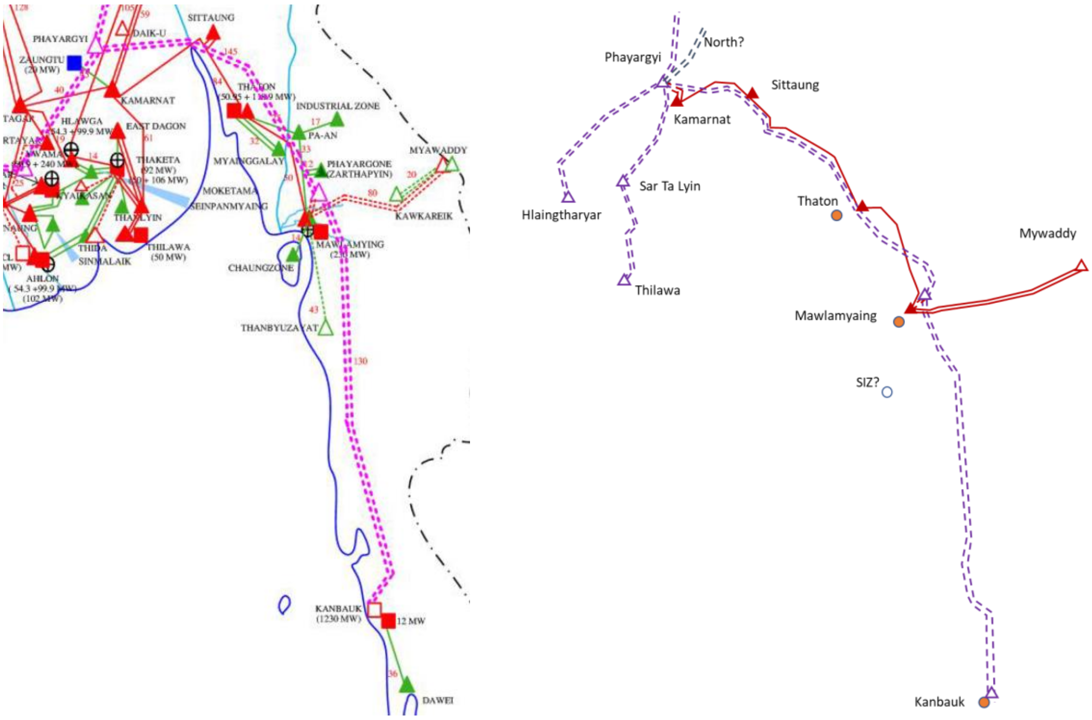
230 kV Primary Substations					
No.	Substation	Voltage ratio (kV)	Capacity (MVA)	230 kV Transmission Lines	Location
1	Kamarnat	230/33/11	100 + 60	Tharyargone (1) Line Tharyargone (2) Line Thanlyn Line Sittaung Line Myaungtagar Line	Kamarnat village, Bago
2	Sittaung	230/33/11	50	Kamarnat Line Thaton Line	Kyeit-hto Township, Tha-hton District Theinzayat village
3	Mawlamyaing	230/66/11	50	Thaton Line Myanmar Lighting (IPP) Line	Mawlamyaing

Source: MOEE Website

The system map from Pharyargyi to the southeast, as obtained from DPTSC, is shown in Figure 1.2-1. 500 kV and 230 kV systems are planned from Pharyargyi to the southeast.

500 kV Pharyagyi - Mawlamyaing 2 lines
500 kV Mawlamyaing - Kanbouk 2 lines
230 kV Mawlamyaing - Myawaddy 2 lines

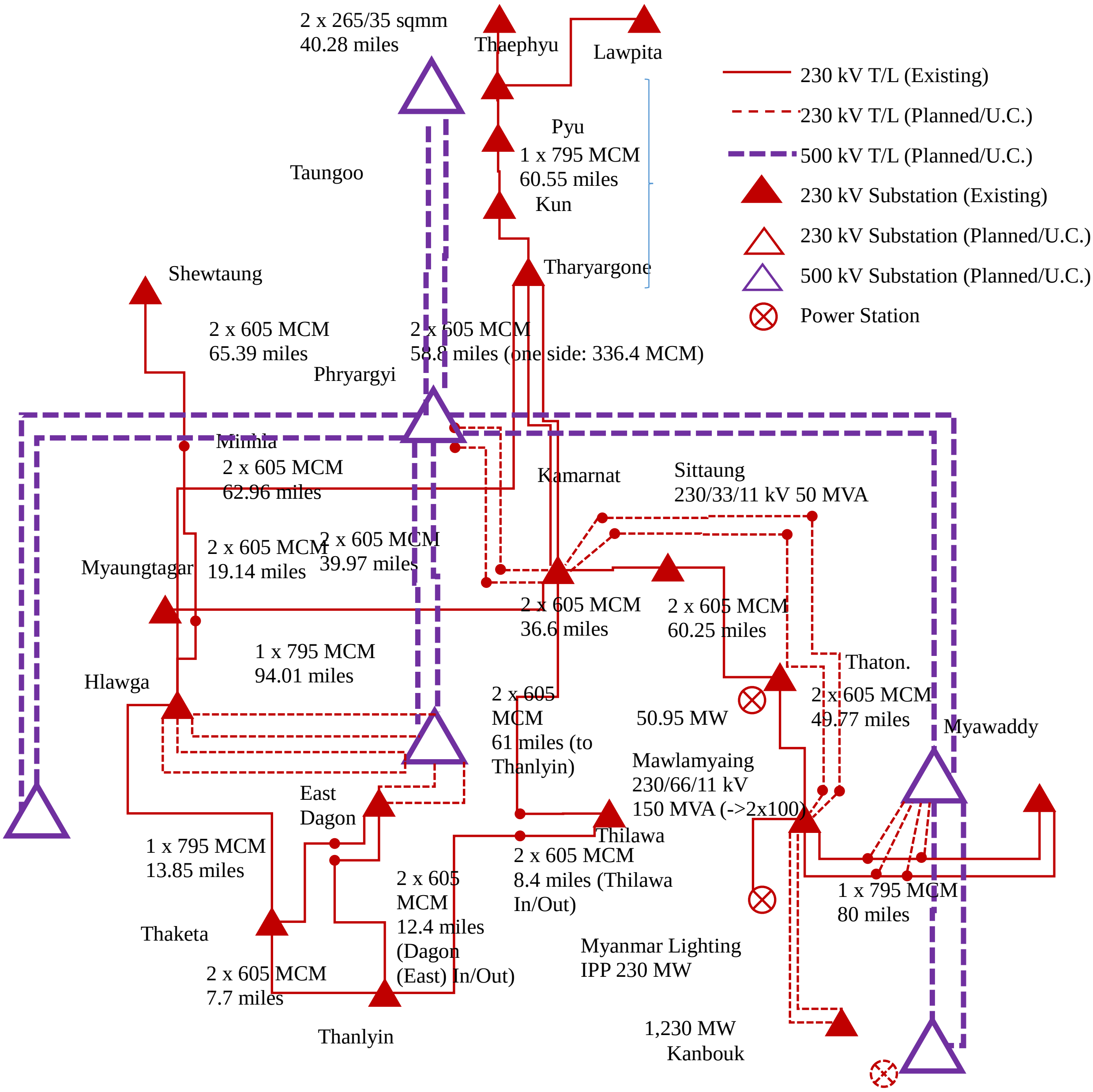
500 kV Mawlamyaing Substation
500 kV Kanbouk Power Plant
230 kV Myawaddy Substation



Source: obtained from DPTSC, November 2018.

Figure 1.2-1 System map from Pharyargyi to the southeast

Phase III is added to this plan because it was not included, and the 230 kV transmission line is also added based on information from DPTSC that the construction of two 230 kV lines between Kamarnat and Thaton has been decided. Also the plan of 500 kV lies from Thilawa to Sar Ta Lin is added to this plan.



Source: Prepared by JICA Survey Team based on information obtained from DPTSC.

Figure 1.2-2 System configuration in eastern Yangon and southeast from Pharyargyi

1.2.2. Existing power supply

Data on the existing power sources connected to the transmission system are shown below. Generator units 1 and 3 at Thaton are old and have small, single unit capacities.

Table 1.2-1 Thaton (EPGE)

Unit	Capacity
Machine-1 Turbine	11.3.1974 MW
Machine-2 Turbine	16.9.2010 MW
Machine-3 Turbine	15.5.1985 MW
Total Installed Capacity	50.95 MW

Source: DPTSC Website

Table 1.2-2 Mawlamyaing (IPP)

Location	Mawlamyaing Township, Mandalay Region
Company Name	Myanmar Lighting (IPP) Co.
Project Type	BOT
Commercial Operation Date	27/5/2014
Total Installed Capacity	230 MW (95 MW (Phase I) + 130 MW (Phase II))
Type of Machine	GE PD 6581B (3 units) LM 2500 (1 unit) GE
Annual Design Generation	1386 GWh
Manufacturer	GE

Source: DPTSC Website

1.3. Examining the adequacy of the power grid plan

The power flow in each section of the system from Pharyargyi to the southeast was estimated, and the validity of the system plan for the target area was briefly discussed based on the power flow and a simple evaluation of stability. Short circuit analysis will be required in a stage of a further study.

Several patterns were considered, including peak demand, off-peak demand (60% of peak), maximum power output of the power supply, and unit shutdown.

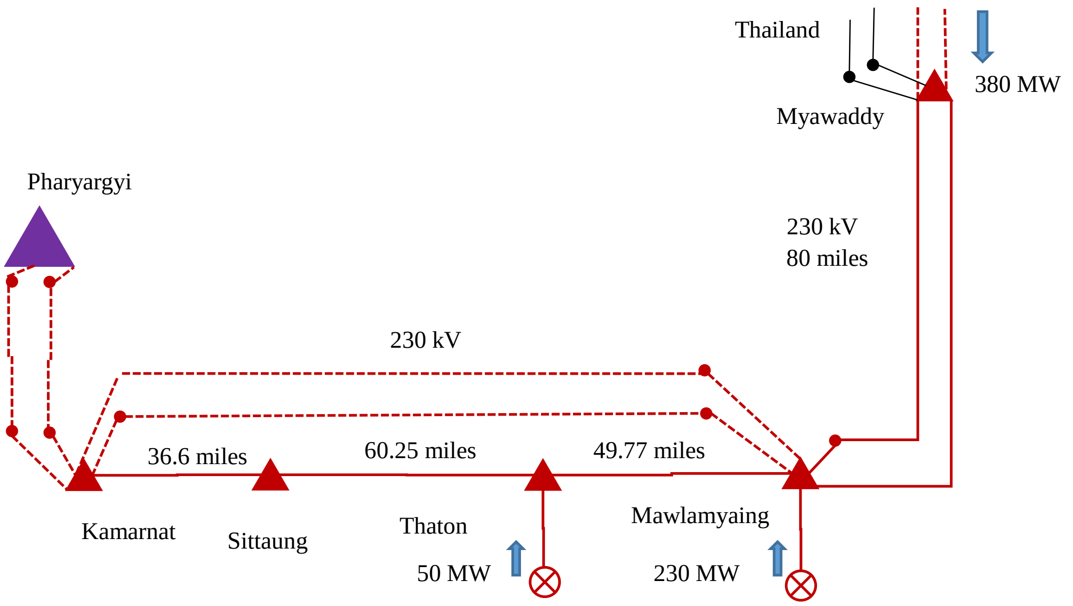


Figure 1.3-1 System to be studied

1.3.1. Power Demand Forecast

The maximum demand at the district level was assumed based on the demand forecast in the JICA MP, taking into account the maximum demand forecast for the regions and the population ratio. The areas to be served by this project are Mon State, Kayin State, and Tanintharyi Region in southeastern Myanmar. It is assumed that 1/4 of the electricity demand for Thaton District in Mon State will be supplied from Sittaung Substation, with 3/4 from Thaton Substation.

Table 1.3-1 Power demand forecast in the target area

	Maximum Power Demand Forecast (JICA MP)			Population (2014)	Maximum Power Demand Forecast	
State/ Region	2020	2030	District		2020	2030
Kayin	62	161	Hpa-an	783,510	32	84
			Hpapun	35,085	1	4
			Kawkareik	475,191	20	51
			Myawaddy	210,540	9	23
Mon	161	416	Mawlamyaing	1,232,221	97	250
			Thaton	822,172	64	166
Tanintharyi	32	82		1,408,401	32	82
Total	255	659		4,967,120	255	659

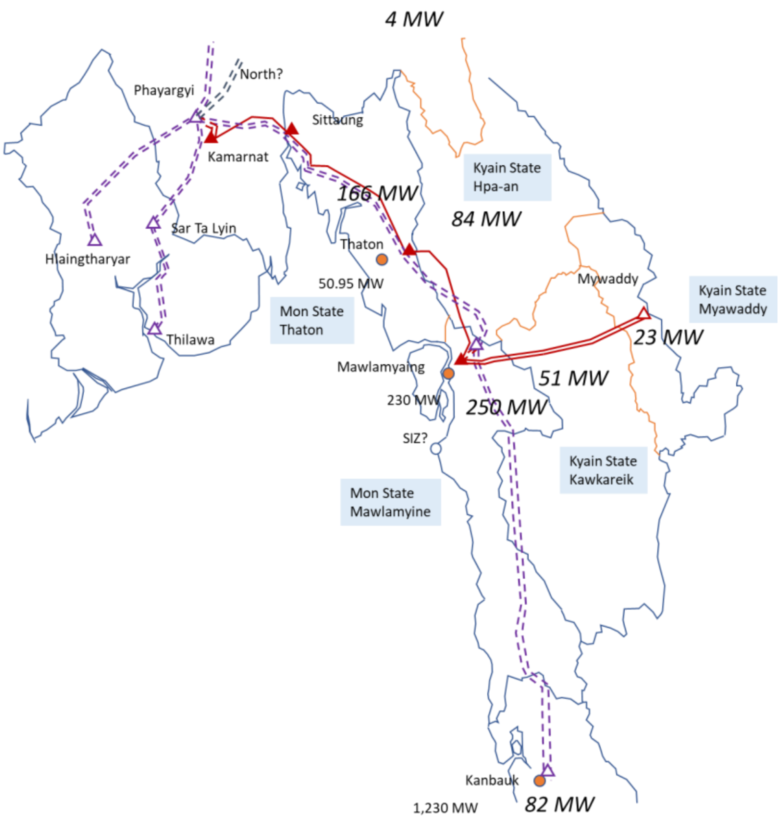


Figure 1.3-2 Power Demand Forecast in 2030 for the Target Area

1.3.2. New power plant construction plan

MOEE is planning an LNG-fired power plant in Kanbauk. According to articles on the web, this project has the following status.

- Articles on the Web, January 2018 (Myanmar Frontier)
  - Granting development rights to a consortium of Total (France) and Siemens (Germany)
  - Project components
    - Power output: 1,230 MW (615 MW x2)
    - Floating storage and regasification system for liquid natural gas

  - High voltage power line to Pharyargyi
  - Completed in 4 years

- Article on the Web, June 2019 (Myanmar Frontier)
  - The above plans may be scaled down, suspended or cancelled. The initial proposal was for US$ 2.1 billion, but in the current proposal, the capacity of the power plant in the first phase is proposed to be reduced from 615 MW to 400 MW, excluding the 500 kV transmission line component to Pharyagyi. Under the new proposal, the power will be transmitted to Yangon via a 230 kV transmission line that will be built with a soft loan from ADB. The environmental and social impact assessment and initial environmental review for the three components - the gas facility, the power plant and the transmission line - have already been completed, although the consortium has yet to sign a power purchase agreement. Siemens is providing the technology for the electricity.

DPTSC commented that the power supply envisioned for Kanbouk is uncertain and therefore does not need to be considered in the study for this plan. Therefore, this power source will not be considered.

- There are plans for an interconnected power line with Thailand.
  - According to the information from EGAT, two 115 kV lines of 80 MW and two 230 kV lines of 300 MW are planned to Myawaddy.

Table 1.3-2 Thailand and Myawaddy Interconnection Line Plan

Voltage	Power Transmission Section	Capacity (MW)	Commissioning Year
115 kV	Mae Sot - Myawaddy	80	2023
230 kV	Mae Sot - Myawaddy	300	2026

Source: EGAT information obtained by JICA survey team

A total of up to 380 MW was assumed to be imported from Thailand.

1.3.3. Approximate power flow forecast

The direction and magnitude of the power tidal current varies greatly depending on the output of the Tathon and Mawlamyine power plants, as well as the imported power from Thailand and the size of the power demand. For this reason, the following four cases were set up to calculate the rough power flow from 2020 to 2035.

Case 1. Peak power demand period. Maximum output of power generation facilities

Case 2. During off-peak power demand. Maximum output of generating facilities

Case 3. Partial shutdown of power generation facilities during peak power demand

Case 4. During peak power demand, all power generation is shut down

The results of the approximate power flow forecast are shown in Table 1.3-3 and from Figure 1.3-3 to Figure 1.3-6.

Table 1.3-3 Power Flow Forecast

Peak 100%	Full Gen.														
		Load	Gen.	Power Flow	Load	Gen.	Power Flow	Load	Power Flow	Load	Gen.	Power Flow	Load	Gen.	Power Flow
	Year	2020			2025			2030		2035			2036		
Kamarnat -> Sittuang				-27			93		155			195			235
Sittaung	230/33 kV	16			29			42		54			57		
Sittuang -> Thaton				-44			65		103			141			178
Thaton	230/66 kV	81			145			209		273			286		
Thaton			-50.95			-50.95					-50.95			-50.95	
Thaton -> Mawlamyaing				-73			-29		-106			-81			-56
Mawlamyaing	230/66 kV	129			230			332		433			453		
Mawlamyaing			-230			-230					-230			-230	
Mawlamyaing->Myawaddy				28			-29		-289			-284			-280
Myawaddy	230/66 kV	28			51			73		96			100		
Thailand						-80					-380			-380	
Kanbouk						0					0			0	
Off Peak 60%	Full Gen.														
	Year	2020			2025			2030		2035			2036		
Kamarnat -> Sittuang				-129			-88		-171			-147			-123
Sittaung	230/33 kV	10			17			25		33			34		
Sittuang -> Thaton				-138			-106		-202			-180			-157
Thaton	230/66 kV	48			87			125		164			171		
Thaton			-50.95			-50.95					-50.95			-50.95	
Thaton -> Mawlamyaing				-136			-141		-308			-293			-278
Mawlamyaing	230/66 kV	77			138			199		260			272		
Mawlamyaing			-230			-230					-230			-230	
Mawlamyaing->Myawaddy				17			-50		-325			-322			-320
Myawaddy	230/66 kV	17			30			44		58			60		
Thailand						-80					-380			-380	
Kanbouk						0					0			0	
Peak 100%	Some Units Stopped														
	Year	2020			2025			2030		2035			2036		
Kamarnat -> Sittuang				154			274		336			376			416
Sittaung	230/33 kV	16			29			42		54			57		
Sittuang -> Thaton				137			246		284			322			359
Thaton	230/66 kV	81			145			209		273			286		
Thaton			0			0					0			0	
Thaton -> Mawlamyaing				57			101		24			49			74
Mawlamyaing	230/66 kV	129			230			332		433			453		
Mawlamyaing			-100			-100					-100			-100	
Mawlamyaing->Myawaddy				28			-29		-289			-284			-280
Myawaddy	230/66 kV	28			51			73		96			100		
Thailand						-80					-380			-380	
Kanbouk						0					0			0	
Peak 100%	All Units Stopped														
	Year	2020			2025			2030		2035			2036		
Kamarnat -> Sittuang				254			273		490			514			538
Sittaung	230/33 kV	16			17			25		33			34		
Sittuang -> Thaton				237			255		458			481			504
Thaton	230/66 kV	81			87			125		164			171		
Thaton			0			0					0			0	
Thaton -> Mawlamyaing				157			169		302			317			332
Mawlamyaing	230/66 kV	129			138			199		260			272		
Mawlamyaing			0			0					0			0	
Mawlamyaing->Myawaddy				28			30		55			58			60
Myawaddy	230/66 kV	28			30			44		58			60		
Thailand						0					0			0	
Kanbouk						0					0			0	

Blue shading indicates transmission section, Load: load at substation, Gen: power generated at power plant, Orange shading indicates power flow at each transmission section, Positive: direction to Mauramyne, Negative: direction to Kamarnat.

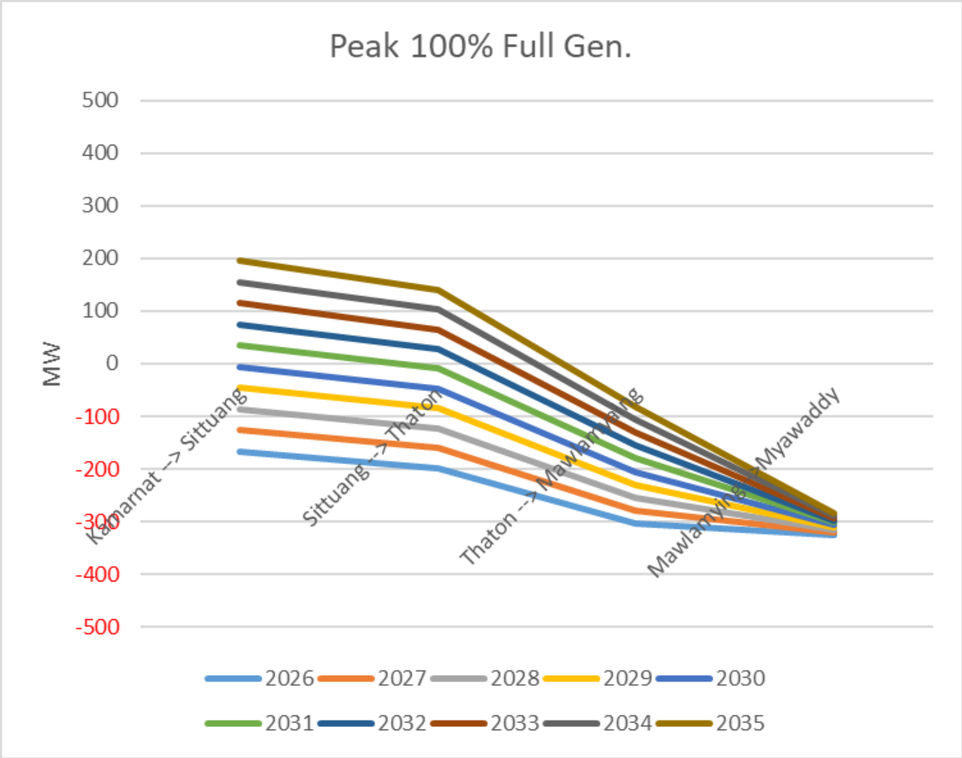


Figure 1.3-3 Case 1. Peak power demand period. Maximum output of power generation facilities

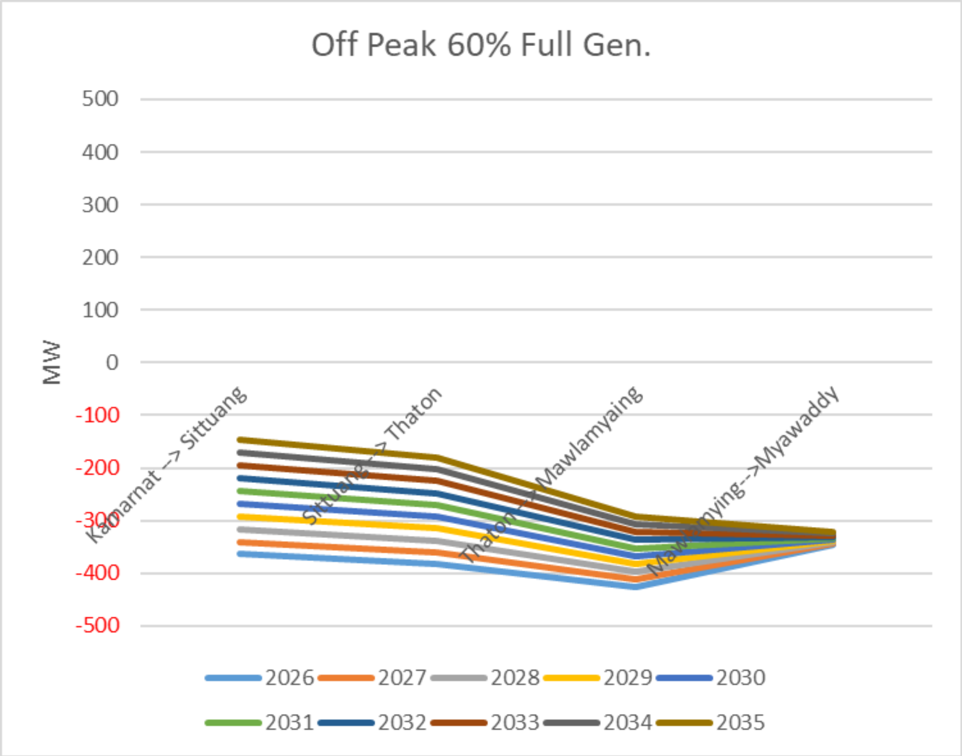


Figure 1.3-4 Case 2. During off-peak power demand. Maximum output of generation facilities

