The Republic of the Union of Myanmar

DATA COLLECTION SURVEY
ON
URGENT UPGRADE OF ELECTRICITY SUPPLY
IN
THE REPUBLIC OF THE UNION OF MYANMAR

FINAL REPORT

October 2017

Japan International Cooperation Agency

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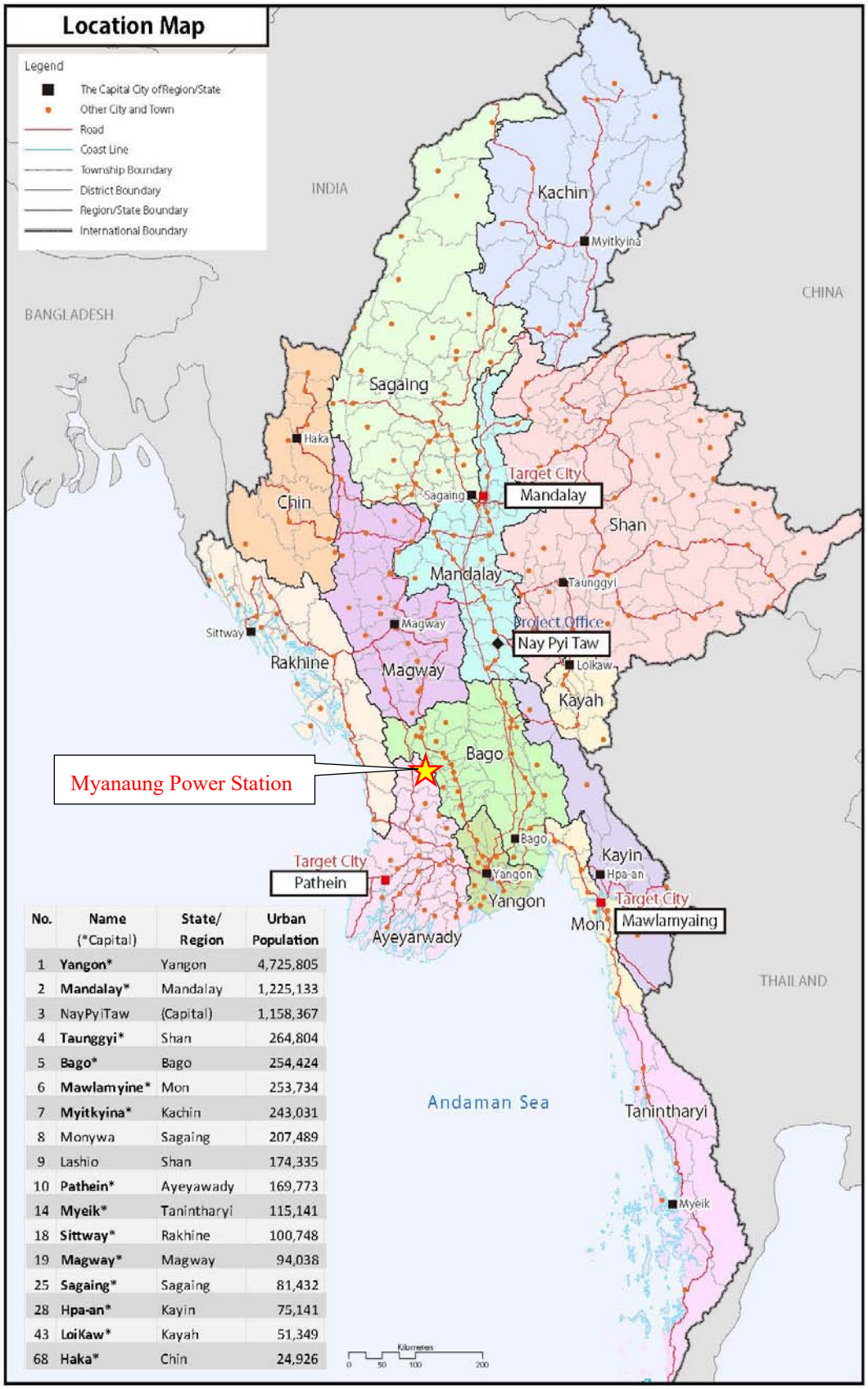
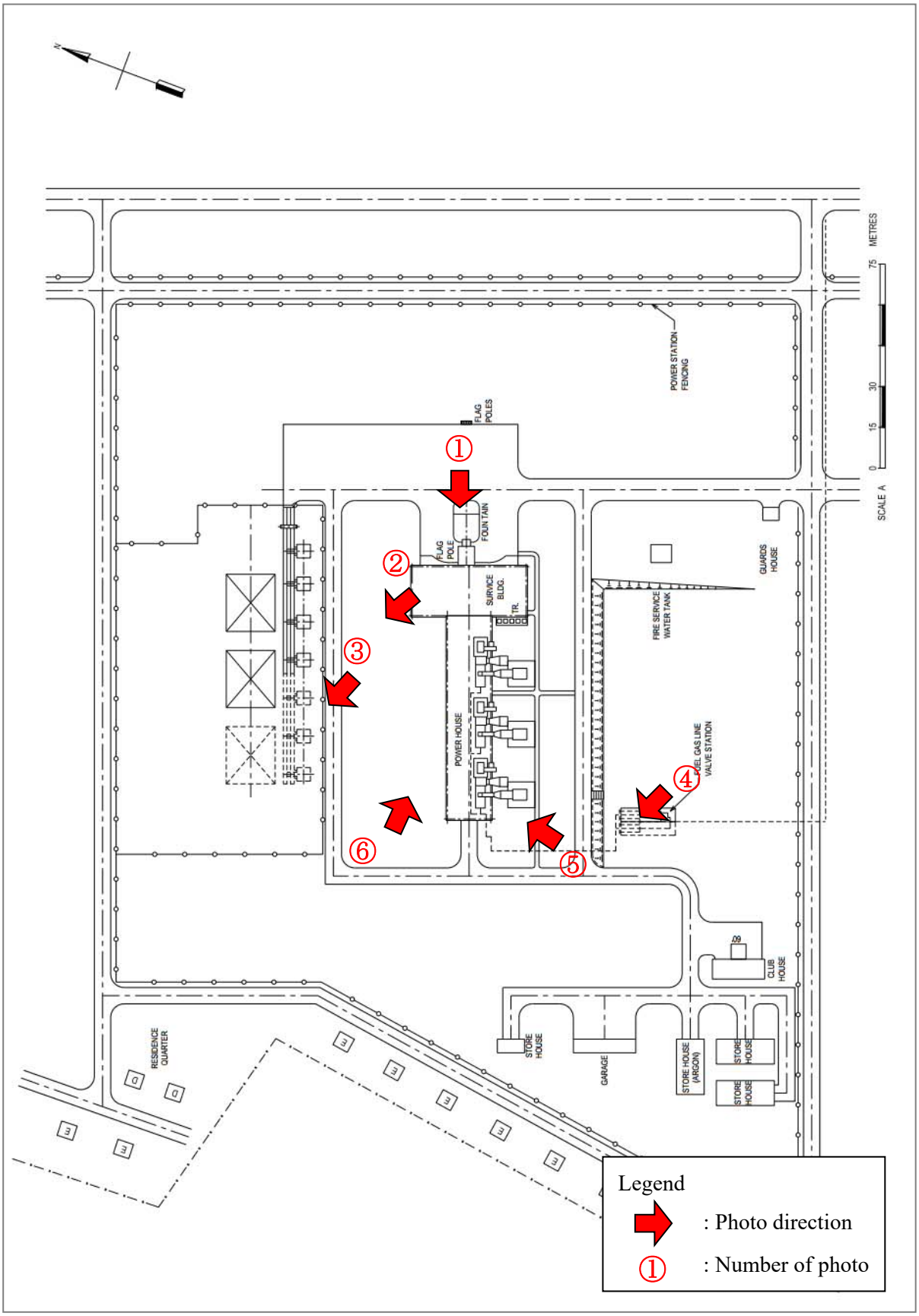


No.	Name (*Capital)	State/ Region	Urban Population
1	**Yangon***	Yangon	4,725,805
2	**Mandalay***	Mandalay	1,225,133
3	NayPyiTaw	(Capital)	1,158,367
4	**Taunggyi***	Shan	264,804
5	**Bago***	Bago	254,424
6	**Mawlamyine***	Mon	253,734
7	**Myitkyina***	Kachin	243,031
8	Monywa	Sagaing	207,489
9	Lashio	Shan	174,335
10	**Pathein***	Ayeyawady	169,773
14	**Myeik***	Tanintharyi	115,141
18	**Sittway***	Rakhine	100,748
19	**Magway***	Magway	94,038
25	**Sagaing***	Sagaing	81,432
28	**Hpa-an***	Kayin	75,141
43	**LoiKaw***	Kayah	51,349
68	**Haka***	Chin	24,926

Source: Data Collection Survey on Urban Development Planning for Regional Cities

Figure 1 Location Map of Myanaung Power Station



Source: Myanaung Power Station Completion Report

Figure2 Layout of Myanaung Power Station

Photo-1 Entrance of Myanaung power station

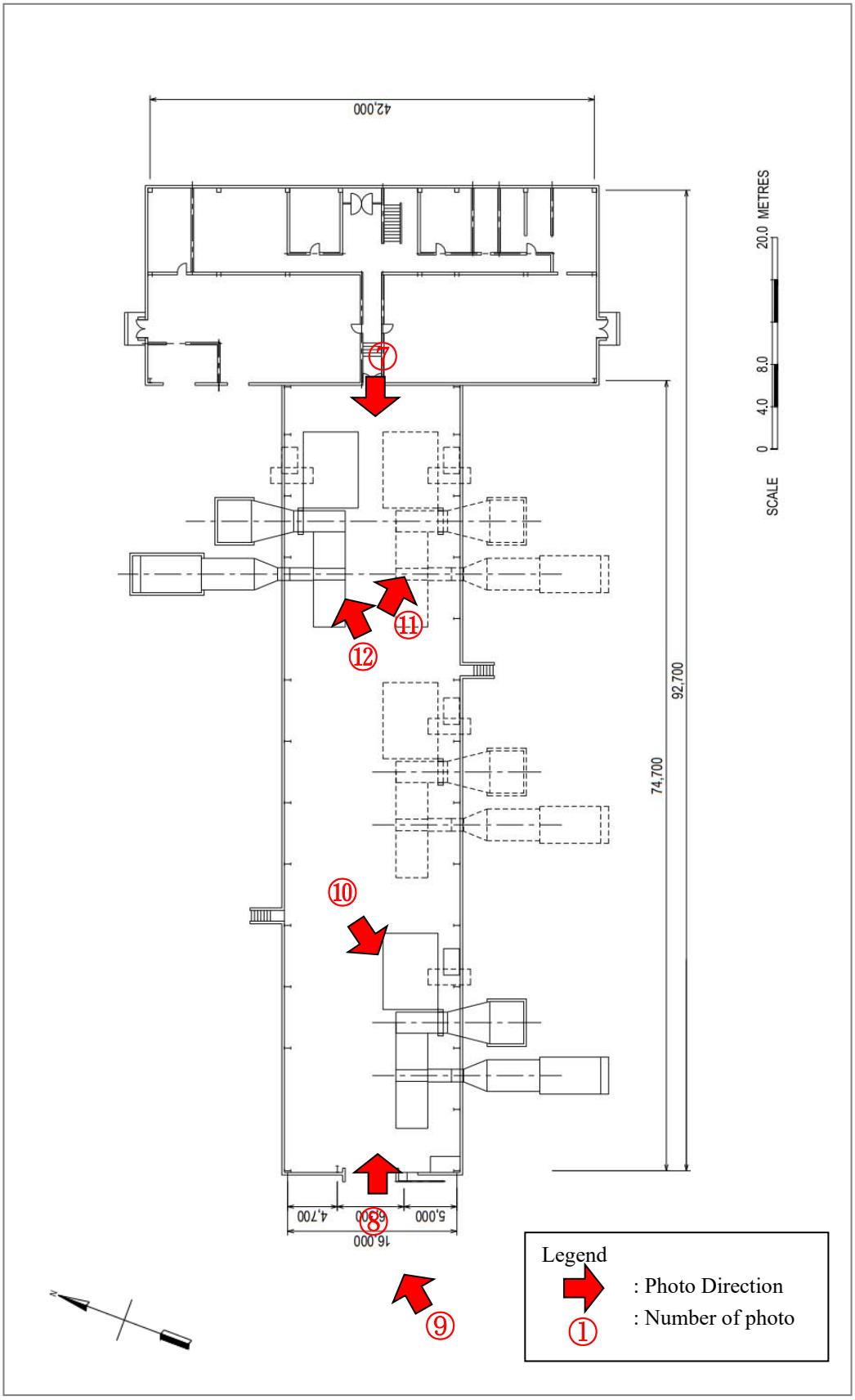
Photo-2 Switchyard overview

Photo-3 Switchyard

Photo-4 Gasyard

Photo-5 Powerhouse from south side

Photo-6 Powerhouse from north side



Source: Myanaung Power Station Completion Report

Figure 3 Layout of Myanaung Powerhouse

Photo-7 from Service Building side	Photo-8 from entrance side
Photo-9 Entrance on west side (W 5 m x H 5 m, 1 m above GL)	Photo-10 Existing gas turbine (Hitachi, under dismantling for parts supply to Thaton)
Photo-11 Bay after removal of gas turbine (Hitachi)	Photo-12 Existing gas turbine (John Brown, in operation)

Urgent Upgrade of Electricity Supply in The Republic of the Union of Myanmar

- Summary -

1. Urgent Upgrade of Electricity Supply

1.1 Outlines of Urgent Electricity Supply – Myanaung Gas Engine Generators (GEG)

The Electric Power Generation Enterprise (EPGE) and the JICA Survey Team discussed the "Urgent Upgrade of Electricity Supply in the Republic of the Union of Myanmar" and confirmed its contents as follows:

(1)	Executing agency	:	Electric Power Generation Enterprise (EPGE)
(2)	Financing body	:	EPGE
(3)	Installation site	:	Myanaung Power Station, Ayeyarwady Region
(4)	Schedule	:	Assumed to start design works within November 2017 and the commercial operation in September 2019
(5)	Goods	:	Gas Engine Generators (GEGs)
(6)	Delivery time	:	11 months from the date of receipt by the Contractor of Notice to Proceed (NTP) after concluding the Contract till the delivery of the GEGs to the Myanaung Power Station. 16 months from the date of receipt of NTP to the commercial operation date.
(7)	Performance required	:	

(a) Fueling the Yadana gas which has the minimum heat value of GCV 710 Btu/scf or NCV 640 Btu/scf and daily supply volume of 7 mmscfd at the price of USD 7.50/mmBtu; GEGs will be selected through tendering and the successful tenderer will be the one that can generate as much electricity as possible at the lowest kWh cost. The potential output, using Yadana gas and the latest models of GEGs available in the market, would be about 25 MW. The gross capacity of GEGs will be the product of unit capacity and unit numbers of the model offered by the successful tenderer. Estimating the capacity based on the unit output of GEG models available in the market, it would be in the order of 23-24 MW[1].

[1] When imported liquefied natural gas (LNG) will be 100% used in the future in between 2021 and 2026, the calorific value would increase by more than 30%, the potential power would be about 35 MW. In this case, it would be possible to install another unit.

ISO 3046 stipulates the tolerance of heat rate at 5%. Based on this clause, there might be a case to present the efficiency on the higher side but within the tolerance. To avoid such inappropriate figure and compare the heat rates and efficiencies fairly, zero tolerance may desirably be included in the tender documents, and not to accept any tolerance from the offered level.

(b) High speed GEG (1,500 rpm at 50 Hz) can be smaller in the size of a cylinder. It will be lower in price but less durable. The GEGs under survey are to be installed in the power station of the state power company for continuous base power generation over a long period of about 30 years. Accordingly, the GEG should be of medium speed. The engine speed will be specified to be 750 rpm[2] or below. The proposed GEGs will target to replace also the IPP rental schemes of small GEGs of 1-1.5 MW for short contract period, which caused the rising of generation costs and needed subsidies to the retail electricity price.

(c) Physical dimensions of the GEGs shall allow installation in the existing building of the Myanaung Power Station.

(d) Nitrogen oxide (NOx) concentration in the exhaust gases shall be less than 200 mg/Nm^3 under oxygen concentration of 15%. The noise level shall be less than 45 dB at any point on the border of the Myanaung compound.

(e) The GEGs will be carried by 1,500 ton-class barge cruising from Yangon Port on the Ayeyarwady River. It will touch the right bank near the Myanaung Township. The trailer carrying one gas engine will land and drive up to the Myanaung Power Station.

1.2 Background of the Selection of Myanaung Power Station and GEGs

The Government of Myanmar (GOM) is planning to urgently install new gas-fired generators to the existing Myanaung Power Station. This site was selected for maximum use of existing land, facilities, and staff at Myanaung Power Station. At the same time, it will avoid the acquisition of expensive land in Yangon and noise of GEG at the center of city life.

Thereafter, it was clarified that even small GEGs installed by independent power producer (IPP) on rental basis in 1 to 2-month period will achieve high efficiency of over 40%. The efficiency of GTG is lower by about 10% compared with large GEG. Accordingly, GEG will consume the same amount of gas as the mobile GTG but its energy output will be greater than that of GTG by about 28% (= 46% / 36% = 1.28). GEGs will contribute to maximize the use of domestic gas resources, reinforce the generation capacity of EPGE, and improve the average heat rates of EPGE's thermals. The JICA Survey Team supports the judgement and request of GOM to give priority to efficiency rather than the delivery time.

1.3 Needs and Effects of the Urgent Grant

In Myanmar, the power demand is rapidly increasing along with the economic growth. The maximum load of 3,075 MW was recorded in May 2017. It is forecasted that the power demand will steadily grow in the future. In accordance with the aging of existing gas thermal power stations, the reserved power will decrease. The power demand reaches an annual peak in the dry season when the hydropower output

[2] Time-degradation curve of heat rate or efficiency may be the basis for judging durability. It is desirable to require the curve in the tender documents and judge the durability.

drops. This increases the risk of supply shortage in the dry season. It is well recognized in Myanmar that the Urgent Upgrade of Electricity Supply is essentially required.

The existing John Brown GTG of Myanaung Power Station will stop operation upon the commissioning of new GEGs. The GEGs will utilize the same amount of gas and will increase the energy output by about 93 GWh[3]. The GEGs will generate about 157 GWh[4] annually and deliver power to the consumers. The Urgent Grant would save an annual expense of EPGE amounting to USD 3.1-3.6 million. At the same time, it would supply stable power to about 260,000 households.

1.4 Consistency with Medium to Long-term Policy for Power Generation

The Myanaung Urgent Electricity Supply will be implemented preceding the large-scale LNG-fired thermals which will be introduced in the short to medium term. Thus, the project will contribute to mitigate the pressed supply-demand balance in the Yangon area. This will replace the IPP rental GEGs for contract period of a few years. It will achieve long-term operation for about 30 years and improvement in efficiency by about 5%, i.e., reinforcing the generation capacity and lowering the average generation costs. At the same time, the GEGs having efficiency of about 46% (with zero tolerance and when the Yadana gas is used) would replace the existing John Brown GTG, which has an efficiency of about 19%. This introduction of new GEG is in line with the national energy policy to achieve the most efficient use of domestic gas resources.

1.5 Issues

(a) If ODA is provided, the potential undertaking of the Japanese side for the Myanaung Urgent Electricity Supply is to supply appropriate set of GEGs, ocean freight to Yangon, and inland transportation up to the Myanaung Power Station. However, for the GEGs to fully exert their performance and continue power generation in the long-run it is a must for the contractor (professional experts of both GEG installation contractor and GEG maker) to undertake the following technical guidance services:

- Installation guidance for full set of GEGs including auxiliary equipment (professional experts of both GEG installation contractor and maker);
- GEG assembling and test operation (by professional experts of GEGs maker); and
- Seminar and training to the operation and maintenance (O&M) staff of EPGE, including at the overseas training facilities of the maker.

(b) The technical guidance above and the supply of GEGs are of the same root and cannot be separated. Accordingly, in the forthcoming tender, necessary man-months (MMs), unit price, remuneration, and trip expense may be estimated by the tenderer and filled in the specified schedule form. For example, the successful tenderer may be required to conclude the contract

[3] (24 MW – 11.5 MW) x 8,760 hr x 0.85 (assumed plant factor) = 93 GWh
[4] 23.4 MW x 8,760 hr x 0.85 x 0.90 (assumed transmission & distribution losses) = 157 GWh

for technical guidance services based on the cost estimates at appropriate time, in addition to the contract for supply of GEGs.

(c) The Yadana Gas Field will start to decline its gas production from 2021 and will be exhausted by 2017. To urgently import liquefied natural gas (LNG), the Myanmar Oil and Gas Enterprise (MOGE) executed the Pre-Feasibility Study of Floating Storage and Regasification Unit (FSRU) with support from the World Bank. The feasibility study (FS) will follow. The FSRU contractor will be invited to start LNG import from 2021. The LNG will replace the Yadana gas to the Myanaung Power Station at some point within the period from 2021 to 2026. The calorific value will increase after changing to the LNG. The GEGs under study will be able to adjust to the new calorific value by changing the engine setup and confirming the combustion conditions.

2. Recommendation to Power Sector

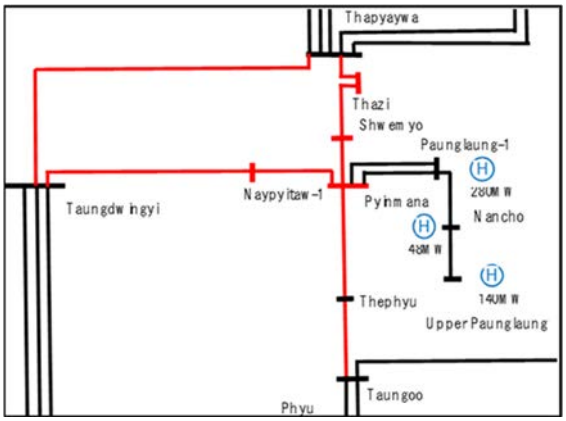
2.1 Issues and Recommendation on Transmission of Bulk Power in the Northern Area to Yangon

Upon completion of the planned 500 kV transmission system, the issue of transmitting sufficient electric power from the northern area to Yangon, which is the current biggest issue, will be solved. However, it is important afterwards that a stable electric power should be transmitted continuously from the northern area to Yangon, the largest demand area. Looking at the electric power system from the point of view of continuous power supply, even after the completion of the 500-kV transmission system, the N-1 criteria[5], a rough standard for stable power supply, is not satisfied.

The transmission tower could collapse due to landslide or erosion by water which are occurring worldwide to the extent that such accident cannot be ignored. Myanmar is no exception. It is possible that an accident such as collapse of a tower occurs somewhere in the 500-kV transmission line built over a long distance of 500 km. In case of tower collapse, the 500-kV transmission line loses its function, i.e., the power supply source will drop out by greater than half, and the national grid instantly collapses. Due to such large and strong shock, many thermal power plants are likely to be affected seriously. As a result, even if power supply is resumed particularly in Yangon area, the situation of limited supply area and partial supply suspension would be prolonged.

Fortunately, Myanmar has been actively promoting the development of hydropower plants. It is a great advantage that hydropower plant has higher durability against such electrical shock than thermal power plant. In addition, most of the hydropower plants are of the reservoir type. It has the capability to continue operation for a certain period with hydropower alone, so these power plants are the center of restoration of the system function at the time of system collapse. However, many hydropower stations are concentrated in the northern area far from Yangon. It is necessary to develop and reinforce urgently the existing 230 kV transmission system so that a certain amount of electricity can be transmitted to the Yangon area even under the shutdown of the 500kV lines.

Looking at the current 230 kV system, the major obstacle in transmitting electricity from the north to the Yangon area is the sections shown in Figure 1. In order to minimize the damage caused by an accident in the 500-kV transmission line, the JICA Survey Team particularly recommends that the weak sections in the 230-kV transmission line be urgently reinforced.



Source: Prepared from the grid map of DPTSC.

[5] The grid under normal and steady conditions is denoted as N and the grid from where one of the elements dropped off due to certain accident is denoted as N-1. The weakness of the grid will be checked for any possible N-1. This is the criteria often adopted in the developing countries.

Figure 1 230 kV System of Pyinmana and its Surrounding Area

Table 1 shows the power flow at 19:00 on May 23, 2017 when the maximum load to date was recorded. Most of the problematic sections of the transmission network shown in Figure 1 use double conductors per phase. The power flow in Table 1 presents high values but being much lower than the allowable capacity. Although not included in Figure 1 (but shown in Figure 3), it should be noted that the Myaungtagar-Hlaingtharyar Line is 605 MCM single conductor per phase. The line would be close to overloading every day.

Table 1 Power Flow at 19:00 on May 23, 2017

Transmission Line		Conductor (MCM)	Allowable Capacity (MW)	Power Flow (MW)	% Load
From	To				
Thapyewa	Taungdwingyi	2x605	460	282.9	61.5%
Thapyewa	Thazi	2x605	460	193.1	42.0%
Thazi	Shwemyo	1x795	273	131.5	48.2%
Shwemyo	Pyinmana	1x795	273	130.5	47.8%
Pyinmana	Thephyu	2x605	460	202.2	44.0%
Pyinmana	Naypyitaw	2x605	460	170.0	37.0%
Naypyitaw	Taungdwingyi	2x605	460	133.0	28.9%
Thephyu	Taungoo	2x605	460	183.4	39.9%
Myaungtagar	Hlaingtharyar	1x605	230	202.3	88.0%

Note: Refer to Figure 3 for the route of the Myaungtagar-Hlaingtharyar line.
Source: Prepared from the power flow analysis of DPTSC

The power flow in Table 1 was under normal operation condition. For example, if the Thapyewa-Taungdwingyi Line fails, its power flow of 280 MW will flow into the Thapyewa-Thazi-Shwemyo-Pyinmana Line, possibly overloading by 130% – 140% or more. In addition, the 132-kV transmission network for the regional power supply will also be greatly affected.

Therefore, it is required to check whether the N-1 criteria are satisfied for the existing 230 kV and 132 kV transmission systems including transmission lines currently under construction. Then, an augmentation plan may be prepared and should be urgently executed.

2.2 Issues and Recommendation on Reinforcement of Power Supply System in Yangon Area

The problem of the transmission system in Yangon area is also related to the 500-kV line. Figure 2 illustrates the 230 kV and 66 kV transmission grid map of Yangon area.

Table 2 shows the power (load) supplied from the 230 kV substations to the customers at 19:00 on May 23, 2017 when the maximum load to date was recorded. The table shows the existing thermal power plants are largely concentrated on the west side. On the other hand, the load is also concentrated in the west, but the urbanization is progressing in the eastern area. The degree of uneven distribution of the demand is not so large as per the power generating/supply capacity.

Table 2 Load of 230 kV Substations in Yangon

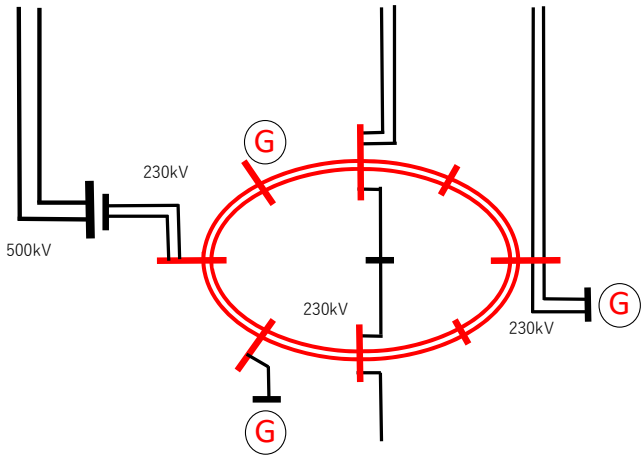
Substation	230kV Line (MW)		Generation (MW)	Load (MW)
	In	Out		
West Area			524.00	927.88
Hlaningtharya	340.70	204.45	0.00	136.25
Bayintnaung	42.98	0.00	0.00	42.98
Ahlone	94.81	0.00	184.20	279.01
Ywama	0.00	128.38	245.00	116.62
Hlawga	257.76	120.51	94.80	232.05
Myaungtagar	333.29	212.32	0.00	120.97
East Area			68.30	333.47
Thaketa	210.24	0.00	68.30	278.54
Thanlyin	179.66	124.73	0.00	54.93
Total			592.30	1261.35

Note: In – Out + Generation = Load
Source: Power Flow Analysis on May 23, 2017 by DPTSC

In addition to the west-concentrated uneven distribution of the thermal power plants, a great power flow will be fed to the western area by the 500-kV transmission line. The power flow on the 66-kV line goes from west to east. After the completion of the 500-kV line, it will further accelerate and the power flow from the west to east will always increase. Thus, the burden on the existing transmission lines of 66 kV and 33 kV will increase, which may cause overloading. Especially in the Yangon area, there are many underground cable lines that are sensitive to heating.

The fault of the 230-kV system including substations, such as failure of the Thaketa Substation or incoming transmission line thereto, would increase the power flow from the west to east and would incur serious risks of overloading, cable firing and so forth.

In order to mitigate the situation above, the JICA Survey Team proposes that the Ring Main System be constructed with double circuit line, as illustrated in Figure 2 by utilizing the existing 230 kV facilities as much as possible.



Source: the JICA Survey Team

Figure 2 Illustration of Ring Main System

After commissioning of the Ring Main System, it will be possible to switch the power supply route promptly if supply fails due to accidents on the transmission lines and/or substation. Almost normal

operation could be continued.

The development plan of transmission network of Yangon area with ADB assistance is newly provided to the JICA Survey Team in September 2017. A loan agreement totaling USD 80 million was signed on April 26, 2016. The plan composed of the following new construction, expansion and enhancement plans:

(a) New double circuit 230/66 kV 8.5 km long overhead transmission line between Thida substation and Thaketa substation;

(b) Single circuit 230 kV overhead transmission line between Thaketa substation and Kyaikasan substation, including the expansion of the 230 kV Thaketa substation, the expansion and upgrading of the Kyaikasan substation into a 230/66/11 kV substation;

(c) Construction of a new 230/66/11 kV, 2x150 MVA South Okkalappa substation; and

(d) Construction of a new 230/33/11 kV, 2x150 MVA, West University substation[6].

With the reinforcement plans above, the Outer Ring of Ahlone- Thida-Thaketa – South Okkalappa – Hlawga – Myaungtagar – Hlaingtharyar – Ahlone[7] will be established. Table 4 shows the transmission lines that make up the ADB-proposed Ring System.

Table 4 Transmission Lines Forming Outer Ring System with ADB Loan

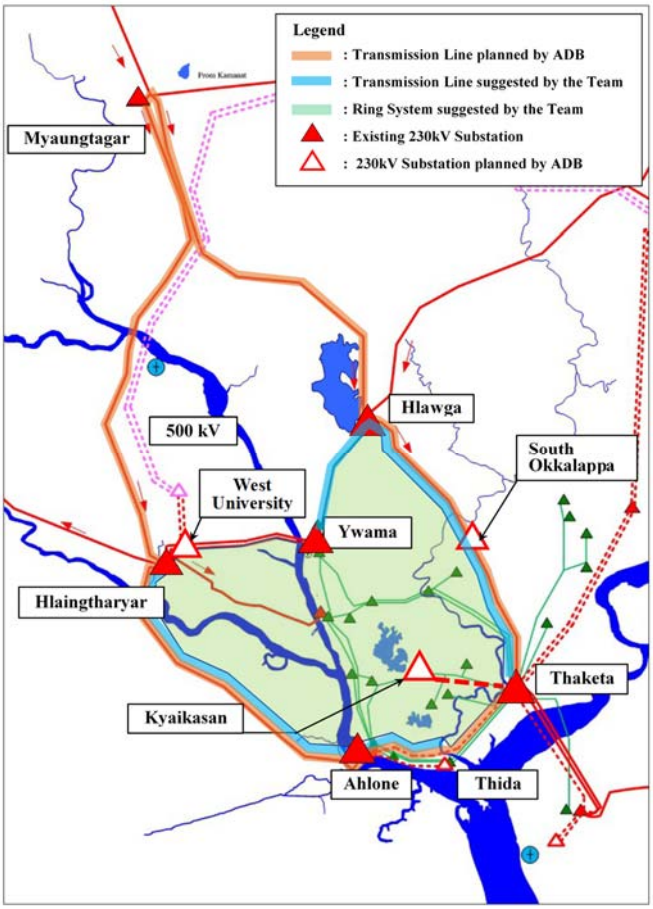
	230kV Transmission Line		Length	CCT	ACSR	Fund
1	Ahlone	Thida	-	-	-	EPDC
2	Thida	Thaketa	8.5	2	-	ADB
3	Thaketa	South Okkalappa	-	1	795	Existing
4	South Okkalappa	Hlawga	-	1	795	Existing
5	Hlawga	Myaungtagar	25.9	1	2x605	Existing
6	Myaungtagar	Hlaingtharyar	40.2	1	605	Existing
7	Hlaingtharyar	Ahlone	22.4	1	2x605	Existing

Source: DPTSC and ADB's Report

Remark: "-" means no information

6 This substation connects the 500 kV lines and 230 kV lines in Yangon area.

7 It is estimated that construction of the Ahlone-Thida lines and Thida substation is being planned by DPTSC. However, there is no information provided by DPTSC and details are not known.



Source：Prepared by the JICA Survey Team on the original map of DPTSC.

Figure 3 230kV Transmission Facilities Forming Ring Main System

In the ADB plan shown in the table and the figure above, the following issues are considered[8]:

(a) The total electricity transmit by the 500-kV transmission line and Ywama Power Station to the Hlaingtharyar substation will be 1,288 MVA. On the other hand, the allowable capacity of the Hlaingtharyar-Ywama Line is 2x642=1,284 MVA, which is marginally below the estimated maximum power fed to the Hlaingtharyar substation. The line will be extremely overloaded in case of one circuit fault.

(b) Electricity is supplied from Hlaingtharyar to the Ring System via two transmission lines to the north and south i.e. Hlaingtharyar-Ahlone Line and Hlaingtharyar-Myaungthagar Line. The allowable transmission capacity of the lines is 542 MVA and 271 MVA respectively, totaling 813 MVA. That is, even if the transformer capacity of 200 MVA of the Hlaingtharyar substation is combined, it is still 1,013 MVA. This is obviously less than the total power fed from the West University substation. The transmission lines for sending out may always be overloaded. Furthermore, in case of one

[8] The data of the existing transmission lines were provided by DPTSC in September 2017. However, these were copy of the input data for the grid analysis and the details of the transmission lines were not included. Therefore, the issues were examined based on the data provided and the following estimates:

- Transformer capacity of 500/230kV substation in Yangon: 2x500 MVA
- Conductor size of Hlaingtharyar – Ywama line: 2x795 MCM (642 MVA/CCT)
- Conductor size of Hlaingtharyar – Ahlone line: 2x605 MCM (542 MVA/CCT)

circuit fault, the remaining circuit becomes extremely overloaded.

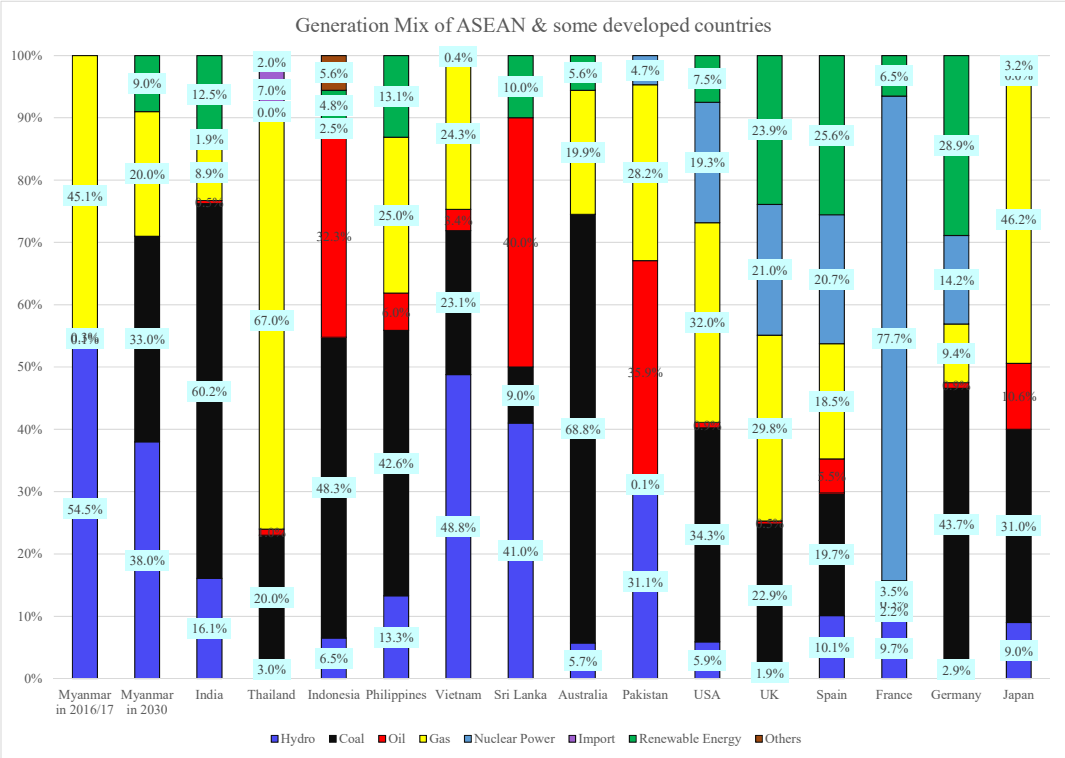
(c) The planned greater Ring System is of eggplant-like shape and utilizes the existing transmission lines to the possible maximum extent. However, it does not necessarily surround only the load center.

Based on the examination in this study, the JICA Survey Team propose that the Heart-shaped Ring System be additionally created, namely, Ahlone-Thida-Thaketa-South Okkalappa-Hlawga-Ywama-West University -Hlaingtharyar-Ahlone as shown in Figure 3. The Heart-shaped Ring System can be created by simply adding "Ywama-Hlawga double circuit overhead transmission lines" which surround the highly loaded area in Yangon. Besides, it does not affect the facilities planned for implementation under the ADB loan.

The proposed Heart-shaped Ring System should be the key to the future power supply in Yangon area. Therefore. the Team propose that four reinforcing plans be implemented in addition to the Ywama-Hlawga Lines above (refer to Section 7.2 for details).

2.3 Recommendation of National Campaign for Coal Information Sharing

The National Electricity Master Plan 2014 (MP-2014) of Myanmar was prepared with support from the Japan International Cooperation Agency (JICA). In the MP-2014, the total generation capacity in 2030 is planned to be 23,600 MW. The generation mix is 38% hydro, 20% gas thermal, 33% coal thermal, and 9% renewables (see 4). In Myanmar, both hydros and gas thermals have been built and currently share 55% and 45%, respectively. On the other hand, Tigyit is the only coal thermal plant constructed in 2004 with 120 MW (2 x 60 MW). Unfortunately, however, no environmental protection devices were provided at Tigyit. Air and water pollutions of the Tigyit reportedly threaten the agriculture and health of the people around and caused serious hazards to the environment. The environmental hazard at Tigyit triggered the opposition to coal thermals in Myanmar. Significant parts of the nation's people participated in the opposition movement against the other coal thermals also. For example, Toyo-Thai planned a coal thermal in Ye, Mon Region and concluded a memorandum of understanding (MOU) with the previous government. However, it faced hard opposition by the people and the Mon Governor declared withdrawal of the Ye Coal Thermal in July 2017.