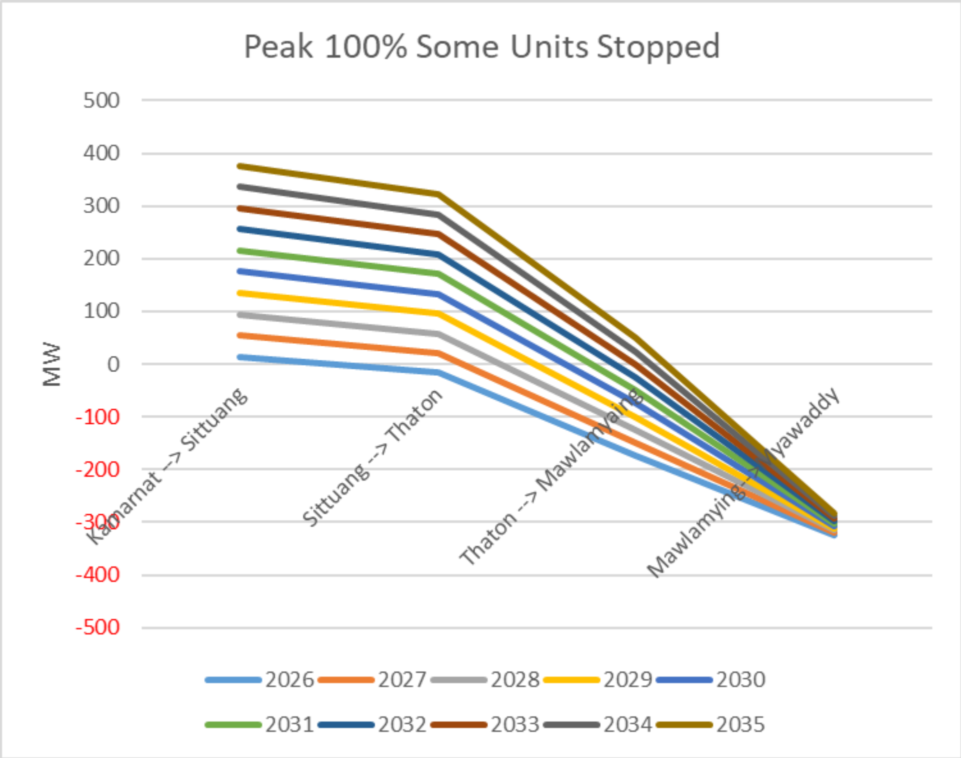


Figure 1.3-5 Case 3. Partial shutdown of power generation facilities during peak power demand

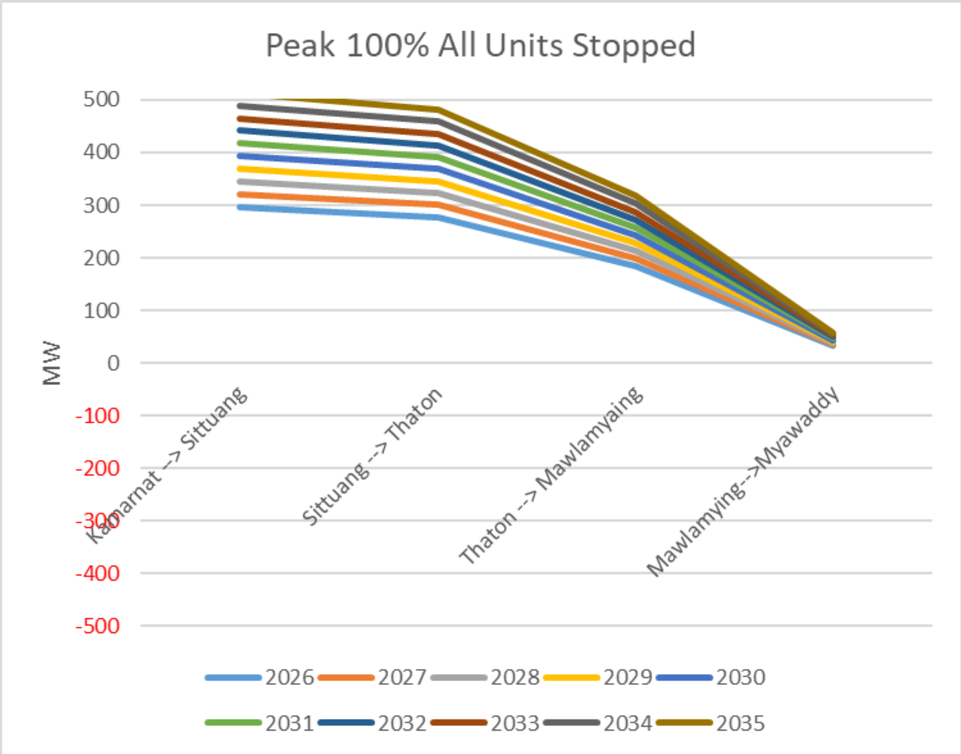


Figure 1.3-6 Case 4. During peak power demand, all power generation is shut down

1.3.4. Evaluation of power flow and power transmission capability

(1) Limitation of power transmission by thermal capacity and stability of transmission lines

In general, transmission lines have limitations on the amount of power that can be transmitted in terms of the thermal resistance of the lines and the suppression of sag, defined as the thermal capacity, which is usually referred to as the line capacity. Moreover, to ensure stable operation of the generator, the length of the transmission line limits the amount of power that can be transmitted in terms of stability. The longer the transmission distance, the stronger the constraint from the stability aspect becomes, rather than the power transmission limit in terms of thermal capacity, so the power that can be transmitted is determined from the stability aspect.

The table below shows the capacities of standard power lines used in Myanmar. When the transmission distance exceeds about 200 km, the power transmission limit due to the degree of stability becomes smaller than the power line capacity.

Table 1.3-4 Conductor capacity

1x 795 MCM (230 kV)	164 MVA
2 x 605 MCM (230 kV)	288 MVA
4x 795 MCM (500 kV)	1,428 MVA

Source: 230 kV is DPTSC's standard value; 500 kV is the survey team's estimate.

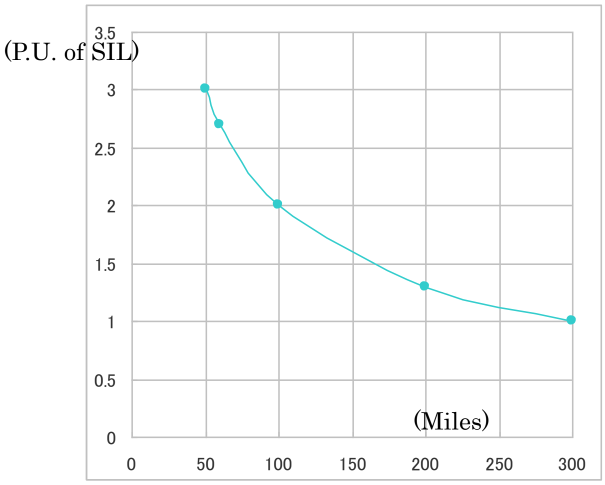
(2) Approximate stable power transmission capability based on SIL value

The amount of power that can be transmitted is estimated from the distance of the transmission line, using the transmission line's inherent SIL (Surge Impedance Load) value as a guide.

The SIL value is the power transmitted when the voltage drop due to the reactance of the transmission line is balanced by the voltage rise due to the capacitance of the transmission line. The relationship between the transmission distance and the amount of power that can be transmitted stably is obtained as a multiple of the SIL value, and is used as a guide for the stability of transmission. The following figure shows the relationship between the transmission distance and the amount of power that can be transmitted stably.

The term "stable power transmission" refers to the condition in which the system can be operated stably in a steady state, assuming transformers and generators at both ends.

For example, at a distance of 50 miles (about 80 km), power can be transmitted stably up to three times' the SIL, but at a distance of 300 miles (about 480 km), power can only be transmitted stably up to the SIL value.



Source: Analytical Development of Loadability Characteristics for EHV and UHV Transmission Lines," R.D. Dunlop, R. Gutman and P.P. Marchenko, IEEE Transactions on Power Apparatus and Systems, Vol. PAS-98, No. 2, March/April 1979. Or Power System Stability and Control, P228, 6.1.12 Loadability Characteristics, P. Kundur, 1993)

Figure 1.3-7 Relationship between the transmission distance of an AC transmission line and the power that can be transmitted stably

The SIL value per line of the 230 kV transmission line in Myanmar is calculated to be about 177 MVA. The heat capacity per line of the standardly-used wire, ACSR 2 x 605 MCM, is 288 MVA, which is about 1.6 times' the SIL value.

From the graph, it can be seen that power flow of 1.6 times that of the SIL can be transmitted stably up to about 150 miles (= 240 km), but beyond that distance, the power that can be transmitted stably is smaller than 1.6 times that of the SIL and smaller than the thermal capacity. The above guideline is applied to the rest of the circuits considering an accident at a single circuit in N-1.

1.3.5. Evaluation of the stability of the Kamarnat - Mawlamyaing - Myawaddy transmission line section

The distance from Pharyargyi to Mawlamyaing is about 170 km, and the distance from Mawlamyaing to Myawaddy is about 90 km. In addition, an interconnected transmission line will be connected from Myawaddy to Thailand. It is necessary to estimate the amount of power that can be transmitted via a stability analysis, including grid connection of the power supply in Thailand. If we assume a strict 400 km (about 250 miles) transmission, the amount of power that can be transmitted on a single circuit will be 200 MVA, which is about 1.2 times' the SIL from the graph.

If the transmission power for the remaining lines of Kamarnat - Mawlamyaing N-1 is less than 1.2 times' the SIL, the transmission power of the two lines between Kamarnat - Mawlamyaing - Myawaddy - Thailand will be 400 MVA. If the power factor is assumed to be 90%, it is about 360 MW. Therefore, based on the approximate stability estimates, it is considered that there may be cases where stable transmission is difficult to achieve with the current 230 kV with a single circuit, and the new 230 kV double circuit lines, depending on the output of the power source and the size of the power demand.

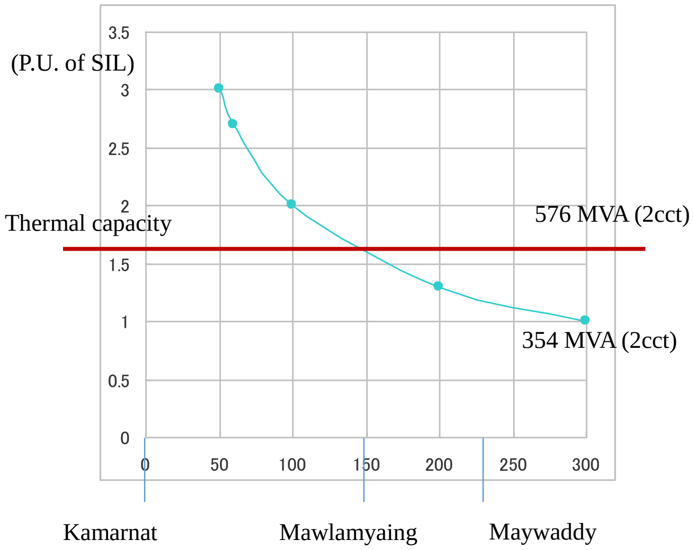


Figure 1.3-8 Relationship between the power that can be transmitted stably and the heat capacity of transmission lines

This may require additional new transmission lines.

1.3.6. Recommended system configuration

When constructing a new transmission line in this section, it is required to construct a 500 kV line to reduce losses and to be able to handle the future Kanbouk and increased demand. The recommended system configuration is as follows.

Existing: 230 kV 1cct Kamarnat - Mawlamyaing

New: 230 kV 2cct Kamarnat - Mawlamyaing

New: 500 kV 2cct Pharyargyi - Mawlamyaing

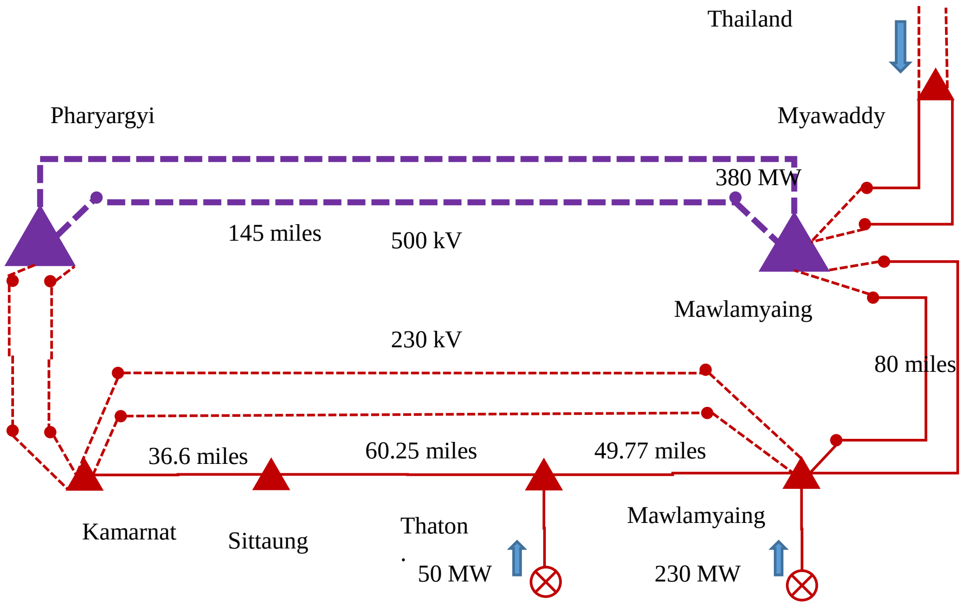


Figure 1.3-9 Recommended system configuration

The SIL of a 500 kV transmission line is about 1,000 MVA, which is sufficient to ensure stable transmission of power.

Note that due to the large charging capacity of the 500 kV transmission line, the voltage increases at light loads, so a 500 kV shunt reactor is required for compensation. In addition, since the direction of power flow is not constant, voltage regulation in combination with power capacitors will be required.

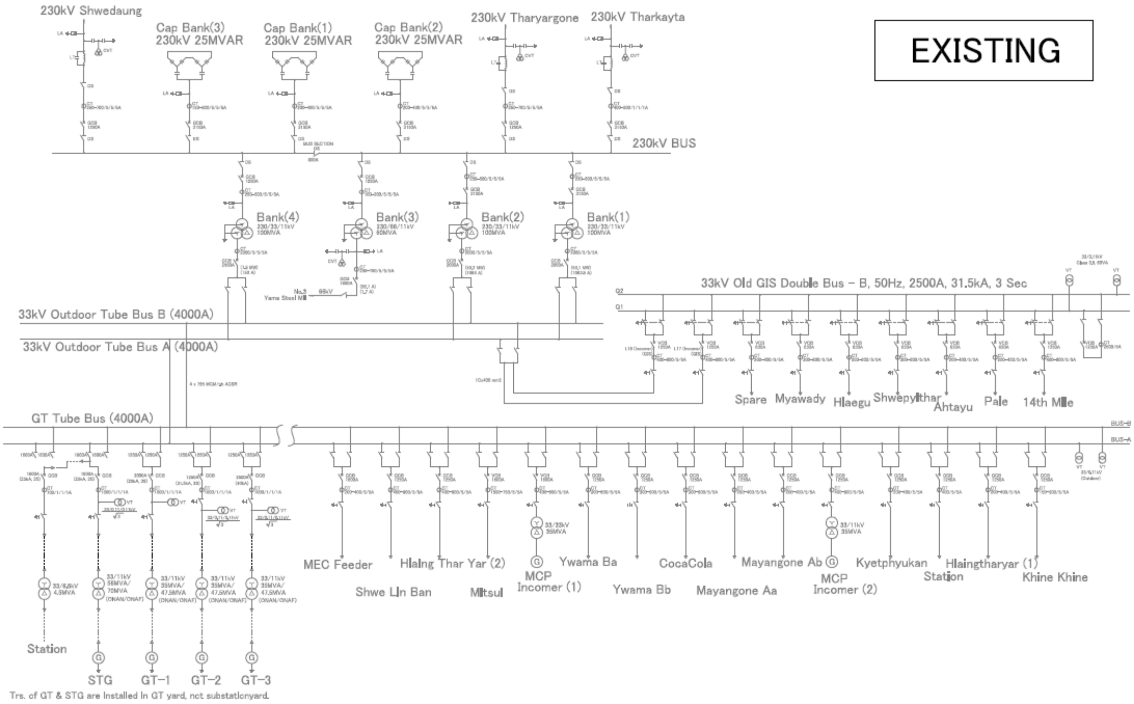
In the future, it will be necessary to examine the amount of power that can be transmitted in detail through stability calculations based on the grid structure of the system in Thailand with the interconnections.

1.4. Single line diagrams of the existing power stations in Yangon

1.4.1. Single line diagram of the Hlawga PS

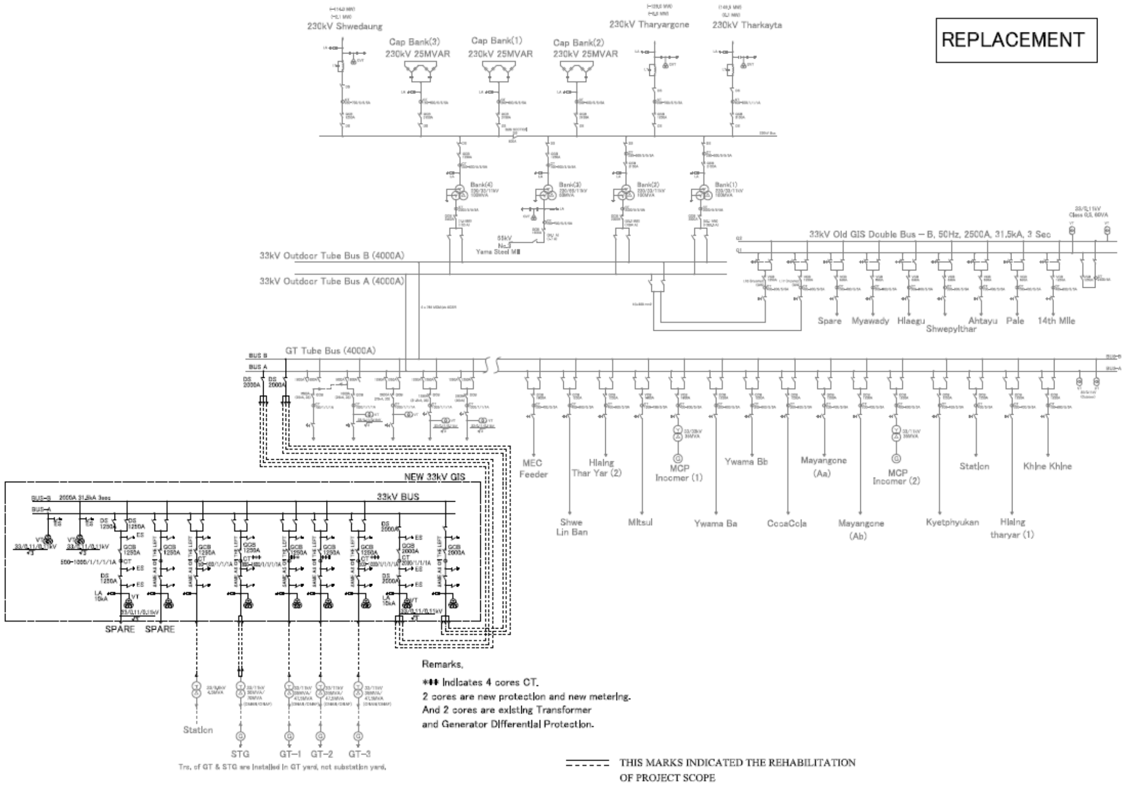
(1) Single line diagram before/after rehabilitation

At present, the urgent rehabilitation and upgrade project phase 1 (package 2) is being carried out. The single line diagram before rehabilitation is shown in Figure 1.4-1. The single line diagram after rehabilitation is shown in Figure 1.4-2.



Source: JICA Survey Team

Figure 1.4-1 Single line diagram of the Hlawga PS (before rehabilitation)



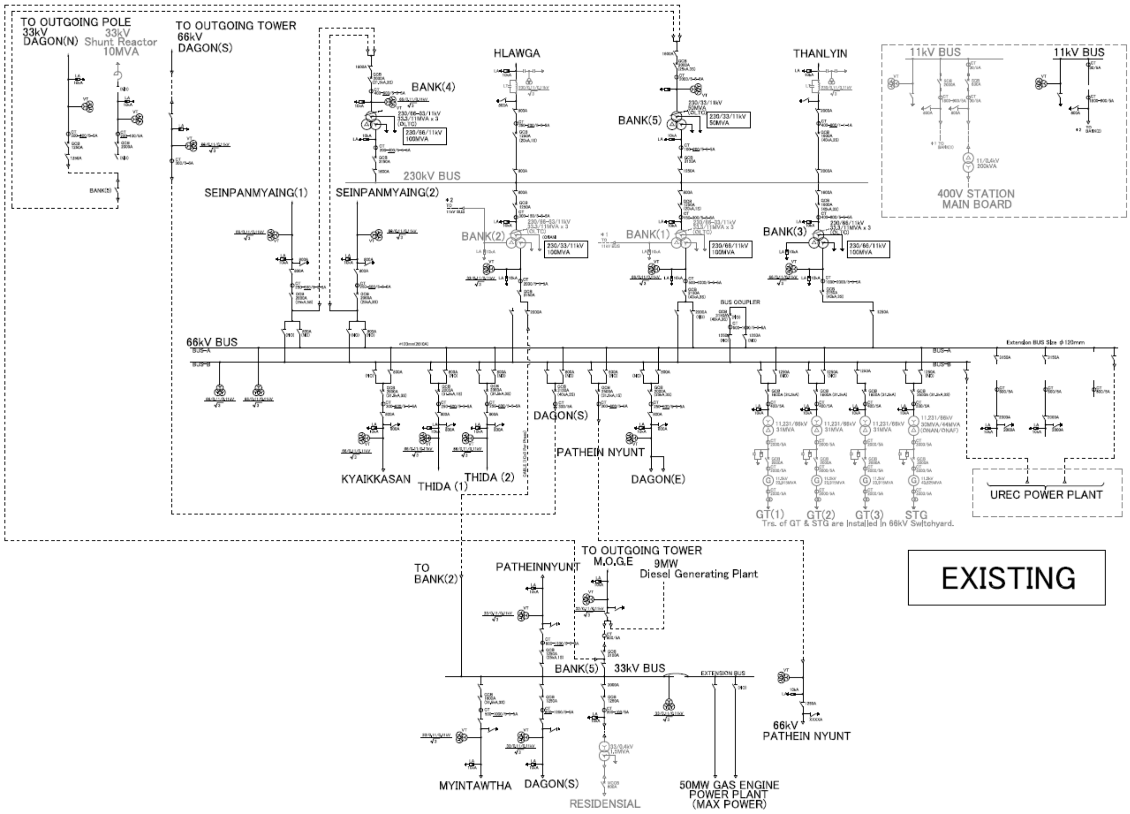
Source: JICA Survey Team

Figure 1.4-2 Single line diagram of Hlawga PS (after rehabilitation)

1.4.2. Single line diagram of the Thaketa PS

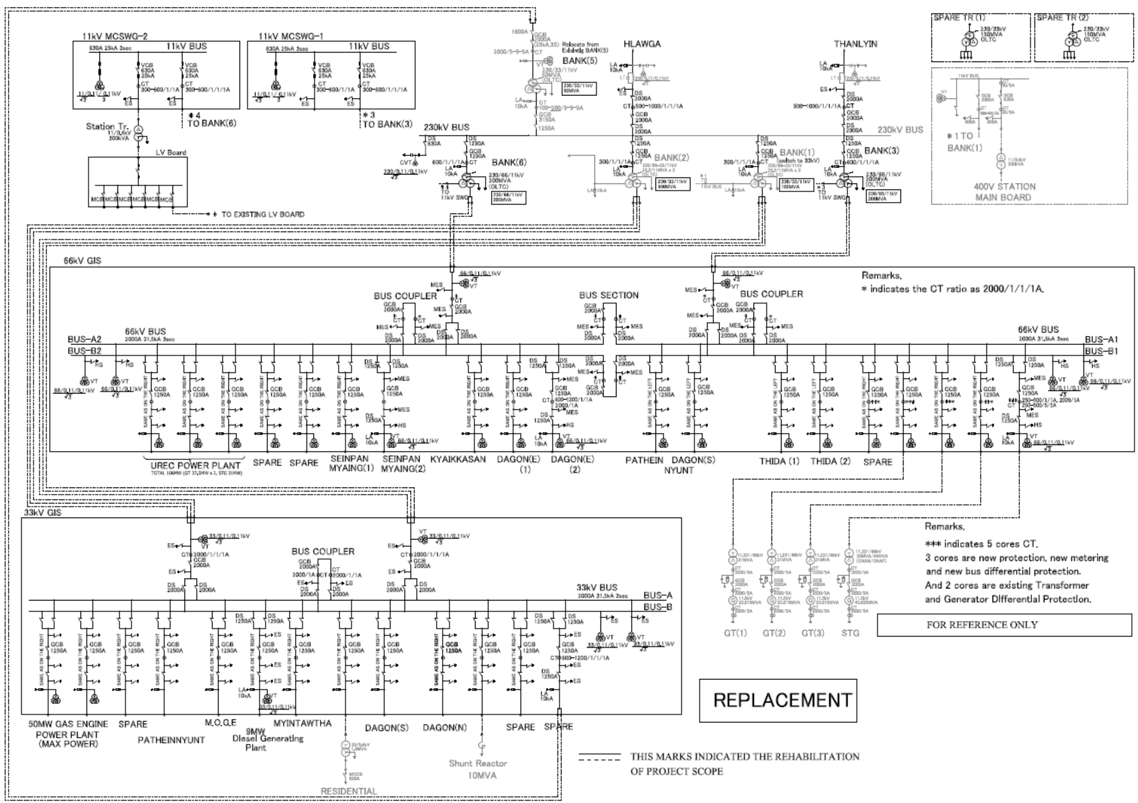
(1) Single line diagram before/after rehabilitation

At present, the urgent rehabilitation and upgrade project phase 1 (package 2) is being carried out. The single line diagram before rehabilitation is shown in Figure 1.4-3. The single line diagram after rehabilitation is shown in Figure 1.4-4.



Source: JICA Survey Team

Figure 1.4-3 Single line diagram of the Thaketa PS (before rehabilitation)



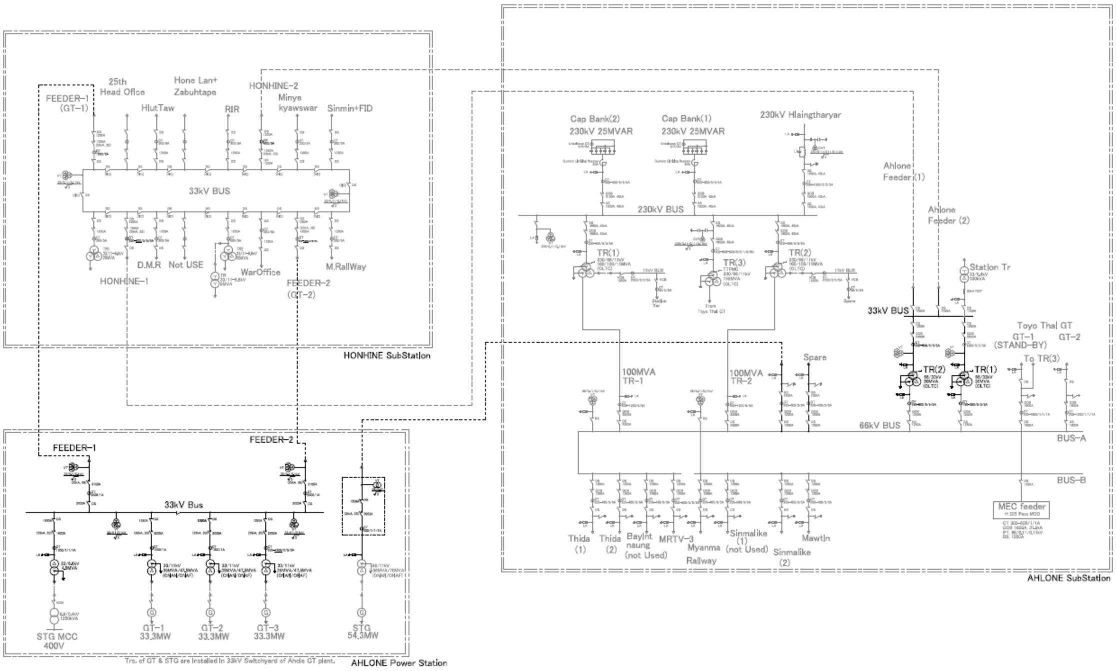
Source: JICA Survey Team

Figure 1.4-4 Single line diagram of the Thaketa PS (after rehabilitation)

1.4.3. Single line diagram of the Ahlone PS

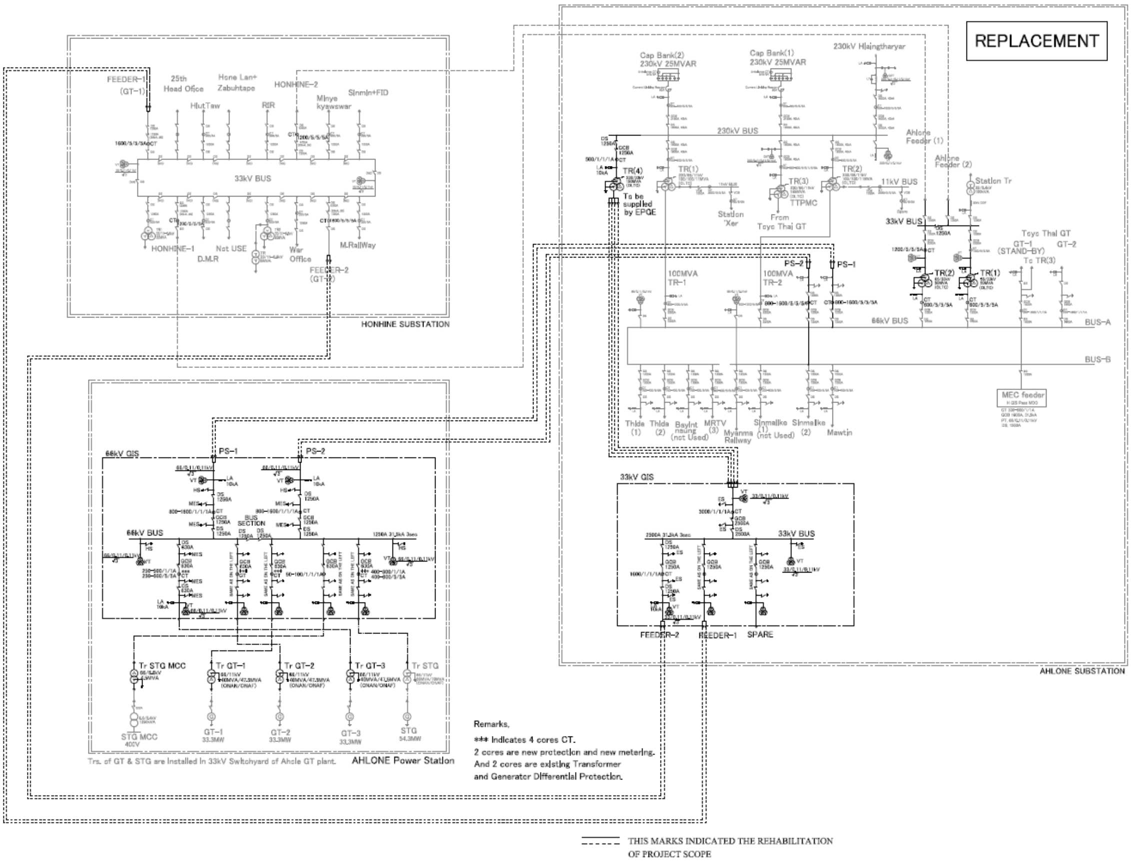
(1) Single line diagram before/after rehabilitation

At present, the urgent rehabilitation and upgrade project phase 1 (package 2) is being carried out. The single line diagram before rehabilitation is shown in Figure 1.4-5. The single line diagram after rehabilitation is shown in Figure 1.4-6.



Source: JICA Survey Team

Figure 1.4-5 Single line diagram of the Ahlone PS (before rehabilitation)



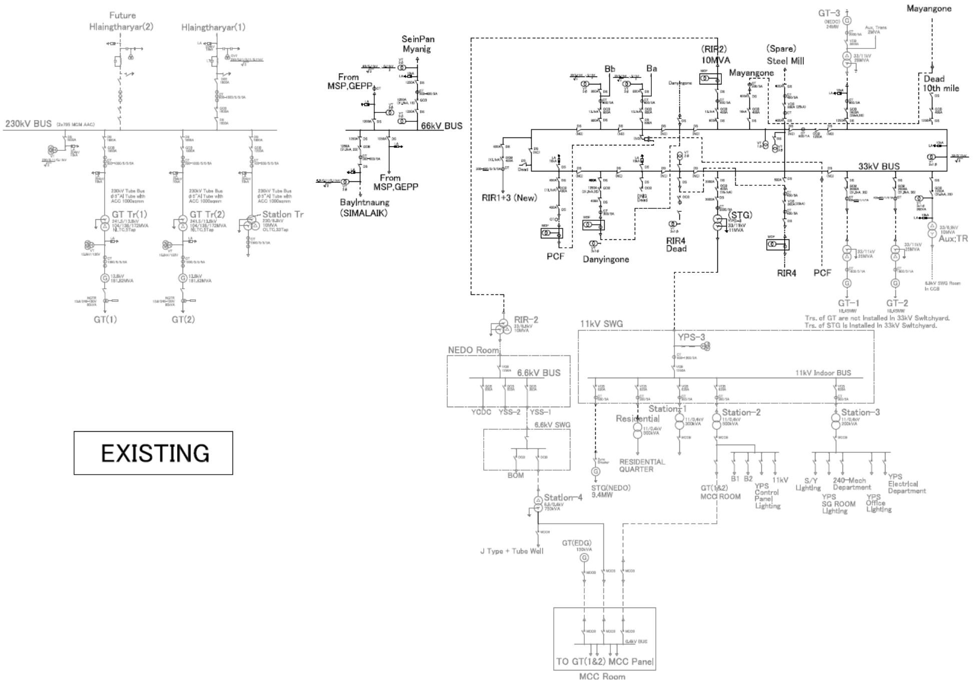
Source: JICA Survey Team

Figure 1.4-6 Single line diagram of the Ahlone PS (after rehabilitation)

1.4.4. Single line diagram of the Iwama PS

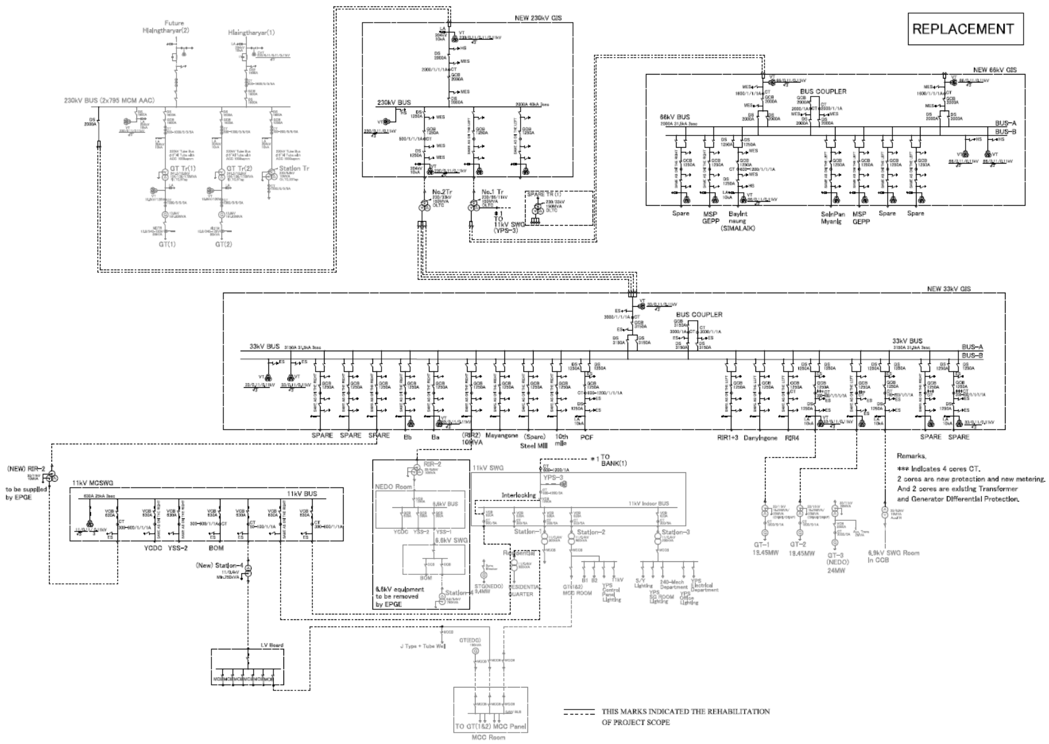
(1) Single line diagram before/after rehabilitation

At present, the urgent rehabilitation and upgrade project phase 1 (package 2) is being carried out. The single line diagram before rehabilitation is shown in Figure 1.4-7. The single line diagram after rehabilitation is shown in Figure 1.4-8.



Source: JICA Survey Team

Figure 1.4-7 Single line diagram of the Iwama PS (before rehabilitation)



Source: JICA Survey Team

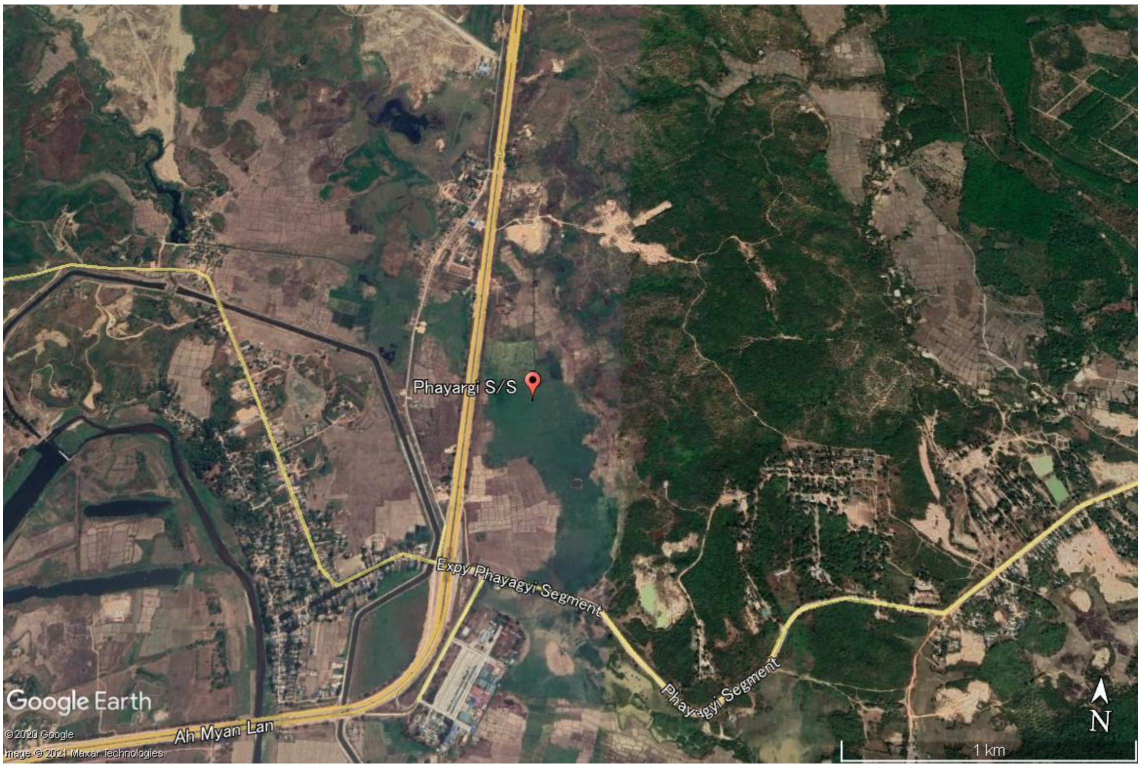
Figure 1.4-8 Single line diagram of the Iwama PS (after rehabilitation)

2. Data Collection for Construction and Expansion of Substations

2.1. 500 kV Pharyargyi Substation

2.1.1. Location

As shown in the following figure, the Pharyargyi S/S is under construction in the Phase II Project at a location of latitude 17° 28’ 35” north and longitude 96° 27’ 17” east, in Bago State.



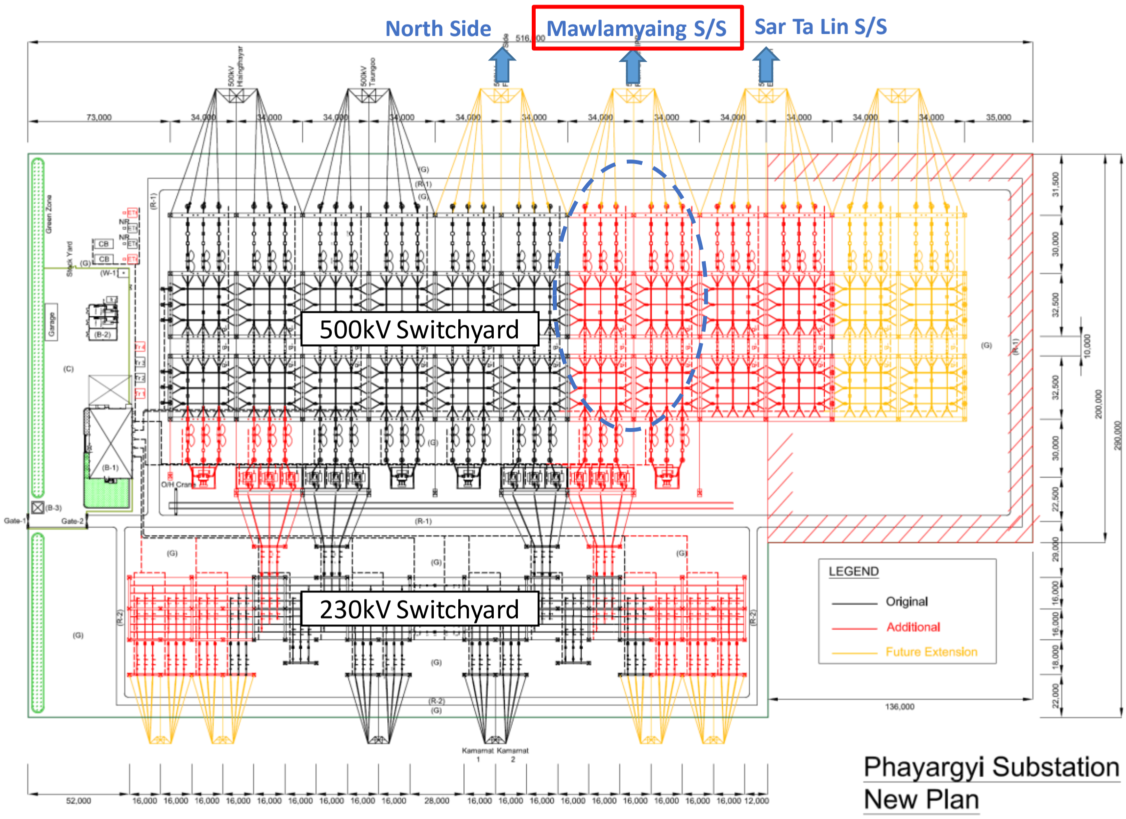
Source: JICA Survey Team using Google Earth

Figure 2.1-1 Location Map of Pharyargyi Substation

2.1.2. Layout

As stated above, the Pharyargyi substation is under construction in the Phase II Project.

In this project, the 500 kV H-GIS, 500/230 kV transformers, 500 kV shunt reactors, 230 kV switchgear (AIS) and control building are planned to be installed in an area of 516 m x 290m, as per the following figure. In addition, since the 500 kV switchgear for the transmission line to Mawlamyaing substation and associated equipment like the transmission line protection panel will also be installed in the Phase II Project, expansion of Pharyargyi substation will not be required and the scope of work in the new project will cover only the connection of the 500 kV transmission line.

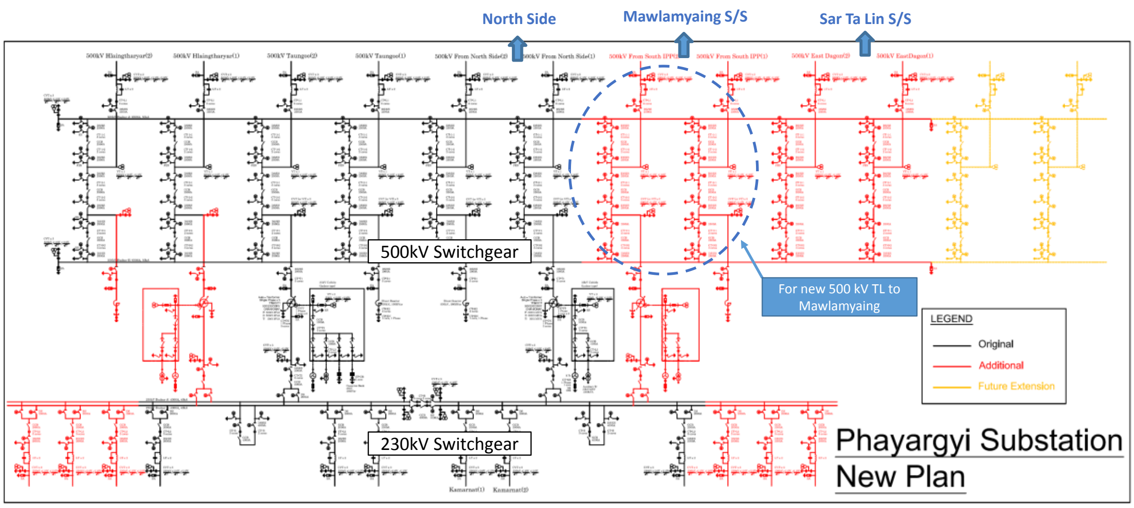


Source: Phase II Project

Figure 2.1-2 Layout of Pharyargyi Substation after Phase II Project

2.1.3. Equipment Configuration

The single line diagram for Pharyargyi substation after the Phase II Project is shown in the figure below. As per another national power transmission network development project by JICA, H-GIS with a one and a half circuit breaker system is adopted for 500 kV switchgear, and AIS with a double busbar system is adopted for 230 kV switchgear.



Source: Phase II Project

Figure 2.1-3 Single Line Diagram of Pharyargyi Substation after Phase Ⅱ Project

Table 2.1-1 Equipment Configuration of Pharyargyi Substation after Phase II Project

Facility name	Overview	Notes
500 kV Switchgear (H-GIS)	To Hlaingtharyar SS x 2 feeders To Taungoo SS x 2 feeders To North IPP x 2 feeders To Mawlamyaing SS x 2 feeders To Sar Ta Lin SS x 2 feeders Connection to 500/230 kV transformer x 4 feeders Connection to 500 kV shunt reactor x 2 feeders	1+1/2 CB system
230 kV Switchgear (AIS)	To Kamarnat 230 kV SS x 2 feeders To other 230 kV SS x 8 feeders Connection to 500/230 kV transformer x 4 feeders Bus Coupler x 2	Double Busbar System
500/230 kV Transformers	Outdoor, single phase, oil-immersed, ONAF/ONAN Capacity: 166.7 MVA/phase x 12 sets	
500 kV Shunt Reactors	Outdoor, three phase, oil-immersed x 2 sets	
Station Service Facility	AC400/230V panel, DC110V panel, DC48V panel, DC battery, EDG, station service transformer (33/0.4 kV)	
Control and Protection	SCADA, transmission line protection panel, transformer protection panel, etc.	

Source: JICA Survey Team

2.1.4. Design Outline

It is not necessary to install new substation equipment in Pharyargyi substation for the transmission line to Mawlamyaing 500 kV substation because all such equipment will be installed in the Phase I Project.

2.2. 500 kV Mawlamyaing Substation

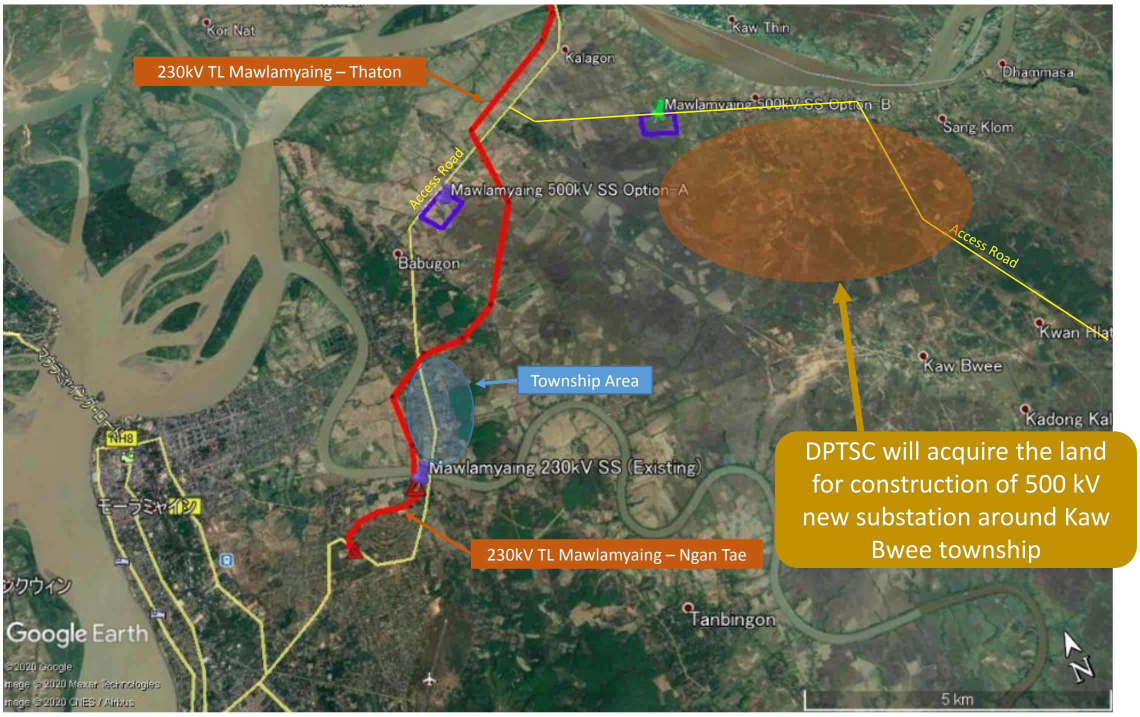
2.2.1. Location

The existing 230 kV Mawlamyaing Substation does not have enough space for the installation of new 500 kV switchgear and 500/230 kV transformer because the area dimensions of the existing substation are limited due to it facing the river on the north side.