Source: Compiled by the JICA Survey Team with assumed generation efficiency and unit emission based on generation mix as follows: India to Pakistan: "Power Situation and Policy in Asia and Oceania Countries", May 2015, JETRO
USA to Japan: METI, http://www.enecho.meti.go.jp/about/pamphlet/pdf/energy_in_japan2016.pdf

Figure 4 Generation Mix of Asian Countries and Some Developed Countries

Meanwhile, GOM invited IPP contractors for the renovation of the Tigyit Coal Thermal Plant. A Chinese IPP contractor replaced the boilers and steam turbines and added environmental protection devices by 2017. Three-month test operation has been finished by July 2017 and one-year reliability run test is ongoing.

The GOM and energy-related officers and experts have detailed information and well recognize that the planned and prompt implementation of coal thermals is vital for Myanmar. However, most of the people do not have such information. Therefore, it might be the actual situation for the people to say "We wish to have access to electricity. But, no environmental pollution! No social adverse impact!" Energy supply is the mother for socioeconomic development of the nation. The policy response to this environmental issue may control the future energy supply in Myanmar. The power policy stands on a critical ridge between the success and failure sides of the socioeconomic development of Myanmar.

Such being the current situation surrounding the coal thermals in Myanmar, it is proposed that the Ministry of Natural Resources and Environmental Conservation (MONREC), which undertakes the environmental policy and administration in Myanmar including coal resources policy, lead the "National Campaign for Coal Information Sharing." The campaign will be supported by the Ministry of Electricity and Energy (MOEE) in the technical aspects of the coal thermals. Through the campaign, correct information will be provided to the people as to the facts: the environmental emissions from the advanced coal thermals in the developed countries are well-managed within the respective regulation levels; and no environmental pollutions are caused. In addition, it is desired that GOM announce and

publicly commit to the Environment and Power Policy: Energy supply is the mother or rice for socioeconomic development of Myanmar; only advanced coal thermals equipped with adequate environmental devices using the latest technology of the developed countries will be approved.

At an appropriate time when the information sharing to the people has deeply spread to a significant level, Japanese technical cooperation may desirably be started with an FS and Strategic Environmental Assessment (SEA) of coal thermals, targeting the future yen loan of JICA.

2.4 Recommendation of Capacity Development through Implementing State Hydros

Under the current acute shortage of national revenue, the practical power policy would be: "In the short term, large-scale LNG-fired gas thermals may be developed by IPPs. This is for the relatively low capital (construction) costs of gas thermals compared with capital-intensive hydros and coal thermals and short lead time of the IPP schemes. Thus, the priority in the generation expansion will be given to solving the current shortage of generation capacity in the dry season by IPP gas thermals. On the other hand, low cost base power by hydros and coal thermals requires long lead time until commissioning. Therefore, the base power will be developed in the medium to long-term in accordance with the long run least cost generation expansion sequence."

(a) Preparation and Updating of Long-run Least Cost Generation Sequence

To commission in a planned manner the base power that has long lead time, the long run least cost generation expansion sequence should be prepared and updated periodically. To back up the output drops of hydros in the dry season, least cost thermals may automatically be identified from within the catalogue of candidate projects and will be included in the sequence. At the same time, hydros, if obliged to release part of the inflow through spillway instead of power generation with the reservoir at full supply level (FSL) in the rainy season, will not form the least cost. Therefore, in the least cost sequence, the best mix of the generation sources will be automatically progressed (by commissioning state thermals that can adjust power outputs in the rainy season, in parallel with hydros) to facilitate the hydros even with full reservoir to generate secondary energy by lowering outputs and saving fuels of state thermals. Also, to minimize the long run generation costs, low-cost base power of hydros and coal thermals will be put into the least cost sequence one after another in the necessary and appropriate capacity, towards achieving the best mix.

The updating works of the long run least cost generation expansion sequence may have been included in the ongoing updating study of the National Electricity Master Plan sponsored by JICA.

(b) Recommendation of Capacity Development through Implementing State Hydros

It is desirable that MOEE and Department of Hydropower Implementation (DHPI) study the Hydro Development Policy as suggested below:

In addition to IPP hydros, Department of Hydropower Implementation (DHPI) should always lead one State Hydro desirably with public finance of long-term and low interest rate. The objectives of this State Hydro to be led by DHPI are: 1) effective mobilization of DHPI-owned construction machineries and hydropower experts, 2) lowering the generation costs by acquiring international public finance, and 3) sustainable capacity development of engineers and experts. In Myanmar where undeveloped hydropower resources are still abundant, State Hydro will provide opportunities for the young engineers and workers to accumulate experience through participating in the actual design and construction works. The actual project is the best field for the capacity development. Thus, Myanmar engineers, foremen, and skilled workers should lead the future development of hydropower in Myanmar.

The implementation mode of DHPI-led State Hydro may be chosen from among 1) three party conventional model, 2) surface civil works by direct management of DHPI and underground works by JV of DHPI and foreign contractor and electro-mechanical works through international tendering, and 3) public-private partnership (PPP) (also referred to in Myanmar as joint venture/build-operate-transfer (JV/BOT)) and so forth. The selection criteria may be by three points, namely: lead time concerned with the environmental impacts, unit generation costs, and contribution to the capacity building.

Data Collection Survey on Urgent Upgrade of Electricity Supply
in the Republic of the Union of Myanmar

Final Report

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Abbreviations

Abbreviations	Full Spell-out
ADB	Asian Development Bank
AFD	Agence Frangaise de Developpement
AIIB	Asian Infrastructure Investment Bank
BBtud	Billion British Thermal Unit per day
BTU	British Thermal Unit
CAPEX	Capital Expenditure
COD	Commercial Operation Date
DEPP	Department of Electric Power Planning
DHPI	Department of Hydro Power Implementation
DSEZ	Dawei Special Economic Zone
DPTSC	Department of Electric Power Transmission and System Control
EDC	Electricity Development Committee Energy Development Committee
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
EMC	Energy Management Committee
EPD	Energy Planning Department
EPGE	Electric Power Generation Enterprise
ESE	Electricity Supply Enterprise
FIL	Foreign Investment Law
FIRR	Financial Internal Rate of Return
FS	Feasibility Study
FSL	Full Supply Level
FSRU	Floating Storage and Regasification Unit
FSU	Floating Storage Unit
GCV	Gross Calorific Value (High Heating Value)
GCC	Generation Control Center
GDP	Gross Domestic Product
GEG	Gas Engine Generator
GTCC	Gas Turbine Combined Cycle
GTG	Gas Turbine Generator
HPGE	Hydropower Generation Enterprise
HRD	Human Resources Development
IEA	International Energy Agency
IEE	Initial Environmental Examination
IFC	International Finance Corporation
IPP	Independent Power Producer
JBIC	Japan Bank for International Cooperation
JETRO	Japan External Trade Organization
JICA	Japan International Cooperation Agency
JOGMEC	Japan Oil, Gas and Metals National Corporation
LNG	Liquefied Natural Gas
MCM	Mcircular mil
MIC	Myanma Investment Committee
MIL	Myanma Investment Law
MJ/Nm^3	Mega Joule per Normal cubic meter
MM	Man-Month
mmBtu	Million British thermal unit
mmscfd	Million standard cubic feet
MP	Master Plan
MEPE	Myanma Electric Power Enterprise

Abbreviations	Full Spell-out
MOA	Memorandum of Agreement
MESC	Mandalay Electricity Supply Corporation
MOEE	Ministry of Electricity and Energy
MOPF	Ministry of Planning and Finance
MOGE	Myanma Oil and Gas Enterprise
MONREC	Ministry of Natural Resources and Environmental Conservation
MOU	Memorandum of Understanding
MPE	Myanma Petrochemical Enterprise
MPPE	Myanma Petroleum Products Enterprise
NCV	Net Calorific Value (LHV)
NEDO	New Energy and Industrial Technology Development Organization
NEMC	National Energy Management Committee
NGO	Non-Governmental Organization
NLD	National League of Democracy
Nm^3	Normal cubic meter
NPV	Net Present Value
ODA	Official Development Assistance
OPEX	Operating Expense
PM	Particle Matter
PPA	Power Purchase Agreement
PPP	Public Private Partnership
SCF	Standard Cubic Feet
SEA	Strategic Environmental Assessment
SPC	Special Purpose Company
SPDC	State Peace and Development Council
SRV	Shuttle Regasification Vessel
ST	Steam Turbine
WB	World Bank
YCDC	Yangon City Development Committee
YESB	Yangon City Electricity Supply Board
YESC	Yangon Electricity Supply Corporation

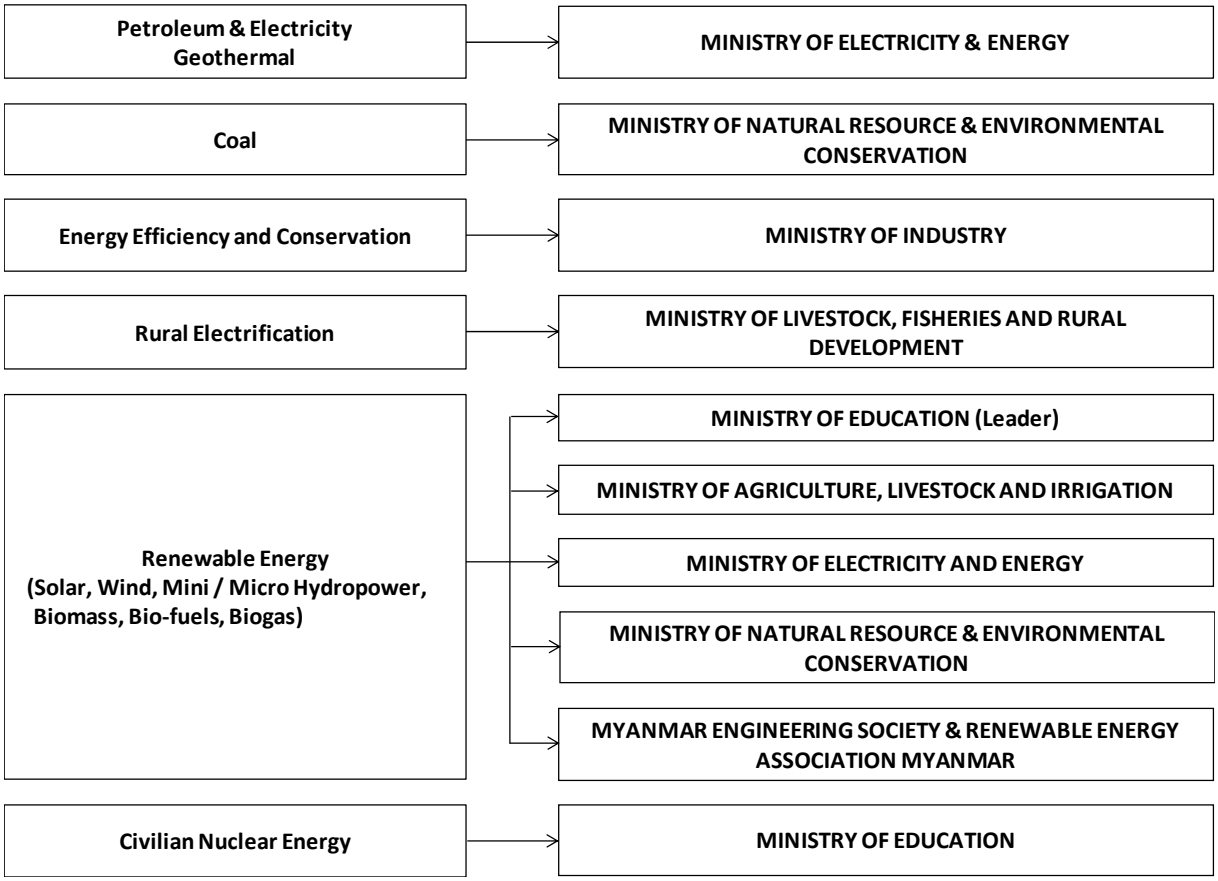
Exchange rate (as of August 1, 2017, Central Bank of Myanamar):

Kyats 1,362 = USD1.00
Kyats 1,233.8 = JPY100
USD1.00 = JPY 110.39

CHAPTER 1 PRESENT SITUATION OF POWER SECTOR

1.1. Organizations and Responsibilities

In Myanmar, the regulatory agencies of the energy sector differ depending on the type of energy. For example, oil and natural gas are under the jurisdiction of the Ministry of Electricity and Energy (MOEE), and mineral resources such as coal are under the Ministry of Natural Resources and Environmental Conservation. The jurisdiction of each ministry in the energy sector in Myanmar is shown in Figure 1.1.1.

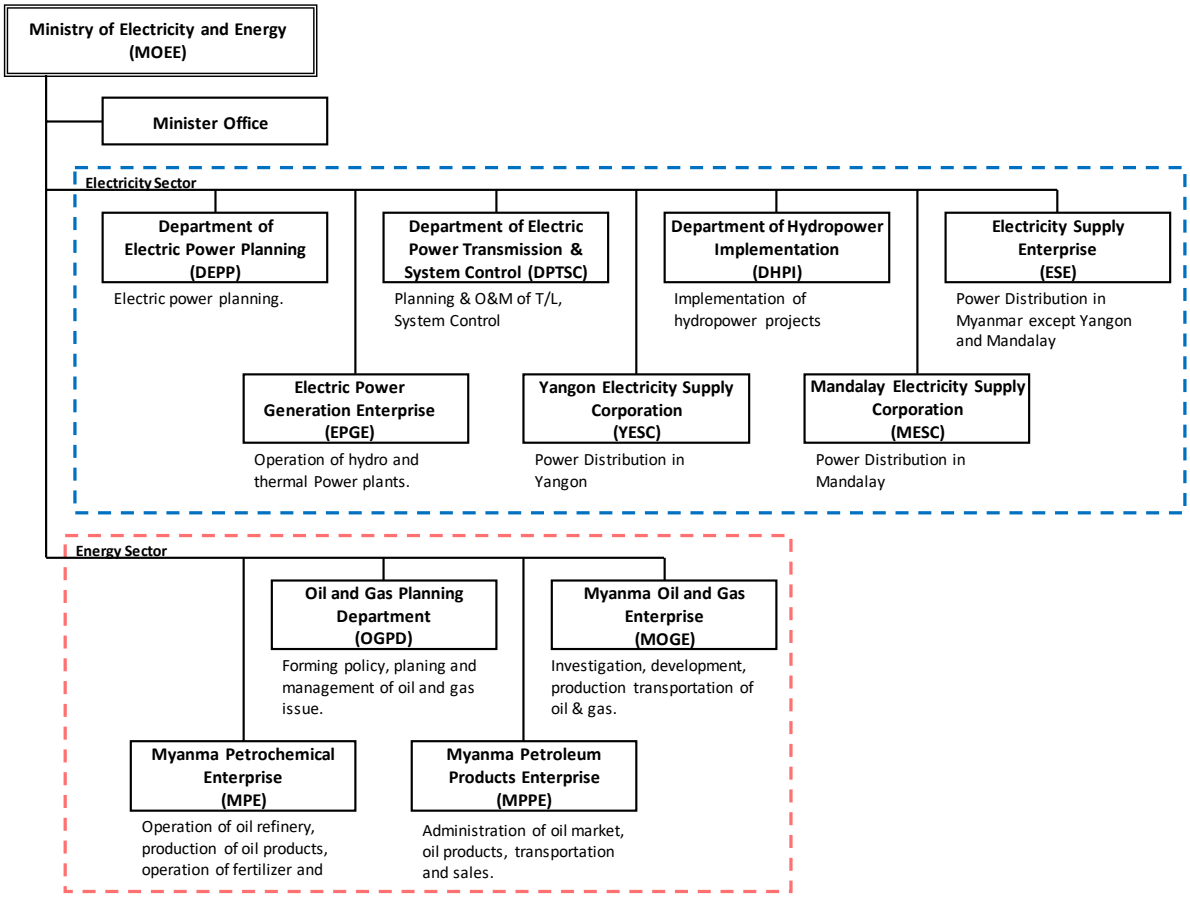


Source: MOEE

Figure 1.1.1 Jurisdiction of Ministries on Energy Policy

The MOEE is responsible for the planning of power policy, budget making, and decision on the electricity tariff strategy in Myanmar. Further, the MOEE has two major roles on power policy, and for the procurement, production, and transportation of oil and gas.

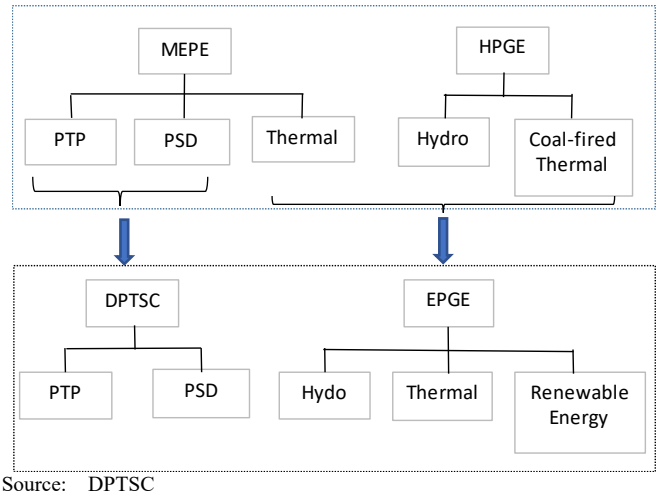
The organization chart of MOEE is shown in Figure 1.1.2.



Source: MOEE, the JICA Survey Team

Figure 1.1.2 Organization Chart of MOEE

The MOEE was established in April 2016 under the structural reform of the government by merging the Ministry of Electric Power and the Ministry of Energy. The staff and departments in the two ministries were basically superseded by MOEE, but some of the departments were merged such as the Electric Power Generation Enterprise (EPGE), which was formed by combining Hydro Power Generation Enterprise (HPGE) and Myanmar Electric Power Enterprise (MEPE).



Source: DPTSC

Figure 1.1.3 Organization of Supervisory Authorities of Trunk Transmission Line Before and After Structural Reform

MOEE has three departments and four enterprises that manage the power sector. The energy sector consists of one department and three enterprises are responsible for gas and oil.

The Department of Electric Power Transmission and System Control (DPTSC) is responsible for the planning, construction and operation of transmission lines and substations, and system control. The load dispatch center exists in DPTSC that controls the power dispatch over the country. The generation divisions and departments are consolidated to EPGE. EPGE oversees the management of domestic hydropower and thermal power stations, power purchase from independent power producers (IPPs), and power supply to the power distribution companies. The Department of Hydro Power Implementation (DHPI) oversees the construction of hydropower plants. The hydropower plants are transferred to EPGE upon the completion of construction.

1.2. Power Development Plan and Power Generation by Existing Power Plants

1.2.1 Existing Power Plants

(1) Thermal Power Plants

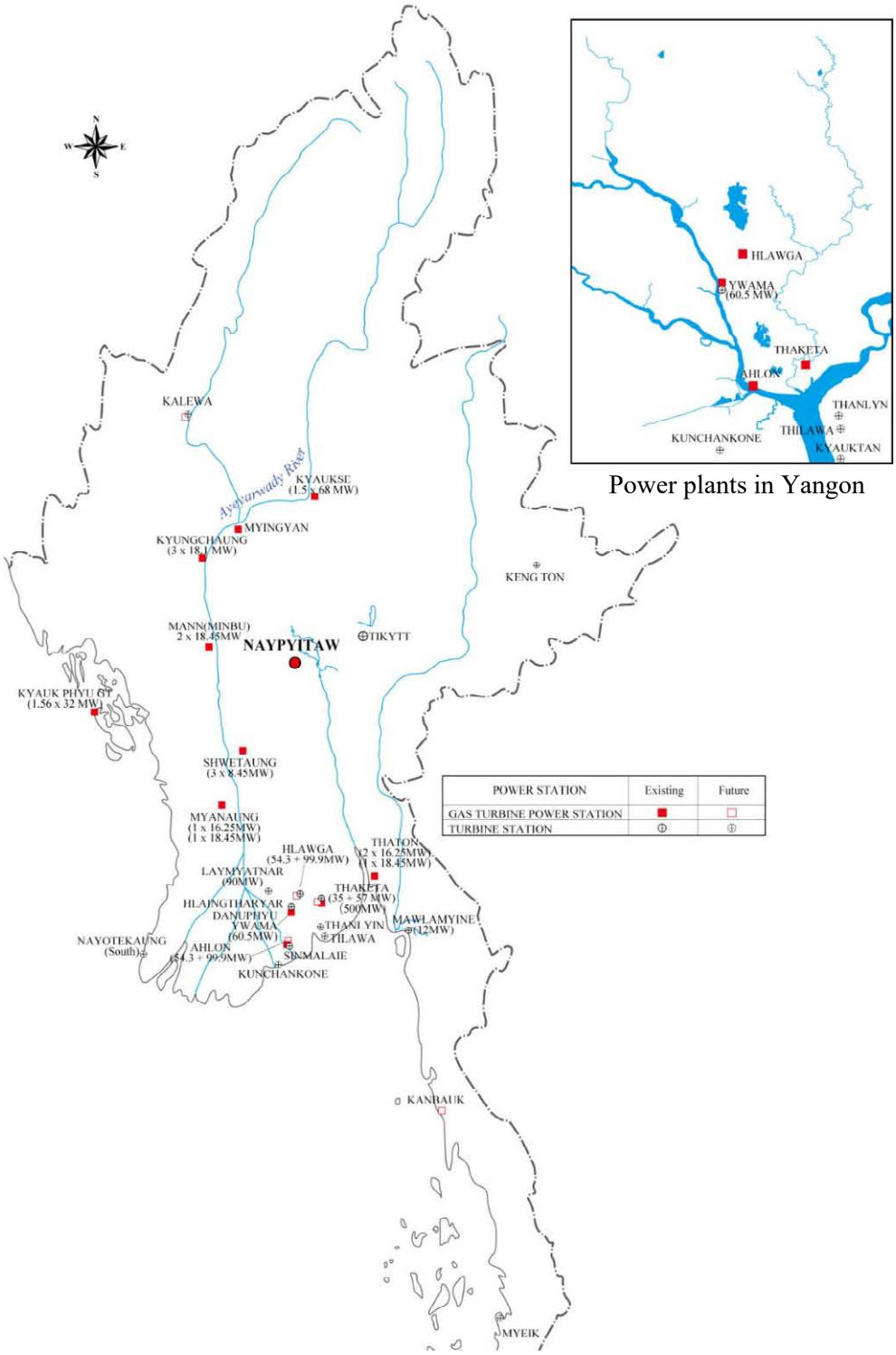
The outline of the existing gas-fired power plants in Myanmar is shown in Table 1.2.1. The location map of gas-fired thermal plants and coal thermal power plants is shown in Figure 1.2.1.

Table 1.2.1 Outline of Existing Thermal Stations

(Include on-going)

Location	Owner	Plant	Type	Installed Capacity				COD	Gas RQMT (mmscfd)	Gas Field	Notes
				MW	No	Total					
Yangon	EPGE	Hlawga	GT	33.30	3	99.9	154.2	1996	39.0	Yadana	
			ST	54.30	1	54.3		1999			
		Ywama	GT	18.45	2	36.9	70.3	1980	28.0		
			GT	24.00	1	24.0		2004			Operation Stop by damage on GT H25
			ST	9.40	1	9.4		2004			
			GT	120.00	2	240.0	240.0	2014	80.0		Donated from EGAT
		Ahlone	GT	33.30	3	99.9	154.2	1995	39.0		
			ST	54.30	1	54.3		1999			
		Thaketa	GT	19.00	3	57.0	92.0	1990	29.0	Zawtika	Operation Stop (1unit) by damage on GT
			ST	35.00	1	35.0		1997			Operation Stop by damage on ST
		Thilawa	GT	25.00	2	50.0	50.0	2016	18.8	Zawtica	H25
	Sub-Total (MOEE)						**761**		**233.8**		
	Zeya (MCP) (Myanmar Company)	Hlawga	GE	1.05	26	27.3	54.9	2013	7.9	Yadana	1st phase in 2013 (Desser-Rand Spain)
			GE	9.20	3	27.6		2015	7.9		2nd phase in 2015 (Rolls-Royce)
	MSP (UPP) (Nyan Shuwe Pyi)	Ywama	GE	4.00	13	52.0	52.0	2013	16.6	Yadana	CAT CG260-16
	Toyo-Thai	Ahlone	GT	41.00	2	82.0	121.0	2013	29.8	Yadana	GE LM6000
			ST	39.00	1	39.0		2014			
	Max Power (CIC)	Thaketa	GE	3.35	16	53.6	53.6	2013	15.0	Yadana	(MITSUI 44%) , MPPL:Singapole, Jenbacher
	Yangon District	Thaketa	GT	25.00	1	25.0	25.0	2017		HFO	
	URSC(Union resources & Enginnnering Co.)	Thaketa	GT	32.00	2	84.0	106.0	2017	no data	no data	Phase I
			ST	42.00	1	42.0		2017		no data	
	Sub-Total (IPP)						**413**		**77.2**		
	Total (Yangon)						**1,173**		**311.0**		
Other Area	EPGE	Kyunchaung	GT	18.10	3	54.3	54.3	1974	18.0	Inland	
		Man	GT	18.45	2	36.9	36.9	1980	12.0	Inland	Operation Stop
		Shwetaung	GT	18.45	3	55.4	55.4	1984	27.0	Yadana	
		Myanaung	GT	18.45	1	18.5	34.7	1984	9 (7)	Yadana	Replace planning by JICA
			GT	16.25	1	16.3		1975			Decommissioned
		Thaton	GT	18.45	1	18.5	51.0	1985	25.0	Zawtika	
			GT	16.25	2	32.5		2001			
		Thaton (World Bank)	GT	40.00	2	80.0	119.0	2016	no data	no data	1) Additional 40MW will be operated from Dec. 2017 GE6F.01
			ST	39.00	1	39.0		2016		no data	2) Additional GT (1unit) & ST (1 unit) will be operated from March 2018
		Mawlamyine	GT	6.00	2	12.0	12.0	1980	4.0	Zawtika	
	Sub-total (MOEE)						**363.3**		**86.0**		
	VPower	KyaukPhyu	GE	1.41	32	45.0	45.0	2015	no data	Shwe	Rental, phase i
		KyaukPhyu	GE	1.41	32	45.0	45.0	2016	no data	Shwe	Phase ii
		Myingyan	GE	1.39	96	133.0	133.0	2016	no data	Shwe	
	Aggreko	Myingyan	GE	1.04	92	95.0	95.0	2015	no data	Shwe	Rental net output
	Sembcorp/MMID	Myingyan	GTCC		2	225.0	225.0	2018	no data	Shwe	
	APR	Kyaukse	GE	1.50	68	102.0	102.0	2014	27.0	Shwe	
	Siamgas and Petrocemicals	Mawlamyine	GTCC	100.00	1	100.0	230.0	2014	no data	no data	
		Mawlamyine	GTCC	130.00	1	130.0		2015	no data	no data	
	APU	Kanbauk								no data	schedule delaied expected 2020
	Sub-total (IPP)						**875.0**		**27.0**		
	Total (Other Area)						**1,238.3**		**113.0**		
Grand Total							**2,411.5**		**424.0**		

Note: GE: Gas engine power plant, GT: Gas turbine power plant, ST: Steam power plant, GTCC: Gas Turbine Combined Cycle
Source: Compiled by the JICA Survey Team referring to materials published by METI, JETRO, and DEPP



Source: MOEE

Figure 1.2.1 Location Map of Thermal Power Stations in Myanmar

As shown in Figure 1.2.1, the gas-fired power plants have been intensively constructed close to Yangon area, which is the largest electricity consumer in Myanmar. In 2017, the IPP's gas turbine power plant was installed in the Thaketa Power Plant site and commenced its operation. There are several gas-fired power plants located along the Ayeyarwady River that supply electricity to the neighboring area.

The issue of Myanmar gas-fired power plants is the degradation of plant performance to the original installed capacity. The beginning and present power plant capacities of the existing-gas fired power plants in Myanmar are shown in Table 1.2.2. The reason of reduction of power output given by EPGE is described in the "Remarks" column.

Table 1.2.2 Current Power Plant Capacity of Existing Gas Fired Power Plants

Location	Owner	Plant	Type	Installed Capacity (Original)				Current Capacity		COD	Remarks
				MW/Unit	No	Total		Unit	MW		
Yangon											
	EPGE	Hlawga	GT	33.3	3	99.9	154.2	2	40	1996	Decrease in power output due to unavailability of gas
			ST	54.3	1	54.3		0	0	1999	Under maintenance. But it is still operable.
		Ywama	GT	18.45	2	36.9	70.3	1	26	1980	One GT is for stand-by.
			GT	24	1	24		1		2004	Operation stopped by damage on GT H25
			ST	9.4	1	9.4		0	0	2004	Under rehabilitation (Turbine blades are damaged)
			GT	120	2	240	240	1	100	2014	
		Ahlone	GT	33.3	3	99.9	154.2	2	50	1995	One is for stand-by. If the gass is available, all units can be operated.
			ST	54.3	1	54.3		1		1999	
		Thaketa	GT	19	3	57	92	2	24	1990	1 unit of GT and ST are under overhaul.
			ST	35	1	35		0	0	1997	ST is heaviliy damaged in generator rotor & excitation system and under overhauling
		Thilawa	GT	25	2	50	50	2	50	2017	
	Total EPGE				20		761		290		
	Zeya (MCP)	Hlawga	GE	1.05	26	27.3	54.9	26	48.0	2013	
			GE	9.20	3	27.6		3		2015	
	Toyo Thai	Ahlone	GT	41	2	82	121	2	115	2013	
			ST	1	1	39		1		2014	
	Max Power (CIC)	Thaketa	GE	3.35	16	53.6	54	14	45	2013	
	MSP (UPP) (Nyan Shuwe Pyi)	Ywama	GE	4	13	52	52	13	48	2014	Efficiency is low due to gas composition.
	Yangon District	Thaketa	GT	25	1	25	25	1	25	2017	
	URSC(Union resources & Enginnnering Co.)	Thaketa	GT	32	2	84	106	2	106	2017	
			ST	42	1	42		1		2017	
	Total IPP				65		413		387		
Total Yangon					85		1173		677		
Local											
	EPGE	Kyunchaung	GT	18.1	3	54.3	54.3	1	12	1974	Two units are stand-by. It uses onshore
		Man	GT	18.45	2	36.9	36.9	0	0	1980	Stop generation due to no availability in gas.
		Shwetaung	GT	18.45	3	55.4	55.4	1	12	1984	
		Myanaung	GT	18.45	1	18.5	67.4	1	13	1984	One GT is still in operation
			GT	16.25	3	16.3		0	0	1975	Decommissioned and moved to Thatone
		Thatone	GT	18.45	1	18.5	51	2	26	1975	As the GT reaches its lifetime, old GT will be demolished and replaced with new GTs by CEEC with 119 MW capacity under WB loan.
			GT	16.25	2	32.5				2001	
			GT	40	2	80	119	2	119	2017	It will start operation in Dec. 2017
			ST	39	1	39		1			
		Mawlamyine	GT	6	2	12	12	0	0	1980	Demolished, because it reaches life time
	Total EPGE				20		396		182		
	UPA	Kanbauk	GE	6	1	6	20	6	20	2015	
				14	1	14		14			
	Sigmas & Petrocemicals (Myanmar Lighting)	Mawlamyine	GTCC	100	1	100	230	1	120	2014	GTCCs are refurbished ones (Second-hand).
			GTCC	130	1	130		1		2014	
	APR	Kyaukse	GE	1.50	68	102	102	68	101	2014	
	V Power	Kyauk Phyyu i	GE	1.41	32	45	45	32	45	2015	
		Kyauk Phyyu ii	GE	1.41	32	45	45	32	45	2016	
		Myingyan	GE	1.39	96	133	133	96	133	2016	Started in June 2016. Planned to reduce to 50% power output due to unavailability of gas
	Aggreco	Myingyan	GE	1.04	92	95	95	87	95	2015	
	Sembcorp/MMID	Myingyan	GTCC		2	225	225	2	225	2018	
	Wuxi Huagaung Electric Power Eng.	Tigyit	Coal	60	2	120	120	2	120	2005	
	Total IPP				328		1015		904		
Total Local					348		1,411		1,086		
Total EPGE					40		1,157		472		
Total IPP					393		1,428		1,291		
Total EPGE + IPP					433		2584		1763		

Note: GE: Gas engine power plant, GT: Gas turbine power plant, ST: Steam power plant, GTCC: Gas Turbine Combined Cycle
Source: JETRO

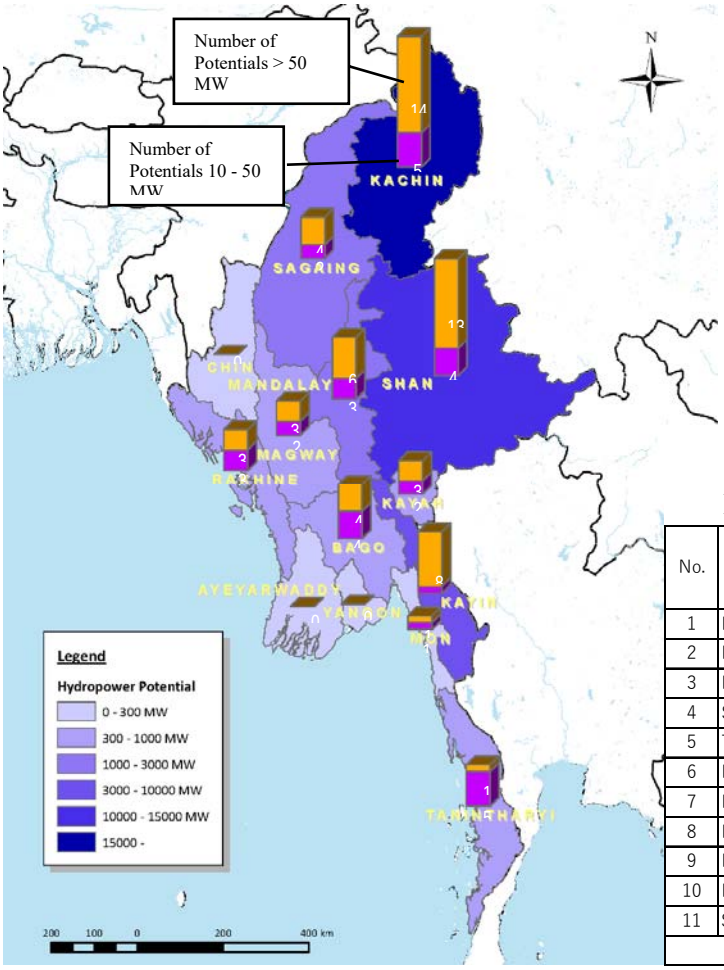
As shown in Table 1.2.2, the installed capacities of the gas-fired power plants operated by EPGE are 761 MW in Yangon area and 277 MW in other areas. However, the current power plant capacities are decreased to 290 MW and 63 MW, respectively. The reason of decrease in plant capacity is summarized below.

- Aging of gas-fired power plants that were constructed before year 2000.
- Reduction in gas yield of on-shore gas fields that were exploited in 1950s.
- Decrease in generation efficiency due to change of composition of gas.

The total nominal installed capacity of gas-fired power plants in Myanmar is 2,584 MW; however, workable capacity is 1,763 MW which is around 68 % of the original installed capacity.

(2) Hydropower Stations

In Myanmar, hydropower potential exists in the mountainous area in the northern part of Myanmar such as in Kachin State or Shan State. The total hydropower potential in the two states accounts for 67% of the country's hydropower potential. The hydropower potential of Myanmar in each state with the number of hydropower potential sites is shown in Figure 1.2.2.



Hydropower Potential in each State

No.	State	Numbers of Potentials		Potential Capacity (MW)
		10~50MW	>50MW	
1	Kachin	5	14	18,745
2	Kayah	2	3	954
3	Kayin	1	8	7,064
4	Sagaing	2	4	2,830
5	Tanintharyi	5	1	711
6	Bago	4	4	538
7	Magway	2	3	359
8	Mandalay	3	6	1,555
9	Mon	1	1	290
10	Rakhine	3	3	765
11	Shan	4	13	12,289
Total		32	60	46,331

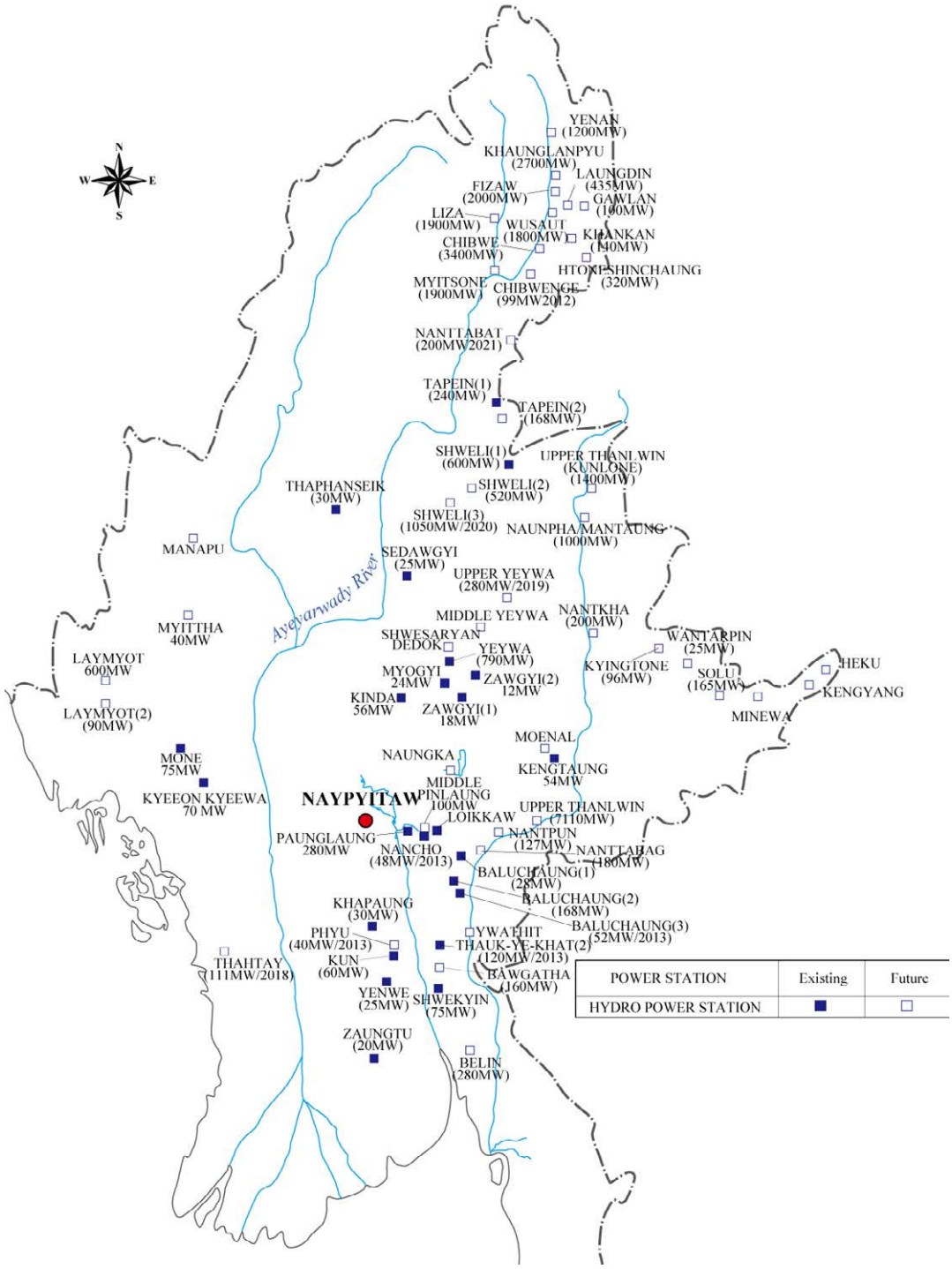
Figure 1.2.2 Hydropower Potential in Each State in Myanmar

As shown in Figure 1.2.2, the hydropower potential is abundant in the northeast part of Myanmar. However, hydropower plants have been developed in Shan State and Kayah State due to their close distance to power consumers and instability of political situation in the northern states. The list of existing hydropower plants is shown in Table 1.2.3 and the location of existing hydropower plants is shown in Figure 1.2.3.