Source: JICA Survey Team using Google Earth

Figure 2.2-1 Location Map of Mawlamyaing 230 kV Substation

Under these circumstances, it is necessary to acquire land for construction of the new 500 kV substation on the north side of the existing substation. DPTSC mentioned that the DPTSC side was in the process of selecting a 500 kV substation site near the Kaw Bwee Township. It is recommended to secure a minimum area of 400 m x 290 m for construction of the 500 kV substation, and Sar Ta Lin Substation, because the system configuration of the new 500 kV substation in Mawlamyaing will be similar to that of Sar Ta Lin Substation, which is to be constructed in the Phase III Project.



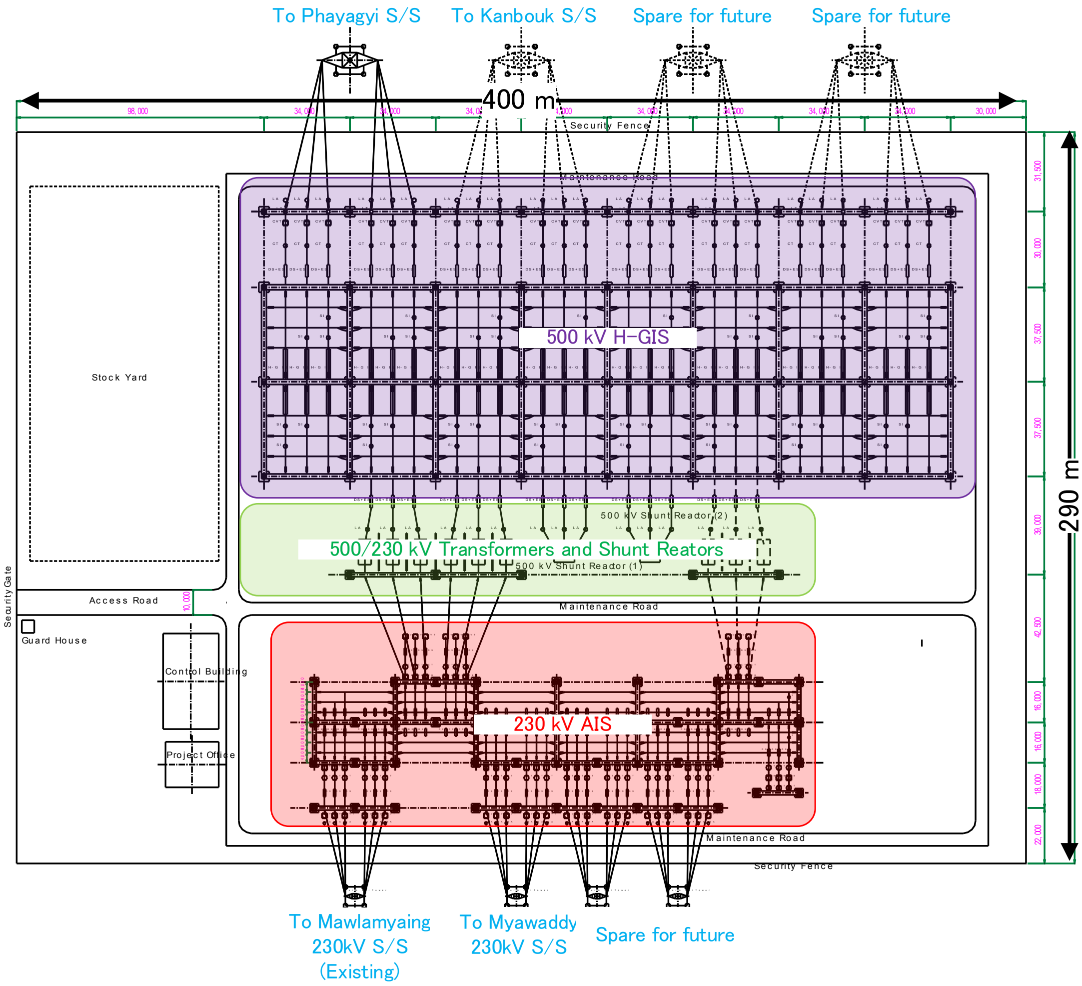
Source: JICA Survey Team using Google Earth

Figure 2.2-2 Area Map for Construction of New Malamyaing 500 kV Substation

2.2.2. Layout

The layout plan for the new Malamyaing 500 kV substation is shown in the following figure. Although it is so far unclear how much land can be secured for its construction, it is assumed that a 500 kV H-GIS with a one and a half circuit breaker system, as per other Phases by JICA, can be installed on the land acquired.

Therefore, the layout is considered to be similar to that of Sar Ta Lin Substation, having the dimensions of 400 m x 290 m, i.e. 30 Acres.



Source: JICA Survey Team

Figure 2.2-3 Layout of New Mawlamyaing 500 kV Substation

2.2.3. Equipment Configuration

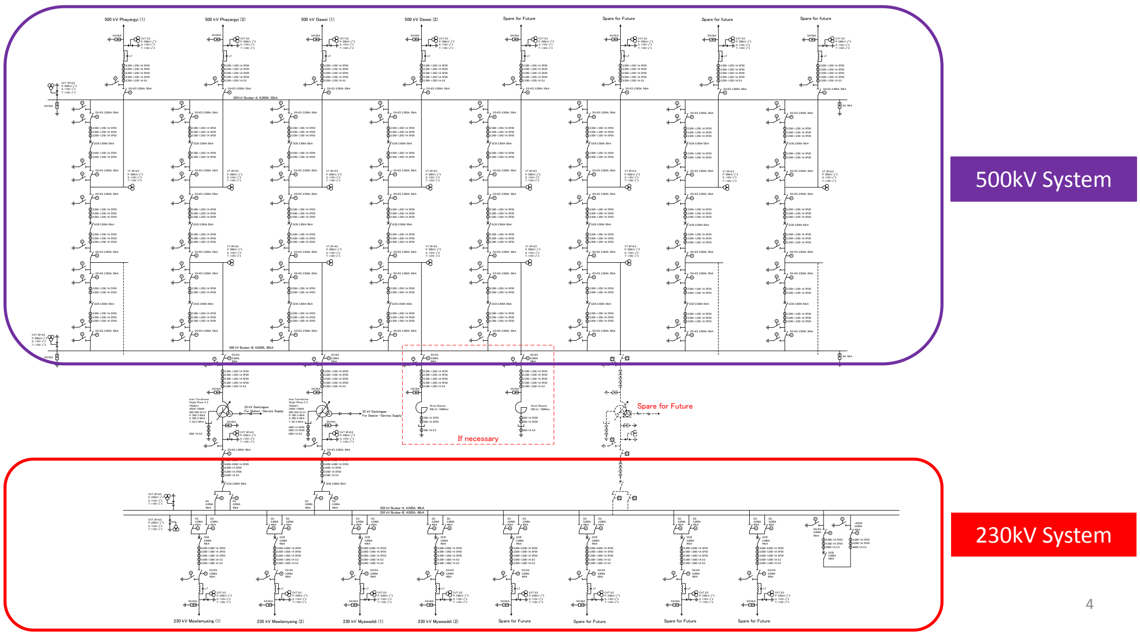
The new Mawlamyaing 500 kV substation will apply H-GIS with a one and a half circuit breaker system for 500 kV switchgear, and AIS with a double busbar system for 230 kV switchgear in reference to similar projects, such as Phase I and Phase II of the JICA project, subject to securing enough space for construction of H-GIS. Major equipment in the new Mawlamyaing 500 kV substation is shown in the following table:

Table 2.2-1 Equipment Configuration of New Mawlamyaing 500 kV Substation

Facility name	Overview	Notes
500 kV Switchgear (H-GIS)	To Pharyargyi SS x 2 feeders To Kanbouk x 2 feeders Spare for future x 4 feeders Connection to 500/230 kV transformer x 2 feeders Connection to 500 kV shunt reactor x 2 feeders	1+1/2 CB system
230 kV Switchgear (AIS)	To Mawlamyaing 230 kV SS x 2 feeders To Myawaddy 230 kV SS x 2 feeders Spare for future x 4 feeders Connection to 500/230 kV transformer x 2 feeders Bus Coupler x 1	Double Busbar System
500/230 kV Transformers	Outdoor, single phase, oil-immersed, ONAF/ONAN Capacity: 166.7 MVA/phase x 7 sets	With OLTC
500 kV Shunt Reactors	Outdoor, three phase, oil-immersed x 2 sets	
Station Service Facility	AC400/230V panel, DC110V panel, DC48V panel, DC battery, EDG, station service transformer (33/0.4 kV)	
Control and Protection	SCADA, transmission line protection panel, transformer protection panel, etc.	

Source: JICA Survey Team

The following figure shows the single line diagram plan for the new Mawlamyaing 500 kV Substation. Since this substation will be part of the national power backbone network, it is recommended to apply one and a half circuit breaker systems for 500 kV switchgear and a double busbar system for 230 kV switchgear so as to secure reliability for the system, considering coordination with other phases.



Source: JICA Survey Team

Figure 2.2-4 Single Line Diagram Plan for New Mawlamyaing 500 kV Substation

2.2.4. Design Outline

(1) Applicable Standards

The design, materials, manufacture, testing, inspection and performance of all electrical and electromechanical equipment shall comply with the latest revision of the International Electrotechnical Commission Standards (IEC), as listed below:

- IEC 60044-1 Instrument transformers – Part 1: Current transformers
- IEC 60044-1 Instrument transformers – Part 5: Capacitor voltage transformers
- IEC 60071 Insulation coordination
- IEC 60076 Power transformers
- IEC 60099-4 Surge arresters – Part 4: Metal-oxide surge arresters without gaps for a.c. systems
- IEC 60265-2 High-voltage switches – Part 2: High-voltage switches for rated voltage of 52 kV and above
- IEC 60694 Common specifications for high-voltage switchgear and control gear standards
- IEC 61850 Communication network and systems in substations
- IEC 62271-100 High-voltage switchgear and control gear – Part 100: High-voltage alternative-current circuit breakers
- IEC 62271-102 High-voltage switchgear and control gear – Part 102: Alternative-current disconnectors and earthing switches
- IEC 62271-203 High-voltage switchgear and control gear – Part 203: Gas-insulated metal -enclosed switchgear for rated voltage above 52 kV

In cases where IEC standards are not applicable to the conditions, international standards such as ANSI, ASTM, BS, JIS, JEC and JEM will be applied.

(2) Insulation Coordination

Insulation co-ordination for the design of 500 kV, 230 kV and 33 kV equipment is as follows:

(1)	Nominal system voltage	500 kV	230 kV	33 kV
(2)	Rated voltage (Highest voltage)	525 kV	245 kV	36 kV
(3)	Rated frequency	50 Hz	50 Hz	50 Hz
(4)	Insulation levels			
	Rated short-duration power frequency withstand voltage (r.m.s.)			80 kV
	Rated lightning impulse withstand voltage (peak value)	1,550 kV	750 kV	195 kV
	Minimum clearance of phase-to-earth	4,100 mm	2,100 mm	400 mm
	Standard clearance of phase-to-earth	8,000 mm	2,600 mm	500 mm
	Minimum clearance of phase-to-phase	5,400 mm	3,000 mm	600 mm
	Standard clearance of phase-to-phase	8,000 mm	4,000 mm	900 mm

(3) Equipment Procurement and Quantities

500 kV switchgear with eight bays of transmission line, two bays of main transformer having a capacity of 500 MVA per unit, two bays of 500 kV shunt reactors and 230 kV switchgears with eight bays of transmission lines, and two bays of transformers and bus coupler bays are to be installed in the new Mawlamyaing 500 kV substation.

1) 500 kV Substation Facility

i) Seven units, including spares for 500/230/33 kV, 166.7 MVA and single-phase main transformer with on-load tap changer (OLTC)

ii) Two units of 500 kV shunt reactor, 100 MVar

iii) 500 kV switchgear in one and a half circuit breaker arrangement

The 500 kV switchgear in one and a half circuit breaker scheme includes eight (8) transmission line bays and two (2) transformer bays

- 500 kV GCB 24 sets
- 500 kV DS/ES 60 sets
- 500 kV CT 60 sets
- 500 kV VT 13 sets
- 500 kV CVT 8 sets
- 420 kV SA 12 sets
- Line trap 16 sets
- 500 kV busbar 1 lot (One and a Half CB arrangement)

➢ The associated gantry structures for the above system shall be supplied and installed.

- ➢ The associated steel support structures and foundations for the above equipment with all necessary connecting materials shall be supplied and installed.
- ➢ The connection work between the dead-end towers, associated gantry structures and the above equipment shall be carried out and all necessary materials for the work, such as power conductors, tension insulator sets, fittings, post insulators, connectors, accessories, power and control cables, etc., shall be supplied and installed.
- ➢ The above equipment shall be properly earthed with underground earthing mesh and all necessary materials such as earthing conductors shall be supplied.

2) 230 kV Switchgear

i) 230 kV double busbar scheme switchgear

The 230 kV double busbar scheme includes eight (8) transmission line bays, two (2) transformer bays and one (1) bus coupler bay.

-	230 kV GCB	11 sets
-	230 kV DS/ES	10 sets
-	230 kV DS	20 sets
-	230 kV CT	11 sets
-	230 kV CVT	12 sets
-	196 kV SA	10 sets
-	Line trap	16 sets
-	230 kV busbar	1 lot (Double busbar scheme)

- ➢ The associated gantry structures for the above system shall be supplied and installed.
- ➢ The associated steel support structures and foundations for the above equipment with all necessary connecting materials shall be supplied and installed.
- ➢ The connection work between the dead-end towers, associated gantry structures and the above equipment shall be carried out and all necessary materials for the work, such as power conductors, tension insulator sets, fittings, post insulators, connectors, accessories, power and control cables, etc., shall be supplied and installed.
- ➢ The above equipment shall be properly earthed with underground earthing mesh and all necessary materials such as earthing conductors shall be supplied.

3) Installation of Control and Protection panels

<u>Protection relay panels</u>

-	Main transformer protection relay panel	2 panels
-	500 kV shunt reactor protection relay panel	2 panels
-	500 kV transmission line protection relay panels	8 panels
-	500 kV busbar protection relay panels	2 panels
-	230 kV transmission line protection relay panels	8 panels
-	230 kV busbar protection relay panels	2 panels

Control panels

- Main transformer primary side control panel 2 panels
- Main transformer OLTC panels 2 panels
- 500 kV shunt reactor control panel 2 panels
- 500 kV transmission line control and synchronizing panel 8 panels
- 230 kV transmission line control and synchronizing panel 8 panels

SCADA (SAS)

- Remote control and monitoring system 1 lot

➢ The associated power and control cables with necessary accessories shall be supplied and installed.

➢ All necessary meters, including ammeters, voltmeters and watt-hour meters, etc., shall be supplied and installed.

➢ SCADA system shall be designed with control, monitoring and measuring of 500 and 230 kV switchyard, 500/230/33 kV main transformers, 500 kV shunt reactors and 33 kV switchgear

4) Installation of communication equipment

The following optical-fiber telecommunication equipment shall be supplied and installed.

- Optical distribution frame (ODF) for connection and 24 core optical fiber cable
- Patch cables connecting ODF with synchronous transport module -1 (STM-1) and multiplexer
- Supply STM-1 and multiplexer with multi channels of not less than 2 Mbit/s interface.
- Optical fiber splicing boxes (i.e., for termination of OPGW on the steel gantry structure in the substation)

5) Miscellaneous electrical equipment

- Indoor type 500 kVA auto start module type diesel generator set with associated switchgear, power cables and fuel tank
- 400 V AC distribution switchboard equipped with double-throw breaker including necessary cables and accessories
- 110 V DC system including two sets of 110 kV battery banks, two sets of chargers, and one set of distribution boards
- 50 V DC system including two sets of 50 V batteries, two sets of chargers, and one set of distribution board
- Earthing system covering the new substation area, including earthing rods, conductors, etc.
- Overhead substation shield wire system, including shield wires and supporting structures for protection against lightning
- Outdoor substation lighting system

6) Civil and building work

The associated civil and building work for the above work shall be carried out as follows:

- Cleaning, cutting, filling, leveling and compacting of the new substation area
- Excavation and backfilling as required

- Gravelling of the complete additional substation area
- Construction of external security fences
- Construction of station service road
- Construction of gantries for 500 kV and 230 kV switchyards
- Construction of steel structures and equipment support
- Construction of concrete foundations for all equipment
- Construction of oil pit from main transformers and shunt reactors
- Construction of drainage pit and conduit
- Construction of cable pit
- Construction of a complete substation control building with control room, 33 kV cubicle room, office, workshop, storage room, battery room, kitchen, toilet, etc.
- Construction of guard house for security personnel beside the main gate
- Supply and installation of air conditioning and ventilation equipment for the substation building
- Supply and installation of water well and storage facility, and wastewater and septic tank facility
- Supply and installation of firefighting equipment associated with air conditioning system for the control building
- All necessary materials for the above work, such as concrete, aggregate, reinforcements, accessories, etc., shall be supplied.

6) Other work

- Spare parts for at least 5 years of operation
- Tools and erection accessories as required
- Complete documentation for operation and maintenance
- Training for DPTSC staff at manufacturer's factory and at site

(4) Specifications of Major Equipment

1) 500/230/33 kV Main Transformer

i) Type

Single-phase, oil-immersed type, outdoor and ONAN/ONAF cooling type with on-load-tap changing device, designed in accordance with IEC 60076 and 60289.

ii) Ratings

Rated voltage	500 kV
Rated	100 MVA
Rated frequency	50 Hz
Rated insulation level at HV side (LI&PF)/current	To be determined in Final Report

3) Gas Insulated Switchgear

i) Type

The GIS or H-GIS shall be metal-enclosed, three-phase busbar and switchgear type, for outdoor use, and filled with SF6 insulation gas.

ii) Circuit breaker

Rated voltage	500 kV
Rated main busbar normal current	6,000 A
Rated feeder normal current	2,500 A
Rated frequency	50 Hz
Rated short-circuit breaking current	40 kA, 1 sec.
Rated interrupting time	less than or equal to 3 cycle
Rated operating sequence	O - 0.3 sec. - CO - 3 min. - CO
Rated closing operation voltage	DC 110 V
Rated control voltage	DC 110 V
Rated insulation level a) Rated short-duration power-frequency withstand voltage (r.m.s. value) b) Rated lightning impulse withstand voltage (peak value)	 750 kV 1,550 kV

The circuit breakers shall be suitable for single-pole tripping and rapid auto-reclosing, provided with a motor-operated spring mechanism, and shall comply with the related IEC standards/recommendations.

The circuit breakers shall be equipped with an operation mechanism for DC and the mechanism shall ensure uniform and positive closing and opening.

iii) Disconnectors and earthing switches

Rated voltage	500 kV
Rated normal current	2,500 A
Rated frequency	50 Hz
Rated short-circuit withstand current	40 kA, 1 sec.
Rated control voltage	DC 110 C
Rated insulation level a) Rated short-duration power-frequency withstand voltage (r.m.s. value) b) Rated lightning impulse withstand voltage (peak value)	 750 kV 1,550 kV

The disconnectors and earthing switch shall both be motor-operated and provided with a manual operating mechanism.

Motor-operated disconnectors and earthing switch shall be designed with three-pole operation and the motor shall be operated on DC auxiliary power.

iv) Current transformer

Highest system voltage	525 kV
Rated frequency	50 Hz
Rated insulation level a) Rated short-duration power-frequency withstand voltage (r.m.s. value) b) Rated lightning impulse withstand voltage (peak value)	 750 kV 1,550 kV
Rated current ratio	2,500-1,250 A : 1 A (TL and busbar) 1,000A : 1A (SS)
Accuracy classes	5P20 for protection, Class 0.2 for metering

v) Voltage transformer

Highest system voltage	525 kV
Rated frequency	50 Hz
Voltage ratio	$\frac{500\ kV}{\sqrt{3}} : \frac{110\ V}{\sqrt{3}} : \frac{110\ V}{\sqrt{3}}$
Accuracy classes	3P+0.5

Rated insulation level a) Rated short-duration power-frequency withstand voltage (r.m.s. value) b) Rated lightning impulse withstand voltage (peak value)	 750 kV 1,550 kV

4) Air Insulated Switchgear

i) Circuit breaker

The 230 kV circuit breakers shall be SF6 gas type, with three-pole collective arrangement and for outdoor use. The circuit breakers shall be suitable for single-pole tripping and rapid auto-reclosing, provided with a motor-operated spring mechanism, and shall comply with the related IEC standards/recommendations.

Rated voltage	230 kV
Rated feeder normal current	2,000 A
Rated frequency	50 Hz
Rated short-circuit breaking current	40 kA, 1 sec.
Rated interrupting time	less than or equal to 3 cycle
Rated operating sequence	O - 0.3 sec. - CO - 3 min. - CO
Rated closing operation voltage	DC 110 V
Rated control voltage	DC 110 V
Rated insulation level a) Rated short-duration power-frequency withstand voltage (r.m.s. value) b) Rated lightning impulse withstand voltage (peak value)	 395 kV 750 kV

The circuit breakers shall be equipped with an operation mechanism for DC power, motor operated and with a manual handle and the mechanism shall ensure uniform and positive closing and opening.

ii) Disconnectors and earthing switches

The 230 kV disconnectors shall be three-phase, two-column, rotary and center air break type with horizontal operation. Earthing switches shall be triple-pole, single-throw, vertical single break and manual three-phase group operation type.

The disconnectors and earthing switches shall be suitable for outdoor use. The earthing switches shall be mounted on the disconnectors whenever necessary and where specified.

Rated voltage	230 kV
Rated normal current	2,000 A
Rated frequency	50 Hz
Rated short-circuit withstand current	40 kA, 1 sec.
Rated control voltage	DC 110 C
Rated insulation level a) Rated short-duration power-frequency withstand voltage (r.m.s. value) b) Rated lightning impulse withstand voltage (peak value)	 395 kV 750 kV

The disconnectors shall be motor-operated and provided with a manual operating mechanism with a hand crank. The earthing switch shall be provided with a manual operating mechanism.

Motor-operated disconnectors shall be designed with three-pole operation and the motor shall be operated on DC power.

iii) Current transformer

The 230 kV current transformers shall be single-phase, porcelain-insulated, oil-immersed and air-tight sealed post insulator type, for outdoor use and shall be designed in accordance with IEC 60044-1.

Highest system voltage	230 kV
Rated frequency	50 Hz
Rated insulation level a) Rated short-duration power-frequency withstand voltage (r.m.s. value) b) Rated lightning impulse withstand voltage (peak value)	 750 kV 1,550 kV
Rated current ratio	4,000-2,000 A : 1 A(TL) 2,000-1,000 A : 1 A(TL) 4,000 A : 1 A (Busbar) 2,500-1,250 A : 1 A (SS) 1,000A : 1A (SS)
Accuracy classes	5P20 for protection, Class 0.2 for metering

iv) Capacitor Voltage transformer

The 500 and 230 kV voltage transformers shall be single-phase, capacitor type and shall be designed in accordance with IEC 60044-5.

Highest system voltage	525 kV	245 kV
Rated frequency	50 Hz	
Voltage ratio	$\frac{500\,kV}{\sqrt{3}}:\frac{110\,V}{\sqrt{3}}:\frac{110\,V}{\sqrt{3}}$	$\frac{230\,kV}{\sqrt{3}}:\frac{110\,V}{\sqrt{3}}:\frac{110\,V}{\sqrt{3}}$
Accuracy classes	3P+0.5	
Rated insulation level a) Rated short-duration power-frequency withstand voltage (r.m.s. value) b) Rated lightning impulse withstand voltage (peak value)	 750 kV 1,550 kV	 395 kV 750 kV

v) Surge Arresters

The 420 and 196 kV surge arresters shall be gapless, metal-oxide, outdoor and heavy duty type. The arresters shall be designed in accordance with IEC 60099-4.

Rated voltage (r.m.s. value)	420 kV	196 kV
Rated frequency	50 Hz	
Nominal discharge current	10 kA	10 kA
Long-duration discharge class	Class 3 (Table-5, IEC 60099-4)	
Pressure-relief current	40 kA	
Rated insulation levels for insulators a) Rated short-duration power-frequency withstand voltage (r.m.s. value) b) Rated lightning impulse withstand voltage (peak value)	 750 kV 1,550 kV	 395 kV 750 kV

2.3. Cost Estimate for Substation

It is assumed that the construction costs for the new Mawlamyaing 500 kV substation will be similar to those of Sar Ta Lin substation, which is to be constructed in Phase III. Therefore, the total price for construction of the new Mawlamyaing 500 kV substation will be about 104 MUSD, in reference to the quantity of equipment and work estimated above, subject to the unit prices for each piece of equipment being the same as those for Sar Ta Lin substation.

3. Data Collection for Transmission Route

3.1. Study for Transmission Route Selection

3.1.1. Methods for Transmission Route Selection

The JICA team performed a desk study for the 500 kV transmission route between Pharyargyi and Mawlamyaing with a route map, using Google Earth and other tools. The transmission line route map was drawn after discussion with C/Ps.

The JICA team confirmed that the Categories to Note (Table 3.1-1) included conservation forest, sanctuary areas, large-scale rivers, etc.

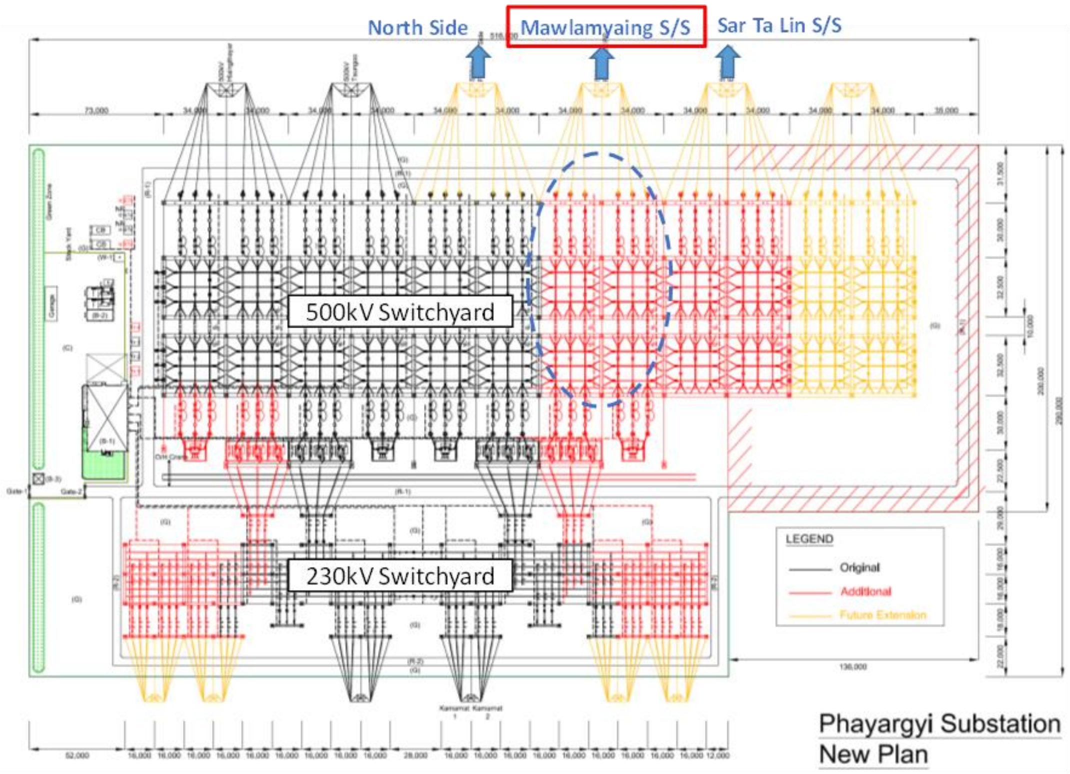
Table 3.1-1 Categories to Note for Transmission Line Construction

General categories representing an obstacle	- National parks: Avoidance in terms of environmental and social considerations - Large-scale rivers: Understanding the possibility of long spans - Extra-high voltage transmission lines - Expressways, major roads - Railroads - Housings/Dwellings: Avoidance and reducing the amount of inhabitant relocation - Cultural assets: Avoidance in terms of environmental and social considerations - Religious facilities/cemeteries and Local community facilities: Avoidance in terms of environmental and social considerations
Individual categories in Myanmar representing an obstacle	- Military facilities/sites: Avoiding military facilities, which are widely distributed and have large site areas in Myanmar - Rubber forests and Mango Gardens: Necessity of avoidance to reduce RoW compensation due to high asset value - Teak forest: Necessity of avoidance to reduce RoW compensation because it constitutes a major part of commercial forest in Myanmar
Categories representing an obstacle for overhead lines	- Areas of weak soil: The foundation support layers in weak areas such as river basins are to be confirmed via visual inspection and geological investigation - Weir areas: Confirmation of weir water level (for examination of foundation configuration) - Roads: Access methods at construction stage, necessity of temporary construction and maintenance methods after construction

Source: JICA survey team

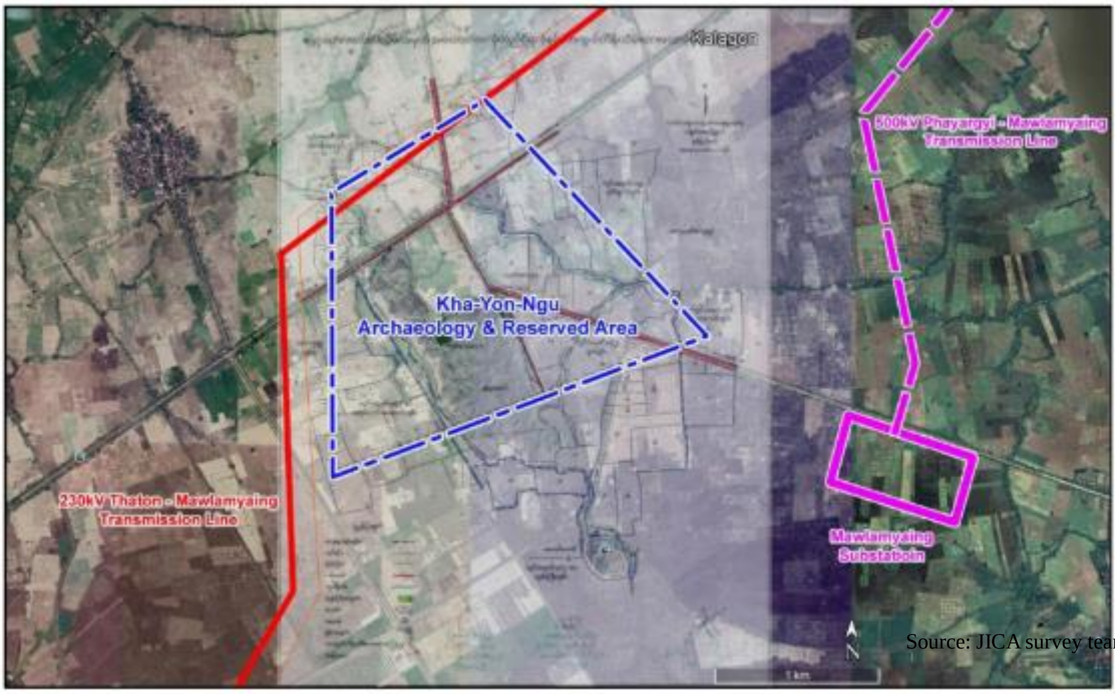
3.1.2. Location of Substations

The target substations for this project are the 500 kV Pharyargyi substation, under construction in the Phase II project, and the new 500 kV Mawlamyaing substation. The base 500 kV Pharyargyi substation (Figure 3.1-1) is about 90 km north of Yangon city. The location of the new 500 kV Mawlamyaing substation (Figure 3.1-2), determined after discussion with C/Ps, is about 170 km southeast of the Pharyargyi substation in a straight line. There is a Kha-Ngu cultural heritage site near the Mawlamyaing substation.



Source: DPTSC

Figure 3.1-1 500 kV Pharyargyi Substation (Under construction)



Source: JICA survey team

Figure 3.1-2 New 500 kV Mawlamyaing Substation

3.1.3. Transmission Route

(1) Overview of Transmission Route

An overview of the 500 kV transmission route between the Pharyargyi substation and the Mawlamyaing substation is shown in Figure 3.1-3. The transmission route is based on the following points.

✓ The shortest distance between substations

✓ Easy to secure access road during construction (South route of the existing 230 kV Kamarnut—Thaton— Mawlamyaing/North route of the future 230 kV Kamarnut— Mawlamyaing)

The existing transmission route of 230 kV Kamarnut-Thaton-Mawlamyaing is detoured to the north side before Mawlamyaing in order to link with the Thaton substation, but the study team proposes the shortest route to avoid the Kalamataung protection forest (Fig 3.1-4).

Source: JICA survey team

Figure 3.1-3 Overview Map of the 500 kV Transmission Route

The legend for Figure 3.1-3 is shown below.

- (red) ; New 500 kV Phayargyi—Mawlamyaing (DC 211km)
- (blue) ; Existing 230 kV Kamarnut—Thaton— Mawlamyaing (SC)
- (green) ; Future 230 kV Kamarnut— Mawlamyaing
- (purple) ; Existing 230 kV Tharyargone — Kamarnet (DC)
- (light blue) ; Existing 230 kV Tharyargone—Hlawgar (SC)
- (cyan) ; Existing 66kV Zaungtu—Kamarnet (SC)

(2) Facility Crossings to Note

Facility crossings to note for the 500 kV transmission route between the Pharyargyi substation and the Mawlamyaing substation are shown in Table 3.1-2.

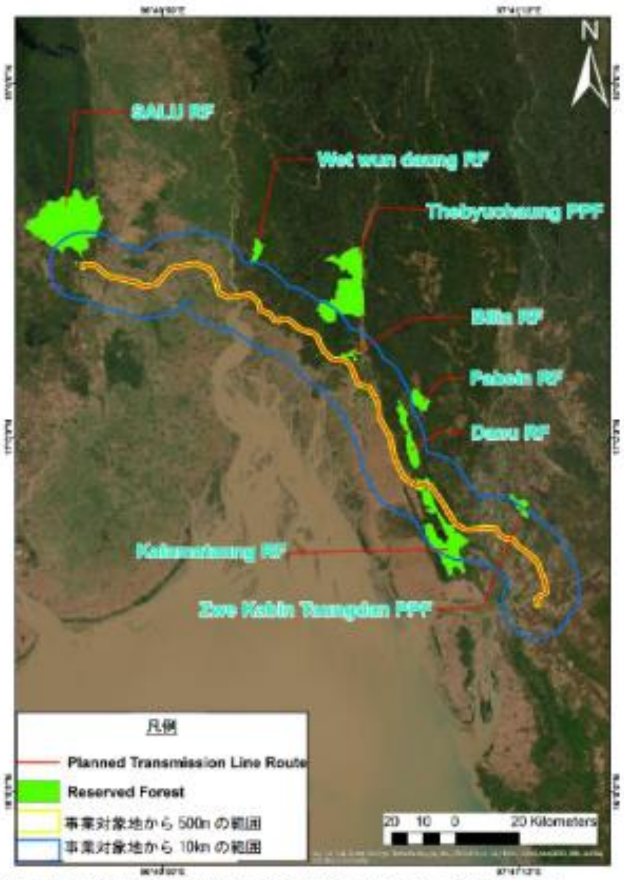
Table 3.1-2 Facility Crossings to Note

Facility Name	Number of Crossings
230 kV Transmission Line	4
66 kV Transmission Line	2
Expressways, major roads	15
Railroads	5
Large-scale rivers	7

Source: JICA survey team

(3) Reserved Forests near the Transmission Route

Rsereved forests near the transmission route are shown in Figure 3.1-4. Details on conservation forests are given in section “4.1 Environmental considerations”. The study team proposes a transmission route that avoids conservation forests.



Source: JICA survey team

Figure 3.1-4 Reserved Forests

(4) Protected Areas near the Transmission Route

Protected areas near the transmission route are shown in Figure 3.1-5. Details on protected areas are given in section “4.1 Environmental considerations”. The study team proposes a transmission route that avoids protected areas.

The closest approach is to the Kelatha Wildlife Sanctuary, near Taung Sun Town on the transmission line route, but a distance of 2.7km can be secured.

Source: JICA survey team

Figure 3.1-5 Protected Areas

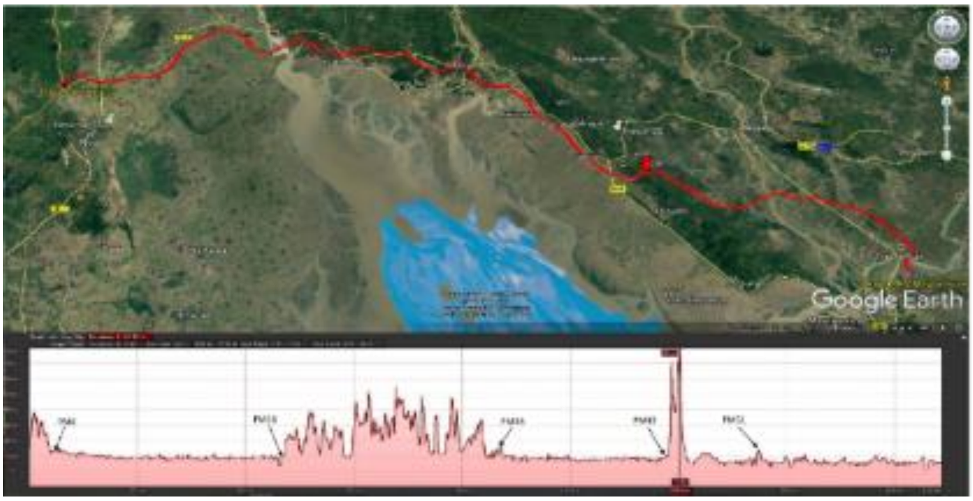
(5) Longitudinal Overview of the Transmission Route

A Longitudinal Overview of the transmission route is shown in Figure 3.1-6.

Most of the transmission route is flat land with an altitude of 5m to 10m. However, the following three places are plateaus and mountainous areas with relatively hard strata.

Hereinafter PM "number" shows the position number of the horizontal alignment break point of the transmission line route, and EL shows the altitude.

1) Near Pharyargyi S/S (PM1~PM4) EL15m~ EL37m
2) Between Sittaung River and south of Bilinmintown (PM18~PM36) EL10m~ EL54m
3) Between south of Thatontown to north of Yay Twn Gone town (PM43~PM51) EL5m~ EL80m



Source: JICA survey team

Figure 3.1-6 Longitudinal Overview map of the Transmission Route

3.2. Study on Soil Conditions of the Transmission Route

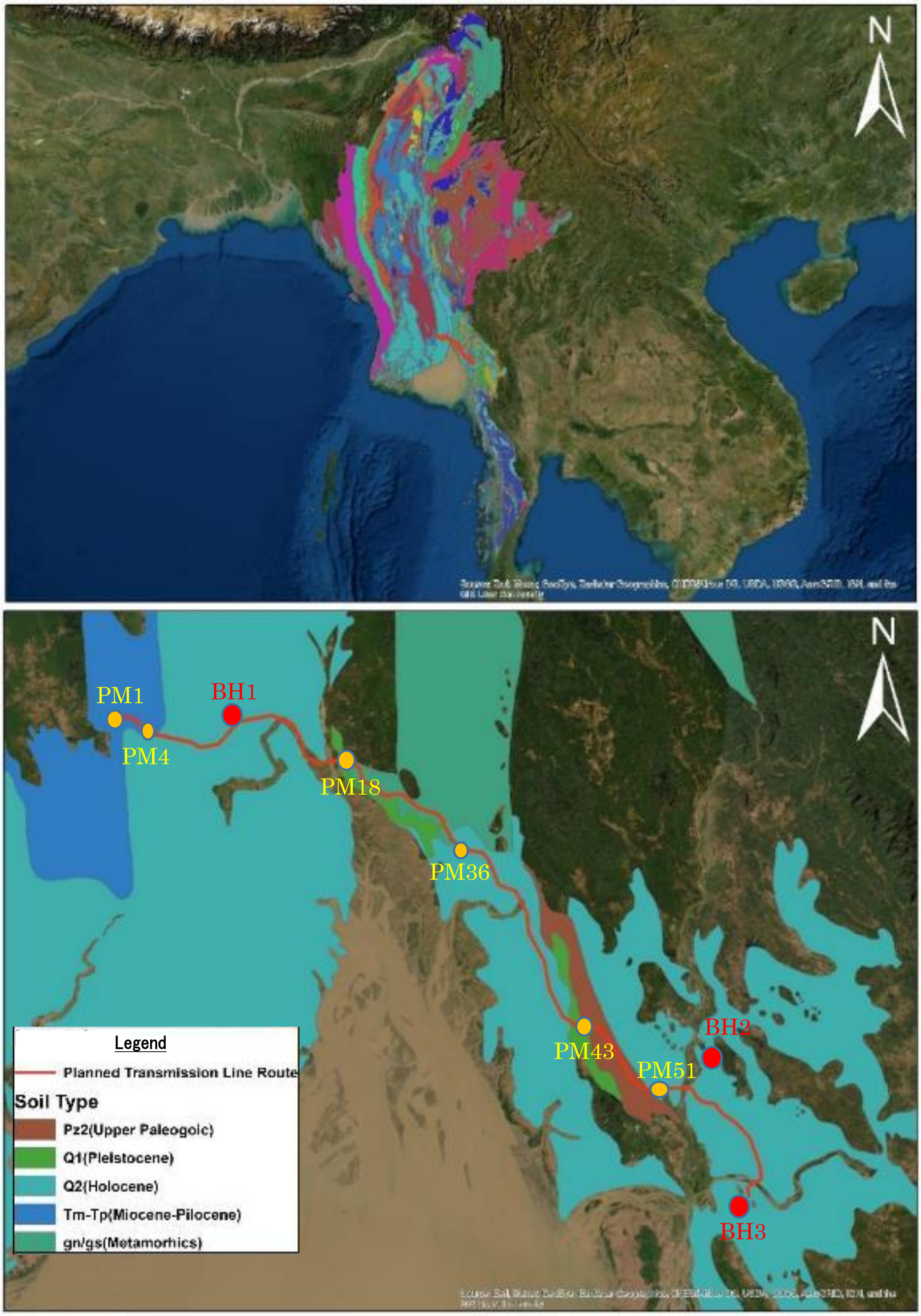
3.2.1. Geology of the Transmission Route

The 500 kV transmission route between the Pharyargyi substation and the Mawlamyaing substation runs from the Myanmar central belt through the Shan Plateau to the Mongok metamorphic belt. A Geological Overview of the transmission route is shown in Table 3.2-1 and Figure 3.2-1. About 70% of the transmission route is on relatively soft and new alluvium Q2 (Holocene). Alluvium is the river terrace deposit of older alluvium and mainly consists of sand, silt, clay and some gravel. The three locations - near Phayargi S/S, between the Sittaung River and south of Bilinmintown, and between the south of Thatontown to the north of Yay Twn Gone town - are on the hard layers of the Irrawaddy and Kathabung layers older than the Pleistocene. The Irrawaddy Formation is the continental and marginal marine deposits of the Miocene – Pliocene belonging to the Irrawaddy Formation. The Kathabung Formation contains metamorphic schist and gneiss.

Table 3.2-1 Geological Overview of the Transmission Route

Geological Name	Surface Stratum	GEO ID	Geological Time	Geological Formation	Stratum	Sedimentary Environment
Myanmar Central Belt	Irrawaddy Delta	Q2	Holocene	Alluvial Fm	Silt, Clay, Sand, Gravel	Recent deposition
		Q1	Pleistocene	Irrawaddy Fm.	Sandstone, Older alluvium and gravels, schist and gneisses	Fluvial
Shan Plateau		Tm-Tp	Miocene-Pliocene	Irrawaddy Fm.	Sedimentary rocks	Eastern Range
		Pz2	Upper Paleozoic	-	Carboniferous-Permian: Plateau limestone	Shallow water
Mogok Metamorphic Belt	Sagaing fault and the west of Shan plateau	gn/gs	Miocene	Kathabung Fm.	Schist, Gneisses	Sedimentary, Igneous

Source: Data from the Geology of Myanmar Website



Source: JICA survey team based on Geology Department information

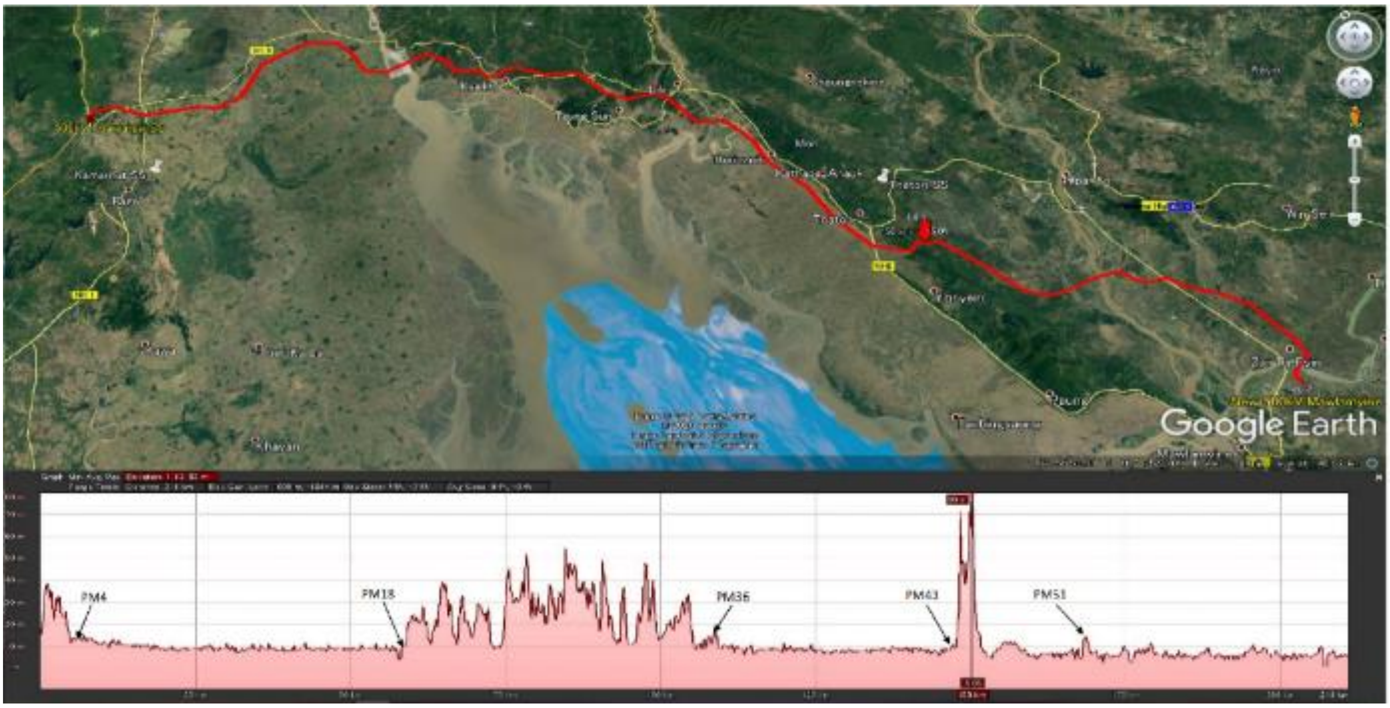
Figure 3.2-1 Geological Overview map of the Transmission Route

3.2.2. **Soil Conditions of the Transmission Route**

The foundations for the overhead transmission line are assumed to be pile foundations, because most of the transmission routes are on the Alluvium, which is relatively new and soft soil. The locations of the three borehole logs (BH1, BH2 and BH3) obtained in the soil literature survey for this project are shown in Figure 3.2-1. The following three places are plateaus and mountainous areas with relatively hard strata (Figure 3.2-2).

1) Near Phayargi S/S (PM1~PM4) EL15m~ EL37m
2) Between Sittaung River and south of Bilinmintown (PM18~PM36) EL10m~ EL54m
3) Between south of Thatontown to north of Yay Twn Gone town (PM43~PM51) EL5m~ EL80m

The JICA team assumed the geological conditions encountered in the literature survey for the transmission route, but the conducting of geological surveys on-site will be required to get more accurate information for the basic design in the future.



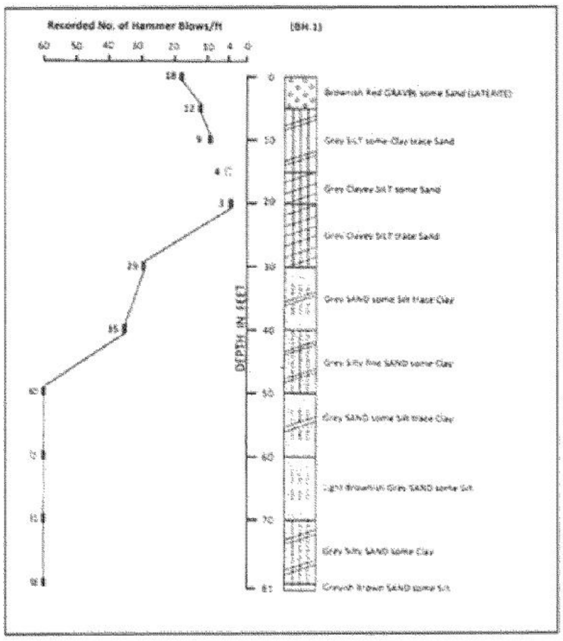
Source: JICA survey team

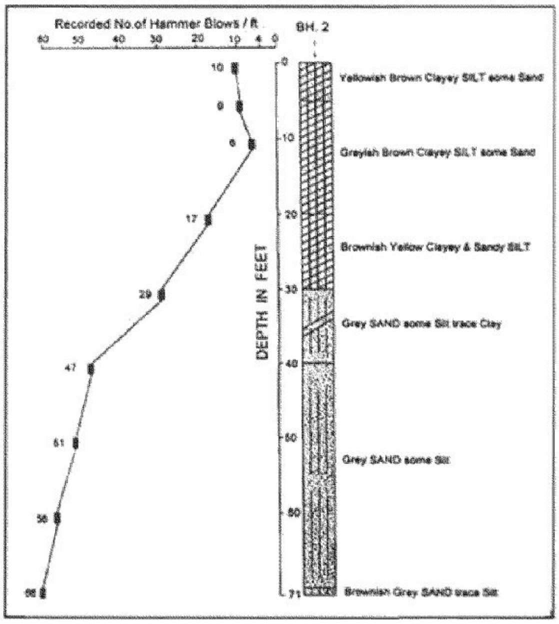
Figure 3.2-2 Longitudinal Overview map of the Transmission Route

Three boring logs for soft soil areas obtained in the soil literature survey for this project are shown in Figure 3.2-3~Figure 3.2-5.