Table 1.2.3 Existing Hydropower Plant Facilities in Myanmar

Owner	Plant	Installed Capacity				COD
		MW/Unit	No	Total	Total Sell to Domestic (EPGE)	
EPGE	Baluchaung-2	28	6	168	168	1960
	Kinda	28	2	56	56	1985
	Sedawgyi	12.5	2	25	25	1989
	Baluchaung-1	14	2	28	28	1992
	Zawgyi-1	6	3	18	18	1995
	Zawgyi-2	6	2	12	12	1998
	Zaungtu	10	2	20	20	2000
	Thapanseik	10	3	30	30	2002
	Mone	25	3	75	75	2004
	Paunglaung	70	4	280	280	2005
	Yenwe	12.5	2	25	25	2007
	Kabaung	15	2	30	30	2008
	KengTawng	18	3	54	54	2009
	Yeywa	197.5	4	790	790	2010
	Shwegyin	18.75	4	75	75	2011
	Kun	20	3	60	60	2011
	KyeeonKyeewa	37	2	74	74	2012
	Nancho	20	2	40	40	2013
	PhyuChaung	20	2	40	40	2014
	UpperPaunglaung	70	2	140	140	2014
	Myo Kyi	15	2	30	30	
	Myint Thar	20	2	40	40	
Total EPGE			59	2,110	2,110	
IPP	Shweli-1	100	6	600	400	2009
	Dapein-1	60	4	240	43	2011
	ThaukYeKhat-2	40	3	120	120	2013
	Chipwinge	33	3	99	99	2013
	Baluchaung-3	26	2	52	52	2014
Total IPP			18	1,111	443	
Total EPGE + IPP			77	3,221	2,553	

Source: METI, JETRO, the JICA Survey Team



Source: MOEE

Figure 1.2.3 Location of Existing Hydropower Stations in Myanmar

The hydropower development in Myanmar started from the construction of Baluchaung No. 2 Hydropower Station as the reparation of Japan after the War. Since then, 22 hydropower stations have been constructed by GOM by 2017. In recent years, five IPPs' hydropower plants commenced commercial operation. As shown in Figure 1.2.3, the hydropower potential exists along the upstream reach of the Ayeyarwady River in Kachin State and in the area close to the border with China in Shan State. However, the rate of hydropower development in these areas is slow due to security issues and

opposition by local residents against hydropower development.

1.2.2 Power Generation in Past Years

(1) Annual Generation Record

The power generation in Myanmar is increasing at a growth rate of 13% to catch up with the growth of electricity demand. The annual power generation in the 2015-2016 fiscal year was 15,864.8 GWh. The majority of power supply in Myanmar comes from hydropower generation, as more than 70% of power is generated by hydropower stations. However, due to the increase in the number of thermal power stations in Myanmar, the share of hydropower generation decreased to 58.9% in 2016. The annual power generation from 2010-11 to 2015-16 is shown in Table 1.2.4.

Table 1.2.4 Domestic Power Production from 2010 to 2016

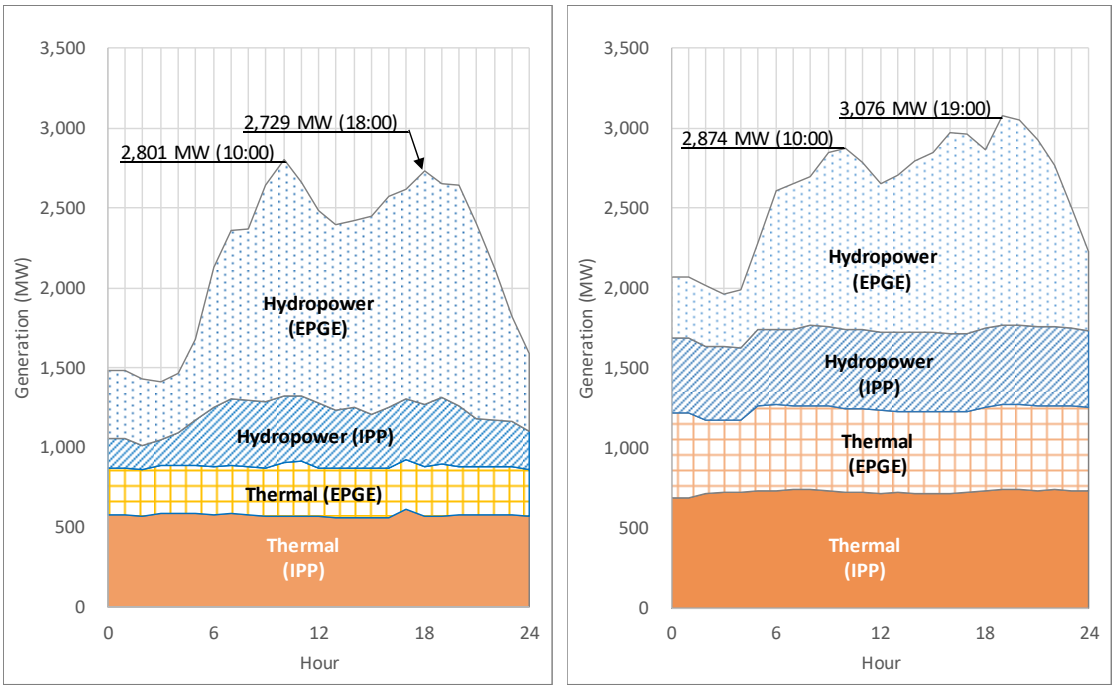
Fiscal Year*	Type of Power Generation								Total
	Hydro		Gas		Thermal		Diesel		
	(GWh)	(%)	(GWh)	(%)	(GWh)	(%)	(GWh)	(%)	
2010 - 2011	6189.0	72.0%	1736.5	20.2%	640.0	7.4%	32.7	0.4%	8598.1
2011 - 2012	7518.0	72.1%	2119.1	20.3%	749.8	7.2%	38.2	0.4%	10425.0
2012 - 2013	7766.2	70.8%	2377.4	21.7%	770.6	7.0%	50.6	0.5%	10964.9
2013 - 2014	8823.1	72.0%	2794.3	22.8%	568.9	4.6%	60.8	0.5%	12247.1
2014 - 2015	8828.8	62.4%	4977.0	35.2%	285.5	2.0%	64.9	0.5%	14156.3
2015 - 2016	9399.0	58.9%	6225.6	39.0%	285.0	1.8%	55.2	0.3%	15964.8

*Fiscal year starts from April.

Source: DEPP, Central Statistics Bureau

(2) Power Generation Pattern in a Day

Hydropower plants are located in the mountainous area in the north and middle part of Myanmar where hydropower potential is abundant. While, gas-fired power plants are constructed in the suburb of Yangon area, which has no hydropower potential. The run-of-river hydropower plants are generating power for base load and the reservoir type hydropower plants are generating power for peak load. The gas-fired power plants in Myanmar generally produce power with almost constant power output in a day, like base load. The typical power generation patterns during the rainy and dry seasons are exemplified by the actual power generation record. The example record is in a day at the end of rainy season in October 2016 where reservoir water level is high, and a day at the end of the dry season in May 2017 where reservoir water level is at its lowest. The typical power generation patterns in May 2017 and October 2016 are shown in Figure 1.2.4.



Rainy Season Power Generation Pattern (on October 19, 2016)

Dry Season Power Generation Pattern (on May 23, 2017)

Source: EPGE

Figure 1.2.4 Power Generation Patterns during Wet and Dry Seasons

As shown in Figure 1.2.4, May has the highest temperature in a year and the electricity consumption is increased due to the use of air conditioner. The increase in power electricity consumption was recorded at 3,076 MW at 19:00. While in October, the use of air conditioner is decreased and electricity consumption is highest at 10:00 due to industrial use. The peak demand in October was 2,801 MW.

The power generation by type of power source is shown in Table 1.2.5. As shown in the table, the thermal power plants of EPGE and IPP increase their power output and the power output is maintained constantly. For the IPP hydropower plants, the power output during daytime from 6:00 to 18:00 is increased to supply electricity for the daytime peak load. When the power demand recorded to 3,076 MW, the power output of thermal power plant reached to 1,271.6 MW which corresponded to 95 % of workable capacity as shown in Table 1.2.2. It is presumed that the peak power demand was barely coped with the power generation by the existing power plants.

The average power outputs of the combined hydropower of EPGE and IPP in May and October are 1,338 MW and 1,391 MW, respectively. There is no significant difference between the two average power outputs. The average power output of EPGE in the rainy season (October) is 100 MW more than that in the dry season (May), while the IPP hydropower output in the rainy season is 150 MW less than that in the dry season. Therefore, it is evident that, during the rainy season, the EPGE's hydropower plant increases its power output; however, the IPPs' hydropower, EPGE thermal, and IPPs' thermal reduce their output.

According to EPGE, the power output of IPPs' hydropower is bound strictly by the contract so as to

keep their outputs in the rainy and dry seasons not less than 60% and 90% of the contracted power output. For IPPs' thermal power, the power outputs during the rainy season and dry season are prescribed to be more than 50% and 80-90% of the contracted power output, respectively. If the actual power output is lower than the prescribed power output, the IPP should pay the penalty. In this regard, the IPP hydropower and thermal increase their power outputs and provide electricity for base power supply.

Table 1.2.5 Power Generation Record during Dry Season on May 23, 2017

Hour	Load (MW)	Hydro Power (MW)			Thermal Power (MW)			Hydro + Thermal (MW)		
		EPGE	IPPs	Total	EPGE	IPPs	Total	EPGE	IPPs	Total
1	2,065	380.14	469.5	849.6	528.9	686.5	1,215.4	909.0	1,156.0	2,065.0
2	2,016	379.63	464.98	844.6	454.3	717.3	1,171.6	833.9	1,182.3	2,016.2
3	1,967	335.93	454.98	790.9	456.8	719.1	1,175.9	792.7	1,174.1	1,966.8
4	1,986	358.34	454.84	813.2	454.6	718.5	1,173.1	812.9	1,173.3	1,986.3
5	2,280	541.53	475.77	1,017.3	528.3	734.4	1,262.7	1,069.8	1,210.2	2,280.0
6	2,608	863.91	476.07	1,340.0	532.2	735.7	1,267.9	1,396.1	1,211.8	2,607.9
7	2,649	906.74	478.3	1,385.0	526.6	737.7	1,264.3	1,433.3	1,216.0	2,649.3
8	2,696	932.7	497.47	1,430.2	529.7	736.4	1,266.1	1,462.4	1,233.9	2,696.3
9	2,846	1089.18	497.35	1,586.5	531.5	728.4	1,259.9	1,620.7	1,225.8	2,846.4
10	2,874	1136.96	494.51	1,631.5	521.5	721.3	1,242.8	1,658.5	1,215.8	2,874.3
11	2,786	1044.67	493.29	1,538.0	522.8	725.0	1,247.8	1,567.5	1,218.3	2,785.8
12	2,652	926.76	490.69	1,417.5	523.7	710.8	1,234.5	1,450.5	1,201.5	2,652.0
13	2,708	983.94	493.15	1,477.1	511.9	719.4	1,231.3	1,495.8	1,212.6	2,708.4
14	2,796	1074.19	492.05	1,566.2	514.1	716.0	1,230.1	1,588.3	1,208.1	2,796.3
15	2,846	1126.61	492.15	1,618.8	512.6	714.3	1,226.9	1,639.2	1,206.5	2,845.7
16	2,971	1257.49	488.1	1,745.6	510.2	715.4	1,225.6	1,767.7	1,203.5	2,971.2
17	2,960	1247.39	489.01	1,736.4	503.3	720.4	1,223.7	1,750.7	1,209.4	2,960.1
18	2,867	1119.27	495.1	1,614.4	518.9	733.6	1,252.5	1,638.2	1,228.7	2,866.9
19	3,075	1306.93	496.92	1,803.9	530.3	741.3	1,271.6	1,837.2	1,238.2	3,075.5
20	3,056	1290.61	498.28	1,788.9	529.6	737.7	1,267.3	1,820.2	1,236.0	3,056.2
21	2,932	1170.22	496.25	1,666.5	530.4	734.9	1,265.3	1,700.6	1,231.2	2,931.8
22	2,764	1003.82	494.01	1,497.8	530.5	735.9	1,266.4	1,534.3	1,229.9	2,764.2
23	2,503	750.78	493.07	1,243.9	524.8	734.2	1,259.0	1,275.6	1,227.3	2,502.9
24	2,229	495.86	474.74	970.6	522.3	735.6	1,257.9	1,018.2	1,210.3	2,228.5
Average	2,631	905	485	1,391	515	725	1,240	1,420	1,211	2,631
Max	3,075	1,307	498	1,804	532	741	1,272	1,837	1,238	3,075
Min	1,967	336	455	791	454	687	1,172	793	1,156	1,967
Load Factor	64.0%									

Source: EPGE

Table 1.2.6 Power Generation Record during Rainy Season on October 19, 2016

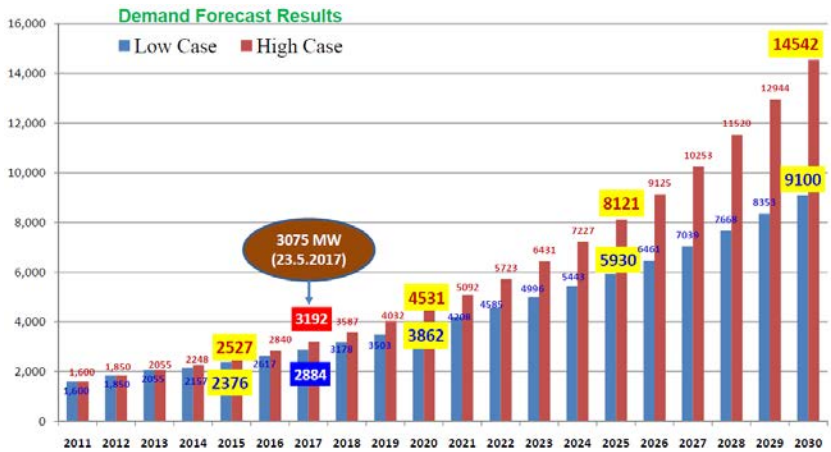
Hour	Load (MW)	Hydro Power (MW)			Thermal Power (MW)			Hydro + Thermal (MW)		
		EPGE	IPPs	Total	EPGE	IPPs	Total	EPGE	IPPs	Total
1	1,479	419.81	185.38	605.2	295.6	578.7	874.3	715.4	764.1	1,479.5
2	1,431	419.74	146.33	566.1	295.5	569.1	864.6	715.2	715.4	1,430.7
3	1,407	362.6	157.79	520.4	302.9	584.2	887.1	665.5	742.0	1,407.5
4	1,461	367.63	206.89	574.5	302.4	584.4	886.8	670.0	791.3	1,461.3
5	1,675	502.91	284.32	787.2	303.8	583.6	887.4	806.7	867.9	1,674.6
6	2,127	874.74	367.68	1,242.4	305.4	579.2	884.6	1,180.1	946.9	2,127.0
7	2,362	1061.26	411.78	1,473.0	305.1	584.2	889.3	1,366.4	996.0	2,362.3
8	2,368	1073.52	411.75	1,485.3	305.1	577.5	882.6	1,378.6	989.3	2,367.9
9	2,639	1351.14	412.39	1,763.5	305.7	569.5	875.2	1,656.8	981.9	2,638.7
10	2,801	1478.77	411.42	1,890.2	341.6	569.5	911.1	1,820.4	980.9	2,801.3
11	2,660	1339.11	405.14	1,744.3	346.4	569.3	915.7	1,685.5	974.4	2,660.0
12	2,481	1203.66	405.58	1,609.2	303.6	568.6	872.2	1,507.3	974.2	2,481.4
13	2,392	1158.37	366.52	1,524.9	304.5	562.9	867.4	1,462.9	929.4	2,392.3
14	2,424	1175.17	379.59	1,554.8	303.7	565.7	869.4	1,478.9	945.3	2,424.2
15	2,445	1235.01	340.55	1,575.6	304.1	565.6	869.7	1,539.1	906.2	2,445.3
16	2,571	1319.1	381.01	1,700.1	306.5	564.6	871.1	1,625.6	945.6	2,571.2
17	2,620	1315.6	383.36	1,699.0	304.4	616.6	921.0	1,620.0	1,000.0	2,620.0
18	2,729	1462.6	382.06	1,844.7	311.7	572.8	884.5	1,774.3	954.9	2,729.2
19	2,655	1337.03	420.3	1,757.3	324.7	573.3	898.0	1,661.7	993.6	2,655.3
20	2,640	1381.5	376.68	1,758.2	303.2	578.6	881.8	1,684.7	955.3	2,640.0
21	2,400	1223.35	295.58	1,518.9	306.0	575.4	881.4	1,529.4	871.0	2,400.3
22	2,118	947.67	292.09	1,239.8	302.7	575.5	878.2	1,250.4	867.6	2,118.0
23	1,821	654.85	285.38	940.2	302.8	578.0	880.8	957.7	863.4	1,821.0
24	1,593	487.84	242.76	730.6	291.8	570.7	862.5	779.6	813.5	1,593.1
Average	2,221	1,006	331	1,338	307	576	883	1,314	907	2,221
Max	2,801	1,479	420	1,890	346	617	921	1,820	1,000	2,801
Min	1,407	363	146	520	292	563	863	666	715	1,407
Load Factor	50.2%									

Source: EPGE

1.2.3 Power Development Plan

(1) Projection of Power Demand

The future power demand was estimated by EPGE for two scenarios, namely, low and high scenarios, depending on the growth rate of electricity demand. The growth rates of the high and low scenarios are 12% and 9%, respectively. The power demand projection in Myanmar until 2030 is shown in Figure 1.2.5.



Source: "Power Development Opportunities in Myanmar" EPGE, 2017

Figure 1.2.5 Peak Power Demand Forecast until 2030

As shown in Figure 1.2.5, the highest peak power demand of 3075 MW was recorded in May 2017. The peak power demands in year 2020 and 2030 for the high scenario are 4,531 MW and 14,542 MW, respectively. For the low scenario, the demands are 3,862 MW and 9,100 MW in 2020 and 2030, respectively.

(2) Power Development Plan

The power development in Myanmar relies on the initiative of IPPs, due to the shortage of fund for power development by the government. For example, the future power development of the hydropower sector is mainly borne by IPPs under the build-operate-transfer (BOT) scheme, although the current hydropower development projects are promoted by the government. For the thermal power plants, 80% of power development is planned by IPP.

The planned and under construction hydropower plants are shown in Table 1.2.7 and the gas-fired power plants are shown in Table 1.2.8.

Table 1.2.7 Planned and Under Construction Hydropower Plants

No.	Plant	Owner	COD(year)	Capacity
Under Construction				
1	Upper Nanhtwan	EPGE	2020/2021	3
2	Thahtay	EPGE	2020/2021	111
3	Upper Keng Tawn	EPGE	2020/2021	51
4	Upper Yeywa	EPGE	2020/2021	280
5	Shweli-3	EPGE	2020/2021	1,050
Total EPGE				1,495
6	Upper Baluchaung	EPGE/IPP	2020/2021	30
7	DeeDoke	IPP	2020/2021	66
8	Middle Paunglaung	IPP	2020/2021	100
Total IPP				196
Total Under Construction				1,692
Planned Project (1)				
9	Bawgata	EPGE		160
10	MiddleYeywa	IPP		175
11	UpperBu	EPGE		150
12	Manipur	IPP		380
13	Saingdin	IPP		76
14	Laymro	IPP		500
15	Shweli-2	IPP		520/260
16	Dapein-2	IPP		168/84
17	Chipwi	IPP		3400/1700
18	Laza	IPP		1900/950
19	Wutsok	IPP		1800/900
20	Pisa	IPP		2000/1000
21	Kaunglanghpu	IPP		2700/1350
22	Yenam	IPP		1200/600

No.	Plant	Owner	COD(year)	Capacity
Planned Project (2)				
23	Gawlan	IPP		100/50
24	WuZhongze	IPP		60/30
25	Lawngdin	IPP		435/217
26	HkanKawn	IPP		140/70
27	Tongxingjao	IPP		320/160
28	Kunlong	IPP		1400/700
29	Ywathit(Thanlwin)	IPP		4000/2000
30	Hutgyi	IPP		1360/680
31	Mongton(Tasang)	IPP		7110/3555
32	Naopha	IPP		1000/500
33	Mantong	IPP		200/100
34	Lemro-2	IPP		90/45
35	KengTong	IPP		96/48
36	WanTaPin	IPP		25/13
37	Solue	IPP		165/82
38	MongWa	IPP		50/25
39	KengYang	IPP		28/14
40	HeKou	IPP		88/44
41	NamKha	IPP		200/100
42	NamTamhpak(Kachin)	IPP		200/100
43	NamTamhpak(Kayah)	IPP		180/90
44	HtuKyan	IPP		105/53
45	HsengNa	IPP		45/23
46	ThaHkwa	IPP		150/75
47	Palaung	IPP		105/52
48	Bawlake	IPP		180/90
Total Planned Projects				17201/32961

Note: Total capacity/Capacity for domestic supply
Source: Compiled by the JICA Survey Team using materials of METI, DEPP, EPGE

Table 1.2.8 Planned Gas-fired Power Plants

Location	Owner	Plant	Type	Installed Capacity			COD	Remarks
				MW/Unit	No	MW		
Yangon								
	EPGE	Hlawga	GT	33	3	154	1996	
		Hlaingtharyar	GTCC			400		
		Thaketa				25		
	Total EPGE					579		
	Marubeni /PTT/EDEN	Thanlyin	GTCC	130	2	400	2019	
	Hydro-lancang	Hlawga	GTCC			486		
	BKB	Thaketa	GTCC			503		
	UREC	Thaketa	GTCC			106	2018	
			GTCC			400		2nd phase
	Daewoo + MCM	Shwedaung				70		
	NIHC	Yangon				300		
	Karpower	Yangon				300		
	Total IPP					2,565		
Total Yangon						3,144		
Local								
	EPGE	Thatone	GT	40	2	106	2018	Under construction
				26	1			
		Kyaukphyu	GTCC			50		
		Pahtoelone	GE			12		
	Total EPGE					168		
	APU	Kanbauk	GTCC			200	2019	
	Sembcorp	Myingyan	GT	72	2	225	2018	Under construction
			ST	82	1			
	Total IPP					425		
Total Local						593		
Total EPGE						747		
Total IPP						2,990		
Total EPGE + IPP						3,737		

Source: Compiled by the JICA Survey Team using materials of METI, DEPP, EPGE

For the coal thermal plant, the construction of coal thermal power plants is difficult due to the opposition of the residents. The rationale of the opposition comes from the environmental issues of emission of harmful substances from the Tigyit Coal Thermal Power Plant, which was constructed by a Chinese IPP. The planned coal thermal power plants in Myanmar are shown in Table 1.2.9; all these projects were stopped due to the opposition of the public. Ten out of twelve planned coal thermal plants are promoted by the Myanmar government as co-investor and the rest of the planned coal thermal power plants are owned solely by IPPs. The installed capacities of those planned by IPPs are just 4% of the total planned coal thermal power plants capacity.

Table 1.2.9 Planned Coal Thermal Power Plants

No.		Project	Location	MW	Remarks
JV/BOT Basis					
	1	Kengtong	Shan	660	MOA
	2	Ye (Andin)	Mon	1,280	MOA
	3	Rammazu	Tanintharyi	500	MOA
	4	Kalaywa	Sagaing	540	MOA
	5	Kyauktan	Yangon	600	MOA
	6	Ngayokekaung	Ayeryarwaddy	540	MOA
	7	Tanintharyi (Myeik)	Tanintharyi	1,800	MOU
	8	Tanintharyi (Myitwa)	Tanintharyi (Myeik)	2,640	MOU
	9	Ayeyarwaddy (Ngaputaw)	Ayeryarwaddy	600	MOU
	10	Yangon (Thilawa)	Yangon	315	MOU
	Total JV/BOT Basis			9,475	
BOT Basis					
	1	Yangon (Kungyangone)	Yangon	300	MOU
	2	Myeik (Thanphyoethu)	Tanintharyi	50	MOU
	Total BOT Basis			350	
Total Coal				9,825	

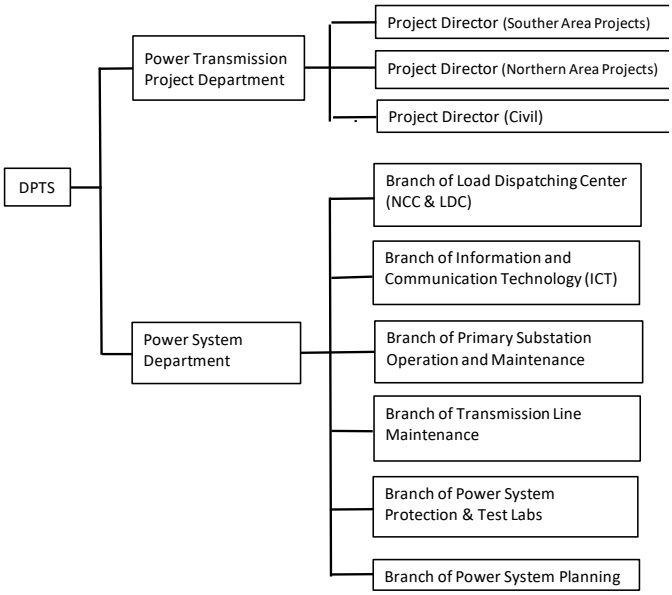
Source: EPGE

1.3 Existing Power Transmission System and Reinforcement Plan

1.3.1 Actual Situation of Power Transmission System

The Department of Power Transmission and System Control (DPTSC), which has jurisdiction over the national transmission grid, has been reorganized from the previous Myanmar Electric Power Enterprise (MEPE) in 2016. The DPTSC has taken over the organization in MEPE.

The technical section of DPTSC is composed of two departments, namely, Power Transmission Project Department (PTP) and Power System Department (PSD). Figure 1.3.1 shows the organization structure of the technical departments of DPTSC. PTP designs and constructs power transmission facilities and PSD is responsible for the operation and maintenance of the power transmission facilities. PSD is further comprised of the load dispatching centers, communication offices, operation and maintenance center of transmission lines and substations, system protection department, and power system planning department. The load dispatching centers are located in Naypyitaw and Yangon.



Source: DPTSC

Figure 1.3.1 Organization of DPTSC

DPTSC is responsible for the planning, construction, operation, and maintenance of power transmission facilities of 132 kV or more. Myanmar's standard transmission line voltages are 66 kV, 132 kV, and 230 kV, and the construction of more than 500 kV transmission system has started. The trend of the length of transmission line over the past five years is shown in Table 1.3.1, which is based on the Statistics 2016 of MEPE. After reorganization of DPTSC, 132 kV, 230 kV and 500 kV are supposed to be under the control of DPTSC in principle. However, 66 kV and 33 kV lines related to power stations (power supply line) are still under the management of DPTSC.

Table 1.3.1 Length of Transmission Lines

(Unit: km)

	2011/12	2012/13	2013/14	2014/15	2015/16	Inc,Rate
230kV	3,017.86	3,046.74	3,068.65	3,867.44	4,005.32	7.3%
132kV	2,108.79	2,172.71	2,172.71	2,196.99	2,190.89	1.0%
66kV	2,806.66	2,837.47	3,003.18	4,035.81	4,461.18	12.3%
33kV	124.89	124.89	124.89	136.15	136.15	2.2%

Source: DPTSC

Figure 1.3.2 shows the single line diagram of the existing transmission system as of 2016. It is note that the diagram is created with emphasis on the relationship between power plants and transmission lines to avoid complication and the lines for the distribution of electric power are omitted.

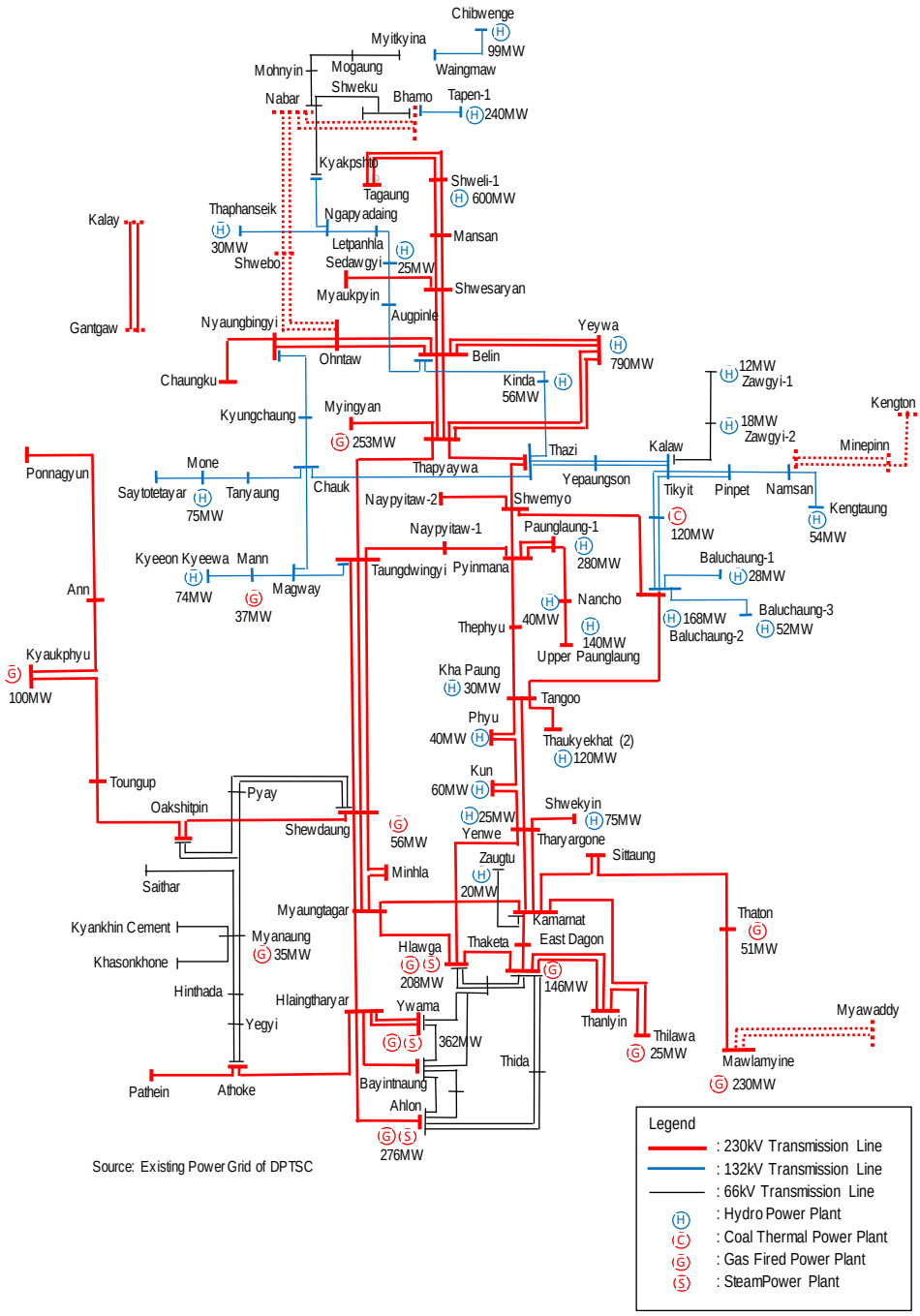


Figure 1.3.2 Single Line Diagram of Existing Transmission System

1.3.2 Reinforcement Plan of Transmission System

The JICA Survey Team asked DPTSC for a list of power transmission facilities that exist, under construction and committed in the five-year plan. However, these were not provided. Details are not known. Such information is presented in Figure 1.3.2 as the power transmission system maps and results of power flow analysis received after completion of the first site survey.

The JICA Survey Team asked the current status of the 500kV power transmission plant that started construction but there was no answer from DPTSC. The following are based on the interview to Tokyo Electric Power Services Co., the consultant for the substation part of the 500-kV project.

Phase-I:

Transmission Line: Design and construction supervision of 500 kV, 234.9 km, Thapyaywa – Taungoo Line

Serbian loan is being used for the construction of the transmission line. The consultant for the design and supervision of its construction is AF Engineering, which is an in-house consultant of DPTSC. The contractor of foundation works and tower erection is BFE EPC (joint venture company with Fujikura). Tower erection of suspension towers only has been made and erection of tension tower has not been started yet. As for the stringing work of conductors, the conductor materials have already arrived at the site, but the contractor for the erection of conductors has not been decided yet.

Substations : (1) Design, preparation of tender documents, and construction supervision of Maikhtila and Taungoo substations

(2) Design of Phayargyi and Hlaingtharyar substations

Japanese official development assistance (ODA) loan is being used. The consultant is the joint venture (JV) of TEPSCO and Nippon Koei. Although it is called as Taungoo substation, it is scheduled to be built at a place different from the existing substation. The official name of the substation is not yet fixed.

Phase-II

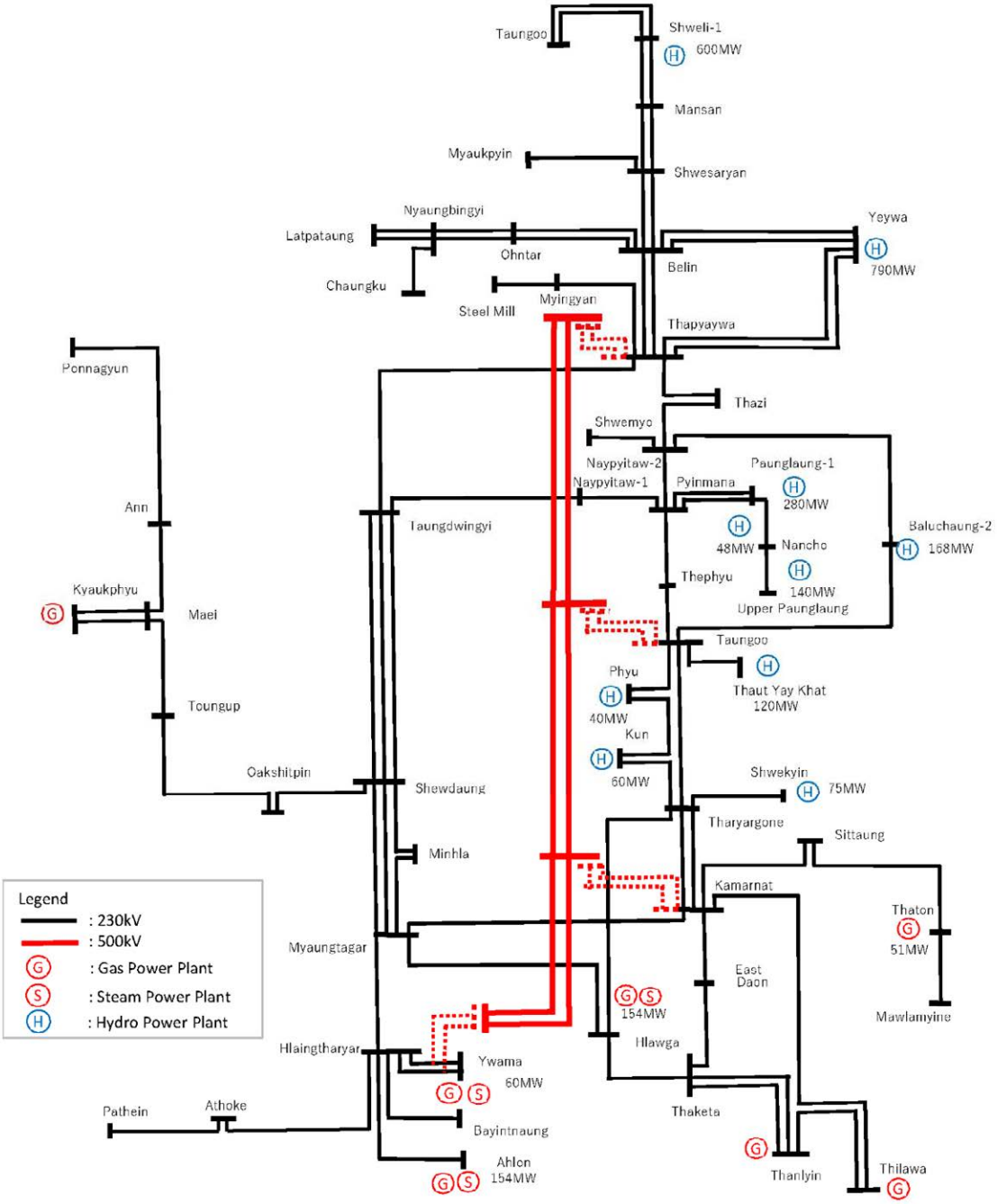
Transmission Line: Design, preparation of bid documents, and construction supervision of 500 kV Taungoo – Phayargyi - Hlaingtharyar transmission line with length of 268.7 km

It is decided that Korean loan will be applied. However, the progress of the project is not recognized at all and a consultant is not decided.

Substations : Preparation of bid documents and construction supervision of Phayargyi and Hlaingtharyar substations

Japanese ODA loan will be allocated.

The single line diagram of 230 kV and 500 kV transmission system including the above plan is shown in Figure 1.3.3.



Source: Prepared by the JICA Survey Team based on the national grid map of DPTSC

Figure 1.3.3 Single Line Diagram of Existing 230 kV and 500 kV under Construction

In Figure 1.3.3, the construction of 230 kV transmission lines and the extension works of the existing substations are planned to be made by the Myanmar side to connect the new 500/230 kV substations and the existing 230 kV substations. However, the consultant of the 500/230kV substations did not know the plan of the Myanmar side. Therefore, the plan is indicated by a dotted line in the figure.

The following are explained based on the description of the "Power Development Opportunities" materials presented by the Chief Engineer of DPTSC, Dr. Maung Maung Kyaw, at the Myanmar

Investment Forum held on July 6-7, 2017.

The development plan of the transmission system in the Five-Year Plan is shown in Table 1.3.2.

Table 1.3.2 Five Year Plan of Transmission System

Volatage	2013-2016			2017-20121		2022-2026		2027-2031	
	miles	km	MVA	km	MVA	km	MVA	km	MVA
500kV	167	269	1,500	1,210	5,000	481	1,000	402	
230kV	1,838	2,957	2,700	3,158	4,010	589	1,150	0	700
132kV	60	90	990	97	0	71	260	80	300
66kV	1,371	2,206	641	1,381	405	150	150	0	75
Total	3,436	5,522	5,831	5,845	9,415	1,290	2,560	483	1,075

Source: DPTSC

Table 1.3.3shows the transmission and substation facilities under construction as of 2017. The details of such facilities are not known because of no information from DPTSC.

Table 1.3.3 Transmission and Substation Facilities under Construction (2017)

Voltage (kV)	Tranmission Line			Substation	
	Nos.	Length		Nos.	MVA
		Miles	km		
500	1	146	235	2	1,500
230	10	603	971	19	1,900
132	—	—	—	1	100
66	13	580	933	16	155
Total	24	1,329	2,139	38	3,655

Source: Myanmar Investment Forum 2017, Power Development Opportunities

The list of the development plan of 500 kV system given by DEPP is shown in Table 1.3.4

Table 1.3.4 Development Plan of 500 kV Transmission System (2017)

No.	From	To	Length (km)	Costruction Period	Remarks
1	Thapyaywa	Taungoo	234.91	2016 - 2021	Servia loan
2	Taungoo	Phayargyi (Kamarnat)	188.25	2017 - 2021	EDCF loan
3	Thapyaywa (Meikhtila) substations			2017 - 2021	Japan ODA loan
4	Phayargyi (Kamarnat)	Hlaingthayar	80.45	2017 - 2021	Japan ODA loan
	Substations				
5	Phayargyi (Kamarnat)	East Dagon	80.45	2020 - 2025	
6	Phayargyi (Kamarnat)	Nangsam	402.25	2020 - 2025	
7	Shweli (3)	Kankaung (Meikhtila)	418.34	2018 - 2023	
8	Kwamlon	Mieyal	292.84	2020 - 2025	
	Mieyal	Nangsam			
9	Phayargyi (Kamarnat)	Mawlamyine	522.93	2020 - 2025	
	Mawlamyine	Dawei			
(Source: DEPP)					

1.4 Power Distribution Industries

The power distribution industries of Myanmar are implemented only by public-owned companies that include the Yangon Electricity Supply Corporation (YESC), which is responsible for supplying

electricity to the Yangon, the Mandalay Electricity Supply Corporation (MESC), which is responsible for electricity supply in the Mandalay area, and the Electricity Supply Enterprise (ESE), which is responsible for power supply in other areas.

YESC was founded on July 1, 2015 by reforming the previous Yangon Electricity Supply Board (YESB). The service area of MESC was the ESE's distribution area, but the Mandalay District area was separated and founded on April 1, 2015. ESE was founded on May 15, 2006 to supply electricity to all areas except Yangon District. In addition, ESE has many isolated power distribution systems that are not connected to the national grid but are supplied by small hydropower stations and diesel power stations. Thus, ESE undertakes power generation business to supply electricity in those isolated areas.

The power supply companies purchase electricity from the electric wholesaler EPGE and operate retail business of electricity to the customers. Table 1.4.1 shows the amount of power purchased by each company over the past five years. ESE purchases a small amount of electricity from a mining company (Lashio and Namtu) and this is included in the figures of the table. The purchase price of electricity from EPGE in 2017 is MMK 58/kWh for YESC and MMK 52/kWh for MESC and ESE. This price difference is due to the fact that YESC has a large number of big customers and average selling price is higher than others. The annual average increase rate of ESE includes the purchase electricity amount of MESC, and the annual average increase rate is as high as 13.9%. It is noteworthy that the increase rate in the rural areas is higher than that in the urban area. This is a result of GOM's effort to promote rural electrification for many years.

Table 1.4.1 Purchased Energy, 2011/12 – 2015/16

Unit: GWh

	2011/12	2012/13	2013/14	2014/15	2015/16	Inc. Rate
YESC	4,365.1	4,612.8	5,197.0	5,981.6	6,705.0	11.3%
MESC					2,143.2	-
ESE	4,978.7	5,325.8	6,112.5	7,367.4	6,227.7	13.9%
Total	9,343.8	9,938.5	11,309.5	13,348.9	15,076.0	12.7%

Source: Statistics 2015/16 of YESC and ESE

In order to supply electricity to the isolated distribution systems, ESE operates 69 units of small hydropower plants with total installed capacity of 29.7 MW, and 628 units of diesel power plants with total capacity of 79.3 MW as of the end of March 2016. The total generated energy was 87.8 GWh in 2015/16.

Table 1.4.2 shows the trends in the number of customers during the past five years. The growth rate of "Temporary Light" demand for street vendors is the highest. It can be said that this represents the activation of general business activities, but the proportion to the total demand is still low.

Table 1.4.2 Historical Growth of Number of Customers by Tariff Category

Year	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	Inc, Rate
General Purpose	2,321,321	2,521,670	2,740,334	3,136,036	3,571,254	11.4%
Domestic Power	33,002	35,057	36,952	39,540	40,227	5.1%
Small Power	44,422	46,073	45,764	47,734	33,359	-6.9%
Industrial	5,987	7,019	8,287	10,386	9,016	10.8%
Bulk	6,782	7,784	8,619	10,365	10,354	11.2%
Street Lighting	8,429	8,666	8,201	9,246	9,653	3.4%
Temporary Light	639	591	905	1,500	1,837	30.2%
Total	2,420,582	2,626,860	2,849,062	3,254,807	3,675,700	11.0%

Source: Statistics 2016 of YESC, ESE, and MESC

Table 1.4.3 shows the amount of sold energy for each customer category over the past five years. The average growth rate is 14.8%, which is considerably higher than the growth rate of the number of customers. The "Company" category records the biggest growth rate. This category undertakes electricity distribution business in a certain region from power supply company for improving the efficiency of electricity supply business in the area; however, the actual state is unknown.

Table 1.4.3 Sold Energy by Tariff Category (GWh)

	2011/12	2012/13	2013/14	2014/15	2015/16	Inc. Rate
General urpose	3,201.4	3,444.3	3,534.5	3,839.7	3,348.1	1.1%
Domestic Power	179.5	210.9	229.5	45.1	219.0	5.1%
Small Power	150.6	151.8	142.1	154.2	126.2	-4.3%
Industrial	2,576.8	2,524.7	2,556.9	2,830.4	2,018.6	-5.9%
Bulk	1,531.7	1,642.8	1,695.1	1,754.6	1,463.8	-1.1%
Street Light	45.4	48.0	50.1	53.2	47.5	1.2%
Temporary Lighting	16.4	14.6	9.6	17.5	11.5	-8.5%
Department	15.1	16.5	15.2	15.1	11.4	-6.8%
Company	0.0	201.5	1,382.7	2,323.1	6,150.4	212.5%
Total	7,716.8	8,255.2	9,612.6	11,255.0	13,396.5	14.8%

Source: Statistics 2016 of YESC, ESE and MESC

Table 1.4.4 shows the total length of distribution lines with voltage of 66 kV and lower, owned and managed by the power distribution companies.

Table 1.4.4 Length of Lines Owned by Distribution Companies

(km)

Sr.No	Line Category	2011/12	2012/13	2013/14	2014/15	2015/16	Inc.Rate
1	66 KV Line	3,230.9	3,429.4	3,808.6	4,684.3	4,989.5	11.5%
2	33 KV Line	7,735.1	7,788.1	7,867.5	8,155.2	8,945.8	3.7%
3	11 KV Line	13,252.9	14,015.8	15,167.0	17,287.5	21,260.0	12.5%
4	6.6 KV line	1,389.0	1,333.6	1,349.0	1,365.0	1,390.5	0.0%
5	3.3 KV Line	14.0	14.0	14.0	14.0	14.0	0.0%
6	0.4 KV Line	18,028.8	19,469.1	20,721.4	23,105.4	27,205.3	10.8%

Source: Statistics 2016 of YESC, ESE, and MESC

The table shows the distribution company's efforts (1) to switch the 33kV transmission line to 66kV, (2) to switch 6.6kV to 11kV for increasing the supply capacity and minimizing distribution losses and (3) not to extend 3.3 kV lines any more.

CHAPTER 2 FUEL SUPPLY FOR THERMAL POWER STATIONS

2.1. Background and History of the Baseline Survey

2.1.1 Operating Gasfield

Production of natural gas has been increased by development of offshore gasfields: Yadana gasfield (operated from 1998), Yetagun gasfield (operated from 2000), Shwe gasfield (operated from 2013), and Zawtika (operated from 2014). Total volume of natural gas production from offshore gasfields is 1,750 mmscfd where 1,320 mmscfd of gas is exported to Thailand and China. Natural gas is considered as a valuable resource for Myanmar to acquire foreign currency. The distribution of gas to domestic and export to foreign countries from each gasfield is summarized in Table 2.1.1.

Table 2.1.1 Offshore Gasfield in Myanmar and Distribution to Domestic/Export

Gas field	Total Gas (mmscfd)	Domestic (mmscfd)	Export (mmscfd)
Yadana	650	230	420 (Thailand)
Shwe	500	100*	400 (China)*
Zawtika	350	100	250 (Thailand)
Yetagun	250	0	250 export only (Thailand)
Total	1,750	430	1,320

Note*) : Gas volume as of end of July 2017
Source: MOGE

(1) Yadana gasfield

Yadana gasfield started its operation as the first offshore gasfield in Myanmar in 1998. A 36-inch pipeline was installed and 420 mmscfd of gas is exported to Thailand via Kanbauk City. On the other hand, a pipeline with a 24-inch diameter was installed and 230 mmscfd of gas is supplied for domestic demand. Gas from Yadana gasfield is used for thermal power stations from Yangon area to Kyawswa area.

Twenty years have been elapsed from the commissioning of the Yadana gasfield, and the gas production volume is anticipated to decline from 2021. The gas will be depleted by 2027 (Table 2.1.2). Alternative fuel (imported LNG) is required for power stations from Yangon area to the north area.

Table 2.1.2 Forecast of Gas Production from Yadana Gasfield

Year	Gas Supply (mmscfd)
2021	200
2022	180
2023	160
2024	120
2025	90
2026	25
2027	25
2027	-

Source: Power Development Opportunities in Myanmar, EPGE, June 2017

(2) Shwe gasfield

Shwe gasfield started its operation in 2013. 400 mmscfd of gas produced at Shwe gasfield is exported to China through a 40-inch pipeline. For domestic demand, gas from Shwe is supplied to thermal power stations located in the north of Shwedaung via some off-take point. MOGE is in negotiations with China to transfer 50 mmscfd, of the gas quota to China, to domestic supply.

(3) Zawtika gasfield

Zawtika gasfield started its operation in 2014. Gas from Zawtika gasfield is sent to Kanbouk by a 28-inch pipeline. Of the total gas volume (350 mmscfd), 250 mmscfd is exported to Thailand, while the remaining 100 mmscfd is allocated to domestic demand. The gas yield from Zawtika gasfield is used for power generation in the power plant that is located in the area between Kanbouk and Yangon.

(4) Yetagun gasfield

Yetagun gasfield started its operation in 2000 and all of the gas yield is exported to Thailand. In the beginning, 400 mmscfd gas was produced in Yetagun gasfield. But this gas volume is decreasing and the current yield is 250 mmscfd. It is anticipated that gas volume will continue to decrease.

Gas components and average calorific value of each offshore gasfield are shown in Table 2.1.3. Average calorific value of Yadana gasfield is 744 Btu/scf, which is lower than that of other gasfields. According to MOGE, minimum guaranteed calorific value of Yadana gasfield is 710 Btu/scf.

Table 2.1.3 Gas Components and Average Calorific Value of Each Offshore Gasfield

	Offshore		
Field	**Yadana**	**Shwe**	**Zawtika**
Component	Mole (%)	Mole (%)	Mole (%)
Methane(C_1)	72.8490	99.58822	95.6740
Ethane(C_2)	0.7320	0.09139	0.1486
Propane(C_3)	0.1270	0.02234	0.0407
Iso-Butane(IC_4)	0.0140	0.00879	0.0120
Normal-Butane(NC_4)	0.0200	0.00211	0.0059
Iso-Pentane(IC_5)	0.0050	0.00335	0.0031
Normal-Pentane(NC_5)	0.0030	0.00000	0.0016
Neo-Pentane($NeoC_5$)	0.0010	0.00000	0.0000
Hexane (C_6)	0.0000	0.00000	0.0000
Hexane plus(C_6 +)	0.0160	0.01067	0.0082
Nitrogen (N_2)	23.1650	0.17273	3.9750
Carbon Dioxide (CO_2)	3.0650	0.09805	0.1303
Hydrogen Sulfide (H_2S)	0.0013	0.00001	0.0000
Water (H_2O)	0.0020	0.00234	0.0064
TOTAL	100.00	100.00	100.01
GCV (BTU/SCF)	743.876	1011.02477	958.2717

Source: MOGE

2.1.2 Planned Gasfield

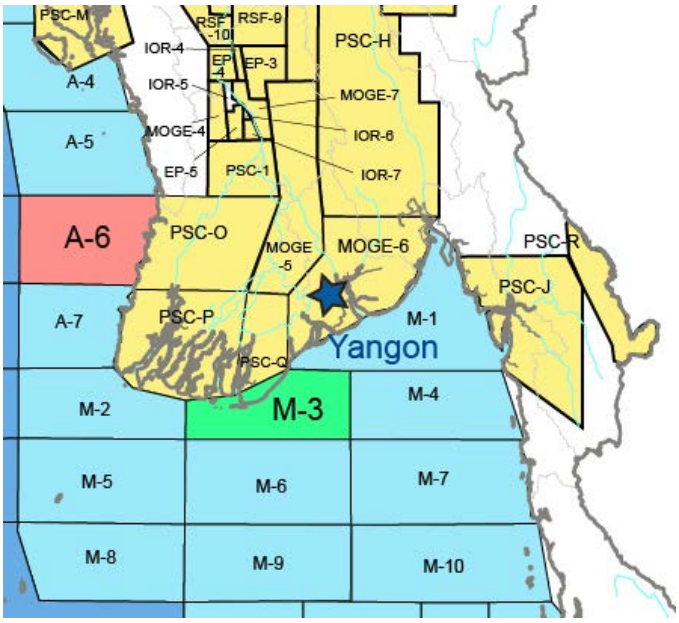
In response to the declining gas production from the existing gasfields in Myanmar, the development of new gasfield has been started. Development of gasfields (M-3 area and A-6 area) is in progress. On the other hand, onshore gasfield development is also ongoing. However, large-scale gasfield is not found currently. It is unlikely that gas supply will increase on a large scale in the short term.

(1) M-3 gasfield

M-3 gasfield is located offshore of Yangon. Expected gas volume of M-3 gasfield is approximately 90 mmscfd. PTTEP South Asia Limited is developing this gasfield with USD 3 million and they have submitted a feasibility study (F/S) to GOM. However, feasibility of this gasfield is low because of the following reasons: 1) removal of CO^2 is required because CO^2 ratio is high (34%), 2) expected available gas yield (90 mmscfd) is not commercially viable.

(2) A-6 gasfield

A-6 gasfield is located offshore of the south of Pathein. MPRL (Myanmar), TOTAL (France), and Woodsite (Australia) are investigating jointly. The potential of natural gas was identified in this area, but it is not declared for commercial operation. The required time for development is assumed approximately at seven years.



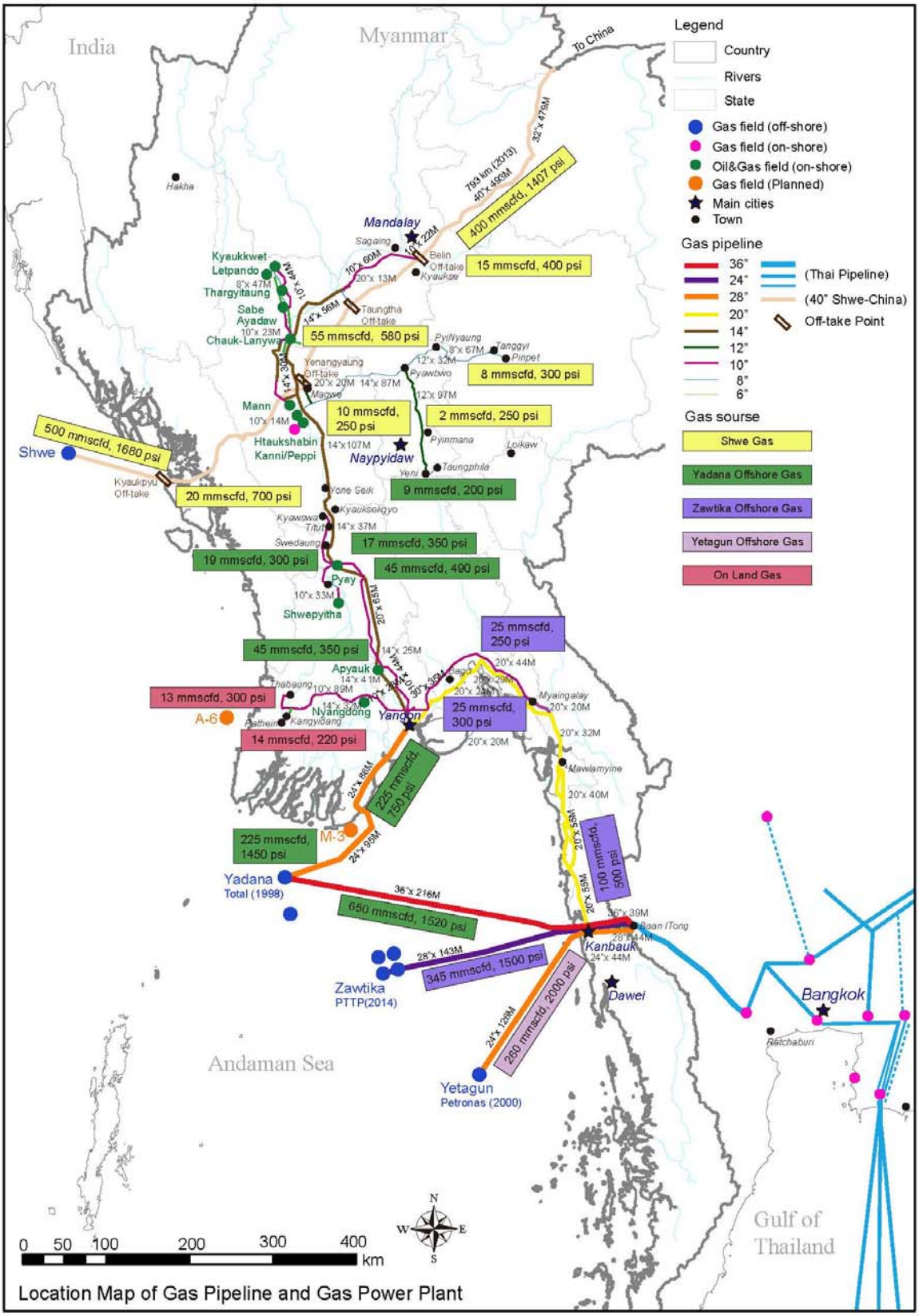
Source: Study on Gas Application in Myanmar, METI

Figure 2.1.1 Location of M-3 Gasfield and A-6 Gasfield

2.1.3 Pipeline

The existing pipeline is shown in Figure 2.1.2. Most of the gas pipelines were installed in 1990s. Many pipes were not treated to protect against corrosion. Therefore, replacement of pipelines from each offshore gasfield (Yadana, Zawtika, Yetagun, Shwe) to inland is required to mitigate the degradation of the existing pipes from corrosion.

In the pipeline between the south of Myanmar to Yangon, the pipeline from Kanbouk to Mawlamyaing was constructed from 2000 to 2001 and it has corrosion problem due to saltwater intrusion. Since the pipelines along Kanbouk, Mawlamyaing, Thaton and Yangon have not been protected against corrosion, the replacement of these pipelines is required. According to MOGE, a length of 35 miles of pipeline is replaced annually, and the total length is 330 miles. So far, replacement has been done for 100 miles of the pipelines. Protection against corrosion has been carried out for half of the length. After completion of this replacement, the gas feeding capacity will be increased from 100 mmscfd to 115 mmscfd, and the pressure will be increased from 600 psi to 850 psi.



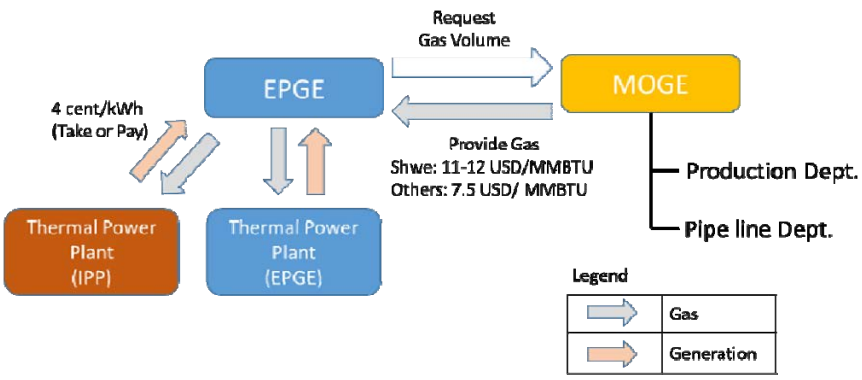
Source: Study on Gas Application in Myanmar, METI

Figure 2.1.2 Gasfields and Pipelines in Myanmar

2.2. Domestic Procedures for Fuel Procurement

The development of domestic natural gas and oil, maintenance of pipeline to each power station, and supply of gas are carried out by MOGE. For the generation of gas thermal power stations, EPGE purchases gas from MOGE and then supplies it to the gas thermal power stations of EPGE and IPPs.

In order to supply gas to meet EPGE's requirement, MOGE makes the plan to produce and manage natural gas and maintain the pipelines. However, according to MOGE, there is no written agreement between MOGE and EPGE to secure gas supply for a certain period, at a certain quality such as calorific value, and with specific gas components. In general, MOGE has responsibility only for gas supply volume (mmscfd). EPGE should pay fee to MOGE for gas volume supplied to each power station monthly.



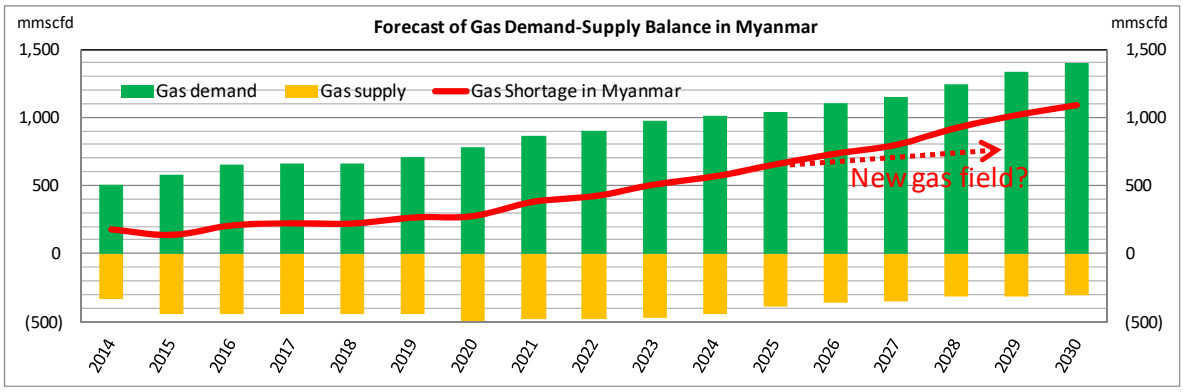
Source: EPGE and MOGE

Figure 2.2.1 Domestic Flow for Fuel Procurement

2.3. Domestic and Overseas Market and Price Standard

2.3.1 Domestic Fuel Market

As described in Section 2.1, gas volume (especially of Yadana gasfield) tends to decline. However, new gas thermals are planned and will eventually need additional gas supply. Therefore, shortage of gas supply for domestic gas thermals is anticipated. Future domestic gas demand was studied in the "Study on Gas Application in Myanmar, METI", and the gas demand forecast is shown in Figure 2.3.1. The graph shows the shortage of gas supply against gas demand and the shortage will exceed 1,000 mmscfd in 2030. In the future, new fuel procurement or fuel redistribution is mandatory.



Source: Study on Gas Application in Myanmar, METI

Figure 2.3.1 Forecast of Gas Demand in Myanmar

2.3.2 Overseas Fuel Market

In general, countries in Southeast Asia have been energy-production area. These countries have acquired foreign currency through export of natural gas and coal. However, each country plans to import fuel because of: 1) increase of energy demand by economic growth and 2) slow rate of natural gas production. To overcome the natural gas shortage, LNG import is planned as an alternative to the domestic natural gas. For example, Thailand started natural gas import from Myanmar through pipeline from 1998, and started the operation of LNG onshore plant at Map Ta Phut, which is the first in Southeast Asia. In addition, Indonesia, which exported LNG to other countries in the past, now started LNG import.

Middle eastern countries (Qatar and Iran), North American countries (USA and Canada), Southeast Asian countries (Malaysia and Indonesia), Russia, and Australia are main countries of natural gas production. However, Natural gases are imported and exported as LNG in Southeast Asian countries because of: 1) there are a lot of small islands and 2) no pipeline network exists. Main import countries of LNG are Europe, Japan, Korea, China, etc.

2.3.3 Sale Price of Gas in Myanmar

The sale prices of gas from MOGE's gasfields to EPGE for domestic power stations are shown in Table 2.3.1. Gas sale price is updated annually, but it is not changed significantly except for Shwe gasfield. The gas price of Shwe gasfield is the highest because of: 1) it has higher calorific value than Yadana and Zawtika, 2) Shwe gasfield was developed recently (in 2013), and 3) amortization of construction cost is necessary. The price may be decreased if MOGE recovers the development cost by revenue through gas sale.

Table 2.3.1 Sale Price for Domestic Generation

Gas field	Price (USD/MM BTU)	Note
Yadana	7.5	
Shwe	11-12	
Zawtika	7.5	
Yetagun	7.5	To Thailand only

Source: MOGE

2.4. Urgent Import Plan of LNG

In response to the decline of gas production of each gasfield due to the depletion, the following two LNG import plans by Floating Storage Regasification Unit (FSRU) were studied for the upgrade of electricity supply in Myanmar. If these projects are implemented, the gas supply could get released from the current shortage. It is expected to improve the electricity supply in the short-term.

2.4.1 FSRU by PPP

The World Bank carried out the pre-FS for LNG import and pipeline installation. In this study, three large-scale (500 mmscfd) projects and two medium-scale (200-300 mmscfd) projects were proposed. As of end August 2017, MOEE is considering the proposed sites and has not decided the final site yet. After MOEE's decision, it will start the following process: 1) discussion with related ministries, 2) feasibility study funded by International Finance Corporation (IFC), and 3) bidding by MOGE.

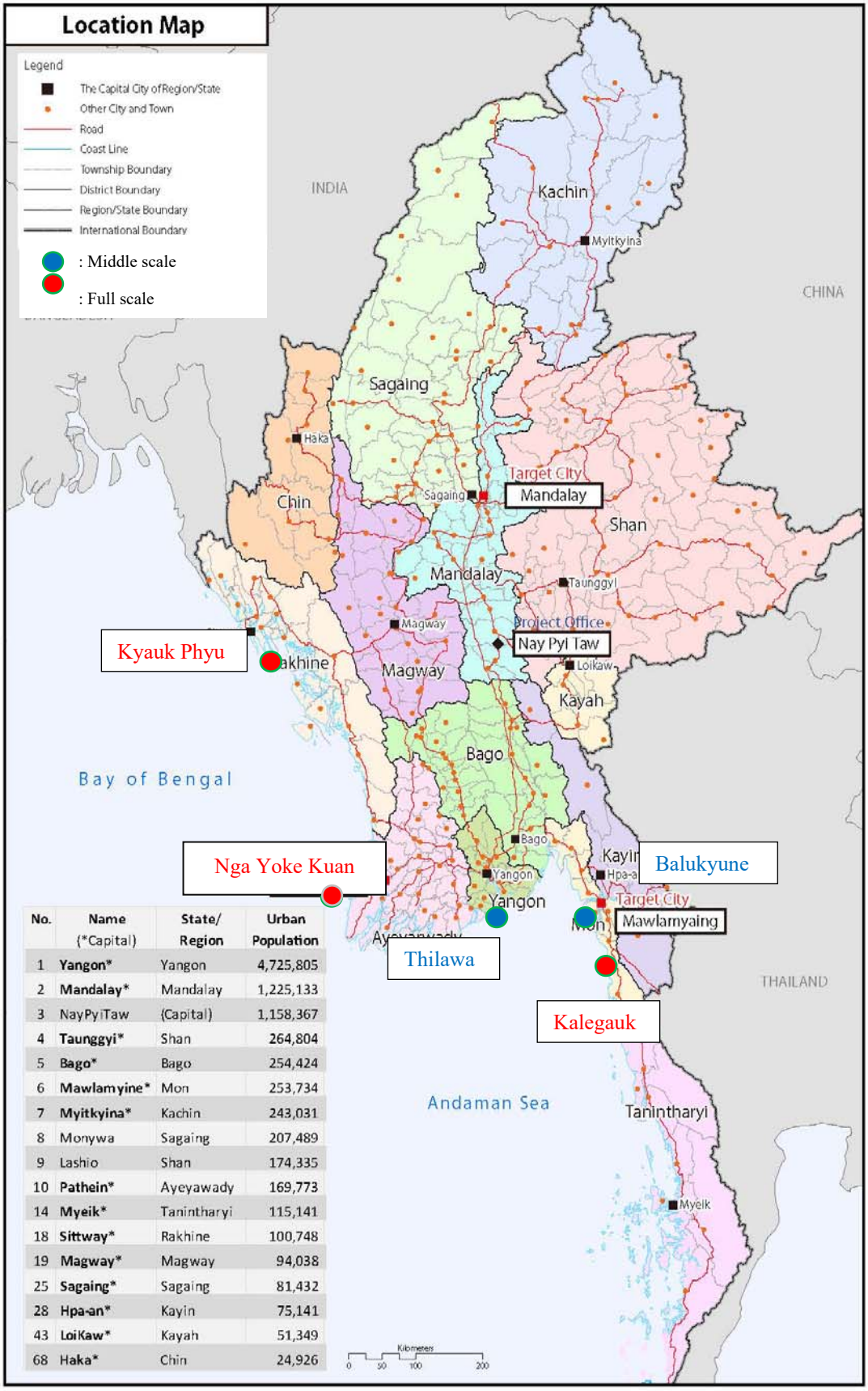
The large-scale project of FSRU will take time for construction. On the other hand, the construction period of medium-scale project is estimated at two years, and it will be finished by the end of 2021.

This project will be carried out as public-private partnership (PPP). It will be under lease contract and updated every year. More than 100 companies were interested in this project and submitted Letter of Expression of Interest (Letter of EOI).

Table 2.4.1 Proposed Location of FSRU Project Carried Out by World Bank

Scale	Location	Feature
Large Scale (Max. 500 mmscfd)	Kyauk Phyu	- It is located near Shwe gasfield - Long pipeline length
	Nga Yoke Kuang	- It is in a tourist area - Large impact on the environment
	Kalegauk	- 380 km from Yangon - LNG will be transmitted by pipeline under the sea.
Medium Scale (200-300 mmscfd)	Thilawa	- 90 km from Yangon - Nearest location, but dodger is necessary.
	Balukyune	- It is located near Mawlamyaing (southeast of Yangon) - Longer pipeline than Thilawa

Source: MOGE



No.	Name (*Capital)	State/ Region	Urban Population
1	Yangon*	Yangon	4,725,805
2	Mandalay*	Mandalay	1,225,133
3	NayPyiTaw	(Capital)	1,158,367
4	Taunggyi*	Shan	264,804
5	Bago*	Bago	254,424
6	Mawlamyine*	Mon	253,734
7	Myitkyina*	Kachin	243,031
8	Monywa	Sagaing	207,489
9	Lashio	Shan	174,335
10	Pathein*	Ayeyawady	169,773
14	Myeik*	Tanintharyi	115,141
18	Sittway*	Rakhine	100,748
19	Magway*	Magway	94,038
25	Sagaing*	Sagaing	81,432
28	Hpa-an*	Kayin	75,141
43	LoiKaw*	Kayah	51,349
68	Haka*	Chin	24,926

Source: MOGE

Figure 2.4.1 Location of FSRU Project Carried Out by World Bank

2.4.2 FSRU by Private Company

Private companies, i.e., JV of PTT (Thailand), TOTAL (France), and SIEMENS (Germany), are carrying out an LNG import project plan by FSRU at Kanbauk. Since the pipeline towards Yangon area does not have excess capacity (100 mmscfd), LNG will be exported to Thailand through pipeline. This project is out of MOGE's jurisdiction.

2.4.3 Import of LPG

In Myanmar, liquefied petroleum gas (LPG) is imported only to four districts for home use. There is no example of LPG import for power generation. Because LNG import plan by FSRU is ongoing, there is no LPG import plan for power generation in Myanmar.

CHAPTER 3 POWER SUPPLY-DEMAND BALANCE IN YANGON REGION

3.1. Existing Gas-fired Power Plants, Fuel Supply and Power Generation Record

Gas-fired power plants: Hlawga, Ywama, Ahlone and Thaketa supply electricity to Yangon Region and its vicinity. There is no existing hydropower plant in Yangon Region. The IPP gas power plants are constructed within an available yard of existing power stations. For example, Toyo Thai company built gas turbine power plant in Ahlone PS and UPP company also built a gas turbine power plant in the Ywama PS compound. The fuel is supplied to these IPP's power plants from Yadana and Zawtika gasfields. The gas-fired power plants in Yangon with their gasfield sources are shown in

Table 3.1.1 Gas-fired Power Plants in Yangon Region

Location	Owner	Plant	Type	Installed Capacity				COD	Gas RQMT (mmscfd)	Gas Field	Notes
				MW	No	Total					
Yangon	MOEE (Ministry of Electricity and Energy)	Hlawga	GT	33.30	3	99.9	154.2	1996	39.0	Yadana	
			ST	54.30	1	54.3		1999			
		Ywama	GT	18.45	2	36.9	70.3	1980	28.0		
			GT	24.00	1	24.0		2004			Operation Stop by damage on GT H25
			ST	9.40	1	9.4		2004			
			GT	120.00	2	240.0	240.0	2014	80.0		Donated from EGAT
		Ahlone	GT	33.30	3	99.9	154.2	1995	39.0		
			ST	54.30	1	54.3		1999			
		Thaketa	GT	19.00	3	57.0	92.0	1990	29.0	Zawtika	Operation Stop (1unit) by damage on GT
			ST	35.00	1	35.0		1997			Operation Stop by damage on ST
		Thilawa	GT	25.00	2	50.0	50.0	2016	18.8	Zawtica	H25
	Sub-Total (MOEE)						**760.7**		**233.8**		
	Zeya (Myanmar Company)	Hlawga	GE	1.05	26	27.3	54.9	2013	7.9	Yadana	1st phase in 2013 (Desser-Rand Spain)
			GE	9.20	3	27.6		2015	7.9		2nd phase in 2015 (Rolls-Royce)
	MSP (Nyan Shuwe Pyi)	Ywama	GE	4.00	13	52.0	52.0	2013	16.6	Yadana	CAT CG260-16
	Toyo-Thai	Ahlone	GT	41.00	2	82.0	121.0	2013	29.8	Yadana	GE LM6000
			ST	39.00	1	39.0		2014			
	Max Power	Thaketa	GE	3.35	16	53.6	53.6	2013	15.0	Yadana	(MITSUI 44%) , MPPL:Singapole, Jenbacher
	Yangon District	Thaketa	GT	25.00	1	25.0	25.0	2017		HFO	
	URSC(Union resources & Enginnnering Co.)	Thaketa	GT	32.00	2	84.0	106.0	2017	no data	no data	Phase I
			ST	42.00	1	42.0		2017		no data	
	Sub-Total (IPP)						**281.5**		**77.2**		
	Total (Yangon)						**1,042.2**		**311.0**		

Note: GE: Gas engine power plant, GT: Gas turbine power plant, ST: Steam power plant,
Source: METI, JETRO, DEPP

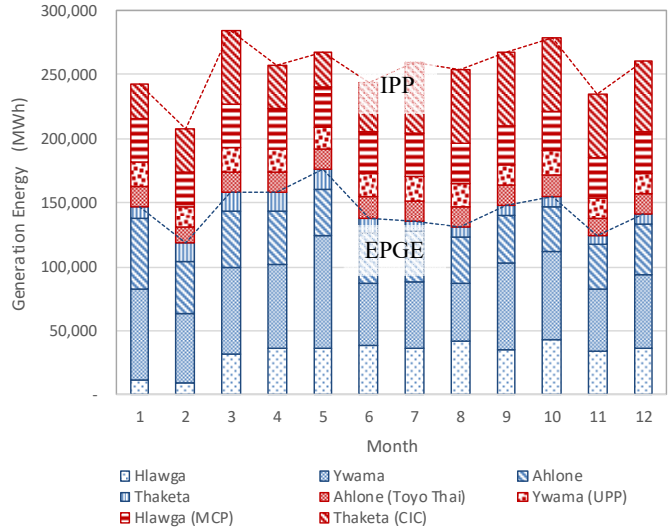
EPGE provided the JICA Survey Team with the power generation records in Yangon Region from 2013 to 2016. The data are summarized annually as shown in Table 3.1.2. The monthly power generation records at each power station in 2016 are shown in Figure 3.1.1.

Table 3.1.2 Annual Power Generation Record of Gas-fired Power Plants in Yangon Region

(unit: MWh)

Year	EPGE				IPP				Total
	Hlawga	Ywama	Ahlone	Thaketa	Ahlone (Toyo Thai)	Ywama (UPP)	Hlawga (MCP)	Thaketa (CIC)	
2013	658,053	344,659	620,923	402,155	139,977	207	40,866	10,425	2,217,264
2014	512,029	717,768	688,855	295,171	557,890	320,600	183,380	326,376	3,602,068
2015	242,635	841,885	565,228	163,658	164,811	52,545	368,617	693,402	3,092,781
2016	393,593	729,919	483,219	125,078	184,997	210,854	380,417	551,828	3,059,905
Average	451,578	658,558	589,556	246,515	261,919	146,052	243,320	395,508	2,993,005

Source: EPGE



Source : EPGE

Monthly Power Generation in 2016 (MWh)

Month	EPGE Total		IPP Total		Total
Jan	147,264	61%	95,888	39%	243,152
Feb	118,717	57%	88,509	43%	207,226
Mar	157,961	55%	126,660	45%	284,621
April	158,451	62%	98,768	38%	257,219
May	175,907	66%	91,658	34%	267,565
June	137,765	56%	106,543	44%	244,308
July	135,928	52%	123,450	48%	259,378
Aug	131,560	52%	122,260	48%	253,820
Sep	147,450	55%	120,125	45%	267,575
Oct	154,874	56%	124,139	44%	279,013
Nov	124,863	53%	110,036	47%	234,899
Dec	141,069	54%	120,062	46%	261,130

Figure 3.1.1 Monthly Power Generation Record of Gas-fired Power Plants in Yangon Region in 2016

As shown in Figure 3.1.1, EPGE increases its output in response to the power demand increase from March to May. The share of power generation by IPPs in April and May dropped to 30-40%, while that for other period is over 40%.

Annual power generation increased in 2014 owing to the commencement of power generation of IPP's gas-fired thermals at Ywama. The generated energy amounted to about 3,000 GWh after 2014.

3.2. Power Demand and its Prospects

3.2.1 Power Demand of Yangon Area

As explained in Chapter 1, power distribution business in Yangon is managed by YESC. Table 3.2.1 shows the historical increase in the number of customers during the past five years. The rate of increase in industrial and bulk demands is significantly higher than the average. It shows a steady increase in accordance with the industrial growth.