Waw Township
Waw Bridge
BH No. 389

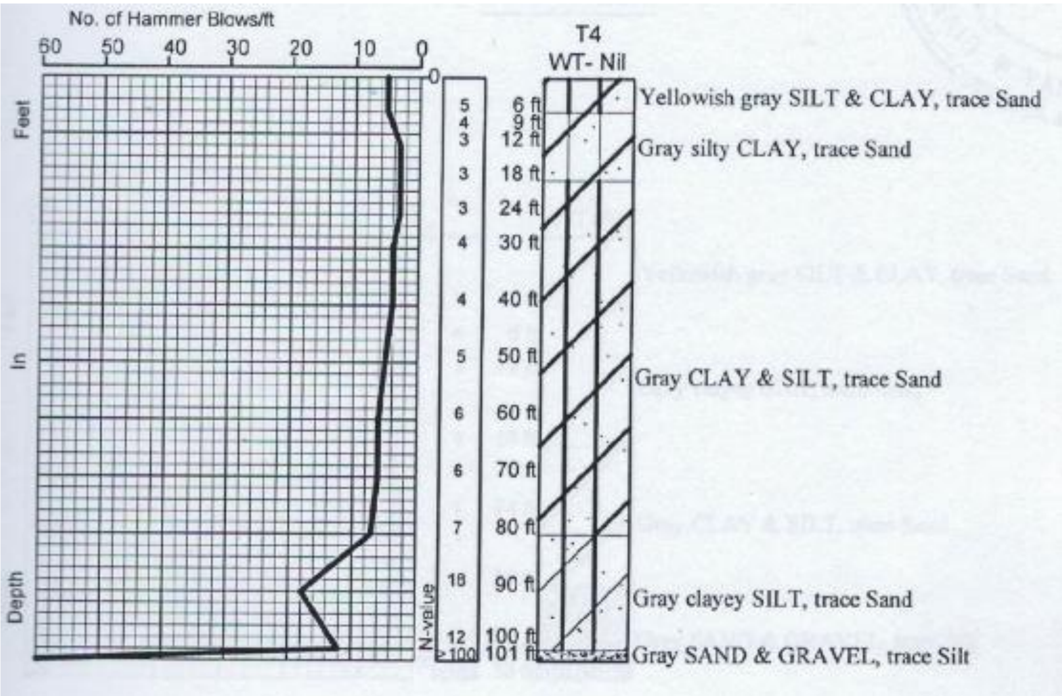
Hpa An Township
Aye Chan Tha Bridge(Bridge No-1/1)
BH No. 82





Source: Data from the Geology of Myanmar Website

Figure 3.2-3 Boring Log B1 (Waw) **Figure 3.2-4 Boring Log B2 (Hpa An)**



Source: Data from the Geology of Myanmar Website

Figure 3.2-5 Boring Log B3 (Mawlamyaing)

(1) Soil Conditions for Pile Foundations

The concept for the supporting layer of pile foundations is in accordance with the Basic Design in "500 kV TRANSMISSION LINE BETWEEN PHAYARGYI AND HLAING THARYAR FOR NATIONAL POWER TRANSMISSION NETWORK DEVELOPMENT PROJECT PHASE I". A supporting layer should be a clay layer for which the N-value is 20 or more, or a sand layer, gravel or rock for which the N-value is 30 or more.

The deepest supporting layer is B3 (Mawlamyaing) based on the boring logs shown in Figure 3.2-3 to Figure 3.3-5, and the depth is more than 100 feet (30.5m).

The depth of the support layer in this outline study is assumed to be 33.0 m considering the safety aspect, per the concept in the "National Power Transmission Network Development Project Phase III". However, the conducting of geological surveys on-site will be required to get more accurate information for the basic design in the future.

(2) Soil Conditions for Pad and Chimney Foundations

The following three places are plateaus and mountainous areas with relatively hard strata, the Irrawaddy or Kathabung layers older than the Pleistocene (Figure 3.2-2). Since most of the hard layers are Irrawaddy layers, the Kathabung layer is also considered to be equivalent to the Irrawaddy layer in this outline study.

1) Near Phayargi S/S (PM1~PM4) EL15m~ EL37m
2) Between Sittaung River and south of Bilinmintown (PM18~PM36) EL10m~ EL54m
3) Between the south of Thatontown to the north of Yay Twn Gone town (PM43~PM51) EL5m~ EL80m

Per the basic design in "500 kV TRANSMISSION LINE BETWEEN PHAYARGYI AND HLAING THARYAR FOR NATIONAL POWER TRANSMISSION NETWORK DEVELOPMENT PROJECT PHASE I", most of the tower foundations on Irrawaddy were Pad and Chimney, and the soil conditions of this Irrawaddy are applied for Type I in Table 3.2-2.

Table 3.2-2 Classification of Foundations

Geological Data						
Selective number for calculation			1	2	3	4
Foundation type			I	II	III	IV
Underground water level			low	few subsoil water	few subsoil water	high
Land use			Hilly area, Solid farm	Soft farm	Paddy field	Paddy field
Unit weight of concrete	Wc	(kN/m^3)	24	24	24	15
Unit weight of soil	We	(kN/m^3)	18	16	14	10
Angle of repose	θ	(°)	30	20	0	0
Yielding bearing capacity	w	(kN/m^2)	600	300	200	100
Yielding bearing capacity for lateral force	wf	(kN/m^2)	750	400	250	130

Source: JICA survey team

3.3. Conceptual Design of Transmission Line

3.3.1. Design Concept

Conceptual design of the transmission line was carried out based on the collected information. For the line, in order to systematically connected to the Phayargyi substation in the future with Phayargyi - Sartalin line and Phayargyi - Hlaingthaya line, the same equipment specifications were implemented considering system reliability and O&M for the 500 kV transmission system.

3.3.2. Design Conditions

The design conditions are as mentioned below.

(1) Temperature

Maximum air temperature	46 ºC
Minimum air temperature	10 ºC
Annual average temperature	27 ºC

(3) Conductor Temperature

Maximum temperature	75 ºC
Minimum temperature	10 ºC

(4) Wind Velocity

Maximum wind velocity	35 m/s

(5) Wind Pressure

Tower	2,150 Pa
Conductor	900 Pa
Ground wire	970 Pa
Insulator assembly	900 Pa

(6) Pollution Lebel

Medium (IEC standard); 34.7 mm/kV

3.3.3. Condutor and Ground Wires

(1) Type of Conductor and Ground Wires

The results from power flow system analysis showed that 4 bundles of ACSR 468 mm^2 (Drake) for conductors are appropriate for the project. Therefore, ACSR 468 mm^2 for conductor and OPGW 115 mm^2 and AS 110 mm^2 for ground wire are applied. The technical characteristics of the conductor and ground wires are shown in the following tables.

Table 3.3-1 Technical Characteristics of Conductor

Type	ACSR 468 ASTM (Drake)
Component of stranded wire (Units/Dia.)	Al: 26/4.442 mm St: 7/3.454 mm
Overall Diameter	28.13 mm
Cross Sectional Area of Aluminum wires	402.8 mm^2
Cross Sectional Area (Total)	468.6 mm^2
Nominal Weight	1,628 kg/km
Ultimate Tensile Strength	140.2 kN
Modulus of Elasticity	76.0 GPa
Co-efficient of linear expansion	19.1 x 10^{-6}/℃
DC Resistance at 20℃	0.07167 Ω/km

Table 3.3-2 Technical Characteristics of Ground Wires

Type	OPGW115 mm^2	AC110 mm^2
Component of stranded wire (Units/Dia.)	AA: 12/2.85 mm AS: 19/2.85 mm SUS: 1/2.80 mm	20SA: 19/2.7 mm
Overall Diameter	14.25 mm	13.5 mm
Cross Sectional Area (Total)	114.83 mm^2	108.8 mm^2
Nominal Weight	483 kg/km	722.5 kg/km
Ultimate Tensile Strength	72.4 kN	145.8 kN
Modulus of Elasticity	97.7 GPa	155.2 GPa
Co-efficient of linear expansion	17.5 x 10^{-6}/℃	12.6 x 10^{-6}/℃
DC Resistance at 20℃	0.366 Ω/km (including OP unit)	0.787Ω/km

3.3.4. Insulation Design

(2) Type and Size of Insulators

The insulator unit applied to the transmission line is a standard disc type porcelain insulator with ball and socket, complying with IEC 60305. 210kN type insulators are applied for the suspension towers and 300kN type insulators are applied for the tension towers. The technical characteristics of the insulators are shown in the following table

Table 3.3-3 Technical Characteristics of Insulators

Rated Ultimate Strength	210 kN	300 kN
IEC Designation	U210B	U300B
Shell Diameter	280 mm	320 mm
Unit Spacing	170 mm	195 mm
Nominal Creepage Distance	405 mm	505 mm
Ball & Socket Coupling	20 mm	24 mm

(3) Number of Insulator Units per string

The number of insulator units per string is 30 units for the suspension towers and 26 units for the tension towers.

3.3.5. Tower

(1) Tower Type

(a) Type DA

- Suspension type tower on a straight section of the line or on a section of the line with a horizontal deviation angle up to 3 degrees with suspension insulator sets.

(b) Type DB

- Tension type tower on a section of the line with a horizontal deviation angle up to 20 degrees with tension insulator sets.

(c) Type DC

- Tension type tower on a section of the line with a horizontal deviation angle from 20 degrees to 40 degrees with tension and jumper suspension insulator sets.

(d) Type DD

- Tension type tower on a section of the line with a horizontal deviation angle from 40 degrees up to 60 degrees with tension and jumper suspension insulator sets.

(e) Type DE

- Tension type tower used at the terminal of the line with tension insulator sets having jumper insulator sets where required with a horizontal angle up to 40 degrees.

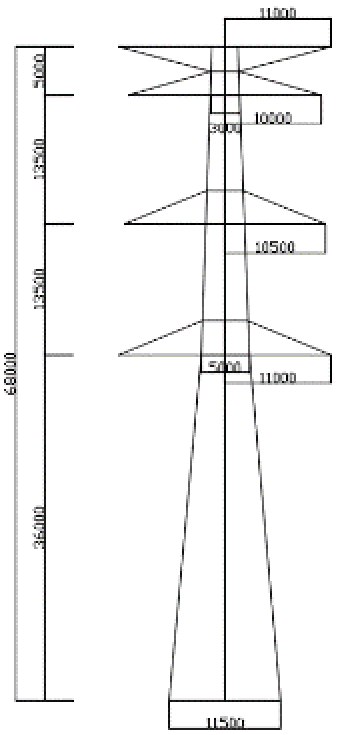


Figure 3.3-1 Type DA Tower

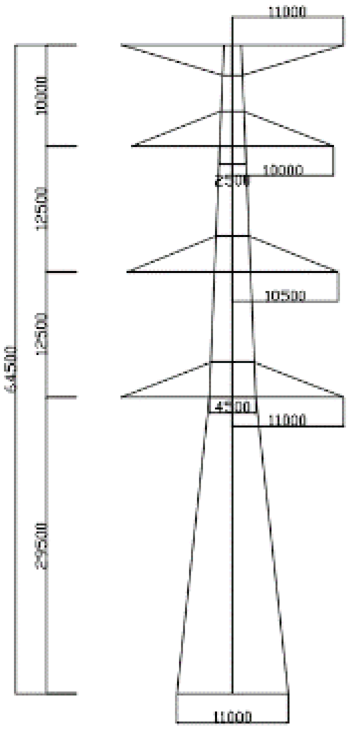


Figure 3.3-2 Type DB Tower

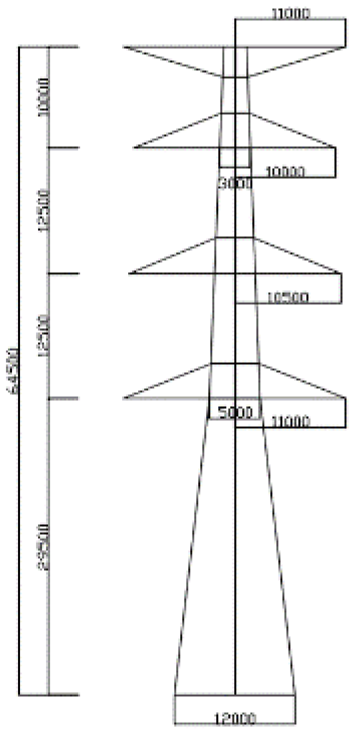


Figure 3.3-3 Type DC Tower

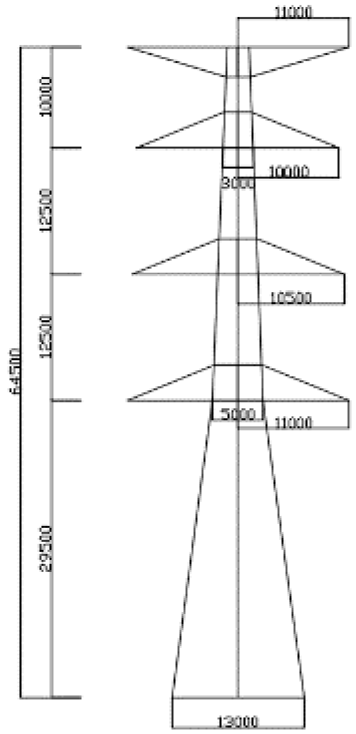


Figure 3.3-4 Type DD Tower

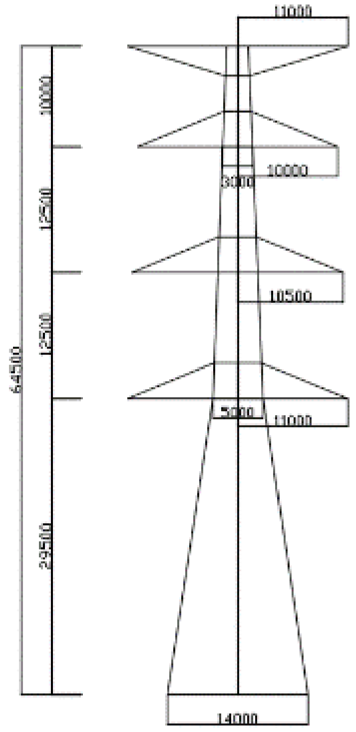
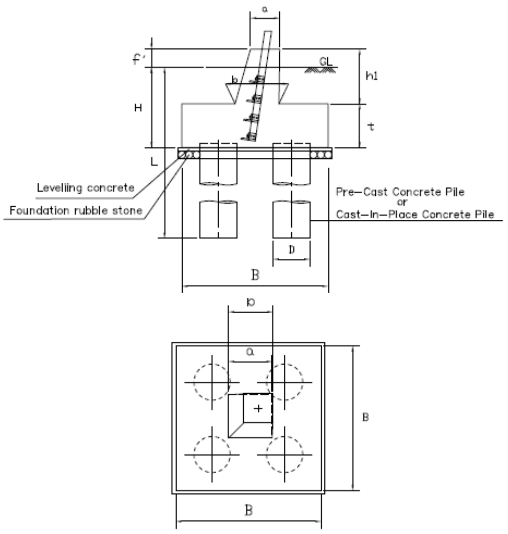


Figure 3.3-5 Type DE Tower

(2) Foundations of Towers

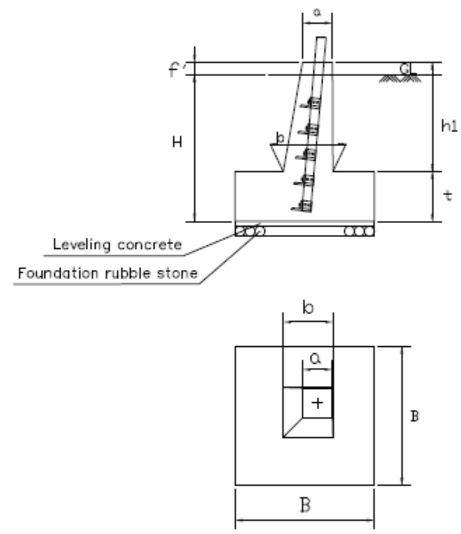
The dimensions of the tower foundations are as per the concept in "National Power Transmission Network Development Project Phase III" because this transmission line is assumed to be the same specifications as the 500 kV Phayargyi-Sar Ta Lin transmission line.

The foundations of the towers in this project are shown in Figure 3.3-6 and Figure 3.3-7.



Tower Type				DA	DB	DC	DD	DE
Chimney		(a)	m	0.60	0.75	0.75	0.75	0.75
		(b)	m	0.85	1.00	1.00	1.00	1.00
		(f')	m	0.50	0.50	0.50	0.50	0.50
		(h1)	m	1.50	1.50	1.50	1.50	1.50
Pad		(B)	m	3.20	3.20	3.70	4.80	3.50
		(t)	m	1.00	1.00	1.00	1.00	1.00
Depth of Pad Bottom		(H)	m	2.00	2.00	2.00	2.00	2.00
Pile	Length	(L)	GL-m	34.00	34.00	34.00	34.00	34.00
	Diameter	(D)	mm	800	800	800	800	800
	No. of Piles	(n)	-	4	4	4	4	4

Figure **3.3-6** Pile foundations



Tower Type			DA	DB	DC	DD	DE
Geological Type			Ⅱ	Ⅱ	Ⅱ	Ⅱ	Ⅱ
Chimney	(a)	m	0.60	0.80	0.80	0.80	0.80
	(b)	m	1.20	1.40	1.40	1.50	1.40
	(f')	m	0.50	0.50	0.50	0.50	0.50
	(h1)	m	3.50	3.60	3.90	4.00	3.80
Pad	(B)	m	4.30	5.30	6.30	7.00	6.00
	(t)	m	1.00	1.00	1.00	1.00	1.00
Depth of Pad Bottom	(H)	m	4.00	4.10	4.40	4.50	4.30

Figure **3.3-7** Pad and Chimney foundations

3.3.6. Subjects to be Solved

(3) Examination of Pollution Level

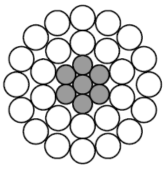
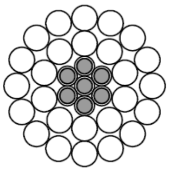
Since around 33% of the length of the line passes within 30 km from the sea, examination of areas where will be applied to IEC pollution level "Heavy" on the route is necessary after selectiing the final route, and then the appropriate number of insulator will be determined.

(4) Application of Corrosion Resistant Conductor

If long-term corrosion of the conductors in the above-mentioned heavy pollution areas is concerned, it may be necessary to consider the application of corrosion-resistant conductor. Examples of the conductor (ACSR / HRAC: Aluminum Conductor, High Corrosion Resistant Aluminum-Clad Steel Wires) is shown below. This conductor improves corrosion resistance by coating the steel core with aluminum clad (AC) that includes an Al-Mg-based aluminum alloy.

When the ACSR / HRAC is applied, the diameter and weight are the same as those of the conventional ACSR Drake, so it can be applied by increasing only the conductor price by 5%.

Table 3.3-4 Technical Characteristics of ACSR Drake and ACSR/HRAC (Reference)

Description		Unit	ACSR Drake	ACSR/HRAC Drake
Construction		Nos/mm	26/4.442 – AL 7/3.454 – St	26/4.442 – AL 7/3.454 – HRAC*1
Nominal diameter		mm	28.13	28.13
Rated tensile strength		kN	140.24	136.0
Cross sectional area	AL	mm^2	402.8	402.8
	Core		65.8	65.8
	Total		468.6	468.6
Nominal weight		Kg/km	1628 **[100]***5	1549 **[95.1]***5
DC Resistance at 20 °C		Ohm/km	0.07167 **[100]***5	0.0692 **[96.6]***5
Modulus of elasticity		GPa	82.0	74.8
Co-efficient of linear expansion		/°C	19.0×10^{-6}	20.0×10^{-6}
Current capacity (AC resistance)	At 75 °C	A (Ω/km)	638 A at 75 °C (0.0879 Ω/km)	649 A at 75 °C (0.0850 Ω/km)
	At 90 °C		835 A at 90 °C (0.0922 Ω/km)	850 A at 90 °C (0.0891 Ω/km)
Sag of 400 m span	At 75 °C	m	12.13 m at 75 °C	12.29 m at 75 °C
	At 90 °C		12.74 m at 90 °C	12.92 m at 90 °C
Cross sectional view		-		

4. Environmental and Social Considerations

4.1. Environmental considerations

4.1.1. Current Conditions of the Protected Areas and Areas Surrounding the Planned Transmission Line Route

(1) Current conditions of the protected areas around the project area

In Myanmar, there are two forest areas under the control of the Ministry of the Environment for Natural Resources Conservation-Forest Department (MONREC-FD): Reserved Forest (RF) and Protected Public Forest (PPF). In addition, MONREC-FD designated protected areas (PA) to protect the diverse ecosystems and species richness of Myanmar. In the Forest Policy (1995), the MONREC-FD set a goal of keeping 30% by area of the national land for PPF and 10% for PA. Table 4.1-1 shows the scale of PA, RF, and PPF in Myanmar as of December 2020.

Table 4.1-1 RF and PPF in Myanmar

No.	Category	Area (Acres)	Percentage of the land (%)
1	Protected Area (PA)	9,783,684.42	5.85%
2	Reserved Forest (RF)	29,702,095.99	17.77%
3	Protected Public Forest (PPF)	12,909,460.99	7.72%

Source: Forest Department/MONREC (2020)

KBA (Key Biodiversity Area) and IBA (Important Bird and Biodiversity Area) are also important areas for environmental considerations. KBA are areas containing endangered species in terrestrial/freshwater/marine ecosystems. There are 123 KBAs in Myanmar. Of the 123 KBAs, 35 are designated as PA and eight have been proposed as PA. IBAs are sites identified as being globally important for the conservation of bird populations on the basis of an internationally agreed set of criteria. Of the 123 KBAs, 57 are registered as IBAs in Myanmar.

(2) PAs and KBAs/IBAsaround the project area

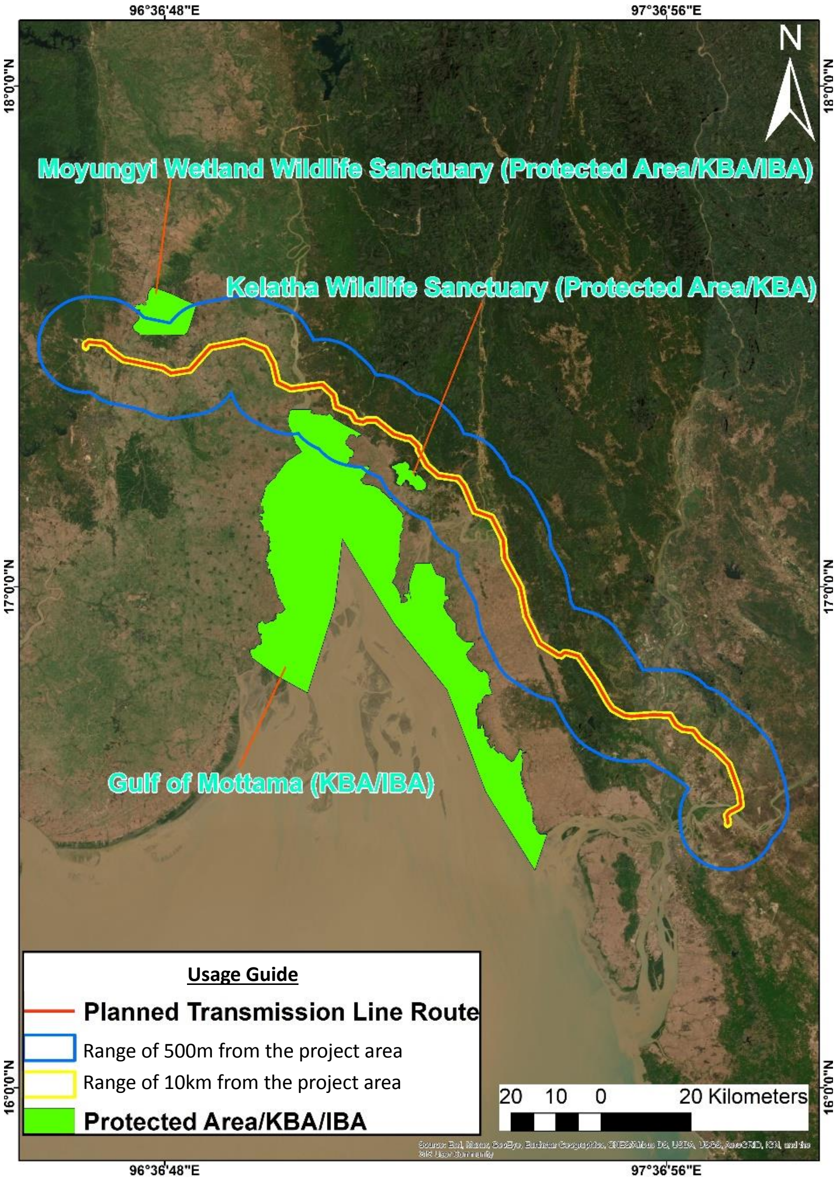
As shown in Table 4.1-2, PAs occupy about 5.9% (about 9,784,000 acres) of the land area, and there are 45 in total. There are no PAs and KBAs/IBAs on the planned transmission line route from Phayargy to Mawlamyaing. In addition, although the area of impact on the environment differs depending on the impact item, the JICA Survey Team confirmed that Pas and KBAs/IBAs exist within a range of 10 km from the project area. Table 4.1-2 and Figure 4.1-1 show the confirmation results, including the shortest distance to the project area.