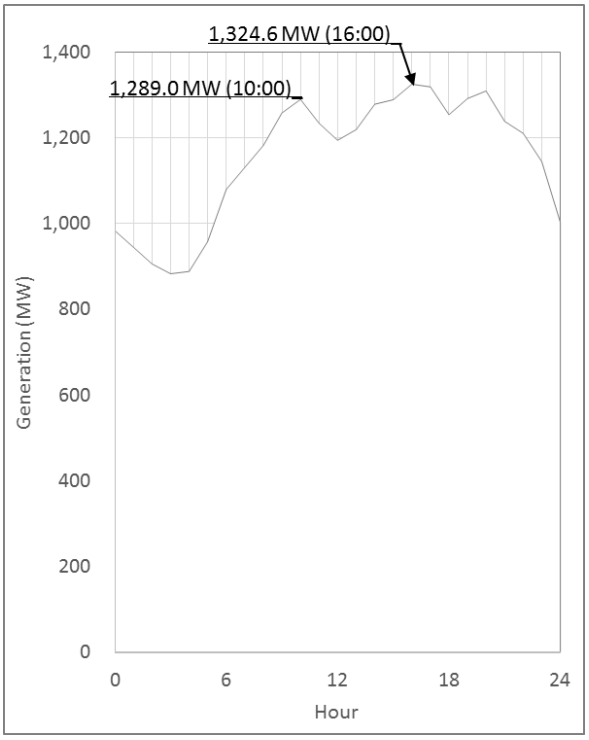
Table 3.2.1 Increase in Number of Customers in Yangon

	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	Inc.Rate
General Purpose	842,750	894,742	912,589	1,044,064	1,124,405	7.5%
Domestic Power	31,080	32,020	33,261	34,776	36,599	4.2%
Small Power	16,551	16,690	15,193	15,527	9,977	-11.9%
Industrial	3,562	3,899	4,335	4,888	5,535	11.6%
Bulk	2,187	2,406	2,602	2,882	3,335	11.1%
Street Lighting	734	758	743	962	1,494	19.4%
Temporary Lighting	315	340	605	1,181	1,596	50.0%
Total	897,179	950,855	971,195	1,106,743	1,192,362	7.4%

Source: Statistics 2016 of YESC

YESC owns small emergency diesel generators, but purchases all electricity, to be sold to customers, from EPGE. Table 3.2.4 shows the growth of electric energy purchased and distribution loss. The annual average increase rate of purchased energy is lower than that of the sold energy because the distribution loss improved to 2015/2016. The electricity consumed in the Yangon area in FY 2015-2016 was 6,705 GWh. In the same year, the electricity generated and supplied at the power stations in the Yangon area amounted to about 3,000 GWh in total. The electricity exceeding the 3,000 GWh was supplied from the power stations outside Yangon.

Figure 3.2.1 shows the daily load curve on May 23, 2017. The maximum power demand of Yangon was recorded at 1,324.6 MW at 16:00.



Source: DPTSC

Figure 3.2.1 Load Curve of Yangon

3.2.2 Prospects of Power Demand of Yangon Area

Table 3.2.2 shows the demand forecast of the master plan study implemented with the support of JICA. The annual average increase rate for 2020 was calculated for the eight years from 2012. The one for 2030 was based on the ten years from 2020. Since the actual increase rate in Yangon area is high being close to the high demand forecast of the master plan, it is expected to maintain a further high increase rate in the future.

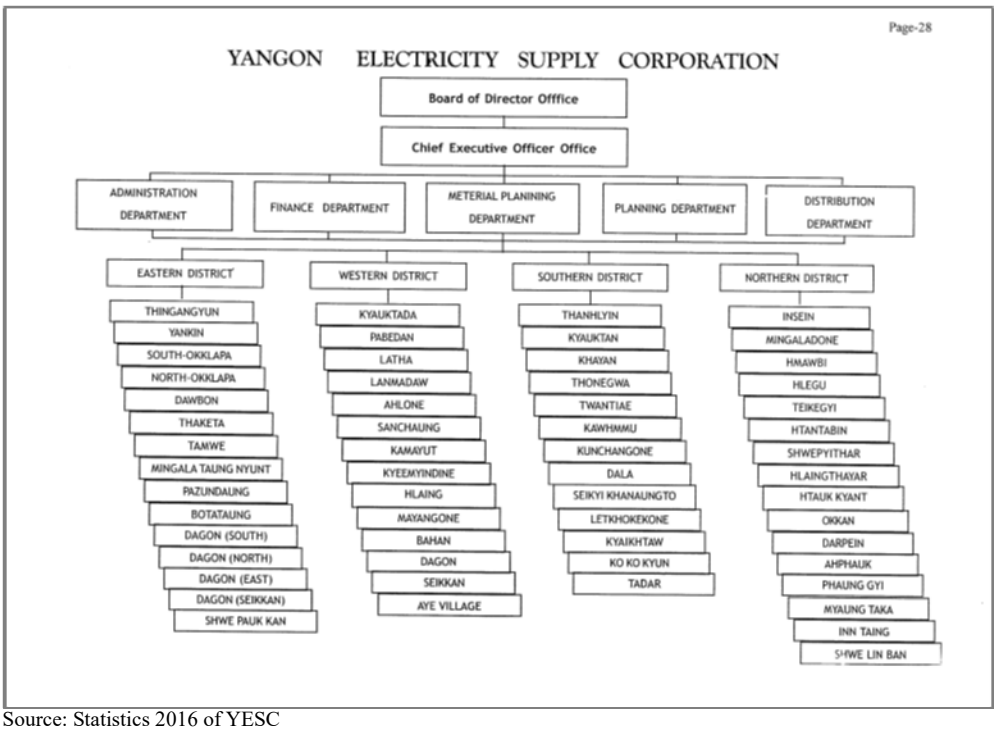
Table 3.2.2 Demand Forecast of Master Plan

		2012	2020		2030	
		MW	MW	Inc.Rate	MW	Inc.Rate
Whole Country						
	High Forecast	1,874	4,531	11.7%	14,542	12.4%
	Low Forecast		3,862	9.5%	9,100	8.9%
Yangon						
	High Forecast	742			8,209	14.3%
	Low Forecast				4,019	9.8%

Source: Outline of National Electricity Master Plan – Version as of 2030

3.3. Actual Situation of Transmission and Distribution Facilities

YESC divides the Yangon area into four districts, i.e.: east district, west district, south district, and north district, and separately manages these districts. The organization structure is given in Figure 3.3.1.



Source: Statistics 2016 of YESC

Figure 3.3.1 Organization Structure of YESC

3.3.1 Transmission Facilities

The power transmission facilities in Yangon area is for supplying the electricity purchased from EPGE, through the 230 kV substations of DPTSC and thermals in the region, to the customers. The 66 kV and 33 kV facilities are under operation. Table 3.3.1 shows the extension of transmission lines by voltage. In comparison with the increase rate of power demand, the construction of transmission lines, especially 66 kV line, is not progressing.

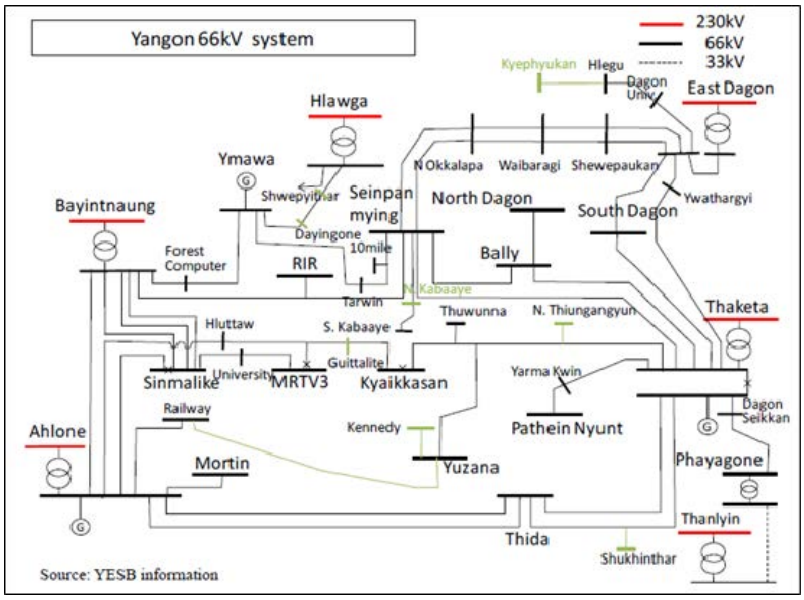
Table 3.3.1 Extension of Transmission Lines in Yangon Area

						km
Year	2011/12	2012/13	201/14	2014/15	2015/16	Inc.Rate
66kV Line	166.0	195.2	195.2	204.8	204.8	5.4%
33kV Line	1,269.6	1,294.9	1,318.1	1,359.8	1,376.7	2.0%

Source: Statistics 2016 of YESC

The 66 kV transmission line is 148.0 km long according to the list of transmission lines received from YESC. It is in 20 sections, 5 of which are double-circuit lines with length of 45.7 km, and the total circuit-km of 193.7. This is not consistent with the figure in Statistic 2016. As for the 33 kV line, the underground cable line has 28 sections and 62.0 km long. All the underground lines consist of three single core cables. According to Statistics 2016, the total length of the 33 kV lines is 1,376.7 km.

The single line diagram of the 66kV system is given in Figure 3.3.2.



(Source: Preparation Survey for power improvement project in greater Yangon, Feb. 2014, by Chubu Electric Co. Inc.)

Figure 3.3.2 Single Line Diagram of 66 kV System in Yangon

3.3.2 Substation Facilities

In Yangon area, there are 34 substations of 66 kV owned and managed by YESC, and 48 transformer units with a total capacity of 1,407 MVA. In addition to YESC's substations, there are switching stations for power plants owned and managed by EPGE and IPPs. The details of the 66 kV transformers are shown in Table 3.3.2.

Table 3.3.2 66 kV Substation in Yangon Area

Transformer	66/33	66/11	66/11-6.6	Total
Nos. of Substation	13	18	11	-
Nos. of Unit	14	23	11	48
Capacity (MVA)	510	587	310	1,407

Source: YESC

On the other hand, there are 114 substations of 33 kV, having 174 transformers and total capacity of 1,703 MVA. Details are shown in Table 3.3.3.

Table 3.3.3 33 kV Substation in Yangon Area

Transformer	33/11	33/11-6.6	33/6.6	Total
Nos. of Substation	51	11	54	-
Nos. of Unit	70	21	83	174
Capacity (MVA)	738	240	725	1,703

Source : YESC

3.3.3 Distribution Facilities

Table 3.3.4 shows the extension of the distribution lines. Like the transmission line, the increase rate of line length seems lower than the demand growth. However, the laying of 11 kV distribution lines to lower the loss is progressing.

Table 3.3.4 Extension of Distribution Lines in Yangon Area

						km
Year	2011/12	2012/13	2013/14	2014/15	2015/16	Inc.Rate
11kV Line	1,526.0	1,678.2	1,883.4	2,081.9	2,222.5	9.9%
6.6kV Line	1,064.7	1,072.9	1,073.1	1,078.5	1,078.6	0.3%
3.3kV Line	3.2	3.2	3.2	3.2	3.2	0.0%
0.4kV Line	5,170.3	5,267.4	5,370.9	5,557.7	5,677.8	2.4%

Source: Statistics 2016 of YESC

As a result of the site survey in the Yangon area, although the situation of 11 kV and 6.6 kV distribution lines was almost satisfactory, the situation of the low voltage lines was quite problematic. The following two points were particularly noticed:

(1) Several distribution transformers with capacity of 1,000 kVA or greater were installed. Even though the area supplied by this large transformer includes relatively large customers, the low voltage line to general customers with small contract capacity becomes long. This results in increasing the distribution losses. The director of YESC expressed his intent to procure a transformer of 200 kVA or less in the future for reducing the losses.

(2) The second point is the wiring from the low voltage distribution line to the meter of each customer. As shown in Photo3.3.1, a lot of service wires of small size were drawn from the pole into the house building and connected to the meters (Photo3.3.2). The meters are attached to the

pole (Photo3.3.3) experimentally in part. It will reduce the losses of the supplier but will transfer the losses to the customers.

 Photo taken by the JICA Survey Team	 Photo taken by the JICA Survey Team
Photo 3.3.1 Wiring from one pole	Photo 3.3.2 In-house meter
 Photo taken by the JICA Survey Team	
Photo 3.3.3 Multiple meters attached to one pole	

Owners of the distribution transformers in Yangon area are categorized into DEPT (government-related organizations), Private, Rural (village), and YESC. Transformer data consist of voltage, capacity, substation name, district name, township name, owner, etc.. These data are structured to make it easy to classify and organize. Transformer classified as Rural are installed by villager in remote area. YESC collects electricity charge based on the meter reading on the primary side of the transformer. Meter reading and collection of electricity charge for the individual customers in the village are made on the village side.

Table 3.3.5 shows the number of transformers and installed capacity by voltage, by district and by owner. There are 12,474 units of distribution transformers in total and the total installed capacity is 4,320 MVA. The capacity is sufficient for the demand. The number of transformers owned by YESC is 2,983 units (23.9% of the total) and the capacity is 1,135.9 MVA (26.3%).

Table 3.3.5 Distribution Transformers by Voltage, District, and Owner

Voltage Ratio	Area	YESC		DEPT		Private		Rural		Total	
		Nos.	MVA	Nos.	MVA	Nos.	MVA	Nos.	MVA	Nos.	MVA
11/0.4kV	East	521	197.5	168	48.7	1,283	451.1	0	0.0	1,972	697.3
	West	0	0.0	10	11.4	22	36.9	0	0.0	32	48.2
	South	80	17.5	27	7.1	137	42.5	175	40.3	419	107.4
	North	206	57.1	293	77.6	2,435	944.1	148	32.1	3,082	1,110.9
	Toal	807	288.4	498	144.8	3,877	1,454.7	323	70.8	5,505	1,963.9
11-6.6/0.4kV	East	284	114.6	28	9.5	325	100.2	0	0.0	637	224.3
	West	350	129.4	174	71.6	1,181	314.6	0	0.0	1,705	515.7
	South	226	54.2	25	6.6	167	39.8	57	16.2	475	116.8
	North	311	86.0	53	14.6	523	133.9	21	7.2	908	241.8
	Toal	1,171	377.3	280	90.7	2,196	581.6	78	21.4	3,725	1,098.6
6.6/0.4kV	Easr	448	193.2	207	74.3	696	214.3	0	0.0	1,351	481.8
	West	373	210.0	216	105.1	597	200.0	0	0.0	1,186	515.1
	South	57	17.7	78	33.9	39	9.8	2	0.6	176	62.0
	North	127	51.7	219	84.8	177	59.1	1	0.5	524	196.0
	Toal	1,005	470.2	720	298.1	1,509	482.8	3	1.1	3,237	1,255.0
3.3/0.4kV	South		0.0	7	2.9		0.0		0.0	7	2.9
Groand Total		2,983	1,135.9	1,505	536.4	7,582	2,519.1	404	93.3	12,474	4,320.3

Source: : YESC

Transformers with capacity of 1,000 kVA or greater in Yangon area are listed in Table 3.3.6. Transformers of 1,000 kVA are the most common, accounting for 59.5% of the total. As for the transformers owned by YESC, 84.6% is 1,000 kVA unit. The rate is higher than that of the other owners. The maximum capacity of each owner's transformer is: YESC: 6,300 kVA, DEPT: 10,240 kVA, Private: 8,480 kVA, and Rural: 1,095 kVA.

Table 3.3.6 Transformers with 1,000 kVA or More

	YESC	DEPT	Private	Rural	Total
Nos.	225	115	388	-	728
Capacity (MVA)	242.8	176.5	503.9	-	922.4
1,000kVA(MVA)	205.0	65.0	279.0	-	549.0
（%）	84.4%	36.8%	55.4%	-	59.5%

Source: YESC

Regarding the transformers smaller than 999 kVA owned by YESC, 841 units of 200 kVA (168.2 MVA) are mostly installed, followed by 733 units of 500 kVA (366.5 MVA), 632 units of 315 kVA (199.1 MVA), and 214 units of 300 kVA (64.2 MVA). The total number of these four type transformers is 2,420 units (81.1% of the total below 999 kVA) and the total capacity is 798.0 MVA (70.8%). From this, the supply range per unit is quite wide. To reduce the losses on the low voltage lines, it is effective to shorten the distance from the transformer to the customers. Efforts to increase the number of small transformers of 50 to 100 kVA are necessary.

3.4. Power Development Plan in Yangon Region and Approaches by Myanmar Government, International Donners and IPPs

(1) Project and Studies related to Power Development Plan

The existing power development plans are listed and briefed below:

- National Electricity Master Plan: under updating with JICA support
- Myanmar Energy Master Plan: formulated in 2015 with the support of the Asian Development Bank (ADB)
- Introduction of mobile gas turbine (TM 2500), US General Electric (GE) supplied mobile gas turbine system to the Yangon Regional Government through local company, Golden Green Energy Co., Ltd. The power output of TM 2500 is 25 MW and it can supply electricity to 160,000 households. This fast track power plant is purchased using the budget of the Presidential Reserve Fund. EPGE and YESC are in charge of the operation and maintenance.
- Renewal of Thaton gas-fired power plant: Myanmar government will renew three units of GTG into combined cycle (GTCC) with the assistance of IDA. The total power output is 118 MW. A Japanese trading company (Mitsubishi Co., Ltd.) was awarded. The plant is under construction.
- Renewal of Thaketa gas-fired power plant: three gas turbines in the existing Thaketa gas-firedd power plant will be renewed using Japanese yen loan. The current power output is 11-12 MW while the installed capacity is 19 MW. The power output will be increased to 22 MW per unit.
- Myiangyan gas-fired power plant: Singapore-based Sembcorp holds 80% of the share of the Myiangyan gas-fired power plant. The plant with 225 MW capacity will be constructed through co-financing by ADB, IFC, and Asian Infrastructure Investment Bank (AIIB).
- Shweli-3 Hydropower Station: the station is planned with installed capacity of 1,060 MW. It is located in Shan State. EdF will be the major shareholder and GOM (DHPI) will also have a share. The project is formed under PPP scheme and financers of the project are expected to be ADB, French Development Agency (*Agence française de développement*: AFD), and the World Bank.
- Others: private companies (General Electric, ABB, Aggreko, etc.) promote small gas engine rental business to urgent power supply, and further large-scale projects are ongoing, e.g., Kanbauk (AP) 200 MW, Thaketa (UREC) 106 MW.

(2) Power Import

In order to cope with the rapid power demand increase, GOM starts negotiation for power import from China, India, Laos, and Thailand. The detailed power import plan for importing electricity from

Yunnan Province is being negotiated with China.

(3) Power Transmission Line Development Plan

500 kV Transmission Line:

- Between Thapyaywa (Meikhtila) to Taungoo: design and construction supervision of 234.9 km transmission line; under implementation with Serbian loan.
- Between Taungoo to Phayargyi to Hlaingtharyar: design, tendering, and construction supervision of 268.7 km transmission line; under implementation with Korean loan.

230 kV Transmission Line:

The following projects are planned under ADB loan:

- Between Thida to Thaketa, and
- Between Thaketa to Kyaikasan.

Substation:

The following three substations are under construction with Japanese yen loan:

- Design, procurement, and construction of Meikhtila and Taungoo substations,
- Design of Phayargyi and Hlaingtharyar substations, and
- Design and construction of Phayargyi and Hlaingtharyar substations.

The following are ongoing with ADB loan:

- Extension of Thaketa substation,
- Upgrade of Kyaikasan substation, and
- Construction of new South Okkalappa substation.

Power Distribution:

- Power Distribution System Improvement Project: the project is to improve and reduce the electricity loss of the power distribution system of 11 major cities in Myanmar. The project is implemented with Japanese yen loan.
- Power distribution improvement for Yangon, Mandalay, Sagaing, and Magway is ongoing with ADB support.

(4) Others

- LNG import (with the support of WB): LNG import by FSRU is proposed in three locations for large-scale LNG import of 500 mmscfd, and in two locations for medium-scale import of

300 mmscfd. Separately, the joint venture of PTT (Thai), TOTAL (France), and SIEMENS (Germany) formulates the project of LNG import by FSRU with 200-300 mmscfd to Kanbauk area.

- Reinforcement of gas pipeline (with Myanmar government fund): the gas pipeline between Pyey to Myanaung will be rehabilitated. The 14-inch pipeline between Yenangyang to Pyey was constructed in 1987 and has already aged. Along the Shwe-Pyey pipeline, the Yenangyang-Pyey section will be rehabilitated with support from the Korean Exim Bank.
- The World Bank (WB) and ADB are implementing respective rural electrification projects. According to the report under the Myanmar Grid Expansion Project financed by WB, 5,080 villages will be newly electrified in 2017. The WB loan will be USD 400 million in 2016-2021. In the first phase, the villages situated within 2 miles from the existing transmission lines will be electrified. In the second phase, the existing transmission lines and receiving substation will be rehabilitated and 7.50 million households will be electrified by 2030.
- With financial assistance from the German government, 1,484 villages in Taunggyi, Loilem, and Langkoh districts in Shan State will be electrified in 2017-2018.

3.5. Necessity of Urgent Reinforcement of Supply Capability to Yangon Area

3.5.1 Power Supply Balance of Yangon Area

Table 3.5.1 shows the supply and demand situation of electricity in Yangon given in Statistics 2016 of YESC. The “Firm Power” in the table refers to the electric power supplied by EPGE at the time when the maximum load is recorded. YESC purchase the total amount of necessary electricity from EPGE. The meaning of supply-demand situation in Yangon is different from the usual case. In general, supply capacity means the capability of power supply at the time of interest. In the case of Yangon area, the power supplied is the supply capacity, being the same with the demand. In other words, the supply capacity is not known on the Yangon side. The electricity equal to the demand is supplied by EPGE. Then, YESC recognizes that the demand is met.

Table 3.5.1 Historical Power Balance of Yangon Area

(Unit: MW)

Particulars	2011/12	2112/13	2013/14	2114/15	2015/16
Firm Power	745.9	791.7	913.2	1,009.6	1,125.3
Maximum Demand	800.0	841.7	913.2	1,009.6	1,125.3
Power deficit	-54.1	-50.0	0.0	0.0	0.0

Source: Statistics 2016 of YESC

Table 3.5.2 shows power shortage in 2011/12 and 2012/13. The shortage is the estimated power when scheduled power supply suspension is implemented to large-scale customers like factories. YESC declares to implement the suspension in order to continue the supply to general customers,

upon receipt of the prior notification from the power supply side. The maximum demand in the table is the actual supply plus the supply suspended. From the table, shortage of supply capacity to Yangon area did not occur in 2013 and onward. At the hearing to DEPP, the maximum demand was recorded in 2017, but it was proudly explained that there was no power shortage. In the table, the annual average increase rate of demand based on the electric power supplied to Yangon area is 11.1% and 9.2% on adjusted base.

On the other hand, Table 3.5.2 shows the supply and demand situation of electric power in Statistics 2016 of MEPE. According to the statistics of MEPE, it is unknown what kind of calculation criteria are employed, but it is said that there is considerable supply shortage every year.

Table 3.5.2 Supply and Demand of National Grid

(MW)

Particulars	2011-12	2012-13	20 13-14	2014-15	2015-16	Inc.Rate
Firm Power	1200	1200 .0	1498.0	1724.0	2672.0	22.2%
Demand	1850.0	1850.0	2104.0	2300.0	2800.0	10.9%
Balance	-650.0	-650.0	-606.0	-576 .0	-128.0	

Source: Statistics 2016 of MEPE, published in 2017

In the table, a large power shortage is presented as the balance between the “Firm Power” and demand. Table 3.5.3 shows the list of Firm Power and Maximum Power generated in August 2016. The data are obtained from the Generation Control Center (GCC), which controls and manages the hydropower stations of EPGE. The column (6) is the ratio of Firm Power to the maximum output and column (7) is the plant factor based on the maximum output. No certain rule was found from the ratio in column (6). On the other hand, there are some rules that show the same value of this ratio and the plant factor in column (7), but the relationship is not clear in the others. In addition, there are power plants where Firm Power is greater than the maximum output. The calculation criteria are not known.

Table 3.5.3 Maximum Power and Firm Power of Hydropower

Sr No	Station Name	Installed Capacity (MW)	Design Generation (GWh)	Max Power (MW)	Firm Power (MW)	(4)/(3) (%)	(2)/((3) *8.76) (%)
		(1)	(2)	(3)	(4)	(6)	(7)
1	Baluchaung No.1	28.00	200.00	28.00	26.00	92.9	81.5
2	Baluchaung No.2	168.00	1190.00	165.00	155.00	93.9	82.3
3	King Tar	56.00	165.00	52.00	21.00	40.4	36.2
4	Sal Taw Kyi	25.00	134.00	24.00	20.00	83.3	63.7
5	*Zaw Kyi-1	18.00	35.00	17.00	4.00	23.5	23.5
6	Zaw Kyi-2	12.00	30.00	12.00	3.43	28.6	28.5
7	Zaung Du	20.00	76.00	19.00	8.68	45.7	45.7
8	Tha Phan Seik	30.00	117.00	30.00	13.38	44.6	44.5
9	Mone	75.00	330.00	72.00	37.67	52.3	52.3
10	Paung Laung	280.00	911.00	270.00	104.00	38.5	38.5
11	Ye N we	25.00	123.00	19.50	14.04	72.0	72.0
12	Kha Paung	30.00	120.00	28.00	13.70	48.9	48.9
13	*Shwe Li-1	600.00	4022.00	400.00	174.80	43.7	114.8
14	Kyaing Taung	54.00	377.60	52.00	43.11	82.9	82.9
15	Ye Ywar	790.00	3550.00	760.00	175.00	23.0	53.3
16	Shwe Kyin	75.00	262.00	72.00	50.60	70.3	41.5
17	*Tar Pain-1	240.00	1065.00	10.00	30.05	300.5	1215.8
18	Kon Chaung	60.00	190.00	58.00	17.50	30.2	37.4
19	Kyi Ohnkyi Wa	74.00	370.00	60.00	42.00	70.0	70.4
20	Thout Yay Khat-2	120.00	604.00	118.00	101.00	85.6	58.4
21	Phyu Chaung	40.00	120.00	35.00	28.40	81.1	39.1
22	*Nan Cho	40.00	152.00	40.00	12.60	31.5	43.4
23	Upper Paung Laung	140.00	454.00	135.00	84.00	62.2	38.4
24	Myo Kyi	30.00	135.70	14.50	15.50	106.9	106.8
25	*Chi Phwe Ngal	99.00	599.00	36.00	25.90	71.9	189.9
26	*Baluchaung-3	52.00	334.00	51.00	40.00	78.4	74.8
Total		3181.00	15666.30	2578.00	1261.36	48.9	69.4

(Source: GCC of EPGE)

Rem (1) * Run of River Type

(2) Column (6) and (7) are added by the team..

(3) Column (7) is plant factor by using maxpower of column (3).

(4) Yellow colored cells show similar figures between columns (6) and (7).

Source: GCC of EPGE

The supply and demand situation of electric power is changing from moment to moment and should be expressed by the supply capacity (MW) and demand (MW). The supply capacity is the available output of the power stations under operable conditions. As for the hydropower plant, it is the output to be determined from the reservoir level, reservoir inflow, reservoir storage, etc. It should be continuously operable for certain duration (day or several hours). The supply capacity should be determined taking into consideration the season, reservoir conditions and inflow.

Table 3.5.4 shows the results of analyzing the operation records of all the power stations in the rainy season (October 19, 2016 when monthly maximum load was recorded) and the dry season (May 23, 2017 when maximum demand to date was recorded). Since the data on the operating condition of generating facilities could not be obtained, the available capacity was estimated by subtracting the capacity of those power plants which were not operated at all on that day from the system capacity. The capacities of Shweli-1 and Tar Paing-1 were set at 400 MW and 10 MW, respectively.

Table 3.5.4 Power Supply and Demand at the Time of Maximum Demand

	Season	Hydro Power			Thermal Power			Hydro + Thermal		
		EPGE	IPPs	Total	EPGE	IPPs	Total	EPGE	IPPs	Total
Installed Capacity	Wet Season 19.10.2016	2,110	690	2,800	993	974	1,967	3,103	1,665	4,768
Outage		77	0	77	263	22	284	340	22	361
Abailable Capacity		2,033	690	2,723	730	953	1,683	2,763	1,643	4,406
Installed Capacity	Dry Season 23.05.2017	2,110	681	2,791	993	974	1,967	3,103	1,655	4,758
Outage		88	0	88	122	0	122	210	0	210
Abailable Capacity		2,022	681	2,703	871	974	1,845	2,893	1,655	4,548
Max Output (MW)	19.10.2016	1,479	420	1,890	346	617	921	1,820	1,000	2,801
Max Output (MW)	23.05.2017	1,307	498	1,804	532	741	1,272	1,837	1,238	3,075

Remarks: (1) Outage means "not put into operation on the day, and includes scheduled outage.
(2) Thermal EPGE includes Tigyit coal-fired plant.
(3) Installed capacity Shweli-1 is 400MW and Tar Paing-1 is 10MW.

Source: EPGE

In the table, total value of the maximum output equals to the maximum demand of the day, which was 2,801 MW on October 19, 2016 in the wet season and 3,075 MW on May 23, 2017 in the dry season. That is, the reserve capacity in the dry season was 57% and the rainy season was 45%. However, since the available output is calculated based on the installed capacity of the stations that were not operated on the day, neglecting the derating in the output due to aging, low water level of the reservoir, etc., it is actually necessary to discount the available output significantly.

3.5.2 Issue on Transmitting of Power of Large-scale Hydropower Stations in Northern Area

After the planned 500 kV transmission system is completed, transmitting sufficient electric power from the northern area to Yangon will be substantially solved. However, it is important that the power should be transmitted continuously from the northern area to Yangon, the largest load center. Looking at the national grid for continuous supply, even if the 500 kV transmission system is completed, the N-1 criteria, a simple standard for stable power supply, is not satisfied.

Transmission tower may collapse due to landslide, foundation erosion by river flow, etc. This occurs worldwide to the extent that accident risk cannot be ignored. Myanmar is no exception. The possibility of collapse of one of the 500 kV towers somewhere in the 500-km long section cannot be completely avoided. When one tower collapses, the 500 kV transmission line loses its total function, i.e., there will be dropout of the power supply source by more than half, and the national grid instantly collapses. Due to such large and strong impact, many thermal power plants, in particular, are likely to be affected seriously. As a result, even if power supply is resumed particularly in Yangon area, the situation of power supply restriction, partial supply suspension, etc., will be prolonged.

For the restoration of the national grid after the system collapse, safety confirmations of the transmission system takes priority. In other words, the connection to customers will be proceeded sequentially, after electrical safety confirmation of transmission line from safe and sound power station, electrical safety confirmation of substation equipment and so on. This restoration work is not carried out simultaneously for the entire system, but it is necessary to expand the supply range from

some power stations while checking the safety of the surrounding power transmission system individually. Finally, the power supply systems will be integrated and the national grid restored. Fortunately, Myanmar has actively developed hydropower plants. It is great advantage that hydropower plants have higher durability against such electrical shock than thermal power plant. In other words, most hydropower plants will maintain their function for power generation even after the accidents. In addition, most of the plants are of reservoir type. These have the capability to continue operation for a certain period with hydropower alone, so these power plants may be the center of restoring the system function at the time of system collapse.

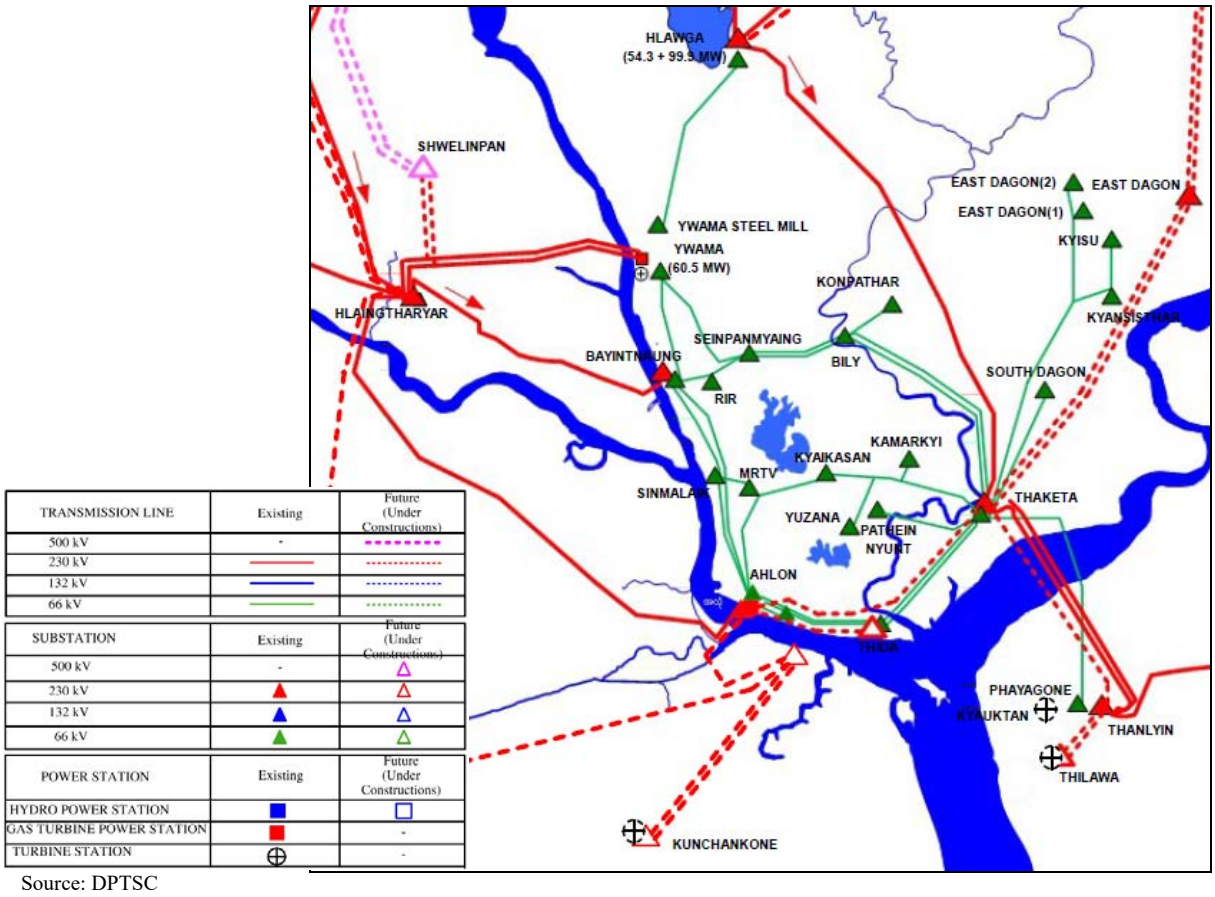
Even in the dry season, in order to cope with the accident, it is necessary to supply power for a certain level by the hydropower alone. In other words, efforts should be made to keep the reservoir water level as high as possible to the extent that it is economically acceptable to avoid extreme lowering of the reservoir water level in normal operation. For that purpose, the JICA Survey Team proposes to review the operation rule of the reservoir. For the review of hydropower stations of toe-of- dam type in particular, it is usually most economical to operate in the water range of 30-50% or 1/3 of the reservoir drawdown (= FSL - MOL) throughout the year. This will also contribute to coping with droughts once in 10-20 years.

Even if it takes time to restore the condition of all the facilities after the large blackout accident, it is important to resume supply at an early stage by using the operable equipment. In this case, the more power supply there is, the more effective it is to reduce people's unrest and anxiety. For this purpose, it is necessary to develop and reinforce urgently the existing 230 kV transmission system so that a certain amount of electricity can be transmitted to Yangon area, the largest demand center, even only with the existing 230 kV transmission facilities.

The further measures and recommendations are presented in Chapter 7.

3.5.3 Issues of Transmission System in Yangon Area

The problem of the transmission system in Yangon area is also related to the 500 kV line. Figure 3.5.1 shows the 230 kV and 66 kV transmission system in the Yangon area.



Source: DPTSC

Figure 3.5.1 Transmission Line Map of 230 kV and 66 kV in Yangon Area

Table 3.5.5 shows the power supplied from the 230 kV substations to the customers. The table was worked out from the power flowing into the bus and the power outgoing from the bus at 19:00 on May 23, 2017 when the maximum load on that day was recorded. The load is the electric power sent out to the customers via 66 kV and 33 kV transmission lines. From the table, the existing thermal power plants are largely distributed on the west side. On the other hand, the load is also concentrated in the west, but the urban development in the eastern area is progressing and the degree of uneven distribution is not as large as the power generating plants. The Thanlyin substation is at a certain distance from the center of Yangon on the opposite bank of the river. The urban development in the area has recently started and it has little relation with the problem discussed in this section.

Table 3.5.5 Load of 230 kV Substation in Yangon Area

Substation	230kV Line (MW)		Generation (MW)	Load (MW)
	In	Out		
West Area			524.00	927.88
Hlaningtharya	340.70	204.45	0.00	136.25
Bayintnaung	42.98	0.00	0.00	42.98
Ahlone	94.81	0.00	184.20	279.01
Ywama	0.00	128.38	245.00	116.62
Hlawga	257.76	120.51	94.80	232.05
Myaungtagar	333.29	212.32	0.00	120.97
East Area			68.30	333.47
Thaketa	210.24	0.00	68.30	278.54
Thanlyin	179.66	124.73	0.00	54.93
Total			592.30	1261.35

Source: Power Flow Analysis on May 23, 2017 by DPTSC

The problem is that, in addition to the uneven distribution of major thermal power plants in the west area, additional huge electric power will be supplied to the west area by 500 kV transmission line. Although it is difficult to discuss numerically without detailed power flow analysis, the power flow on the 66 kV line is in general from west to east. After completion of the 500 kV transmission system, it will further increase the power flow from west to east. As a result, the burden on the existing transmission lines of 66 kV and 33 kV will increase, which may cause overloading. Especially in Yangon area, there are many underground cable lines that are sensitive to heat. Detailed power flow analysis for the condition after the completion of 500 kV system should be executed for formulating necessary countermeasures.

For example, in the event of an accident in the 230 kV transmission line supplying power to the Thaketa substation or an accident in the substation itself, it becomes impossible to supply electricity from Thaketa to the 66 kV and 33 kV systems. Then the power supply from the 230 kV substation on the east side stops, and all the power will be supplied from the 230 kV substation on the west side through the existing 66 kV and 33 kV lines. In this case, a more serious situation will take place.

The further measures and recommendations are presented in Chapter 7.

3.5.4 Uncounted General Customers

In the survey of Yangon area, the JICA Survey Team investigated the condition of transformer facilities and meters of new large customer's condominium. Transformer was Fuji Electric's dry type, 33/0.4 kV, 3,000 kVA. The condominium administrator owns the transformer. Recently, the regulation of YESC was changed so that the transformer of 1,000 kVA or greater should be connected to the 33 kV system. Therefore, this manager also extended the 33 kV transmission line from the nearest 33 kV transmission line. After completing the line connection, the manager handed over the transmission line to YESC free of charge. Now, operation/maintenance is undertaken by YESC.

The meter for collecting electricity tariff is installed on the 33 kV side of the transformer and electricity tariff based on the consumed energy is charged to the administrator. The applicable tariff category is bulk. The meters of the individual customers in the condominium are collectively installed on the low voltage side of the transformer. The meter reading is done by YESC and the administrator collects the tariff from each customer according to the reading of the consumed electricity. For reference, "Bulk" electricity tariff of YESC is shown in Table 3.5.6. Domestic units in the table has the same tariff for Ordinary household customers.