Table 4.1-2 Existing PAs and KBAs/IBAs around the project area

No.	Name, etc.	Area, etc.	Overview
1	Name: Moyungyi Wetland Wildlife Sanctuary Category:	Region: Bago Region Area: 25,598 Acres Distance to the project	Moeyungyi Inn is a dam built in 1904 to supply water to a canal connecting the Sittaung and Bago rivers. It was designated as "Moeyungyi Wildlife Sanctuary" on 22nd April 1988, the aim of this being the following: (1) to protect the grazing lands of migratory birds, (2) to conduct research on bird species, (3) to ensure the sustainability of watershed ecosystem services, (4) to make effective use of watershed ecosystem services, (6) to raise the public's awareness of watershed ecosystems and their importance, (7) to generate public interest and involvement in conservation, and (8) to support ecotourism. It was identified as Myanmar's First Ramsar Site in 2004. Moyungyi Wildlife

No.	Name, etc.	Area, etc.	Overview
	-PA/ -KBA/ -IBA	area: 5.6 km approx.	Sanctuary is located in Waw Township, Bago District, Bago Region and it covers 25,600 acres. The Site supports several wetland habitats with high ecological value for resident and migratory waterbirds. More than 20 aquatic plants are present, including Kaing grass and Nwaysaba (Oxyza Officinalis), growing especially in the shallow areas of the Site, which are a breeding ground for water birds. In addition, 12 species of mammals, 18 species of amphibians and reptiles, 33 species of insects, 59 species of migratory birds, 77 species of endemic birds, 44 species of fish and 74 species of aquatic plants have been recorded in this Wildlife Sanctuary.
2	Name: Kelatha Wildlife Sanctuary Category: -PA/ -KBA	Region: Mon State Area: 5,548 Acres Distance to the project area: 2.5 km approx.	Kelatha Wildlife Sanctuary (Protected Area) is situated in Mon state, Bilin Township. It is a small sanctuary of about 24 square kilometers whose boundaries are demarcated by a road running all around the Site. Settlements, farming and collection of non-timber forest products are allowed.The Transmission line will pass through this protected area. Forest types in the Kelatha Wildlife Sanctuary are mixed deciduous and typical evergreen forest. According to information obtained at the park, leopard, serow, barking deer, sambar deer, wild boar, different species of monkeys, wildfowl, pheasant, hornbill and peacock were observed in the Site in 1996. Shifting cultivation farmers are encroaching on the park's borders. Poaching and illegal logging for subsistence are moderate and localized threats. The Site is surrounded by villages and anthropical activities. According to a survey conducted in 1996, there were no villagers who earn their living from the forest or forest products at the Site. Paddy fields in the surrounding area are fertile, and they produce a good harvest. Villages and horticulture farms are located almost continuously one beside another and villagers are very concerned about forest fire outbreaks.
3	Name: Gulf of Mottama Category: -PA/ -KBA/ -IBA	Region: Yangon/ Bago Region, Mon state Area: 397,987 Acres Distance to the project area: 1.6 km approx.	The Gulf of Mottama is one of the most important and unique intertidal wetland systems in the world. Because of this, it was declared a Ramsar site in 2017. It is home to important habitats, species of conservation concern, commercially important fisheries, and communities that rely on its natural resources. It is bordered by Yangon Region in the west, Bago Region in the north, Mon State in the east, and the Andaman Sea in the south.The Gulf of Mottama is situated at the mouth of the Sittaung River of the larger Gulf of Mottama. The designated area was extended from 42,500 hectares to 161,030 ha in 2020, to include a greater area of this unique estuarine mudflat environment. The Gulf has a tidal range of between six and seven meters; the mouth, which is around 100 km wide, narrows into a funnel-shaped bay to produce a powerful bore phenomenon that can reach heights of over a metre on spring tides in the upper estuary. As a result, the tidal mudflats of the Gulf are among the largest in the world. The Site supports a large number of species including marine fish, invertebrates and up to 150,000 migratory waterbirds in the non-breeding season. Among these waterbirds is the critically endangered spoon-billed sandpiper (Eurynorhynchus pygmeus), of which the Site perhaps hosts more than half of the remaining global population. The Gulf of Mottama also supports the livelihoods of thousands of people by providing fish for local and regional consumption.

Source: Prepared by JICA Study Team based on Forest Department of each township; Protected Area coverage information (2019) and Integrated Biodiversity Assessment Tool (IBAT)



Source: Prepared by JICA Survey Team based on the Forest Department of each township; Protected Area coverage information (2019) and Integrated Biodiversity Assessment Tool (IBAT)

Figure 4.1-1 Location of the PAs around the project area

(3) RFs and PPFs around the project area

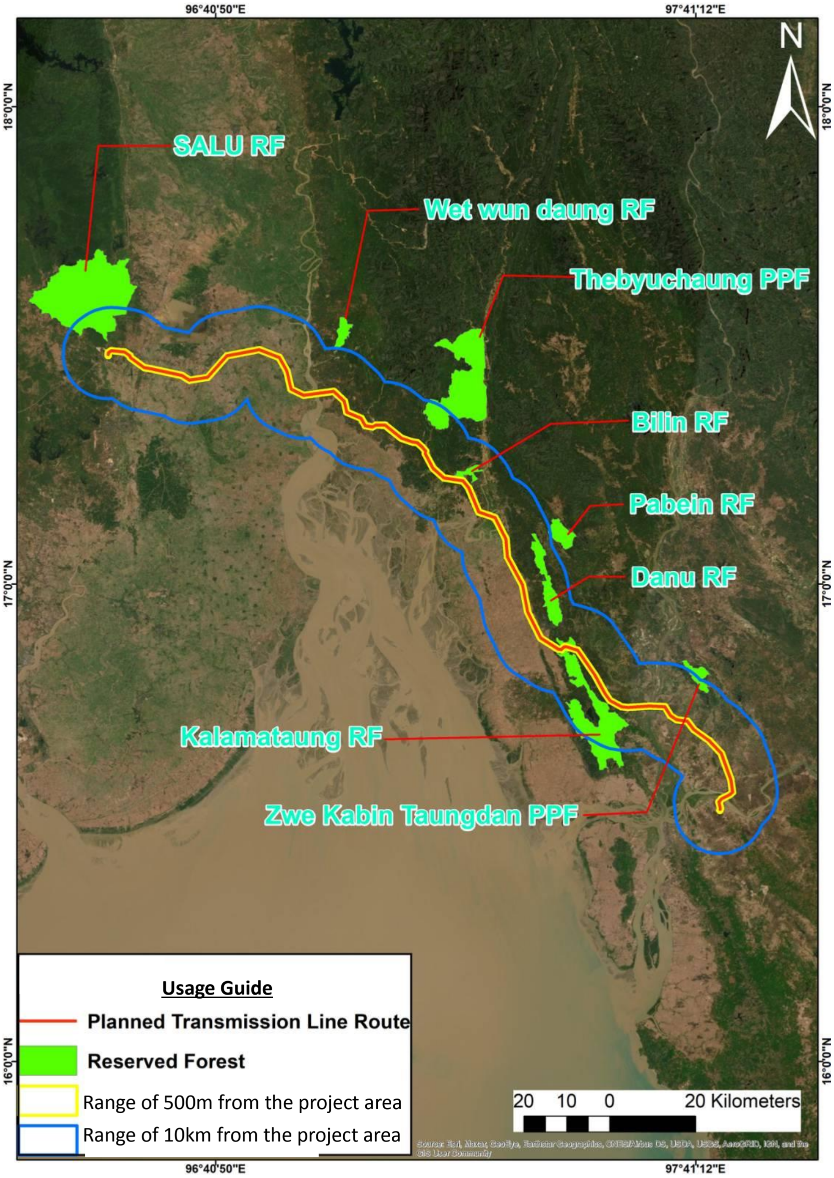
As shown in Table 4.1-1, RFs and PPFs occupy about 25.5% (about 42,600,000 acres) of the land area. The Kalama Taung Conservation Forest exists on the planned transmission line route from Phayargy to Mawlamyaing. According to interviews with the staff of Kalama Taung Reserved Forest, this RF is a conservation forest for the purpose of commercial/local supply/water collection protection as stipulated in the Forest Law (2018), and modification is possible by carrying out the required procedure. In addition, as with the protected areas (PA) mentioned above, the existence of RF, etc. was confirmed within a range of 10 km from the project area. Table 4.1-3 and Figure 4.1-2 show the confirmation results, including the shortest distance to the project area.

Table 4.1-3 RFs and PPFs around the project area

No.	Region	Name	Overview
1	Bago Region	**Name: Salu Reserved Forest** Area: 62,885 Acres Distance to the Project area: 2.3km approx.	SALU Reserved Forest is situated in East Bago Yoma, Bago Township, Bago Region. This area is located between 17◦ 04′ N to 17◦ 50′ N Latitude and 96◦ 24′ E to 96◦ 41′ E Longitude. The total area of SALU reserved forest is 62,885.849 acres. In some research, it is mentioned that disturbances such as logging, charcoal making and firewood collection were the major destructive forces and one of the influencing factors for forest structure. But SALU Reserved Forest is still rich in tree species diversity, even after great disturbances to the ecology. *Melanorrhoea glabra* (Thit-si) and *Cryteronia pubescens* (Anan- bo) *Manglietia insignis* (Taung- sa- ga) are the most abundant species in Salu Reserved Forest. It is situated within the 10 km buffer of the transmission line and north-east of that line.
2	Mon State	**Name: Wet wun daung Reserved Forest** Area: 3,690 Acres Distance to the Project area: 10km approx.	Wet wun daung Reserved Forest is situated in Kyaikto Township, Mon state. This area is located between 17°29'34.74"N to 17°33'31.65"N Latitude and 96°55'51.61"E to 96°56'55.31"E Longitude. The total area of Wet wun daung reserved forest is 3,690.59 acres. It is situated within the 10 km buffer of the transmission line and east of that line.
3		**Name: Thabyuchaung Protected Public Forest** Area: 38,003 Acres Distance to the Project area: 5.2km approx.	Thabyuchaung Protected Public Forest is situated in Bilin Township, Mon State. This area is located between 17°19'45.51"N to 17°32'2.52"N Latitude and 97° 8'22.94"E to 97°13'0.59"E Longitude. The total area of Thabyuchaung protected public forest is 38,003.840 acres. It is situated within the 10 km buffer of the transmission line and east of that line.
4		**Name: Bilin Reserved Forest** Area: 513 Acres Distance to the Project area: 0.5km approx.	Bilin Reserved Forest is situated in Mon state, Bilin Township, Mon State. This area is located between 17°13'0.62"N to 17°14'25.31"N Latitude and 97°13'30.19"E to 97°12'19.32"E Longitude. The total area of Bilin reserved forest is 513.59 acres. It is situated within the 500 km buffer of the transmission line and east of that line.
5		**Name: Danu Reserved Forest** Area: 10,269 Acres Distance to the Project area: 3.4km approx.	Danu Reserved Forest is situated in Thaton Township, Mon State. This area is located between 16°54'42.84"N to 17° 6'18.58"N Latitude and 97°23'48.55"E to 97°20'41.53"E Longitude. The total area of Danu reserved forest is 10,269 acres. It is situated within the 10 km buffer of the transmission line and east of that line.
6		**Name: Pabein Reserved Forest** Area: 5,904 Acres Distance to the Project area: 9.5km approx.	Pabein Reserved Forest is situated in Thaton Township, Mon State. This area is located between 17° 4'35.94"N to 17° 8'8.15"N Latitude and 97°25'21.88"E to 97°23'32.69"E Longitude. The total area of Danu reserved forest is 5,904 acres. It is situated within the 10 km buffer of the transmission line and east of that line.
7		**Name: Kalama Taung Reserved Forest** Area: 33,722 Acres Distance to the Project area: Passing	Kalamataung Reserved Forest is situated in Paung Township, Mon state. This area is located between 16°52'52.74"N to 16°36'57.94"N Latitude and 97°24'28.68"E to 97°31'42.12"E Longitude. The total area of Kalama Taung reserved forest is 33,722.79 acres. The transmission line will pass through this reserved forest.
8	Kayin State	**Name: Zwe Kabin Taungdan Protected Public Forest** Area: No info	Zwe Kabin Taungdan Protected Public Forest is situated in Kayin state, Hpa-An Township. This area is located between 16°46'25.11"N to 16°50'23.48"N Latitude and 97°42'47.14"E to 97°39'44.22"E Longitude. It is situated within the 10 km buffer of the transmission line and east of that line.

No.	Region	Name	Overview
		Distance to the Project area: 7.7km approx.	

Source: Forest Department of each township; RF, and PPF Area coverage information (2019)



Source: Prepared by JICA Survey Team based on the Forest Department of each township; RF, and PPF Area coverage information (2019)

Figure 4.1-2 RFs and PPFs around the project area

(4) Topographical characteristics around the project area

The planned transmission line passes Bago/Waw in Bago, Kyaik Hto/Belin/Thaton/Paung/Kyaik Mayaw in Mon State, and Hpa An in Kayin State. Table 4.1-4 shows the general topographical characteristics of each area.

Table 4.1-4 Overview of the topographical characteristics around the project area

Region/State	Area	Township	Overview
Bago Region	Bago	Bago	Bago township is located at the bottom of the Bago Yoma Range, and the western part of the township is a highland area covered with forests. The township is 21 miles from east to west and 43 miles from north to south, and has an altitude of about 30 m above sea level.
		Waw	The topography of Waw township is flat-plain surfaces and a lowland area covered with water in the rainy season. It is situated about 23.8 feet above sea level.
Mon State	Thaton	Kyaik Hto	Kyaik Hto is located 35 feet above sea level with the mountain ranges in the east, south and north, and valleys in the West. The highest mountain is the Kyaik Htee Yoe mountain in this township, and this is located 36,158 feet above sea level.
		Belin	Belin township features a flat-plain surface covered with forest, and it is situated about 30 feet above sea level.
		Thaton	Thaton township is located 17.6 feet above sea level, and it has a large mountain range in the middle of Thaton township, which runs from East to West. Hills covered by forest can be found in this township, running from North to South.
		Paung	The topography of Paung Township is plain surfaces, except for the mountains which are located in the middle of the township. It has the Zin Kyaik mountain, Kalama mountain, Nwar La Bo mountain and Mottama mountain range, which runs from North to South. Among these mountains, the Kalama mountain is famous in this township. There are three islands in Paung Township. One is inhabited, and the other two are uninhabited. Paung Township is located 24 feet above sea level.
	Mawla Myaing	Kyaik Mayaw	The topography of Kyaik Mayaw Township is bounded by the Gyaing river basin to the North, Ataran river basin and Taung Nyo mountain range to the West. They have an elongated shape, from the North-West to the South-East. This township is situated 18 feet above sea level.
Kayin State	Hpa-An	Hpa-An	Hpa-an Township is mostly highland, with a percentage of lowland topography. The Zwekabin mountain, which is 2727 feet high, and its summit are located 9 miles from the South region of this township. Hpa-an Township is located 53 feet above sea level.

Source: General Administrative Departments, October 2019

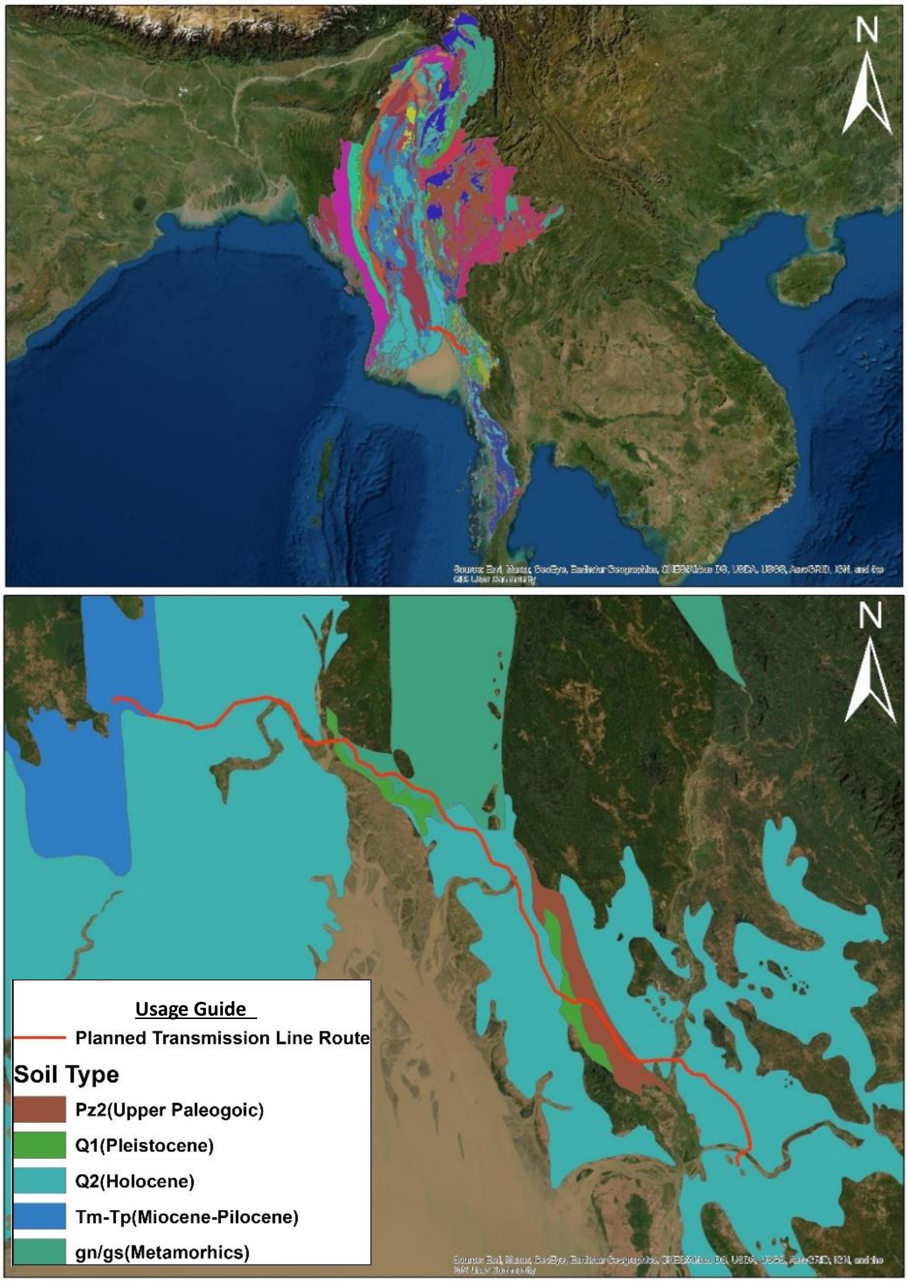
(5) Geological characteristics around the project area

The planned transmission line route runs from the Myanmar central belt through the Shan Plateau to the Mogok metamorphic belt. An outline is shown in Table 4.1-5 and Figure 4.1-3. The lithology is widespread from silt/clay formation to sedimentary rock and limestone.

Table 4.1-5 Geological characteristics around the project area

Geological name	Rock formation surface	GEO ID	Era	Landform	Lithology	Sedimentary environment
Myanmar Central Belt	Irrawaddy Delta	Q2	Holocene	Alluvial Fm	Silt, Clay, Sand, Gravel	Recent deposition
		Q1	Pleistocene	Irrawaddy Fm.	Sandstone, Older alluvium and gravels, schist and gneisses	Fluvial
Shan Plateau		Tm-Tp	Miocene-Pliocene	Irrawaddy Fm.	Sedimentary rocks	Eastern Range
		Pz2	Upper Paleozoic	-	Carboniferous-Permian: Plateau limestone	Shallow water
Mogok Metamorphic Belt	Sagaing fault and the West of Shan plateau	gn/gs	Miocene	Kathabung Fm.	Schist, Gneisses	Sedimentary, Igneous

Source: Data from the Geology of Myanmar website



Source: Prepared by JICA Survey Team based on Geology Department

Figure 4.1-3　Geological map of the project area and its surroundings

(6) Cultural heritage around the project area

There are no special cultural heritage sites on the planned transmission line route from Phayargy to Mawlamyaing. In addition, as with the above-mentioned protected area, the existence of cultural heritage sites was confirmed up to an area of 10 km from the project area. The confirmation results, including the shortest distance to the project area, are shown in Table 4.1-6, Figure 4.1-4 and Figure 4.1-5.

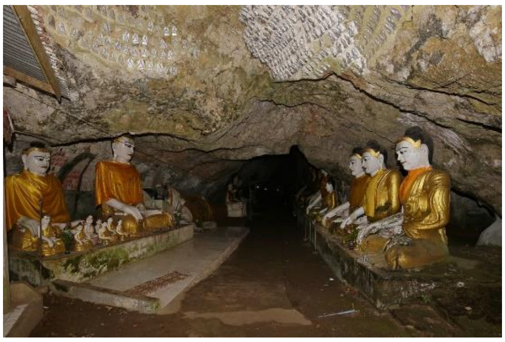
Table 4.1-6 Cultural heritage around the project area

Region/State	Area	Name/Location	Overview
Bago Region	Bago	**<u>Name: Kanbawzathadi Palace</u>** Distance to the project area: 14 km approx.	- This palace is a reconstruction of the original Royal palace of the second half of the 16th century. - It was burned down in 1599 and reconstructed in 1990, and finished in 1992.
Mon State	Thaton	**<u>Name: Kyaik Htee Yoe Pagoda</u>** Distance to the Project area : 15 km approx.	- Kyaik Htee Yoe Pagoda, or Golden Rock, is a popular pilgrimage site in Myanmar and also a tourist attraction. - It is a small pagoda (7.3 metres (24 ft)) built on the top of a granite boulder. - It is covered with gold leaves, and only male devotees can paste on it.
	Mawlamyaing	**<u>Name: Kha Yone Cave</u>** Distance to the project area: 2.4 km approx.	- This is a limestone cave, and it is 150 ft long from North to South and 50 ft wide from East to West. - There are a lot of ancient clay buddha statues along the walls and ceiling of the cave. - It has been regarded as a cultural heritage site by the Department of Archaeology and National Museum of the Ministry of Culture since 1975.
Kayin State	Hpa-An	**<u>Name: Kaw Gon Cave</u>** Distance to the project area: 7 km approx.	- This is one of the most famous limestone caves in Myanmar and is famous for its cultural heritage in Buddhism. - There are a lot of Buddha images engraved on the walls of the mountain and the walls and ceilings of the cave, and ancient inscriptions can also be found inside the cave. - The dimensions of the cave are approximately 170 ft x 70 ft x 25 ft and it is closed at one end.
		<u>Name: Yathe Pyan Cave</u> Distance to the project area: 10 km approx.	- Yathe Pyan Cave is a limestone cave. A lot of engraved Buddha images can be found inside the cave. - It has been regarded as a cultural heritage site by the Department of Archaeology and National Museum of the Ministry of Culture since 1975.