Table 3.5.6 Bulk Electric Tariff

Consumer Category	Energy Charges (Kyats per Unit)		Capacity Charges	Fixed Charges ie.Meter Service
	Domestic Units	Commercial Units		
Bulk	1 - 100 units •35 Kyats	1 - 100 units •75 Kyats	200	Three Phase 2000
		501-10,000 units •100 Kyats		C.T Meter 5000
	101-2oo units•40Kyats	10001-50000 units • 75 Kyats		
		50,001-200,000units •150Kyats		
	201units and above • 50Kyats	200,001-300 ,000units •125Kyats		
		300.000units and above •100Kyats		

Source: Statistics 2016 of YESC

The administrator contracts with YESC per "Commercial Units of Bulk". The problem is that the contract with YESC is concluded as "Commercial Units" by the administrator and the administrator will pay to YESC twice to three times the electricity tariff for Domestic Units. In this case, the fee corresponding to the tariff paid to YESC will be collected from the residents as electricity tariff by the administrator. In other words, the residents of the condominium will not benefit from the subsidized rate that ordinary household customers benefit from. In addition, the residents of the condominium were not counted as YESC customers.

In addition, the residents of the condominium were not counted as YESC customers. Number of customers of the bulk category in 2015/16 were 3,335. It is expected that there are significant number of similar contracts mentioned above. There is a possibility that this may lower the electrification ratio.

As for the apartment house having transformer owned by DEPT, the category of "Domestic units of General purpose" of the tariff table will be applied. All residents have individual meter, and meter reading and collecting electric fees will be made by YESC. For the transformer owned by village (Rural), the category of "Domestic units of Domestic power" of the tariff table will be applied. YESC collects fees per the meter installed on the primary side of the transformer.

3.5.5 Needs to Urgent Reinforcement of Supply Capacity to the Yangon Area

As described in Sub-Section 3.5.1 to 3.5.4, there are the following issues in the power supply to the Yangon Area:

- There may be significant margin in the nominal supply-demand balance. However, it is critical in the net balance.
- A great amount of electricity will be supplied to the Yangon area form the hydros situated in the northern Myanmar. Even after completion of the 500kV transmission lines in the future, in case of fault in the 500 kV lines, it would take a long time to restore the national grid and the blackout may be prolonged.
- Looking at the Yangon area, the great amount of electricity will be supplied to the western part upon completion of the 500 kV lines. In case of fault on the transmission system to inside the city area, there would be a risk of overloading on the 66-kV line running form west to east.

To solve these issues, the weak sections of the 230kV lines should be reinforced. Any fault in the transmission system (N-1) should be well prepared for. New power plant is needed to contribute to reinforcing the supply capacity to the Yangon area as one of the mitigation measures of the pressing balance of supply-demand.

CHAPTER 4 URGENT IMPROVEMENT OF ELECTRICITY SUPPLY

4.1. Background in Selecting Site for Urgent Electricity Supply

The Government of Myanmar (GOM) envisages to urgently install a new gas thermal of about 25 MW at the existing Myanaung PS. This is to target the full utilization of the following:

- Existing gas pipelines from Yangon to Myanaung PS;
- Compound, existing building for turbine-generators, transformers, switching gears, 66 kV transmission lines of Myanaung PS;
- O&M staff for the existing gas turbine of Myanaung PS;
- Avoidance of acquisition of expensive land in Yangon and engine noise in the center of city life.

The Urgent Upgrade of Electricity Supply aims at reducing the power flow from Yangon towards Ayeyarwady Region by reinforcing the existing Myanaung PS and thereby saving the costs. Thus, it will urgently reinforce the supply capacity to the Yangon area.

It was recognized that even small gas engine generators (GEGs) installed by independent power producer (IPP) on a rental basis in a 1-2 month period achieve high efficiency of over 40%. The efficiency of a gas turbine generator (GTG)[1] is lower by about 10% than that of GEGs. Accordingly, GEG will consume the same amount of gas as the mobile GTG but its energy output will be greater than the Mobile GTG by about 28% (= 46% / 36% = 1.28). GEGs will contribute to maximizing the use of domestic gas resources, reinforcing the generation capacity of the Electric Power Generation Enterprise (EPGE), and improving the average heat rates of EPGE's thermals. It is reasonable for Myanmar Oil and Gas Enterprise (MOGE) and EPGE, which are responsible for the gas and power supply, to give priority to GEG.

According to the study by the JICA Survey Team, the commissioning time of GEG would be sometime in September 2019, which is delayed by about 18 months compared with the mobile GTG. However, GEG would generate more annual energy than mobile GTG by about 34 GWh[2]. Therefore, GEG will contribute to the maximum utilization of domestic gas resources, reinforce the generation capacity of EPGE, and fuel saving. It is obvious that GEG will be superior to mobile GTG in terms of electricity generation and power sales revenue. The JICA Survey Team supports the judgement and request of GOM to give priority to the efficiency rather than the delivery time.

[1] There was an initial idea to introduce one Mobile GT of about 25 MW to urgently reinforce the generation capacity in the Yangon Area.
[2] 157 GWh / 46% x 10% = 34 GWh

4.2. Existing Equipment and Auxiliary Facilities of Myanaung Power Station

4.2.1 Generation Facilities

The existing generation facilities of Myanaung Power Station (PS) are outlined in Table 4.2.1. Initially, there were three GTGs supplied by Hitachi (capacity: 16.25 MW each) and one set supplied by John Brown. However, because of the depletion of onshore gasfield, two Hitachi GTGs were relocated to Thaton Power Station (PS) in 2001. After that, two GTGs continued operation (No. 1 unit of John Brown and No. 2 unit of Hitachi). However, operation of the remaining Hitachi unit was stopped upon exhaust of supply from the onshore gasfield in September 2011. The parts of this unit were disassembled and supplied to the two units in Thaton PS. Currently, No.1 unit is continuing operation at 10-13 MW with Yadana gas at 7 mmscfd.

Table 4.2.1 Features of GTGs at Myanaung Power Station

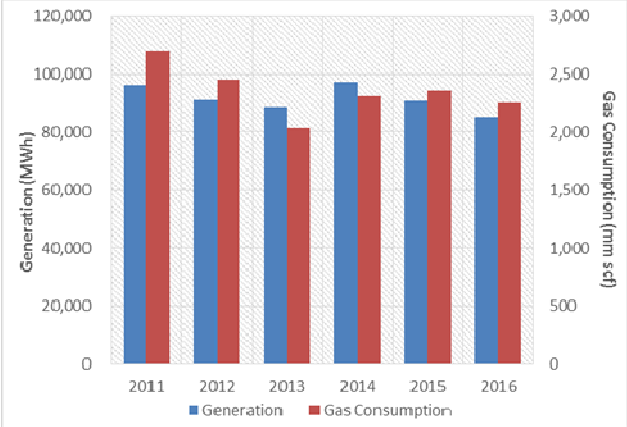
Installed Capacity (MW)	Unit No.	COD	Type	Gas requirement (mmscfd)	Efficiency (%)	Comment
18.45	1	1984	GT	7.0	19.3[3]	De-rated Capacity[4]
16.25	2	1975	GT			(De-commissioned)
Station Total						Average 11.5MW[5]
Gas Source						YADANA Gas Field

Source: JICA Survey Team

Annual energy output and gas consumption from 2011 to 2016 are shown in Figure 4.2.1. Monthly energy output and gas consumption in 2016 are shown in Figure 4.2.2. Average thermal efficiency was 19.3% (LHV) and annual capacity factor was 53%[6] in 2016 (ratio of average power output to rated output). The ratio of the annual average load to the peak load, i.e., the annual load factor was 84%[7]. This value shows base load operation. It is supposed that one reason for the de-rated capacity is the switching of fuel source from the high calorie onshore gas to the low calorie Yadana gas.

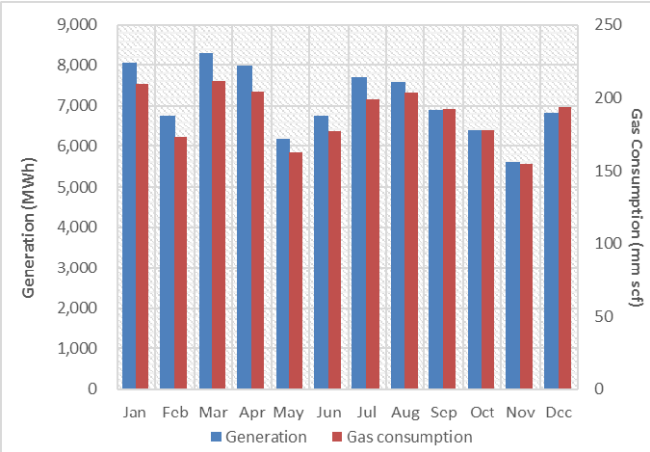
The power generation at Myanaung PS in the recent 5 years was rather stable (see Figure 4.2.1. The data of year 2011 was excluded because the Hitachi unit was also in operation in 2011.).

3 Estimated by JICA Survey Team based on the operation records in 2016: energy generated and fuel consumption.
4 It is considered that the power output reduction was caused by aging and the low calorific value of the Yadana gas compared with the onshore gasfields which supplied in the past.
5 In the case of power generation by GTG, the hourly outputs within a day change by temperature changes, i.e., changes in the air density.
6 Annual capacity factor = 85,090 MWh (annual energy generated in 2016) / 8,760 hr / 18.45 MW (rated power) = 0.53
7 Annual load factor = 85,090 MWh (annual energy generated in 2016) / 8,760 hr / 11.5 MW (peak load) = 0.84



Source: Prepared by the JICA Survey Team based on the operational data provided by Myanaung PS

Figure 4.2.1 Yearly Energy Outputs and Gas Consumption (2011-2016)



Source: Prepared by the JICA Survey Team based on the operational data provided by Myanaung PS

Figure 4.2.2 Monthly Energy Output and Gas Consumption (2016)

Photo taken by the JICA Survey Team
John Brown GTG (in operation)

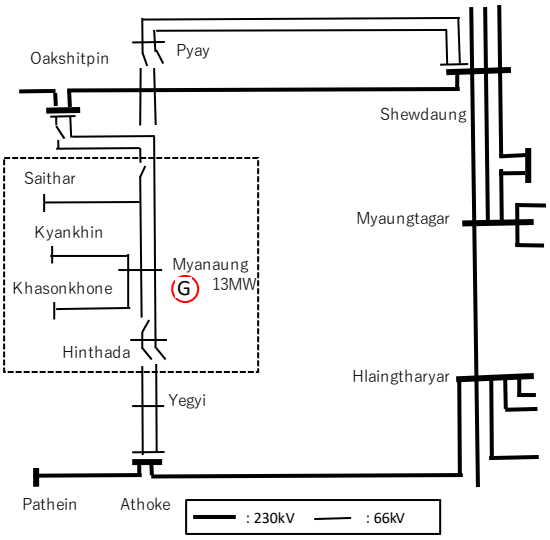
Photo taken by the JICA Survey Team
Cubicle Room

Photo taken by the JICA Survey Team
Central Control Room (Switchyard Control Board)

Photo taken by the JICA Survey Team
Former Control Board (replaced with new system)

4.2.2 Transmission System Related to Myanaung Power Plant

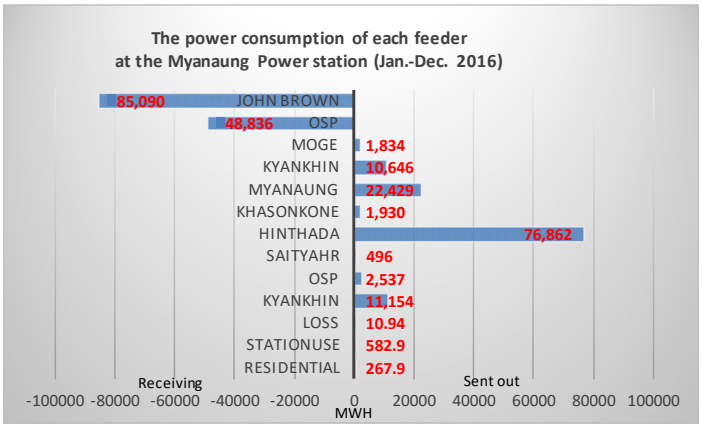
As shown in Figure 1.3.2, the Myanaung Power Plant was originally connected to Pyay and Hinthada substations by 66 kV double circuit lines. According to the explanation of DPTSC, the voltage drop of the Hinthada substation was serious at that time. With the completion of the 230 kV Oakshitpin substation in 2011, the 66 kV line connecting Myanaung and Pyay was switched off at the Pyay substation. Then, the power was supplied from Oakshitpin substation to Hinthada substation via Myanaung. Furthermore, in order to reduce the power supply from Yangon area as much as possible, the Hinthada-Yegyi line was switched off at the Hinthada substation. The system configuration is shown in Figure 4.2.3.



Source: JICA Survey Team

Figure 4.2.3 66 kV System for Myanaung Plant

The power transmission regime above in the Myanaung area is maintained to date. The operation records of the power plant also show the same. In other words, the area from Myanaung to Hinthada is supplied by the Myanaung PS, and the shortfall will be supplemented from the 230 kV Oakshitpin substation. It means that the Myanaung PS will supply to the limited region.

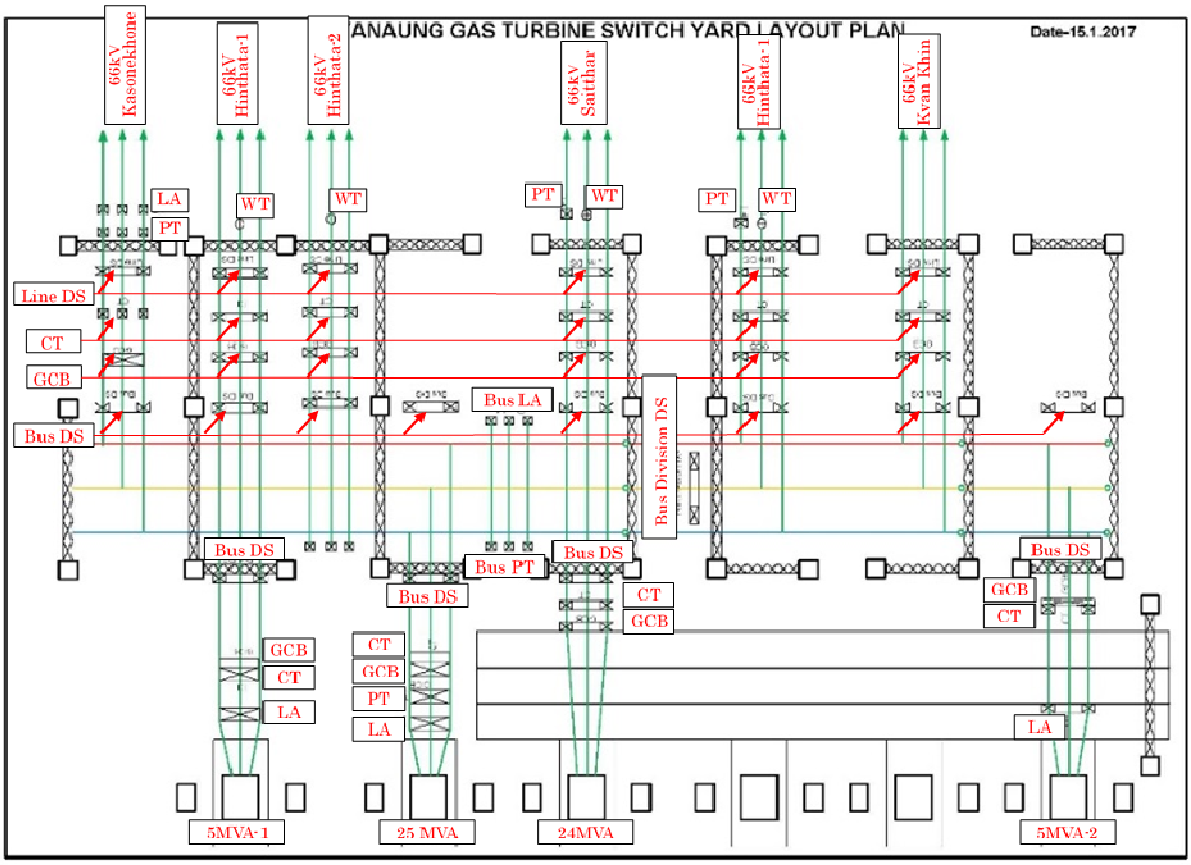


Source: Myanaung PS

Figure 4.2.4 Power Supply Received and Dispatched at Myanaung Switchyard

4.2.3 66 kV Outdoor Switchgear

There are ten bays in the 66 kV switchyard of the Myanaung PS, i.e., 1 bay for Oakshitpin Line, 2 bays for Hinthada Line, 2 bays for main transformers, 2 bays for local supply transformers, and 1 bay each for Saithar line, Kyankhin cement line, and Khason Khone line. The single line diagram is shown in Figure 4.2.5.



Source: Myanaung Power Plant of EPGE

Figure 4.2.5 Single Line Diagram of Myanaung 66 kV Switchgear

Each bay consists of a circuit breaker (CB), disconnecting switch (DS), current transformer (CT), and lightning arrestor (LA). Nationwide renewal of circuit breaker to the gas circuit breaker was started in 2008 and circuit breakers of Myanaung PS were replaced in 2012.

The subject of the study is the main transformer circuit for boosting the generated power to 66 kV. Two 11/66 kV transformers are existing, one is a 25 MVA transformer made by Yorkshire which is in operation. The other is a 24 MVA transformer manufactured by Takaoka (Japan), which is currently not in operation. In other words, the subject of the survey is the two transformers and its related switching equipment.

Takaoka's transformer was made in 1973, and 44 years have elapsed already. Besides, the transformer has not been used in a long time after two Hitachi GTGs were transferred to the Thaton PS in 2011. Even if there was no problem in the test results made during the periodic inspection when it was in operation, inspection should be carried out in detail before the installation of the new GEGs. Even if the inspection results indicate no issue, considering the elapsed long years after production, periodic inspections should be continued also after starting its operation. It may be replaced with a new one in the future. At that time, the related switching equipment may also be replaced. The maintenance record of the transformers was requested, however, it was not available.

The Takaoka's transformer was made in 1973 and more than 40 years have elapsed since then. The insulation oil should have been not only cleaned but also fully replaced for a few times. Therefore, the probability that PCB used up to around 1970s still remain in the transformer is low. It was requested to the Myanmar side to provide records of faults and maintenance of transformers etc. However, these were not provided.

The panoramic views of the switchyard, main step-up transformers, and 66 kV switchgears are shown in the photos below:

Photo taken by the JICA Survey Team

Panoramic view of the Myanaung switchyard

Photo taken by the JICA Survey Team

11/66 kV 24 kVA Step-up transformer

Photo taken by the JICA Survey Team

66 kV Gas-insulated facilities

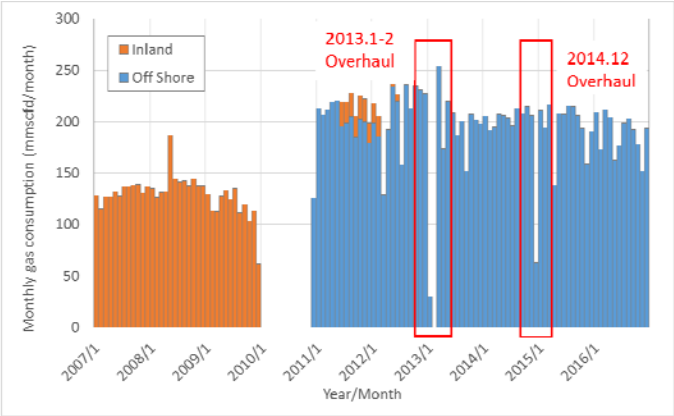
4.2.4 Gas Supply System

(1) Current Situation of Gas Supply System to Myanaung PS

Natural gas for Myanaung PS was supplied from onshore gasfield. From January 2011 to November 2011, the gas supply for Myanaung PS was terminated due to maintenance. After resuming the power generation, natural gas from Yadana gasfield and Shwepitha onshore gasfield (it was exhausted in June 2012) was used. The gas supply record from 2007 to 2016 is shown in Figure 4.2.6. Since

calorific value of Yadana gasfield is low, its gas supply volume is increased compared with the gas from the onshore gasfield. Accordingly, there is no significant change in the generation.

After rehabilitation, gas supply volume (7 mmscfd) is kept constant except from January to February 2013 (for overhaul) and December 2014 (for regular maintenance). Gas pressure is also stable at around 250 psi to 260 psi.

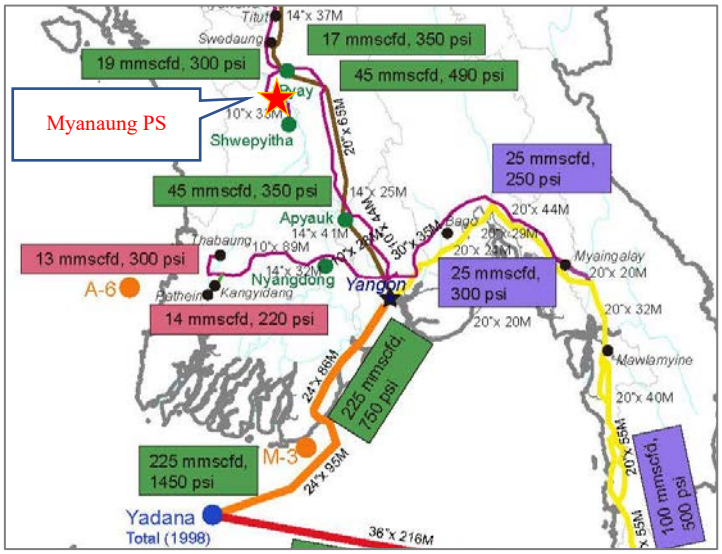


Source: Myanaung PS

Figure 4.2.6 Gas Consumption Record for Myanaung Power Station

(2) Current Situation of Pipeline to Myanaung PS

Gas from Yadana gasfield is supplied through a pipeline via Yangon and Pyey. The pipeline (14 inch, 45 mmscfd, 490 psi) was installed from Yangon to Pyey in 1990s. It has enough capacity to send gas of 7 mmscfd at 300 psi to Myanaung PS. Meanwhile, a 10-inch pipeline was installed from Pyey to Myanaung PS for about 30 mile long. However, it became aged because 30 years have elapsed since its installation in 1986. Therefore, the maximum capacity of this pipeline became 7 mmscfd.



Source: Survey on Gas Application in Myanmar, METI

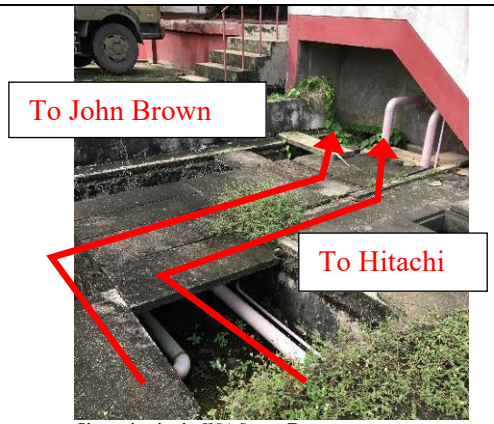
Figure 4.2.7 Pipeline Map Around Myanaung Power Station

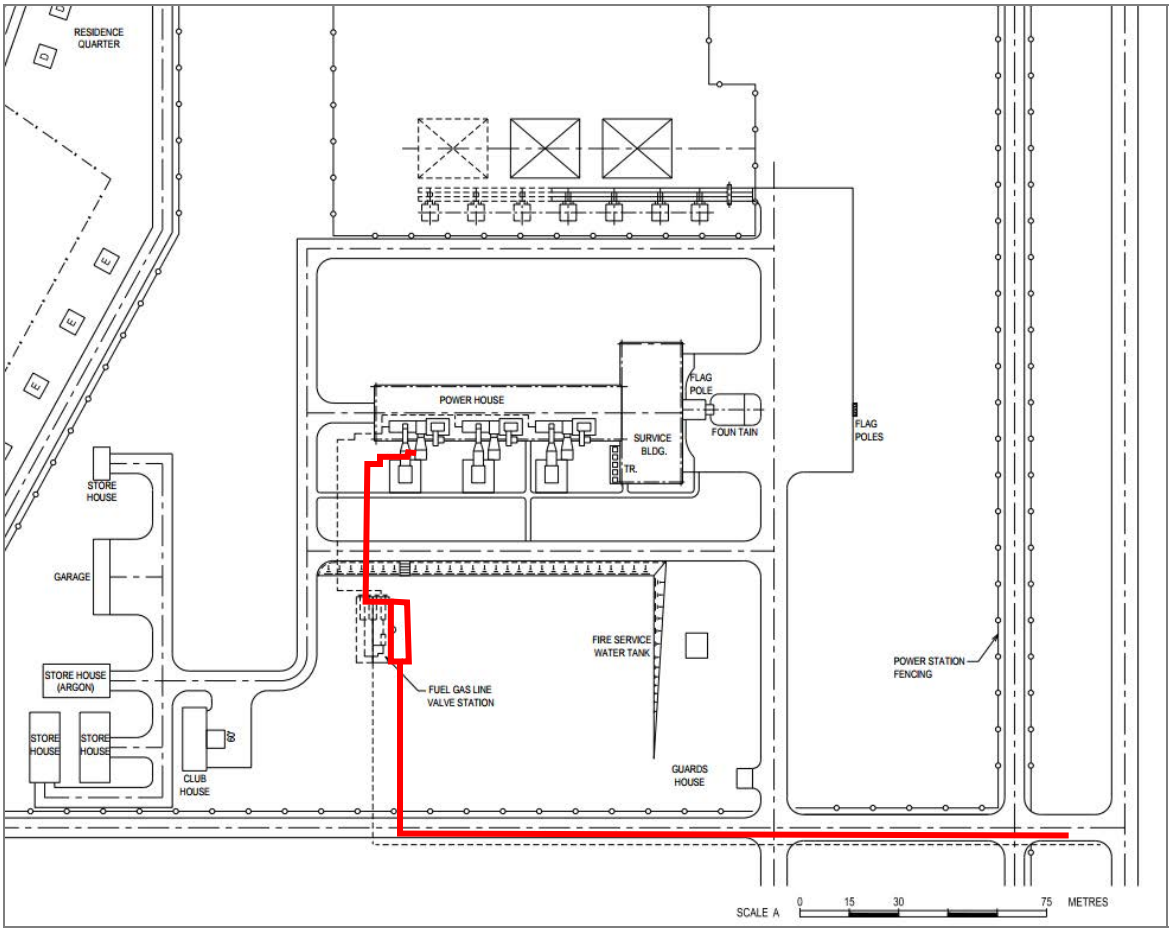
The "MAG MEPE Control Shed" located near Myanaung PS manages the gas supply to Myanaung PS. Since Shwepitha gasfield was exhausted, only the gas from Yadana gasfield via Pyey is measured in the "MAG MEPE Control Shed". Hourly gas supply volume is measured and recorded in MOGE control center in Pyi Taung Tan. Gas from Pyey is supplied to Myanaung PS after Kyan Khin cement factory located upstream of Myanaung PS. However, gas usage of this cement plant was terminated in March 2017.

Photo taken by the JICA Survey Team	Photo taken by the JICA Survey Team
Photo: MAG EPGE control shed overview	Photo: Gas supply in MAG EPGE control shed

(3) Gas Supply System Inside Myanaung PS

The gas received is sent to the gas turbine via the gas yard in Myanaung PS. In the beginning, four pipelines were installed for four units of gas turbine. Currently, there are only two pipelines for gas turbines of John Brown and Hitachi.

Photo taken by the JICA Survey Team	 Photo taken by the JICA Survey Team
Photo: Myanaung PS gasyard	Photo: Pipeline from gasyard



Source: Myanaung PS

Figure 4.2.8 Gas Supply Route in Myanaung Power Station

4.2.5 Building and Ancillary Facilities

(1) Building

Myanaung PS has two buildings, namely, service building and powerhouse. There are operation facilities including a control room and a cubicle room in the service building. Gas turbines and generators are accommodated in the powerhouse.

Materials for the service building and powerhouse are shown in Table 4.2.2. Corrugated asbestos slate is used as roof material on the service building and powerhouse. Acoustic board is used as ceiling material for the control room and office room. But in all the other rooms, cement asbestos board with vinyl paint finish is used as the ceiling material.

In the powerhouse, corrugated asbestos slate is used for the roof, and excelsior board with cement-sprayed was to the interior surface of the corrugated asbestos slate roof. However, some parts of these sprayed excelsior board with cement already fell off, making the corrugated asbestos slate roof directly visible from the floor.

In the service building, cement asbestos board with vinyl paint finish is used for the interior wall, but some joints have already peeled off.

Table 4.2.2 Materials for Myanaung Power Station Buildings

Building	Location	Material
Service Building	Roof	Large wave corrugated asbestos slate
	Ceiling	Acoustic Board (Control room, Office room) Cement Asbestos Board with Vinyl paint finish
	Interior	Cement Asbestos Board with Vinyl paint finish
Power house	Roof	Large wave corrugated asbestos slate
	Ceiling	Excelsior board with cement sprayed

Source: Completion Report and Completion Drawings (WESTJEC)

Photo taken by the JICA Survey Team

Photo: Asbestos board on interior walls in the Service Building

Photo taken by the JICA Survey Team

Photo: Excelsior board with cement-sprayed at the ceiling of the Powerhouse

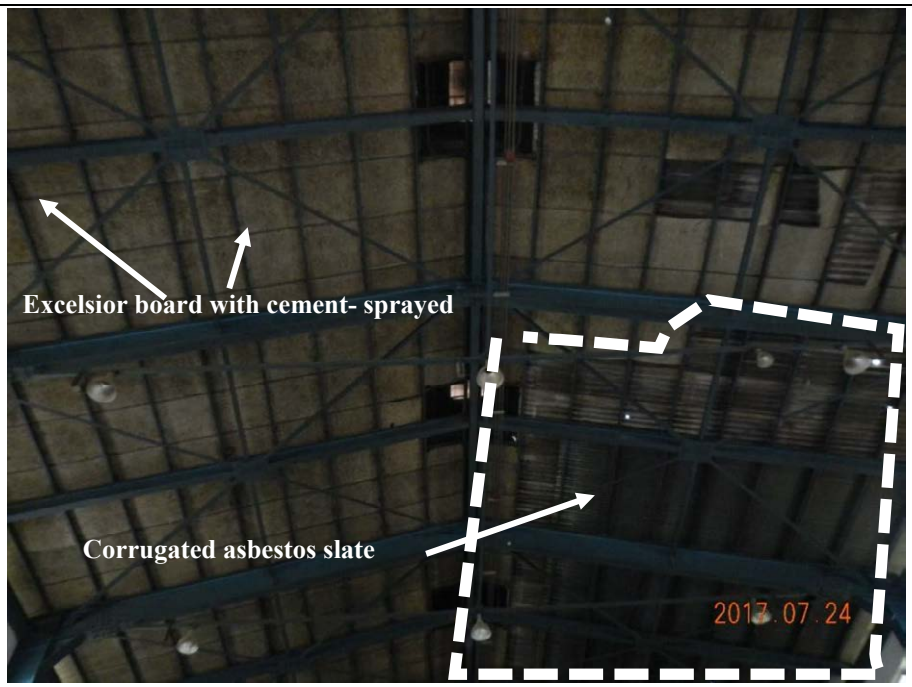


Photo taken by the JICA Survey Team

Photo: Excelsior board with cement-sprayed partially fell off from the roof of the Powerhouse

According the Environmental, Health, and Safety (EHS) Guidelines (2007, IFC), an Asbestos Management Plan is required for the existing asbestos board. In the Asbestos Management Plan, the following information are required to prevent asbestos damage: 1) location of asbestos board, 2) possibility of scattering, 3) monitoring, 4) access, and 5) training of staff. The EPGE is required to prepare an Asbestos Management Plan in the future, especially in the location where excelsior board with cement-sprayed fell off. Action is required following the Asbestos Management Plan.

(2) Noise Reduction

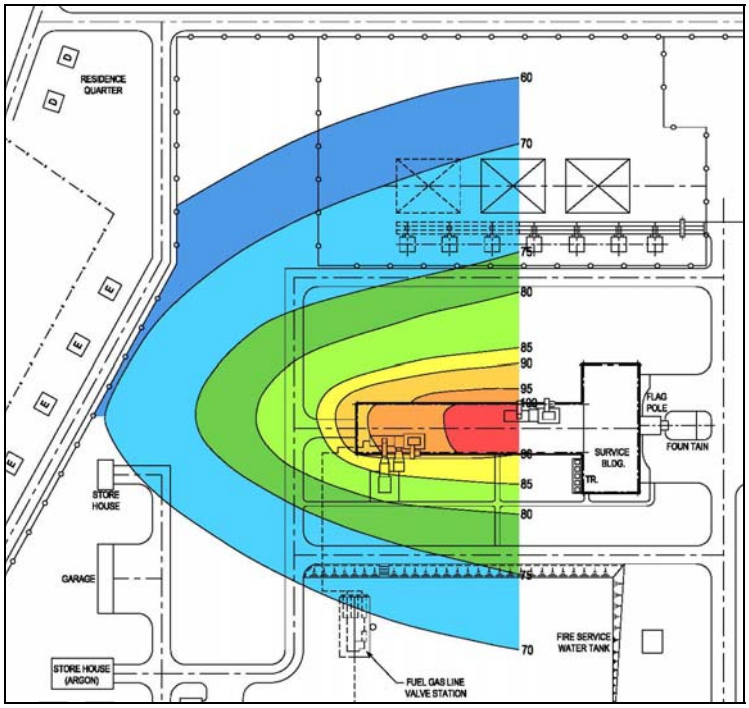
According to the National Environmental Quality (Emission) Guidelines, standard for noise regulation is divided into two areas, namely: 1) residential, institutional, and educational areas, and 2) industrial and commercial areas. Noise regulation standards for these areas are shown in Table 4.2.3.

Table 4.2.3 Noise Standards in Myanmar

Area	One Hour LAeq (dBA)	
	Daytime 7:00 – 22:00 (Public Holiday 10:00-22:00)	Nighttime 22:00-7:00 (Public Holiday 22:00-10:00)
Residential, Institutional, Educational	55	45
Industrial, Commercial	70	70

Source: National Environmental Quality (Emission) Guidelines

Total number of households in Myanaung District is 11,411. However, there is no residence except the ones for staffs of Myanaung PS around the powerhouse. According to the Ministry of Natural Resources and Environmental Conservation (MONREC), Myanaung PS is in a residential area. Noise reduction down to 55 dB in the daytime and to 45 dB in the night-time is required. The JICA Survey Team carried out noise measurement of the existing gas turbine in the direction of the service entrance, switchyard, and gas yard. Results are shown in Figure 4.2.9. Noise from the existing gas turbine exceeds 55 dB at the boundary of the station compound. Noise was loud because of: 1) shutter of service entrance is broken and cannot be closed, and 2) windows are also broken. In order to reduce the noise to less than the standards above, countermeasures for noise reduction such as acoustic board on the wall of the powerhouse are required.



Source: JICA Survey Team

Figure 4.2.9 Result of Noise Measurement in the Myanaung Power Station

(3) Foundation Concrete

(a) Compressive Strength

Foundation concrete of Myanaung PS was constructed more than 40 years ago. It should be checked if the concrete is degraded. The JICA Survey Team conducted concrete strength check using Schmidt hammer. As a result, the average compressive strength of the foundation concrete was 42.4 N/mm^2. According to the completion report of the Myanaung PS (West Japan Engineering Consultants Inc.), the design strength of the foundation concrete was 180 kg/cm^2 (17.6 N/mm^2). The measured values are much higher than the design strength.

There is difference of vibration mechanism between GT (rotating machine) and GE (reciprocating engine). Vibration and noise of GE are greater than GT. However, the base

frame of GE will be placed on the concrete foundation via spring dampers. Therefore, few vibrations from GE act to the foundation (less than 1%). According to the maker's engineer contacted by the team, existing foundation concrete with 2.7 m height would be sufficient for absorption of vibration energy. Diameter and intervals of reinforcement bars are shown also in the completion drawings. Existing reinforcement bars are not for structural reinforcement but for control of surface cracks.

Table 4.2.4 Compression Strength Measured by Schmidt Hammer

Location	N/mm2
No.1	48.0
No.2	50.5
No.3	35.3
No.4	44.1
No.5	39.2
No.6	43.1
No.7	42.1
No.8	37.2
Average	42.4

Photo taken by the JICA Survey Team

Photo: Measurement of compression strength by Schmidt hammer

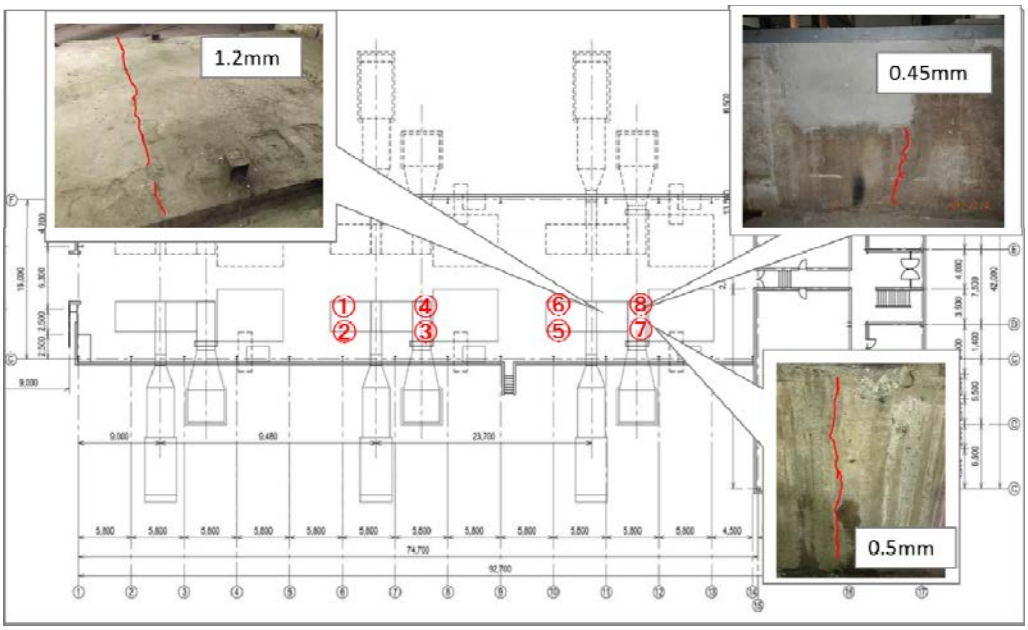
(b) Treatment of Cracks

The JICA Survey Team carried out crack check for the foundation concrete at the powerhouse. There were three large cracks on the foundation concrete surface of the existing gas turbine (Figure 4.2.10, Figure 4.2.11). According to the completion report of Myanaung PS, 5/8 inch (≈16 mm) reinforcing bars were placed with 300 mm intervals. This foundation is of mass concrete and reinforcement bars were placed for the surface crack control. Crack of 1.2 mm was observed on the top of the mass concrete. However, depth of this crack was not known.

Basically, vertical load from GEGs act on the foundation concrete. However, bending moment and shear force will not operate on the foundation concrete. Vibration less than 1 % of GEGs weight act on the foundation concrete. Its vibration energy could be absorbed by weight of the mass concrete. This crack shall be repaired with epoxy resin.

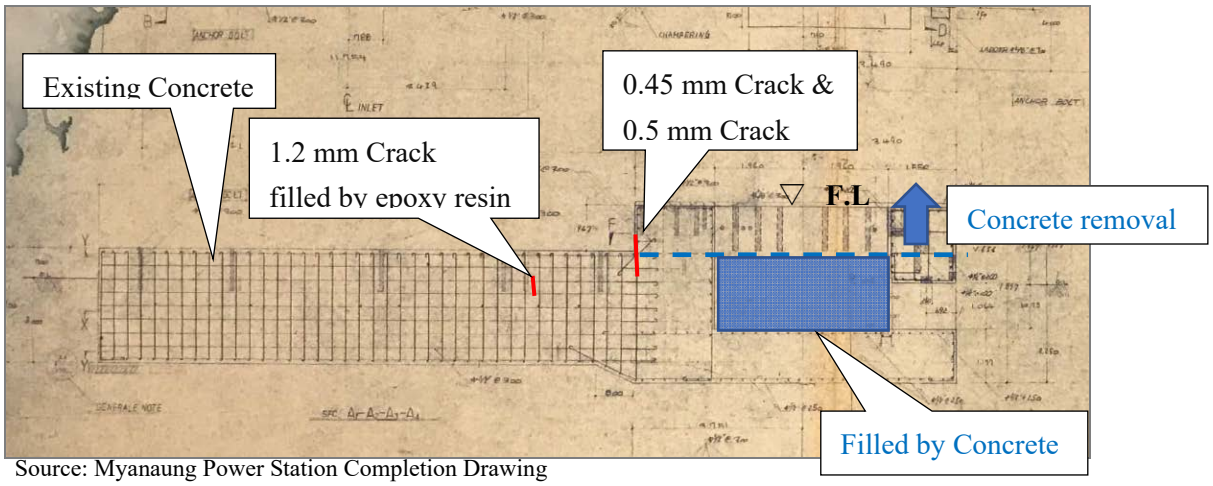
On the other hand, 0.45 mm crack and 0.5 mm crack are observed on the sidewall of the concrete foundation for the purpose of generator installation. This sidewall should be removed prior to GEGs installation. The vacant space shown in Figure 4.2.11 was used for pulling out power cables from Hitachi generators. According to some GEGs makers the survey team contacted, this large gap is not required for their generators. The large gap should be filled by concrete, and the surface should be levelled. After completion of the

these modification works, the area should be handed over to the contractor of GEGs installation. However, the foundation modification should be addressed again with EPGE and makers in the design stage.



Source: JICA Survey Team

Figure 4.2.10 Cracks in Myanaung Power Station and Location of Strength Check



Source: Myanaung Power Station Completion Drawing

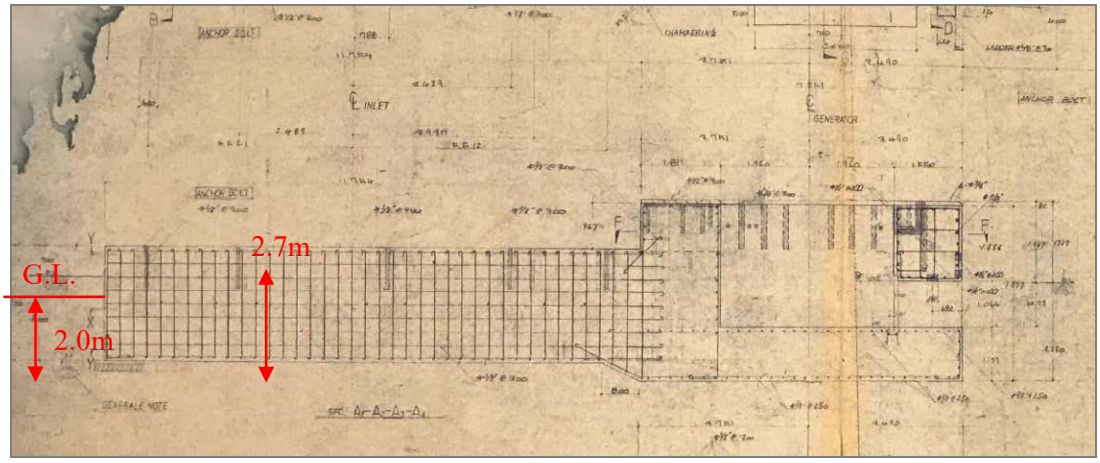
Figure 4.2.11 Location of Cracks in the Section and Image of Modification of Concrete Foundation

(4) Bearing Capacity

According to the completion drawings (WESTJEC), the height of the foundation concrete is 2.7 m, and it was set 2 m below the ground level. The boring results of the powerhouse foundation are shown in the completion report. It shows that N value is 30 at a depth of 2 m from the ground level. This means that the bearing capacity is approximately 30 ton/m^2.

The total weight of the gas turbine is estimated at approximately 75 tons. According to site

investigation, the area of the gas turbine is approximately 120 m^2. In this case, load on foundation becomes 0.6 ton/m^2. The load from gas engine depends on unit capacity, but the bearing capacity has sufficient strength as foundation for GEGs.



Source: Myanaung Power Station Completion Drawings

Figure 4.2.12 Foundation Concrete in Completion Drawings

Table 4.2.5 Boring Results at the Powerhouse

Depth	No. of Hammer Browns	Converted N value	Descriptions of Materials
0.6	45	27	Yellowish brown sandy & clayey silt
1.2	47	28.2	Yellowish brown sandy & clay race sand
1.8	55	33	-ditto-
2.4	50	30	-ditto-
3.0	25	15	Grey silty & clayey medium to fine sand
3.6	38	22.8	-Ditto-
4.2	50	30	-Ditto-

Source: Myanaung Power Station Completion Report

4.2.6 Power Demand of Myanaung Area

The operation record of Myanaung outdoor switchgear from 2011 to 2016 is shown in Table 4.2.6.

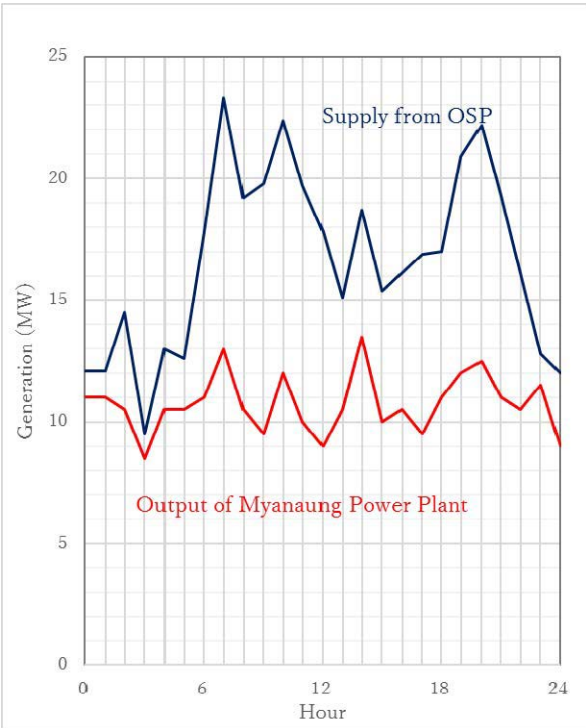
Table 4.2.6 Operation Record of Myanaung Outdoor Switchgear

	Generation and Receiving (66kV)				Sent Out (66kV)						Sent Out (11kV)			Set Out Total	Losses
	from OSP	John Brown	Hitachi	Total	Kyan Khin	Pathein	to OPS	Sait Thar	Hinthada (1)	Khason Khone	Myanaung	Others	Own Use		
2011	9,381	96,313	2,186	107,879	42,644	6	3,561	0	41,402	20	15,668	2,830	914	107,045	834
2012	19,747	90,968		110,714	40,947	2,426	5,705	124	46,425	387	16,443	2,581	914	115,952	663
2013	26,674	88,751		115,425	38,020		4,706	596	49,507	429	13,737	6,069	908	113,972	1,453
2014	18,828	97,366		116,245	23,609		5,695	564	59,165	718	14,153	9,867	922	114,693	1,551
2015	29,544	90,743		120,287	13,240		4,503	517	68,626	1,406	17,251	12,857	854	119,254	1,034
2016	48,836	85,090		133,926	11,154		2,537	496	76,862	1,930	22,429	17,025	851	133,284	642

Note: Figures of Myanaung for 2011 and 2012 include the loads of Khyan Kyan Khin area.
Source: Monthly operation reaacords of Myanaung power station

From the table, the amount of electricity flowing into the switchyard in 2016 was 133.9 GWh (=133.3 + 0.6), and the electric energy generated at the Myanaung PS was 85.1 GWh, which was 63.6% of the total supply to the area by Myanaung and Hinthada substations. In other words, it is the area where electricity is supplied from the substations in the range surrounded by the broken lines in Figure 4.2.3. On the other hand, the amount of electricity delivered from the Myanaung switchyard, i.e., the total demand in the area, is 133.3 GWh, and the largest destination is 93.0 GWh (69.6% of the total demand) in the Hinthada District. It was supplied to customers in the Myanaung area at 11 kV and amounted to 39.4 GWh (29.6%). As for the losses, 0.64 GWh (0.4%) was recorded, but this is considered to include error of recording, difference of precision of each meter, loss of transformers, and the like. The annual increase rate in aggregate demand over six years was 4.48%.

Figure 4.2.13 shows the daily load curve on July 9, 2017 in the Myanaung to Hinthada region. The maximum load of about 23 MW was recorded on the curve. As shown in the figure, the Myanaung PS supplied base power to the area. When high efficiency GEGs are introduced to the Myanaung PS, the maximum power would be about 24 MW which will cover also the peak load of the supply area. Most of the regional load can be supplied from the Myanaung PS.



Source: Myanaung PS

Figure 4.2.13 Daily Load Curve on July 9, 2017

4.3. Proposed Urgent Electricity Supply, Feasibility and Expected Project Effects

4.3.1 Proposed Urgent Upgrade of Electricity Supply

The "Urgent Upgrade of Electricity Supply" of EPGE is outlined below:

- The existing GTG of John Brown is generating at about 10-13 MW (11.5 MW on the average) fueling the natural gas from the Yadana gasfield at 7 mmscfd in volume and 744 Btu/scf on the average (710 Btu/scf at the minimum) in gross calorific value.
- The installed capacity of GEGs would be about 24 MW consuming the same gas volume with the John Brown GTG[8].
- The maximum power will be increased by about 12.5 MW[9] and annual energy by about 93 GWh[10] compared with the existing GTG.

4.3.2 Feasibility

The efficiency, output, and other data of some Japanese manufacturers are presented in Table 4.3.1. The same data of overseas manufacturers are shown in Table 4.3.2. The number of revolutions of all the machines is 750 rpm except the 1500 rpm of Jenbacher.

Table 4.3.1 Comparison of GEGs (Japanese Manufacturers)

Manufacturer		Mitsubishi	Kawasaki	Niigata
Type		18KU30GSI	KG-18-V	18V28AGS
OUTPUT	MW	5.5	7.8	6.0
Unit No.	No.	4	3	4
Total Output	MW	22.0	23.4	24.0
Efficiency (40.6MJ/Nm^3)	%	48.5	49.5	47.5* (30.1MJ/Nm^3)
Efficiency (Yadana Gas)	%	-	45.9 (Zero tolerance)	44.0 (Zero tolerance)
Heat Rate (Yadana Gas)	kJ/kWh	-	7835	8177
Rotation Speed	rpm	750	750	750
Exhaust NOx	ppm	200 (at O_2=0%)	200 (at O_2=0%)	200 (at O_2=0%)
Size Per unit	mm	L:11,500 D:3,200 H:5,000	L:12,960 D:3,240 H:5,720	L:10,740 D:3,600 H:4,600

Note: Efficiency of GEG is based on LHV.
Source: Prepared by the JICA Survey Team based on companies' leaflet and Yadana gas calorific value.

Niigata Power System 18V28AGS certifies the efficiency at 47.5% by low calorie gas down to 30.1 MJ/Nm^3. Some manufacturer's efficiency might sometimes indicate a higher level using the 5%

8 The potential output is about 25 MW. However, there is no unit capacity model of 8 MW+ in the market. Considering the combination of unit capacity and unit number within the potential output, the total power would be around 23-24 MW.
9 =24 MW-11.5 MW
10 = 12.5 MW x 8,760 hr x 0.85, assuming annual plant factor at 85%.

tolerance in the fuel requirement of ISO 3046. To fairly compare the efficiency, it is desirable to provide a clause on "zero tolerance" of heat rate in the specifications.

The time degradation curve of heat rate or efficiency may be used as the basis for judging the durability. It is desirable to request submission of the degradation curve at tendering and to estimate and judge the durability.

Table 4.3.2 Comparison of GEGs (Other Country Manufacturers)

Manufacturer		Wartsila	Jenbacher	RR Bergen	Caterpillar
Type		16V34SG (20V34SG)	J920 Flextra (JMS624	B35:40V16A G2	G16CM34 (CG260-16)
OUTPUT	MW	7.7 (9.9)	10.4 (4.4)	7.5	7.8 (4.3)
Unit No.	No.	3 (3)	2 (6)	3	3 (6)
Total Output	MW	23.5 (29.8)	20.8 (26.4)	22.5	23.4 (21.5)
Efficiency (40.6MJ/Nm^3)	%	46.0 (46.3)	49.1 (-)	48.5	46.6 (44.1)
Efficiency (Yadana Gas)	%	-	- (45.6)	-	- (43.2)
Heat Rate	kJ/kWh	7,825 (-)	- (7,880)	-	- (8,329)
Rotation Speed	rpm	750	1,000 (1,500)	750	750 (1,000)
Exhaust NOx[11]	mg/kWh	90 ppm at O_2=15%	500	500	500
Dimensions	mm	L:11,187 D:3,345 H:4,475 (L:12,917 D:3,345 H:4,501)	L:8,400 D:3,240 H5,720 (L:13,800 D:2,500 H: 2,900)	L11,565 D:3,306 H:4,545	L:10,740 D:3,600 H:4,600 (L: 9,420 D: 2,690 H3,390)
Existing plants if any in Myanmar		none	Thaketa, Max Power, 16x3.35MW	Hlawga IPP Phase II 3x9.5MW	Yuwama 13xCG260-16 4MW η=44.6%

Note : 1. Efficiency of GEG is used LHV base.
2. The each values in parentheses is shown the proposed model for the reference quotation submitted by Wartsila, Jenbacher and Caterpillar.

Source: Prepared by the JICA Survey Team based on each companies' leaflet and Yadana gas calorific value.

The catalog output of each company is presented based on the standard gas (ISO 3046: LHV 40.6 MJ/Nm^3). The following conclusions may be derived based on these output data:

(a) The efficiency ranges from 46.3% to 49.5% for large unit size of GEG at 5 MW or greater. Small unit size of GEGs at about 1.5 MW may be available as ready-made stocks at the manufacturer. The efficiency of these small class would be 40-45%.

(b) On the other hand, in the case of about 25 MW class GTG, the efficiency remains at about 36% when using the low calorie Yadana gas. This efficiency is lower than that of GEG by about 10%. The merit of gas turbine is that it can achieve high efficiency of 50-60% as combined cycle. On the other hand, it will be important to maintain the heat recovery boiler and steam turbine in good conditions.

[11] The raw data as available from each company. Since no condition of NOx is mentioned, these are quoted as available.

(c) The maximum potential output is about 25 MW[12] for Yadana gas composition and gas volume of 7 mmscfd. However, this potential could not be achieved even if the total output is adjusted by changing the number of units. It is difficult to use 100% of the potential. Therefore, the total capacity of each manufacturer will be in the range of about 22-24 MW.

(d) The GEGs of countries other than Japan have efficiencies of about 46%～49% and unit output of 7.5 MW～10.4 MW, which are a little greater than the Japanese models.

(e) Each manufacturer's model may be compared in terms of the highest efficiency and maximum use of the calorie in the Yadana gas, to choose the following combinations of unit output and unit number (in alphabetical order):

- KHI : 7.8 MW x 3 sets; Total = 23.4 MW
- MHET : 5.5 MW x 4 sets; Total = 22.0 MW
- NPS : 6.0 MW x 4 sets; Total = 24.0 MW

(f) The total output will be 20.8 MW with Jenbacher; i.e., 10.4 MW x 2 with standard gas. In this case, the gas utilization factor is about 83%[13] and it is difficult to effectively use the available gas volume. If the number of units is increased to three, the total output will be 31.2 MW, the plant factor will be 80%[14], and the capacity cannot be fully utilized. That is, the initial investment will be excessive in general.

(g) The Wartsila Model has efficiency of 46.3% (standard gas) being slightly lower to the models of the Japanese manufacturers.

(h) The Caterpillar Model has also efficiency of 46.6% (standard gas) being slightly lower than the models of the Japanese manufacturers. .

Based on the study above, it is confirmed that the GEG with the total capacity of about 24 MW is feasible. The selection of GEG by GOM is considered reasonable.

- The highest efficiency of about 45.9%[15] may be achieved with low calorie Yadana gas (7 mmscfd x Minimum GCV 710 Btu/scf) available at the Myanaung PS. Although GTCC achieves higher efficiency than this, it is not practical to apply it to the gas volume available at the Myanaung PS.
- The expected lifetime of gas engines is estimated to be about 40 years, similar with diesel engines, while the auxiliaries would be around 20 years. On the other hand, the IPP rental

[12] The volume of gas is 7 mmscfd, the gas flow rate per hour is 0.2917 mmscfh.(=7/24hour)
When converting GCV to NCV (=0.9 GCV), the calorific value of Yadana gas is GCV 710 Btu/scf is converted to NCV 640 Btu/scf.
Therefore, the total calorific value per hour is 640 × 0.2917 = 187 mmBtu.
Since 1,000 Btu = 0.2928 kWh, when converted to 100% electricity, it becomes 54.8 MWh. Assuming that the efficiency of GEG when low calorie Yadana gas is used is 0.459, the potential output would be about 25 MW.

[13] 20.8 MW/ 25 MW = 0.83

[14] 25 MW/ 31.2 MW = 0.80

[15] Efficiency at zero tolerance

business with small GEGs is for a short-term contract of one to three years. This is to facilitate early recovery of the capital investment. As the result, the purchase price will become high compared to long-term contract. The GEG needs renewal of the control system and auxiliaries in the middle of its lifetime but it would provide more energy at low cost over the long period of 20 to 40 years[16].

- It is estimated that the time from receiving date of the Notice to Proceed to Commercial Operation Date (COD) would be about 16 months. Therefore, this scheme is appropriate for the purpose of "Urgent Upgrade of Power Supply."
- Even if the GEG is commissioned 1.5 year later in comparison to the mobile GTG, the generation cost excluding the fuel cost is estimated to be around USc 2.3/kWh. The cost of electricity generation with grant for GEGs will significantly be lower. It is assumed that the purchase price of electricity generated by IPP rental with small GEGs (gas is provided free of charge) is about USc 3.4 to 4.0/kWh. Compared with this payment level, the power generation cost reduction effect is high. Furthermore, since the efficiency is about 5% higher than that of small GEGs, the energy generation will increase by about 12%[17].

Technical specifications of each company's reference quotation are summarized in Table 4.3.3[18]. Models of Jenbacher and Caterpillar do not meet the middle speed of 750 rpm or lower, so they will not be candidates for the GEGs for Myanaung PS.

Table 4.3.3 Summary of Technical specifications

Manufacturer		Mitsubishi	Kawasaki	Niigata	Wartsila	Jenbacher	RR Bergen	CAT
Type		18KU30 GSI	KG-18-V	18V28A GS	20V34SG	JMS624	B35:40V 16AG2	CG260-1 6
Unit Output	MW	5.5	7.8	6.0	9.7	4.4	7.5	4.3
Total Output	MW	4x5.5: 22.0	3x7.8: 23.4	4x6.0: 24.0	3x9.8: 29.8	6x4.4: 26.4	3x7.5: 22.5	5x4.3: 21.5
Efficiency (Yadana Gas)	%	-	45.9 (Zero tolerance)	44.0 (Zero tolerance)	-	45.6	-	43.2
Rotation Speed	rpm	750	750	750	750	1,500	750	1,000
Heat Rate (Yadana Gas)	kJ/ kWh	-	7,835	8,177	-	7,890	-	8,329

Note: Mark "-" indicates items not submitted or unknown.
Source: The JICA Survey Team

4.3.3 Expected Project Effect

Annual power generation would increase by about 93 GWh[19] with the new GEGs consuming the same amount of gas, compared with the current GTG. It can supply about 160,000 households at the

16 Degradation diagnosis of power generation equipment: Journal of the Electrical Equipment Society (September 2006), Katsuaki Yamaguchi
17 46% / 41% = 1.12
18 Since no reference quotation was submitted by Rolls-Royce, the features of RR Bergen are from its catalogue.
19 (24-11.5) MW x 8760 hr x 0.85 (plant factor) = 93 GW

average household demand of 50 kWh/month/household[20].

If the GEGs are provided by grant, the power generation cost for EPGE including fuel cost will be around USc 6.4/kWh[21]. Compared with the purchase price of US¢ 3.4 to 4.0/kWh before fuel cost of the rental business for a two to three year period (including the fuel cost of US¢ 3.4 to 5.5/kWh, the total cost of rental business will be US¢ 8.9 to 9.5/kWh), the Myanaung energy cost will be reduced to 67% to 72%. By multiplying this cost saving effect with the energy supplied at the substation end at 157 GWh[22], the annual cost of EPGE that will be saved is about USD 3.1 million to USD 3.6 million (equivalent to about JPY 340 to 400 million).

The new GEG can supply up to about 157 GWh of electricity each year to consumers. With the average domestic demand of 50 kWh/month/household, it can supply about 260,000 households. These consumers can receive stable power throughout the year.

Therefore, the urgent electricity supply would save MMK 4.2-4.9 billion per annum. At the same time, it can supply stable electricity to approximately 260,000 households.

4.3.4 Matters for Consideration at Tender Evaluation of GEGs

The Urgent Reinforcement of the Myanaung Power Supply is the generation project to be managed by the national power company of Myanmar, EPGE. It is one of the public works in the developing countries. The assessment criteria of the public works is to maximize the net benefit of the Nation's economy of Myanmar. The net benefit of the Nation's economy is to be obtained as the balance of the economic benefits and costs by evaluating the economic value of electricity and adjusting the costs of labor and capital based on their opportunity costs. Then it is pursued to maximize the net benefit by changing various parameters. Here the public works is power generation business. The benefit is approximated by power sales revenue and the costs by financial expenditures. Thus, the maximum net revenue of the power sales will bring about the maximum net benefit to the Nation's economy.

The Myanaung Project is to utilize the natural gas resources of Myanmar. However, unlike the ordinary resources development project, the following two will be the given conditions to the plan formulation of the Project:

- The total costs for procurement, transportation and technical guidance services for installation should be within the budget of the Japan side;
- The thermal energy available for the GEGs at Myanaung PS should be within 4.97 BBtud (710 Btu/scf x 7 mmscfd) at the maximum.

Tenderers will compete within the two given conditions above. The lower tender price within the budget will be appreciated to the higher level. As to the thermal energy which will be consumed by

[20] 6674.658 GWh / 10.877 million households = 51 kWh/hh/month ➔ about 50 kWh/hh/mo, Power Development Opportunities in Myanmar, EPGE, June 2017, slides # 7 & 8

[21] Annual cost about $10m / annual electricity sold 157GWh (at consumer end) = 6.4c/kWh

[22] 23.4 MW x 8,760 hr x 0.85 x 0.90 = 157 GWh. Annual plant factor at 0.85 and loss rate at 10%.

the GEGs at the Myanaung PS, the higher gas energy consumption within the quota at 4.97 BBtud will be appreciated to the higher level.

On the other hand, there are additional conditions to the above, such as natural conditions like altitude of the site, air temperature and relative humidity; and technical requirements like the middle speed of GEG at 750 rpm or lower. However, these conditions shall be fully met by all the tenderers. In the case of the two given conditions above, for example, the tender price of A-company may be JPY 2 billion while B-company at JPY 3 billion; the thermal energy consumption by A-company is 4.0 BBtud while B company at 4.97 BBtud, to have great differences among the tenders offered. If a number of revolution below 750 rpm is offered, how shall we evaluate it? In that case, we can expect benefit of higher durability. Then, the extent of the decrease in the annual power generation along with year, that is, the annual power sales revenue will be evaluated based on the efficiency-degradation curve. Next, the annual maintenance costs will be estimated for respective offers over the 30 yr assessment period. Thus, the net sales revenue will be estimated for various tenders and reflect the impacts or advantages of the low number of revolution to the tender evaluation.

Under the two given conditions above, the tender that yields the maximum net benefit to the Nation's economy is the best offer for the Myanmar and EPGE.

The maximization of the following individual parameters is desirable. However, if maximization of certain parameter is pursued as the objective of the planning or tender evaluation, it may lead to the self-satisfaction of engineers or economists. The maximization (or minimization) of individual parameters will not guarantee the maximum net benefit of the Nation's economy.

(a) Rated power P_r
(b) Maximum effective power P_e[23]
(c) Generation efficiency or heat
(d) Number of unit of GEGs installed[24]
(e) Annual energy generation E (= average power output)
(f) Generation benefit B (to be estimated as sales revenue)
(g) Generation costs C (to be estimated as total expenditures required for power sales business)
(h) Tender price T_p
(i) Present value M_c pf the maintenance costs over the 30 yr assessment period
(j) Benefit-cost ratio B/C
(k) Investment efficiency IRR

[23] The potential power P_p of Yadana gas is about 25 MW. When GEG with rated power greater than 25 M is offered, its P_e will be smaller than its P_r. However, this itself does not make the tender disadvantageous.

[24] There are various viewpoints on the number of unit of GEGs as shown below. When the number cannot be reasonably determined only from the technical aspects, the net benefit maximization criteria from the viewpoint of Nation's economy may be applied:

- When connected to the grid unlike in an island or in isolated mini-grid, one unit may enjoy the scale of economy.
- Two units may be selected to facilitate sharing of spare parts between the two units.
- Three units may be selected to reduce the power drop to 33% during inspection and maintenance.
- If the number of unit is limited to 3, only one Japanese maker might be eligible. If four number is also accepted, it will contribute to promoting price competition.

These parameters of certain tender will jointly maximize the net benefit B-C for the Nation's economy. This is referred to as the "Net benefit maximization criteria" for the public works in the developing countries. It is the international standard for economic assessment.

4.4. Details of Proposed Contents

The EPGE and the JICA Survey Team discussed and confirmed the "Urgent Upgrade of Electricity Supply" as summarized below:

(1) Executing agency : Electric Power Generation Enterprise (EPGE)

(2) Financial obligation : EPGE

(3) Installation site : Myanaung Power Station, Ayeyarwady Region

(4) Schedule : Assumed to start design works within November 2017 and the commercial operation in September 2019

(5) Goods : Gas Engine Generator(s), total capacity of about 24 MW

(6) Time for delivery : 11 months from the date of receipt by the Contractor of Notice to Proceed (NTP) after concluding the Contract till the delivery of the GEGs to the Myanaung Power Station. 16 months from the date of receipt of NTP to the commercial operation date.

(7) Specifications:

(a) Specifications of Gas Engine

The specifications of gas engine such as unit capacity, heat rate, etc. are different by manufacturer. Therefore, it will be required that the best combination of unit capacity and unit number be offered by the tenderer for maximum utilization of the gas available at the Myanaung PS. For securing the long lifetime, the middle speed engine will be specified for higher efficiency and higher durability compared with the high-speed engine. The number of revolution is specified as 750 rpm or lower. At the same time, the heat rate will be required to be of "zero tolerance". This is not to allow the downward fluctuation in the heat rate or efficiency. Also, the degradation curve of efficiency or heat rate will be required for submission at the tendering.

Total capacity may be selected with three or four units of suitable model to be offered by the tenderer.

The selection will be by competitive tendering. The selection criteria will not only be the initial procurement price of GEG but also based on the comprehensive assessment taking into consideration the costs of spare parts and maintenance, technical aspects, thermal efficiency, inspection criteria, and the contents of the proposed technical guidance services

(see Section 4.3.4 for more details).

The middle speed engine will be adopted herein. The features of the middle and high speed engines are compared in Table 4.4.1.

Table 4.4.1 General Features of Middle and High Speed Engines

	Middle Speed Type	High Speed Type
Number of revolution	750 rpm or lower (50 Hz)	Around 1,500 rpm (50 Hz)
Cylinder size	Relatively large	Relatively small
Durability (lifetime)	Relatively high	Average
Electrical efficiency	45-50%	40-45%
Customers	Mainly utility companies who often generate for long time	Leasing company, Construction power in the remote site without power, Private generator for backup during black out
Output control	by governor or frequency control	unit on-off
Price	Relatively high price	Relatively low price

Source ：JICA Survey Team

(b) Specifications of Generator

- Output: Depends on unit output of the model offered by the tenderer
- Type: Horizontal shaft three-phase alternate-current synchronous generator
- Number of revolution: 750 rpm or lower
- Frequency: 50 Hz
- Power factor: 80%
- Heat resistant class: F
- Temperature rise limit: B rise
- Standard: IEC60034
- Exciting system: Brushless excitation system with PMG

(8) Remarks for Specifications

(a) Using natural gas that has the minimum gross calorific value (GCV) of 710 Btu/scf, unit price of USD 7.50/mmBtu, and gas volume of 7 mmscfd to generate as much energy as possible by new GTG.[25]

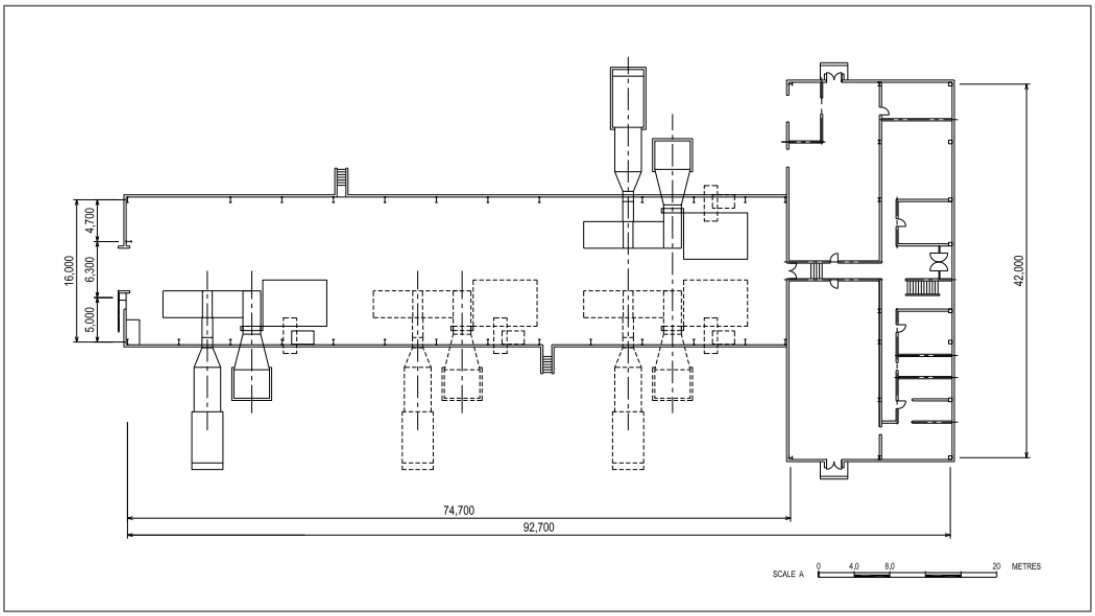
[25] The annual power sale revenue is obtained with the average retail price of USc 7/kWh and the annual energy. Annual net income is calculated by deducting the annual generation cost which consists of depreciation cost of initial capital investment, fuel cost, operating and maintenance cost, transmission and distribution cost. The project evaluation

(b) Physical dimensions of GTGs are to fit inside the existing building shown in Figure 4.4.1.[26]

(c) Sample layout of GEGs is shown in Figure 4.4.2 for the case of three and four units. Depending on the manufacturer's model capacity, the unit number may increase to four.

(d) Maintenance works of GTG should be possible using the existing crane (lifting capacity of 15 tons).

(e) The environmental emission limit of NOx concentration is under 200 mg/Nm^3 (Oxygen concentration at 15%). Allowable noise level is under 45 dB on the border of the compound.



Source: JICA Survey Team traced on CAD from the plan drawing during construction time.

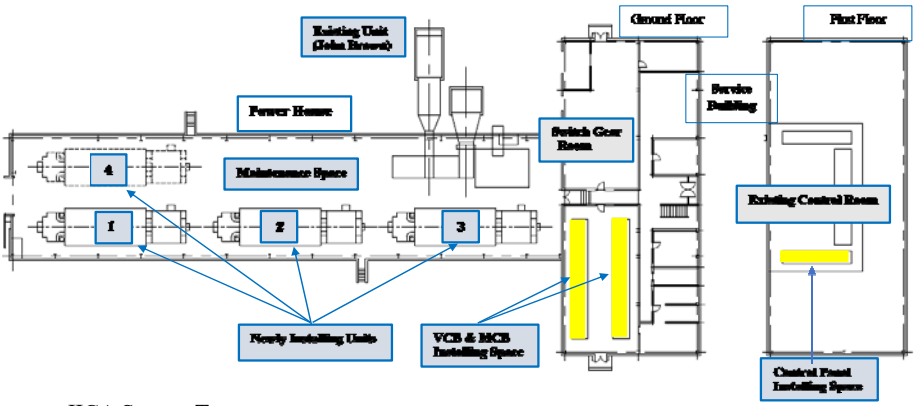
Figure 4.4.1 Plan of Existing Building of Myanaung Power Station

(f) The transport from Yangon Port on the Ayeyarwady River is by a 1,500-ton class barge. It will land to the right bank of Myanaung. A 6-axis class trailer loading one set of gas engine will land by driving through the tentative jetty up to the Myanaung PS. The maximum height above the road surface is within 4.5 m.

(g) Performance guarantee will be required for the proposed heat rate of the GEGs for one year.

period may be set at 30 years. The tender that maximizes the present value of the net sales income is the most valuable for Myanmar. Therefore, it would be reasonable to select the tender as the Lowest Evaluated Tender.

26 The foundation area is wide at 123 m^2. The bearing stress of the GEG weight will not matter.



Source ：JICA Survey Team

Figure 4.4.2 Sample Layout of GEGs

(h) In addition, after the start of the commercial operation, the contractor shall bear the liability for defects for one year. If defect is identified, it shall be promptly repaired at the contractor's responsibility and cost and the liability period shall be extended by another year.

(i) The calorific value of the gas will change in the near future after declining of the supply of Yadana gas. GEGs should be equipped with facilities and controls to facilitate adaption to the new calorific value.

(j) The contractor shall include the costs of the consumables for two years to avoid deterioration of the quality due to long storage and spare parts cost for four years in the bid price.

(k) The contractor shall submit the degradation curve of heat rate and maintenance plan. In addition, the contractor shall submit cost estimates of spare parts and for dispatching supervisors for maintenance which would be required within the 10-year period from the commissioning. This cost estimate is not included in the bid price. However, it is referred to in the price evaluation of tenders.

(l) The Technical Guidance Services above are inseparable from the supply of GEG and, therefore, comprehensive assessment is necessary. Then, the tenderers will be required to estimate the necessary MM, unit price of remuneration, trip expenses, etc. and fill in the specified form attached to the tender documents. As long as no substantial changes take place, the contractor will be required to conclude the contract for the Technical Guidance Services based on the cost estimate submitted. A form for declaration to that effect may be included in the tender documents.

4.5. Procurement Quantity and Price, Installation and Assembly Cost

4.5.1 Procurement Quantity

Subject to the unit capacity of the model offered by the tenderer, the number of GEG units is estimated to be three to four based on the thermal energy of the gas and the existing models available in the market. In the future, if the gas is switched from the Yadana gas to 100% imported LNG, there may be a possibility of adding another unit.

4.5.2 Maintenance and Technical Support System

(1) Installation and Management on Power Station

The gas-fired power plants owned by EPGE were procured under turnkey contract. Most of the newly introduced gas thermals in or after 2013 are of IPPs. EPGE did not participate in the installation and O&M and had no opportunity to acquire the installation and maintenance technology. The undertaking of the Japan side is only the supply and transport of the GEGs. Myanmar engineers will be engaged in the installation works under the guidance of the expatriate experts. Therefore, it is essential to organize a project management unit (PMU) under the management of EPGE's headquarters. The PMU is to manage the project and coordinate with the Japan side.

Also, at the power station, it is necessary to set up a project implementation unit (PIU). Members of the PIU will be engaged in various training and installation/assembly works. After the start of the operation, they will be the key experts in operation and maintenance including the daily operation, electrical and mechanical maintenance, and monitoring/updating control system.

(2) After-sales Service System

When dispatching technical personnel as after-sales service is necessary, the contractor would dispatch its experts probably from its base in Southeast Asia. Some companies already have service bases in Thailand and Malaysia. Some spare parts may also be supplied from these bases. Also, to maintain the high-efficiency operation for a long period, it is necessary to periodically have inspection by the manufacturer’s engineer.

The contractor will be required to provide technical guidance in the installation, test operation, and operation/maintenance until the overhaul upon two years after the start of operation. After that, if advice and support are needed for maintenance, the manufacturer shall respond to the order with a fee each time. When simple advice by the manufacture’s experts is required, it may be possible to check and advise remotely by making full use of IT. If EPGE requires it, the control panel can also be monitored by the manufacturer via the internet. Also, the tenderer will submit a list of spare parts and a price list, as well as personnel costs for inspection and repair by manufacturer’s experts. This aims to have the reasonable unit price of consumables and spare parts when EPGE needs these in the future.

4.5.3 Procurement Method of Fuel Gas

Branching facilities will be provided to the existing gas station inside the Myanaung PS. From the gas station, gas will be supplied to each unit of GEGs by individual gas pipes. MOGE will supply the gas to EPGE.

4.5.4 Costs for Procuring Fuel Gas

EPGE will receive the gas from MOGE and will make the payment. The current gas tariff is presented in Table 2.3.1.

4.5.5 Existing Facilities around the Myanaung Power Station

It is said that there was no town when the Myanaung PS was constructed in 1974. After construction of the gas exploiting and transporting facilities of MOGE and power station of EPGE, the Myanaung Township gradually grew. Accordingly, the power station and the township have been in coexistence and co-prosperity. Total number of household in Myanaung District is 11,411. However, there is no residence except the ones for staffs of Myanaung PS around the powerhouse. There has been no social problem in terms of the exhaust gas and noise of the power station. However, the power station is situated inside the residential zone. It will be required for the power station to meet the environmental standards of the Ministry of Natural Resources and Environmental Conservation.

4.5.6 Method of Inspection and Maintenance

Maintenance inspection methods are divided into daily inspection, routine inspection (per month or periodically at every certain operation hours), and periodic inspection (including disassembly inspection and maintenance). It will be prescribed in the tender documents so that detailed contents will be presented in the operation and maintenance manual to be prepared by the contractor.

In addition, manufacturers generally recommend Equivalent Operation Hours (EOH) as guidelines for inspection and parts replacement. For example, inspection items are specified for every 2,000 hours. Disassembly and inspection at every 16,000 hours to replace worn consumables; and at every 32,000 hours to replace bearings.

- Daily inspection is a task to check GEGs in operation at daily or weekly intervals;
- Regular inspection is done to check certain operation hours and replace simple parts like spark plugs (the shutdown period is one to two days)
- Periodic inspection (disassembling for inspection and maintenance) is to remove the cylinder cover, and replace piston rings, bearings, and some parts. It includes replacement of important parts (the shutdown period is two to three weeks).