Source: Renown Travel, Asia EZ travel, flickr.com, Go Myanmar Tours, Myanmar Business Directory

Picture of Kanbawzathadi Palace
Source: Renown Travel

Picture of Kyaik Htee Yoe Pagoda
Source: Asia EZ travel



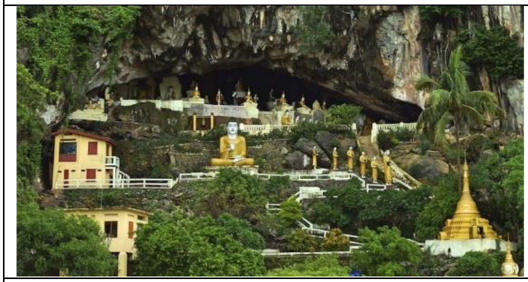
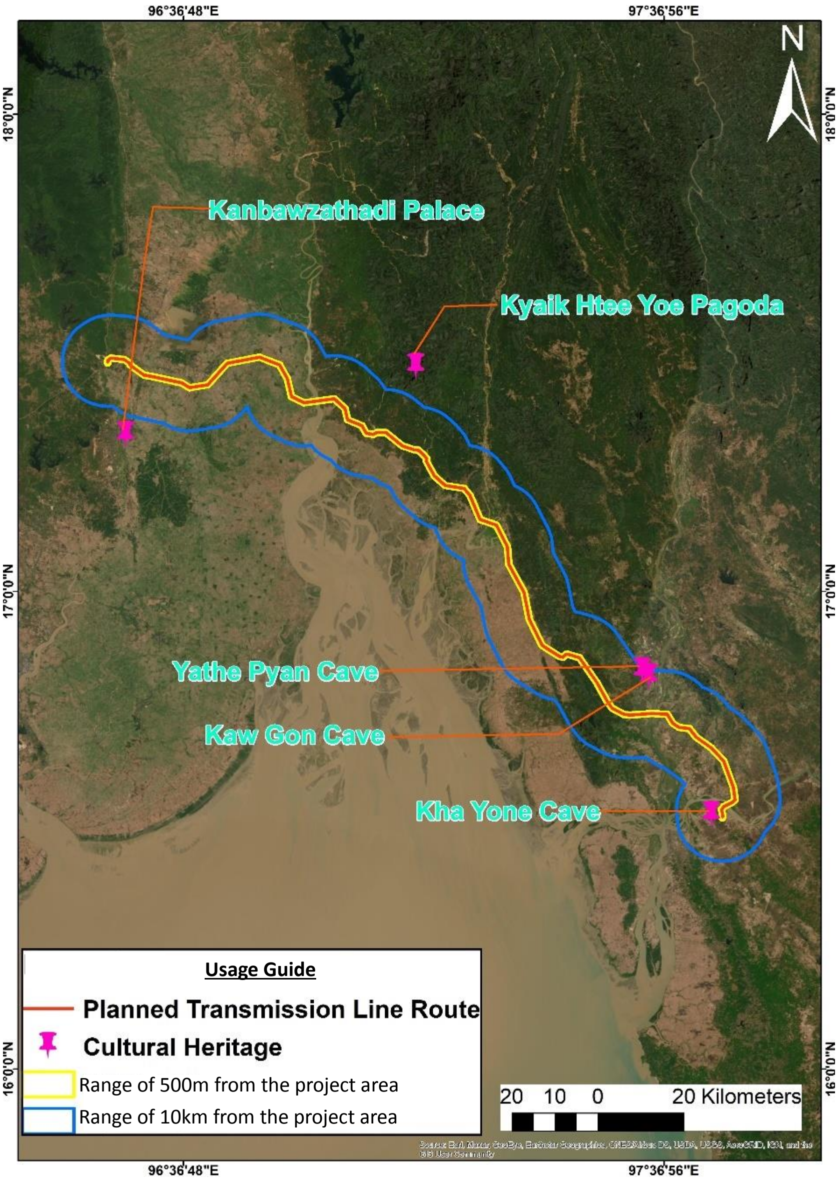
Picture of Kha Yone Cave Source: flickr.com	Picture of Kaw Gon Cave Source: Go Myanmar Tours
	
Picture of Yathe Pyan Cave Source: Myanmar Business Directory	

Figure 4.1-4 Pictures of the cultural heritage around the project area



Source: JICA Survey Team

Figure 4.1-5 Locations of the cultural heritage sites around the project area

4.1.2. Overview of the Environmental and Social Considerations required by the Environmental and Social Considerations Guidelines

(1) Environmental and Social Considerations Procedures based on the EIA Procedure (2015) in Myanmar

For the implementation of projects of a certain scale in Myanmar, it is necessary to carry out an environmental assessment (EIA) or initial environmental assessment (IEE) in accordance with the "Environmental Impact Assessment Procedure" (Ministerial Ordinance No. 616/2015) (hereinafter, EIAP). The scale requirements are described in Annex 1 of EIAP. Project components that have an environmental and social impact are classified according to the type and scale in EIAP Annex 1. As shown in Table 4.1-7, this project "requires IEE or EIA".

Table 4.1-7 Requirements of EIA/IEE for this Project in Myanmar

No.	Project type	Require IEE	Require EIA	Remarks
ENERGY SECTOR DEVELOPMENT				
27	Electrical Power Transmission Lines ≥ 230 kV	All sizes	All activities where the Ministry requires that the Project shall undergo EIA	-

* EIA: Environmental Impact Assessment
IEE: Initial Environmental Examination
Source: EIA Procedure (2015)

Per an example of a DPTSC-implemented transmission line project and interviews with MONREC-ECD, which is the implementing organization for EIAP, no transmission line project has required EIA. In addition, the JICA National Power Transmission Network Development Project Phase III in Myanmar was classified as two IEE projects as a result of screening by MONREC-ECD. Since there is one RF and the total length is about 200km of the planned transmission line route, it is considered that there is a possibility that EIA will be required as a response on the Myanmar side. In actual fact, there are many unclear parts because MONREC-ECD will classify the Project. The RF can be modified through appropriate procedures.

(2) Environmental and Social Considerations Procedures based on the JICA Guidelines for Environmental and Social Considerations

This Project has a possibility of being classified as an EIA project according to the EIA Procedure in Myanmar. However, MONREC-ECD does not have clear criteria for the classification of Project, and the results of screening vary depending on the staff at MONREC-ECD, which means there are no clear criteria for the scale of Project.

The JICA Survey team carried out a comparison and organization of the planned Project and the items listed in "Appendix 3. Illustrative List of Sensitive Sectors, Characteristics, and Areas" of the JICA Guidelines for Environmental and Social Considerations (2010). It was assumed that the number of Project Affected Persons (PAPs) related to the construction of new substations and the development of transmission lines would be kept to a minimum so that the relocation of residents, businesses, and commerce due to land acquisition would not occur as far as possible. Therefore, this Project does not have any characteristics as listed in Appendix 3 of the JICA Guidelines, as shown in Table 4.1-8.

Table 4.1-8 Overview of this Project in line with JICA Guidelines for Environmental and Social Considerations (2010)

Category	Contents	Overview of this Project
1. Illustrative List of Sensitive Sectors	(6) Power transmission and distribution lines involving large-scale involuntary resettlement, large-scale logging, or submarine electrical cables	Technically, large-scale involuntary resettlement and large-scale deforestation can be avoided.
2. Illustrative List of Characteristics	(1) Large-scale involuntary resettlement (2) Large-scale groundwater pumping (3) Large-scale land reclamation, land development, and land clearing (4) Large-scale logging	Technically, (1) Large-scale involuntary resettlement and (4) Large-scale logging can be avoided. The Project does not have any activities related to (2) Large-scale groundwater pumping, or (3) Large-scale land reclamation, land development, and land clearing.
3. Illustrative List of Areas	(1) National parks, nationally-designated protected areas (coastal areas, wetlands, areas for ethnic minorities or indigenous peoples and cultural heritage, etc. designated by national governments) (2) Areas that are thought to require careful consideration by the country or locality 1) Primary forests or natural forests in tropical areas 2) Habitats with important ecological value (coral reefs, mangrove wetlands, tidal flats, etc.) 3) Habitats of rare species that require protection under domestic legislation, international treaties, etc. 4) Areas in danger of large-scale salt accumulation or soil erosion 5) Areas with a remarkable tendency towards desertification	No direct alterations are expected for protected areas, cultural heritage, or key areas of biodiversity conservation (KBA). Although the project passes through one RF, it is a reserved forest for commercial/local supply/water collection protection under national law and this can be modified through related procedures. In addition, it will not modify vulnerable areas, such as areas where soil erosion is likely to occur and areas where desertification tends to occur.

Note: The numbers listed correspond to the numbers listed in Appendix 3 of the JICA Guidelines for Environmental and Social Consideration Guidelines (2010).
Source: Prepared by JICA Survey Team based on the JICA Guidelines for Environmental and Social Considerations (2010)

4.2. Social Considerations

4.2.1. Properties to be affected at the 500 kV Mawlamyaing Substation

(1) Location and surrounding environment

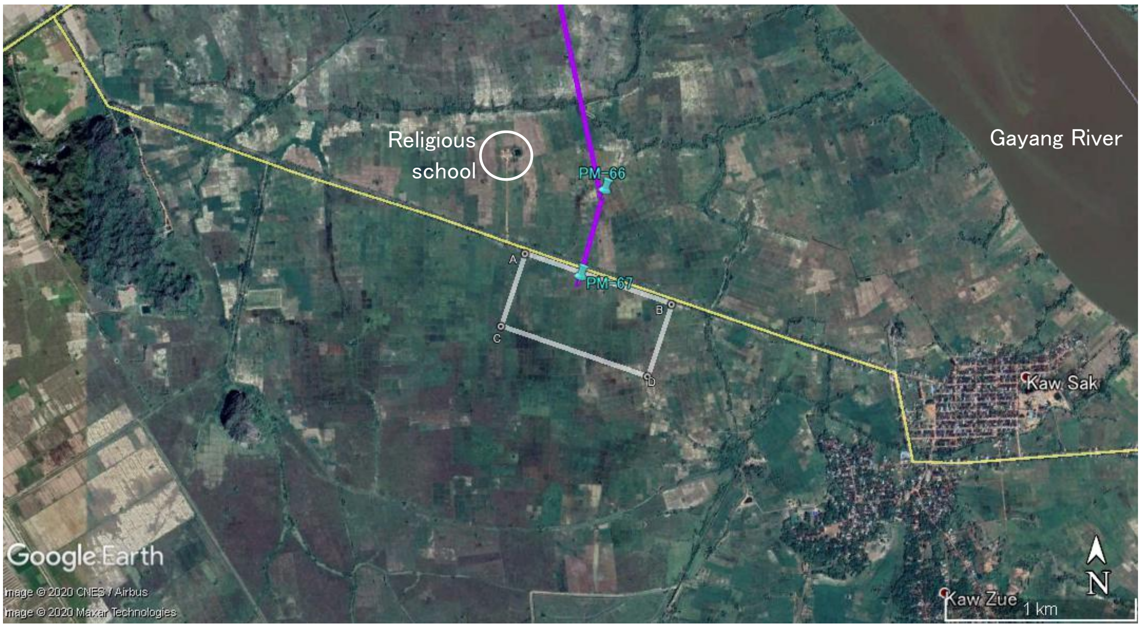
The 500 kV Mawlamyaing Substation (80 acres/32.4ha) is proposed to be in Mawlamyaing District, Mon State.

Satellite photos of the area surrounding the proposed site, as well as a close-up of the proposed site, were collected from Google Earth. The oldest available photos were taken in the year 2002, and the most up-to-date were taken in 2019. The latest photos, taken in July 2019, were not suitable for the analysis since the site was covered by clouds. The photos taken in December 2018 were used to identify and count the assets (such as structures, trees, and crops) at the site and in the area surrounding the site to understand the significance of the impacts of the substation construction.

The land use at the site is mainly rice paddies. The distance to the nearest village border to the south-east is about 930 m. The northern border of the site faces a road. At about 120 m from the north-west corner of the site, there is a branch road that leads to a religious school. The distance from the main road to the school is about 500 m. (Figure 4.2-1)

The Gayang River is situated at a distance of about 1.7 km north-east from the north-east corner of the site. The width of the river is about 600 m.

The surrounding area is used as rice paddies, similar to those within the site.



Source: JICA Survey Team, Google Earth (December 2018)

Figure 4.2-1 Satellite Photo of the Proposed Substation Site and Surrounding Area

(2) Count of properties

Properties were identified and counted using satellite photos mainly taken in December 2018 (Table 4.2-1, Figure 4.2-2).

The site consisted of rice paddies. Scattered trees were counted at about 34.

The square shapes within the site are expected to be artificial roofs, and the several of them are found on site depending on the photos. The size of the roofs is small at about 4 m on one side, compared to about 10 m on one side in the village houses. The structures are, therefore, probably seasonal huts for resting and storage.

Table 4.2-1 Properties Identified in the Proposed Substation Site

Type	Number	Notes
Rice paddies	About 32.4ha About 424 paddies	No significant changes were found in the subdivision of the paddies between 2002 and 2019.
Trees	About 34 trees	Jointed canopies may be counted as one tree.
Structures	About 3 - 6 structures	The size of the roofs is small at about 4 m on one side. High probability of their being seasonal huts for resting and storage. Three roofs can be seen in most of the photos. Another three roofs cannot however be found in some photos.

Source: JICA Survey Team, Google Earth (December 2018)

Source: JICA Survey Team, Google Earth (December 2018)

Figure 4.2-2 Substation Site (December 2018)

4.2.2. Satellite Photo Analysis of the Proposed Route for the 500 kV Transmission Line Between Phayargy and Mawlamyaing Substations

The proposed route for the transmission line between Phayargy and Mawlamyaing Substations was studied using satellite photos of the surrounding area collected from Google Earth.

It was found that the route passes mainly rice paddies and rubber plantations. Structures are located within the ROW (30 m one side) at a few locations. In the detailed study for the tower locations, it will be possible to ensure those structures are not included in the ROW and avoid impacts (Table 4.2-2, Figure 4.2-3).

Advice for the detailed study on the ROW location covers the following 4 points.

1. Minimize the clearance of productive rubber trees. Where clearance cannot be avoided, adequate counter measures such as compensation will be implemented.
2. In areas susceptible to flooding or inundation, areas with soft soil, or areas that may be affected by cyclones, the towers must be well-designed to be resilient to those conditions, and the lines must be monitored closely so that electrical accidents and black-outs are avoided.
3. Impacts on farmland, paddies, residential structures, schools, religious facilities, and other public infrastructure must be minimized. Where the impacts cannot be avoided, adequate counter measures such as compensation will be implemented.

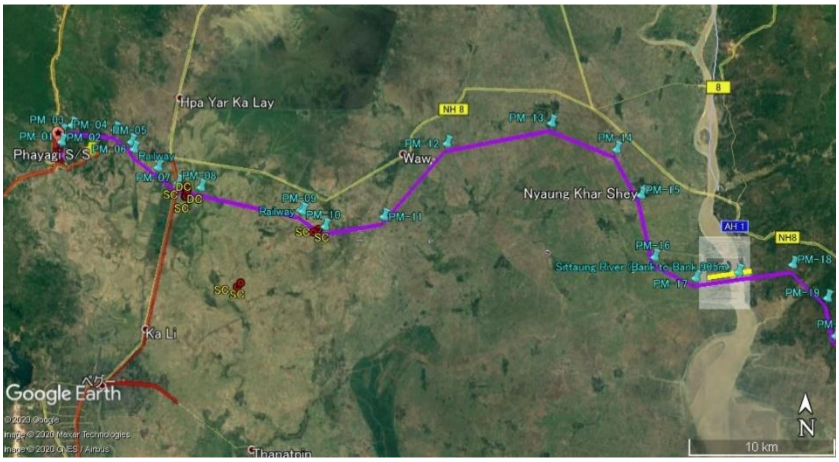
Table 4.2-2 Study of the Proposed Route for the 500 kV Transmission Line Between Phayargy and Mawlamyaing Substations

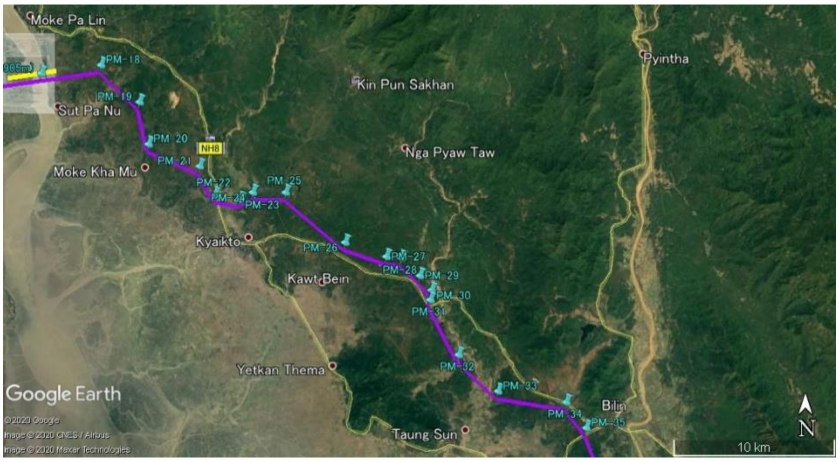
PM	PM	State	Prominent environment				Significant features
Start	End		Paddies	Rubber	Woodland	Other	
1	2	Bago	X		X		
2	3	Bago			X		
3	4	Bago	X	X	X		Sand quarries
4	5	Bago	X				Canal

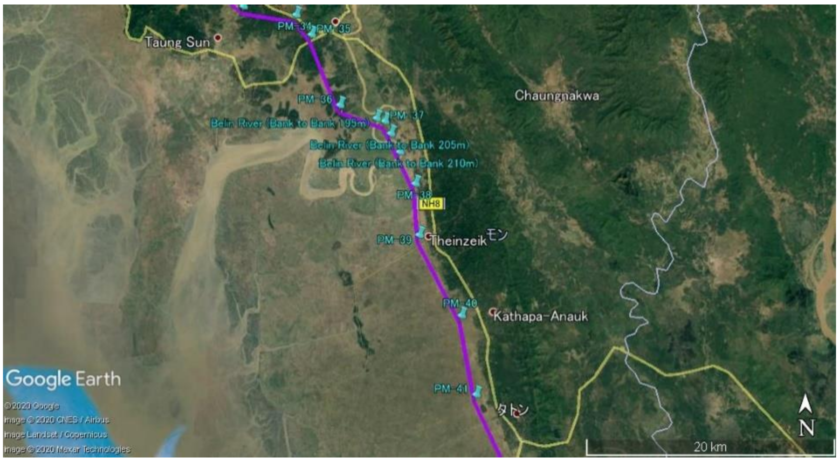
PM	PM	State	Prominent environment				Significant features
Start	End		Paddies	Rubber	Woodland	Other	
5	6	Bago	X				NH8
6	7	Bago	X				Canals, Railway
7	8	Bago	X				AH1
8	9	Bago	X				Canals
9	10	Bago	X				Railway
10	11	Bago	X				River
11	12	Bago	X				
12	13	Bago	X				
13	14	Bago	X				
14	15	Bago	X				200m to Nyaung Khar Shey town
15	16	Bago	X				
16	17	Bago	X				
17	18	Bago/Mon	X	X		Fishponds	Sittaung River (Bank to Bank 905m)
18	19	Mon	X	X			
19	20	Mon	X	X		Farmland	
20	21	Mon	X	X		Farmland	
21	22	Mon	X	X			Structures (house or storage)
22	23	Mon	X	X			NH8, river
23	24	Mon		X	X		
24	25	Mon		X	X		50m to Pagoda
25	26	Mon		X	X	Farmland	
26	27	Mon		X	X		50m to Pagoda
27	28	Mon		X	X		
28	29	Mon		X	X		50m to Pagoda, 50m to school
29	30	Mon		X	X		
30	31	Mon		X	X		NH8
31	32	Mon	X	X	X		
32	33	Mon	X	X			40m to Pagoda, river
33	34	Mon		X			30m to house
34	35	Mon		X		Farmland	
35	36	Mon	X	X		Farmland	50m to house
36	37	Mon	X	X			Belin River (Bank to Bank 195m)
37	38	Mon	X				Belin River (Bank to Bank 205m, 210m)
38	39	Mon	X				150m to town
39	40	Mon	X				
40	41	Mon	X				
41	42	Mon	X				
42	43	Mon	X				NH8
43	44	Mon	X	X			
44	45	Mon		X			
45	46	Mon		X			
46	47	Mon	X	X			
47	48	Mon	X	X			
48	49	Mon	X				
49	50	Mon	X				
50	51	Mon	X	X			20m to house
51	52	Mon	X	X			
52	53	Mon/Kayn	X			River	Donthami River (Bank to Bank 732m), 50m to house
53	54	Kayn	X				Thanlwin River (Bank to Bank 815m)
54	55	Kayn	X				
55	56	Kayn	X				
56	57	Kayn	X				
57	58	Kayn	X			Ponds	
58	59	Kayn	X			Canals, creeks	
59	60	Kayn	X	X			
60	61	Kayn	X	X			
61	62	Kayn	X				
62	63	Kayn	X				

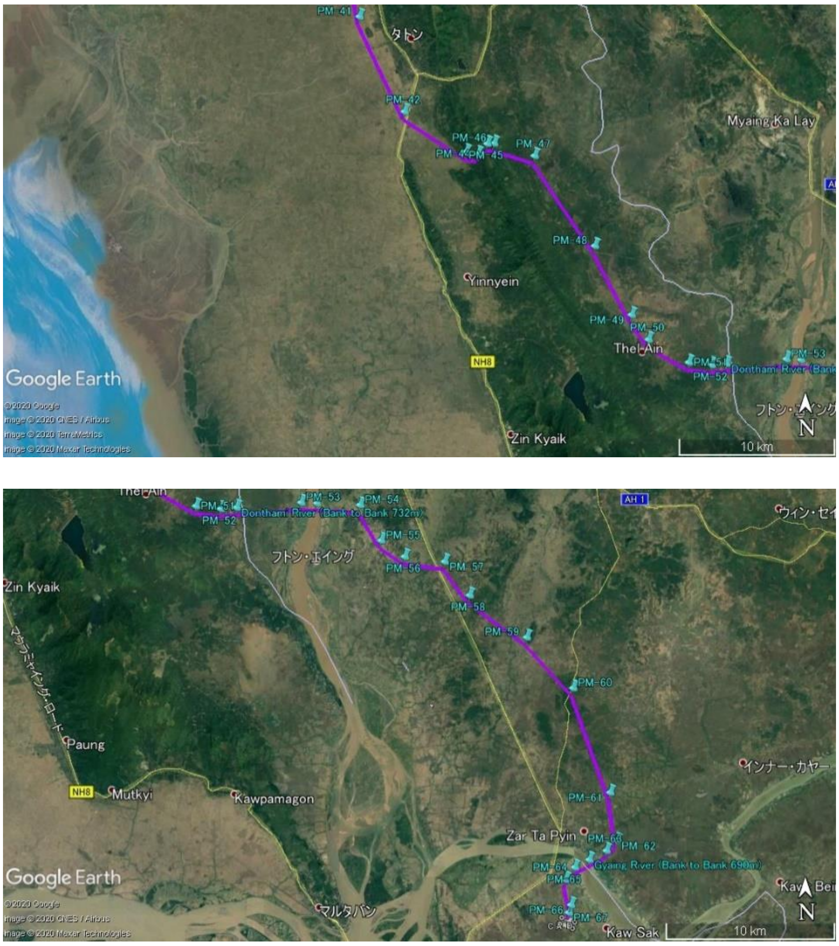
PM	PM	State	Prominent environment				Significant features
Start	End		Paddies	Rubber	Woodland	Other	
63	64	Kayn/Mon	X		X	River	Gyaing River (Bank to Bank 690m), Kaw Thin Road
64	65	Mon	X				
65	66	Mon	X				
66	67	Mon	X				

Source: JICA Survey Team, Google Earth









Source: JICA Survey Team, Google Earth

Figure 4.2-3 Satellite Photos of the Proposed Transmission Line Route

4.2.3. Preliminary Comparative Study of Alternatives

The results of a preliminary comparative study of alternatives are shown in Table 4.2-3. A comparison was made between the proposed plan, the no-project option, and the same Project at a different site. The comparison was done qualitatively.

When the scale and the type of the Project are the same, similar positive and negative impacts are expected no matter the location of the Project. The Proposed Plan for the substation and the transmission line is designed to minimize the negative impacts, and there is a possibility that the negative impacts may be larger when other locations are chosen for the Project.

With the no-project option, the electrification rate in Mon State may stay the same as the current 35.7%, and the improvement in various economic activities and livelihoods may be smaller compared to the with-project option.

In the Preparatory Study Phase of the Project, another comparative study of alternatives, including evaluation of cost, technical aspect, and social and environmental aspect, must be implemented.

Table 4.2-3 Preliminary Comparative Study of Alternatives

		Alternative 1	Alternative 2	Alternative 3
		No-project option	Proposed plan	Project at different site
Project	Substation	None	80 acres, 32.4ha	Same as Alternative 2

		Alternative 1	Alternative 2	Alternative 3
		No-project option	Proposed plan	Project at different site
scale	Transmission line	None	・Length about 210 km, ・ROW width about 61m	・Length may be longer than Alternative 2 ・ROW width will be the same as Alternative 2
Impact type	Land acquisition	None	・32.4ha will be purchased for substation ・Land use will be restricted within the ROW	・Same as Alternative 2
	Resettlement	None	None	May be generated
	Livelihood	No change	・Acquisition of rice paddies will negatively affect the livelihoods of the owners and workers ・Project-related employment and procurement will generate positive impacts on local economy ・Higher electrification rate may lead to improvements in employment or income increases for personal businesses	・The same type of positive and negative impacts will be generated as Alternative 2 ・The significance of the impacts may vary depending on the location of the Project
	Infrastructure	・No change ・Electrification rate in Mon State (2014) was 35.7% (National average 32.4%)*	・Higher electrification rate in the area near to the substation is expected	・Same as Alternative 2

*Source Data Collection Survey on Regional Infrastructure in Myanmar, Final Report, January 2019