4.6. Prospective of Gas Fuel Supply

4.6.1 Gasfield

Continuous gas supply for Myanaung PS is possible if 7 mmscfd gas from current gas supply sources (Yadana gasfield) is available. However, the gas yield from Yadana is anticipated to decline. The decline will start from 2021. In order to cope with the gas supply declining, the following three alternatives may be considered to secure the gas supply to Myanaung PS:

(1) LNG Import by FSRU

A project to import LNG by FSRU under PPP scheme is currently studied by MOEE. 500 mmscfd for large-scale import project or 200-300 mmscfd for medium-scale will be developed. With medium-scale project, it can start gas supply in the end of 2021-22 fiscal year. The gas supply Myanaung PS can be changed to imported LNG before the Yadana gasfield is exhausted.

(2) Supply from Shwe gasfield

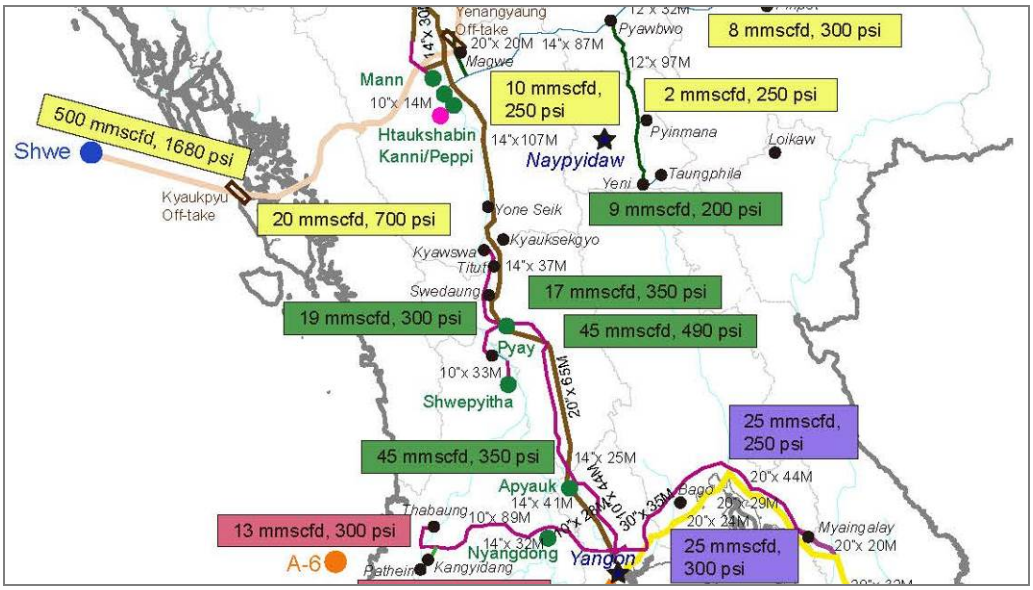
Gas of Shwe gasfield is allocated to domestic and export to China. MOEE negotiates with China to reallocate 50 mmscfd of the quota to China, to domestic. As a result if the gas supply for domestic use is increased, Shwe gas could be supplied to Myanaung PS. However, even if Shwe gas volume is increased for domestic use, it is likely that MOGE will supply Shwe gas to other gas thermal power stations since their capacity is larger than Myanaung PS and there is no other source therefor.

(3) Development of Shwepitha gasfield

Shwepitha gasfield is located 17 miles from Myanaung PS and is under exploration as a PPP project with Petronas (Malaysia). Gas production can be started earlier because Shwepitha gasfield is onshore, and its development is simpler than offshore. MOGE is trying to drill two numbers of holes. However, gas did not appear in the 1st hole. Currently, MOGE is drilling the 2nd hole. Detailed information was not obtained since this project is at initial stage.

In the three options above, gas supply from Shwe gasfield depends on the negotiation with China and distribution plan for other gas thermal power stations; MOGE has no idea to supply it to the Myanaung PS. Also, feasibility of Shwepitha gasfield is not clear at this time. Therefore, gas supply from imported LNG is the most dependable among these options.

Until the Yadana gas yield volume declines (assumed in 2021), gas will be supplied from Yadana gasfield to Myanaung PS. At certain time between 2021 and 2026, imported LNG by FSRU should be sent to Myanaung PS so that Myanaung PS can continue its power generation.



Study on Gas Application in Myanmar, METI

Figure 4.6.1 Gas Resources to Myanaung Power Station

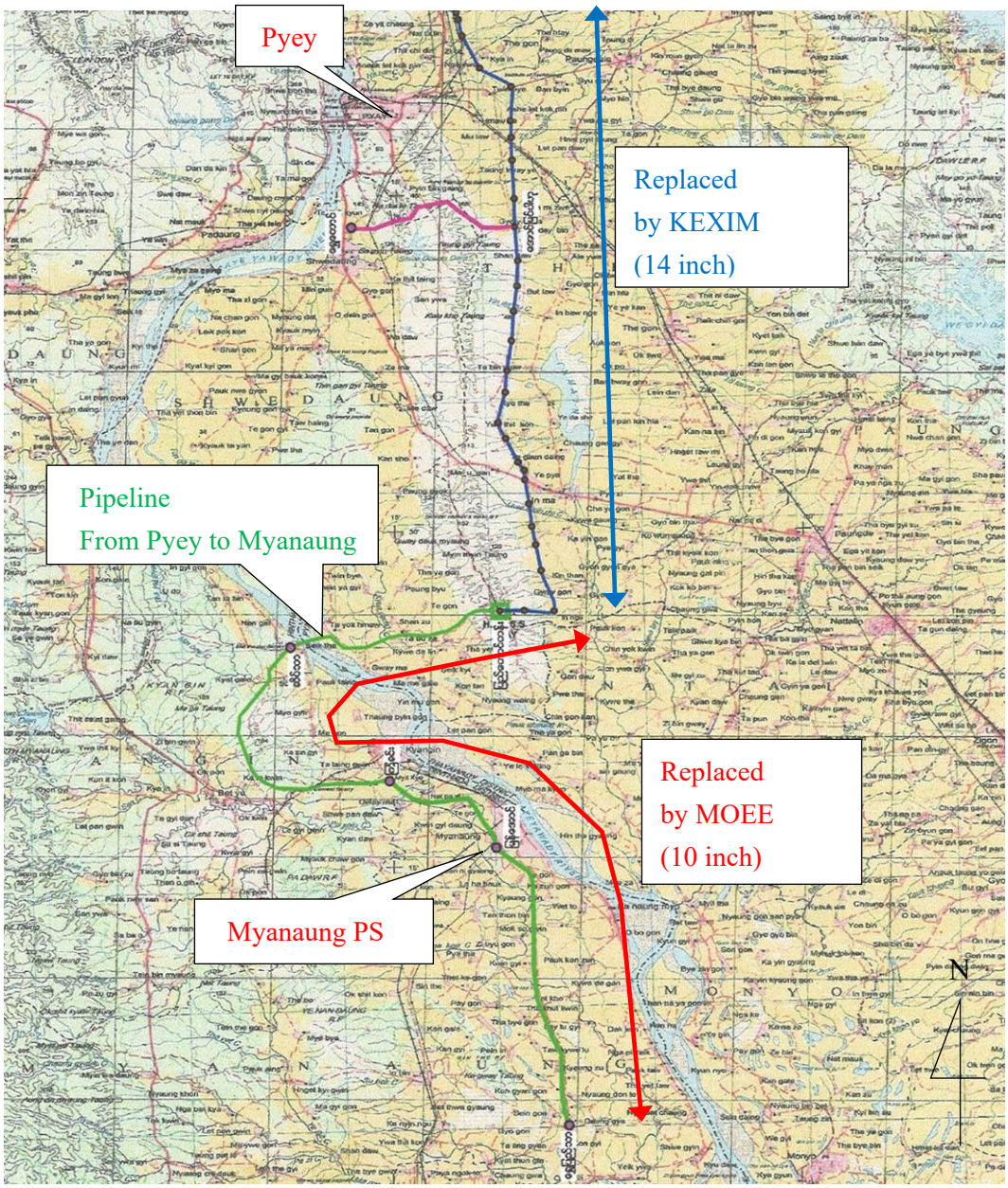
4.6.2 Gas Pipeline

(1) Pyey-Myanaung

Regarding gas supply for the Myanaung PS, in order to continue supplying Yadana gas or LNG from 2021, maintenance for the 10-inch old pipeline from Pyey to Myanaung is required. MOGE has already studied a replacement plan for the pipeline and planned its implementation in the 2018 FY budget. With the relevant Ministry's approval, the pipeline may be replaced within one year. Currently, gas supply volume for the Myanaung PS from Yadana gasfield is limited to 7 mmscfd. However, greater volume of gas can be carried to Myanaung PS owing to the replacement of the pipeline.

(2) Shwe- Pyey

If a part of Shwe gas can be allocated from export use to domestic use, replacement of gas pipeline from Yenangyang to Pyey, which was constructed in 1987 will be required. This pipeline will be replaced with the fund from the Export-Import Bank of Korea (KEXIM). Currently, they are carrying out FS and will finish it in September 2017. The planned construction period for this project is 18 months. It will be commissioned in 2021. If this pipeline is replaced, all of the major pipelines from Shwe (including Pyey-Myanaung) will be restored to its original capacity.



Source: MOGE

Figure 4.6.2 Pipeline Map Around Myanaung Power Station

4.7. Auxiliary Facilities Based on the Proposal

Existing facilities of Myanaung PS and the auxiliary facilities are described in Section 4.2.

4.7.1 Interfacing Points with Existing Equipment

■ Fuel Supply

MOGE supplies fuel gas to the gas stations in the premises of Myanaung PS through a pipeline. From this gas station, each GEG is supplied with gas by individual pipes. The interfacing point will be the joint of the fuel gas before the primary filter. However, the contractor will supply the

valve for gas pressure reduction.

- Generated Power

Starting from the generator terminal via the 11 kV VCB installed in the cubicle room on the ground floor of the service building, the interface point of the generated power will be set on the 11 kV side terminal of the step-up transformer inside the existing switchyard. The single line connection diagram of the new installation is presented in Figure 4.7.1.

- Auxiliary Power

The interface point is at the reception side terminal of the 11 kV VCB circuit breaker of the cable from the 66 kV/11 kV step-down transformer in the cubicle room at YESB.

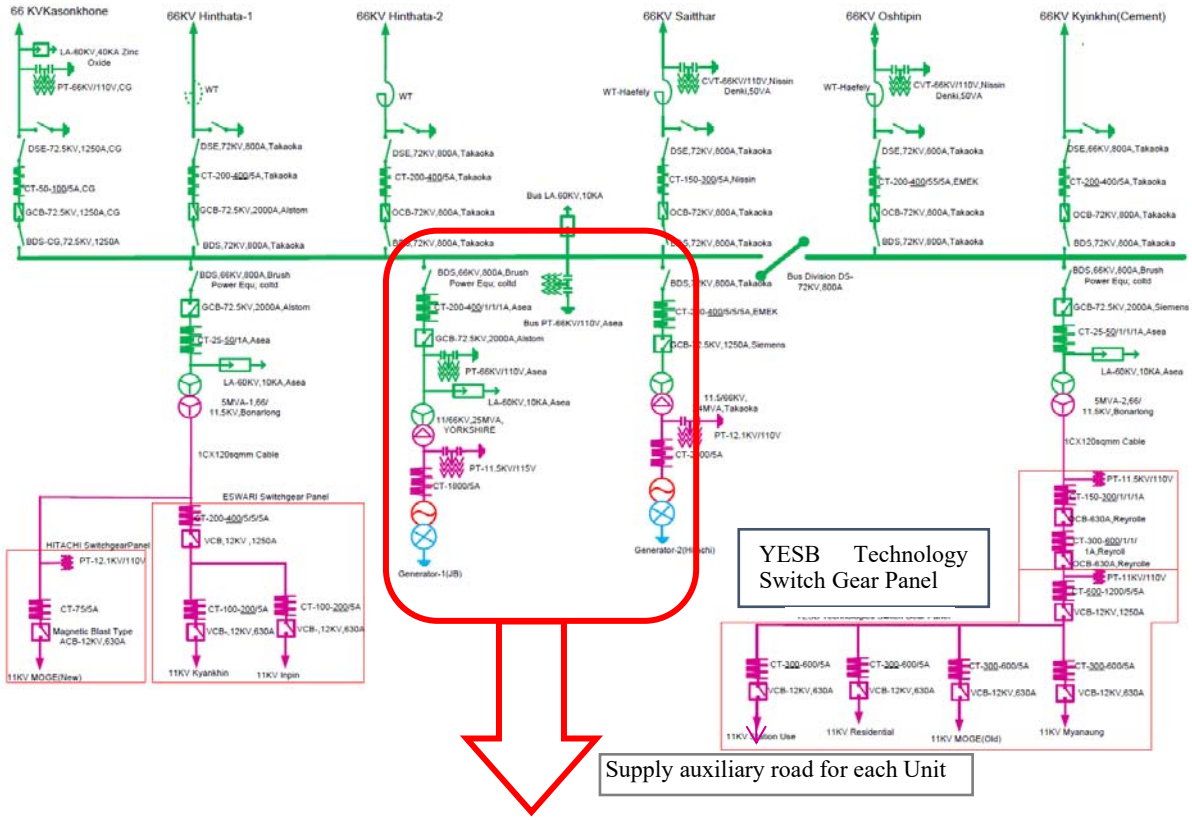
- Service and Wastewater

The existing GT facilities use groundwater and drain water discharged directly to the Ayeyarwady River. It is necessary to determine, at the time of detailed design, the interface points including the water quality standards.

Water will be used as the medium for cooling cylinders of GE. It is only to refill the water once the water is filled initially. In addition, some manufacturers may propose the method of cooling tower system (CTS). CTS would use water at about 28 m^3/ hr. The sufficient amount of water can be supplied from the existing groundwater well.

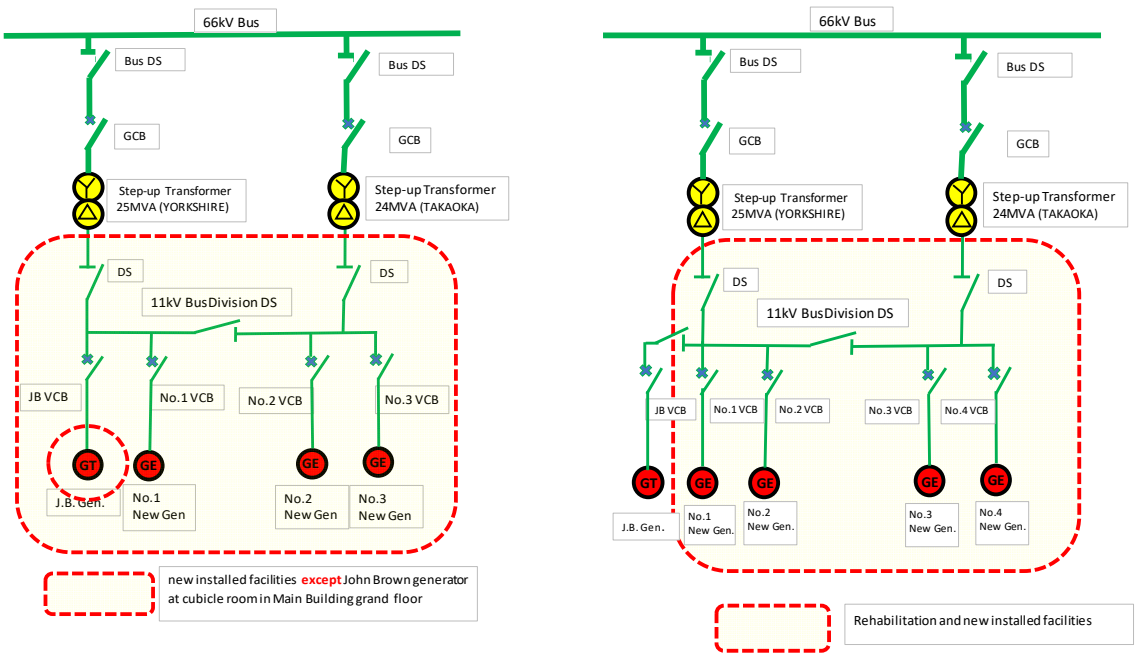
- Noise Control

GEG generates high noise of 110-115 dB. The glass window should be removed and closed with appropriate materials. Acoustic absorbing materials like rock-wool (e.g., 80 kg/m^3, 606 mm x 910 mm x 75 mm thick and covered with glass-wool) will be installed on the walls and ceiling of the powerhouse building. Noise will leak from the ventilation air outlet from which the air used for cooling the generator will exit the building. This opening should be designed with noise reduction structures. In addition to the installation of the acoustic-absorbing panels, planning and design of the noise-absorbing structure, materials, and construction method of the openings will be required at the design stage.



Case 1: Three Unit Installing Plan

Case 2: Four Unit Installing Plan



Source: Prepared by JICA Survey Team based on provided Myanaung PS Data

Figure 4.7.1 Single Line Diagram of Rehabilitation Area

4.7.2 Transportation Route

The following four routes were studied as transportation route of GEGs for Myanaung PS:

Source: Google Earth

Figure 4.7.2 Options of Transportation Route

(1) Option 1

This route is used for the transportation of gas turbine in the past, and it has no big issue for transportation in the rainy season. However, a sandbar appears at the riverside of the landing place and so the river width at the landing place is narrow during the dry season. When the 1st site investigation was carried out on June 22, 2017, the sandbar appeared around the landing place. But during the 2nd site investigation, which was carried out last July 25, 2017, the sandbar did not appear around the landing place due to the high water level. According to a Myanaung PS staff, transportation of equipment was carried out from July to August because the rain and water level is highest from July to August.

This route has six corners, but it has enough width for the turning of the GEGs since the road width is wide enough. There are 50 electric cables across the road, and some branches of trees are above the transportation route. Therefore, termination of electricity in this area, putting up of electric cable, and cutting branches of trees are required.

If water level is low, and the sandbar appears on the water surface, it is difficult for barges to come into the landing place at the right angle. Therefore, this landing place is available only in the season of high water level (from August to October).

 Photo taken by the JICA Survey Team	 Photo taken by the JICA Survey Team
Photo: Landing place, June 2017	Photo: Landing place, July 2017

(2) Option 2-1

Since landing place of option 1 is limited in the rainy season (July to October), this route was studied for the landing place of the barge and trailers and the transportation route at the upstream side. This route has no critical issue for turning of trailer because there are only few corners in this route. However, this road has large traffic; therefore, traffic control is necessary. There are 90 electric cables across the road. Therefore, termination of electricity in this area, and putting up of electric cable are required.

Landing place is used for passenger boats that cross Ayeyarwady River few times a day. However, landing of trailer will be an issue because road width is narrow (4.6 m) with few spaces. In addition, according to the staff of Myanaung PS, passengers climb up steep slope since water level goes down approximately 30 feet (≈ 9 m). Temporary jetty is required for landing of trailer from barge. Landing place should be connected to existing road by excavating river bank (see photos below). If temporary jetty is constructed in the dry season, site investigation for checking topography is required.

 Photo taken by the JICA Survey Team	 Photo taken by the JICA Survey Team
Landing place (road width: 4.6 m)	House feeding wires above the road

 Photo taken by the JICA Survey Team	 Photo taken by the JICA Survey Team
Landing place	Passenger boat for crossing the Ayeyarwady River

(3) Option 2-2

Since option 1 is limited only during the rainy season (July to October), this route was studied for the landing place of the barges and trailers and transportation route at the upstream side. This route has no critical issue for the turning of trailer because there are only few corners in this route. However, this road has large traffic and therefore traffic control is necessary. There are 90 electric cables across the road. Therefore, termination of electricity in this area, and putting up of electric cables are required. Temporary jetty for trailer with cargo, and demolition of stairs for passengers are required.

 Photo taken by the JICA Survey Team	 Photo taken by the JICA Survey Team
Landing place (road width: 5 m)	Landing place

(4) Option 3

This route is for the transportation from the downstream side of Ayeyarwady River. This route does not cross the township like Options 2-1 and 2-2 but it is the longest route (approximately 11.5 km). Road width at the landing place is narrow (2.1 m), and temporary jetty is required. There are sharp and narrow corners in this route and so it should be enlarged for the turning of trailers. There are two bridges on this route and the allowable weight of one of them is only 8 tons. Therefore, a temporary bridge or a replacement of this bridge is required. The cost of this route is higher, and the construction period is longer compared with Options 1, 2-1, and 2-2. There are 40 electric cables across the road.

 Photo taken by the JICA Survey Team	 Photo taken by the JICA Survey Team
Landing place	Bridge on Route (1)
 Photo taken by the JICA Survey Team	 Photo taken by the JICA Survey Team
Bridge on Route (2) with design road of 8 tons	Conditions of pavement

(5) Summary of Transportation Route

The summary of the comparison of the transportation routes is shown in Table 4.7.1. If transportation of GEGs is carried out from July to October during the rainy season, and high water level and water depth is higher than 3 m on the sandbar, Option 1 (old transportation route) is the best option. If transportation is carried out in months except July to October, Option 2-1 may be the best way.

In addition, since this site survey was carried out in July 2017, investigation of the landing place should be carried out to confirm the condition of the Option 2-1 site during the dry season.

Table 4.7.1 Summary of Comparison of Transportation Route

	Option 1 (Old transportation route)	Option 2-1 Upstream	Option 2-2 Upstream	Option 3 Downstream
Seasonal restriction	△ Limited in Jul. to Oct. and 3 m depth from sandbar is necessary	○ No restriction (It is necessary to check availability of Temporary Jetty Construction	○ No restriction (It is necessary to check availability of Temporary Jetty Construction	○ No restriction (It is necessary to check availability of Temporary Jetty Construction
Transportation road	○ Few sharp corner	○ Few sharp corner Traffic control is required	○ Few sharp corner Traffic control is required	△ Bad road Long distance Sharp corner
Required construction	◎ Special construction work is not required.	○ Temporary jetty is required	△ Temporary jetty is required Demolition of stairs for passengers of boat is required.	× Temporary jetty is required Replacement of the two bridges is required. Enlargement of road is required.
Total evaluation	○ Best way if water level is high (3 m higher than sandbar) and barge can dock at landing place.	○ Best way if transportation is carried out except from Jul. to Oct.	△ Demolition of stairs at landing place is necessary. Excavation for long approach to the road is necessary	× Large construction is necessary Long construction period It is not appropriate for urgent grant project.

Legend: ◎ good, ○ possible, △ marginal, ×not suitable
Source: JICA Survey Team

4.8. Consistency with Medium to Long-term Power Supply Policy

It has been the issue of top urgent in the power sector to backup the drop in the power outputs of hydropower in the dry season. Therefore, EPGE concluded rental contracts with IPPs like Kyaukse PS where 68 units of 1.5 MW GEG each were installed. EPGE bore subsidy to the consumers at K420 billion in 2016-17. It is required on short to medium-term to expedite the LNG import by FSRU. In parallel with the FSRU, it is prerequisite to install large scale GTCCs that are fuelled by the imported LNG, low cost compared to small GEGs of IPP rental, and can stop power generation during the rainy season. On the medium to long-term, it is essential to input the low-cost base power by steady implementation of coal thermals and hydros.

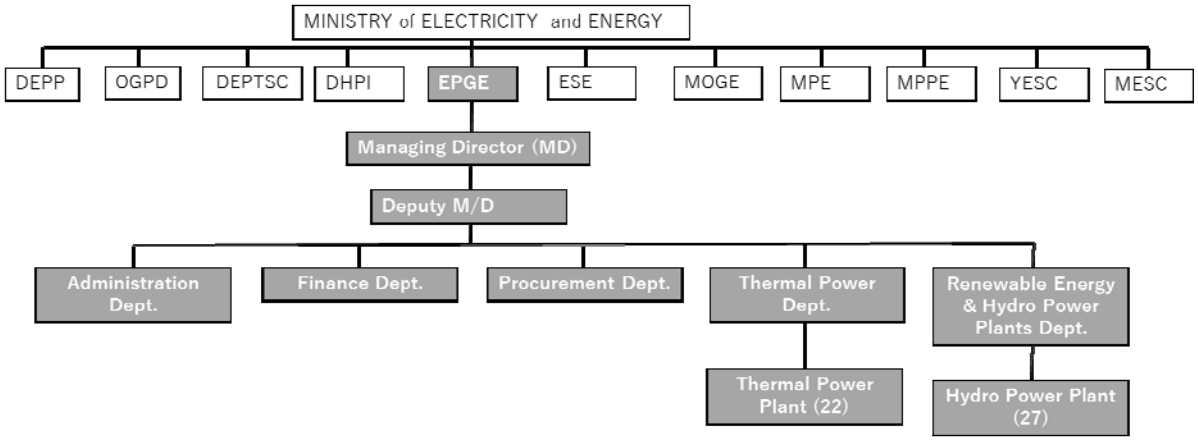
Such being the situation, the Myanaung Urgent Upgrading is to reinforce the generation capacity in advance of the GTCCs firing the imported LNG which is the measures on short to medium-term. Thus, the pressed supply-demand gap in the Yangon area will be mitigated. This is to replace the IPP rental business for a few years and to achieve the long-term operation for about 30 years and efficiency improvement by about 5%, that is, lowering the generation costs and reinforcing the energy generation. At the same time, the project will replace the existing John Brown GT of about 19.3% in the present efficiency with the GEGs of about 46% in the efficiency (with Yadana gas and on zero tolerance basis).

CHAPTER 5 OUTLINE OF RECIPIENT INSTITUTION AND ORGANIZATION FOR OPERATION AND MAINTENANCE

5.1. Structure of Organization

5.1.1 EPGE

MOEE consists of four departments, five enterprises, and two corporations. EPGE is one of the enterprises under MOEE. The organizational structure of MOEE and EPGE is shown in Figure 5.1.1.



Source: EPGE

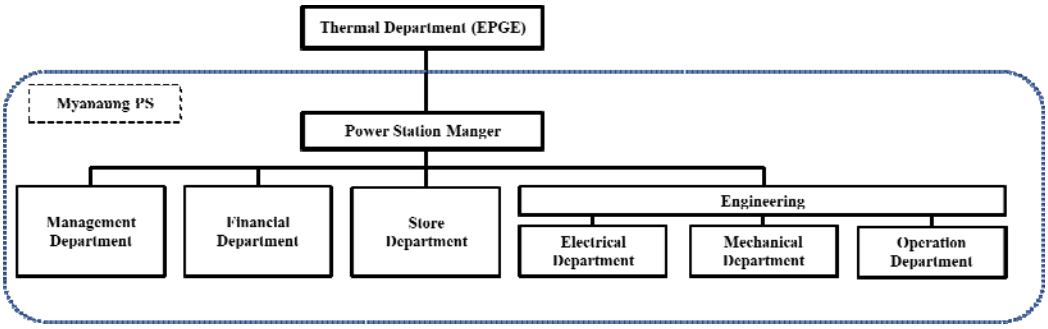
Figure 5.1.1 Organizational Structure of MOEE and EPGE

As shown in the figure, EPGE has three administration departments, one department for thermal power, and one department for hydropower plants. The thermal power department and hydropower department are also in charge of the power purchase from the IPPs.

Myanaung PS belongs to the thermal power department under EPGE.

5.1.2 Myanaung Power Station

The organizational structure of Myanaung PS is shown in Figure 5.1.2.



Source: Myanaung PS

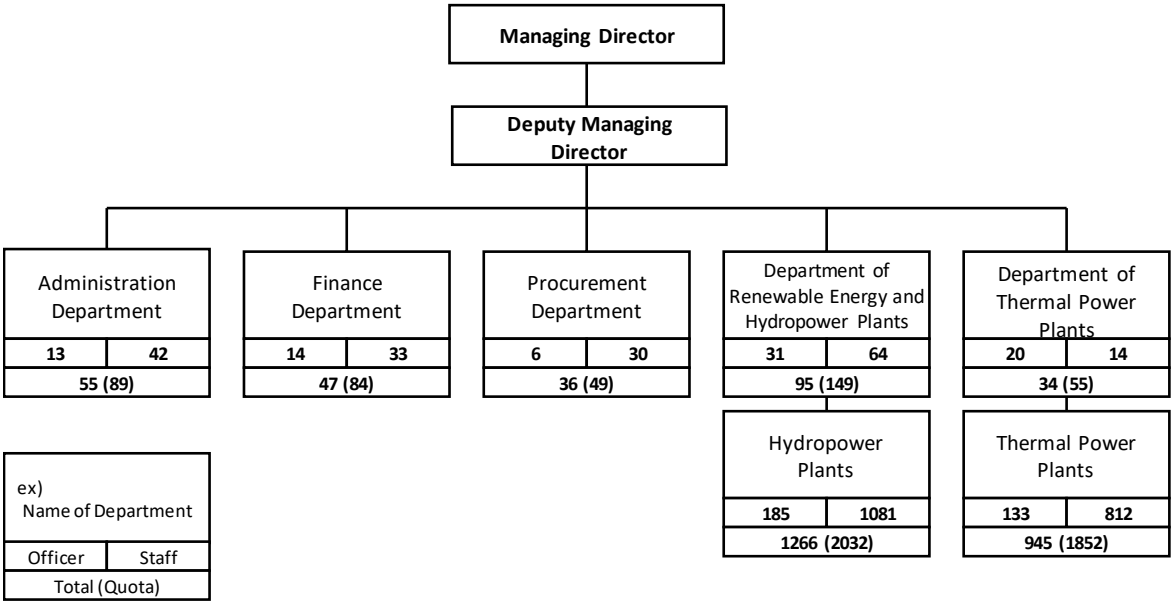
Figure 5.1.2 Organizational Structure of Myanaung Power Station

As shown in the figure, the organizational structure of Myanaung PS consists of two administration divisions, which include the departments of management, financial, store of materials, and three engineering departments of electrical, mechanical, and operation. The operation and maintenance of gas turbine generator is overseen by the operation department. The operation department manages the operation of the gas turbine generator for 24 hours a day with four shifts of staff.

5.2. Number of Staff

5.2.1 EPGE

The total number of staff in EPGE is 2,478 as of August 2017. Of the total staff, 402 are officers, 1,345 are technical staffs, and 748 are for administration. The number of staff who has attained at least a bachelor's degree is 1,084. The organizational structure of EPGE with the number of staff is shown in Figure 5.2.1.



Source: EPGE

Figure 5.2.1 Organizational Structure of EPGE and Number of Staff in Each Department

The figures in parenthesis are the quota of staff. The quota of officers is 576, but current actual number is 402. The total number of staff excluding officers is 2,076, while the quota is 4,310.

5.2.2 Myanaung Power Station

In Myanaung PS, there are 60 staffs working. Of the total, eight are officers. 20 have a bachelor's degree, and two have a master's degree.

The organizational structure of Myanaung PS with the number of staff in each department is shown in Figure 5.2.2. The figures in parenthesis are the quota of staff.

Power Station Manger (Superindentent Engineer) (Administration Officer)

Management Department

Rank	No
Office Superintendent	1
Branch Clerk	1
Senior Clark	1
Assistante Computer	1
Lower Division Clerk	1 (+1)
Driver-4	- (+1)
Deputy-Computer	- (+1)
Driner-5	2
Guard-5	2
Offer Helper	1
Cleanning Helper	1
Security Man	2

Financial Department

Rank	No
Accountant (1)	1
Accountant (2)	1
Accountant (3)	1
Accountant (4)	1

Store Department

Rank	No
Store Keeper (3)	1
Store Keeper (4)	1 (+1)

Engineering

Electrical Department

Rank	No
Executive Engineer	1
Assistant Engineer	2
Senior Assistant Engineer (2)	1 (+4)
Other Artisan Grade (1)	- (+1)
Other Artisan Grade (2)	- (+1)
Other Artisan Grade (3)	3
Other Artisan Grade (4)	4 (+4)
Other Artisan Grade (5)	- (+7)
Worker	- (+5)

Mechanical Department

Rank	No
Executive Engineer	1
Assistant Engineer	2
Senior Assistant Engineer (2)	- (+4)
Other Artisan Grade (1)	- (+1)
Other Artisan Grade (2)	1
Other Artisan Grade (3)	2
Other Artisan Grade (4)	3 (+6)
Other Artisan Grade (5)	- (+7)
Worker	- (+5)

Operation Department

Rank	No
Assistant Engineer	1 (+1)
Senior Assistant Engineer (2)	3 (+4)
Other Artisan Grade (2)	2
Other Artisan Grade (3)	3
Other Artisan Grade (4)	10
Other Artisan Grade (5)	1 (+12)
Worker	- (+16)

Formation	Permis	Present	Necessity
Staff Officer	9	8	1
Staff	134	52	82
Total	143	60	83

Source: Myanaung PS

Figure 5.2.2 Organizational Structure of Myanaung Power Station and Number of Staff in Each Department

In Myanaung PS, the quota of officer is nine and that of other staff is 134. Currently, there is only one generator in operation and, therefore, the number of staff is 60, being 42% of the quota 143. According to Myanaung PS, if the new GEGs are installed and the existing John Brown gas turbine is kept as an emergency back up, then additional staffs are required up to the quota of 143.

5.3. Financial Statements

The financial statements were provided to the JICA Survey Team by the EPGE as shown in Table 5.3.1 to Table 5.3.3. EPGE has been formulated by merging the thermal power division of MEPE and hydropower division of HPGE. The financial statement before 2016 is that of HPGE.

Table 5.3.1 Profit and Loss Statement of EPGE

(Kyats in Thousand)

No.	Particular	2014-2015	2015-2016	2016-2017
I	**Income**	**108,130,811**	**116,892,184**	**943,786,443**
	Sale of Electricity	108,062,835	114,449,455	914,014,208
	Electricity Supply Enterprise(ESE)			328,454,789
	Mandalay Electry Supply Enterprise(MESC)			160,310,536
	Yangon Electricity Supply Corpoartion(YESC)			424,194,577
	Industrial			922,251
	General Purpose			132,055
	Others	67,976	2,442,729	29,772,235
II	**Loss; Expenditure**	**50,701,167**	**52,653,795**	**1,363,908,246**
1	**Generation**	**35,905,356**	**34,535,334**	**1,304,817,376**
	Operation salaries	1,371,869	2,263,247	3,717,191
	Maintenances	2,033,214	1,388,381	2,570,640
	Fuel oil & Lubrican	3,490,514	447,616	865,226,566
	Others	1,253,186	1,548,465	118,285,361
	Depreciation	27,756,573	28,887,625	44,299,910
	Purchase of Electricity			270,717,708
2	**Transmission**	**24,965**	**24,965**	**346,242**
	Depreciation	24,965	24,965	346,242
3	**Distribution**	**20,282**	**25,539**	**27,352**
	Depreciation	20,282	25,539	27,352
4	**General**	**12,642,462**	**12,345,484**	**15,192,790**
	Operation salarie	1,579,838	1,547,221	2,639,070
	Maintenances	582,400	719,249	549,184
	Fuel oil & Lubrican	284,473	309,710	485,577
	Others	205,920	277,939	1,114,862
	Depreciation	1,146,381	1,175,085	2,822,186
	Interest	8,843,450	8,316,280	7,581,911
5	**Commercial Tax**	**2,108,102**	**5,722,473**	**43,524,486**
6	**Payable Expendifure for MOEP(2)**			**-**
III	**Profit/(Loss) before Tax**	**57,429,644**	**64,238,389**	**-420,121,803**
IV	**Income Tax**	**14,357,411**	**16,059,597**	**-**
V	**State Contribution**	**11,485,929**	**12,847,678**	**-**
VI	**Profit/(Loss) After Tax**	**31,586,304**	**35,331,114**	**-420,121,803**

Source: EPGE

As shown in Table 5.3.1, before the 2015/2016 fiscal year, the profit after tax exceeded MMK 30 billion. This is mainly due to the contribution of low power production cost of hydropower plants especially plants that complete depreciation. After 2016, since the profit/loss of MEPE joined the EPGE account, the profit after tax turned to deficit at MMK 420 billion. This is mainly due to the revenue from sale of electricity that is exceeded by the cost of fuel and purchase of electricity from IPPs. As the profit after tax in 2016 is negative, EPGE is exempted from paying income tax and state contribution.

The balance sheet of EPGE is shown in Table 5.3.2.

Table 5.3.2 Balance Sheet of EPGE

(Kyats in Thousand)

No.	Particular	2014-2015	2015-2016	2016-2017
1	**Fixed Assers**	**928,182,614**	**924,333,243**	**1,592,037,852**
	Capital Expenditure	1,006,363,878	1,032,817,619	1,748,022,149
	Accumulated Provision for Depreciation	-78,181,264	-108,484,376	-155,984,297
2	**Current Assets**	**30,901,657**	**41,585,576**	**97,933,645**
	Fuel,Petrol,Oil and Lubricant	794,537	795,593	1,766,325
	General Stores	11,094,812	13,893,658	18,050,172
	Debtors	19,012,308	26,896,325	78,117,148
	Receivable Sale Of Electricity	76,976	10,102,033	34,722,354
	Debtors Others	-	293,272	10,786,984
	Debtors Others (Commercial Tax)	859,624	569,722	11,061,565
	Debtors (Income Tax)	9,428,360	8,237,021	8,049,542
	Debtors(State Contributton)	8,647,348	7,694,277	7,544,294
	Work in Progress	-	-	-
	Advance to Office			5,952,409
		959,084,271	**965,918,819**	**1,689,971,497**
1	**GOVERNMENT ACCOUNT (1)**	**290,046,195**	**290,406,287**	**980,733,785**
2	**GOVERNMENT ACCOUNT (2)**			
	(Operating Investment)	**64,270,869**	**40,778,964**	**408,588,356**
	Opening Balance	438,232,212	64,270,869	40,778,964
	Deposit	-522,837,819	-124,153,410	-1,012,797,226
	Withdrawal	148,876,476	100,661,505	1,380,606,618
3	**Grant**	**35,371,304**	**51,312,990**	**51,004,731**
4	**Capital Reserve**	**71,153**	**71,153**	**71,154**
5	**Current Account With HO**	**64,915,676**	**64,915,676**	**64,915,676**
6	**Profit & Loss Adjustment Account**	**131,251,009**	**167,289,254**	**-251,650,542**
7	**Net Profit (Accumulated)**	-	-	-
8	**Current Liabilities**	**200,526**	-	**89,811,432**
	Other (5&9 Set Up)	-	-	89,811,432
	Creditor (Commercial Tax)	-	-	-
	Creditor (Income Tax)	-	-	-
	Creditor (State Contribution)	-	-	-
	Creditor Electricity	200,526	-	
9	**Long Terms Liabilities**	**372,957,539**	**351,144,495**	**346,496,905**
	Loan	372,957,539	351,144,495	346,496,905
		959,084,271	**965,918,819**	**1,689,971,497**

Source: EPGE

According to the balance sheet above, the following are identified:

- As the thermal power plants of MEPE are joined to EPGE, the aggregated depreciation cost of fixed asset is increased,
- Fixed assets are increased significantly due to the joining of MEPE's thermal plants, and
- Long-term liabilities are stably decreased due to the repayment of loan.

The cash flow statement of EPGE is shown in Table 5.3.3.

Table 5.3.3 Cash Flow Statement of EPGE

(Kyats in Thousand)

No.	Particular	2014-2015	2015-2016	2016-2017
I	**Sources of Fund**			
	Internal Cash Generation			
	Net Income Available for Fixed Charges			
	Depreciation	28,725,137	30,303,113	47,499,920
	Total Internal Cash Generation	**28,725,137**	**30,303,113**	**47,499,920**
II	**Borrowing**			
	Local Bank rrowing			
	Foreign Loan			17,165,454
	Total Borrowing			**17,165,454**
III	**Other Sources of Fund**	-14,256,414	28,848,118	638,888,836
	Total Sources of Fund	**14,468,723**	**59,151,231**	**703,554,210**
IV	**Application of Fund**			
	Capital Investment Program			
	Capital Expenditure	15,744,168	26,453,741	715,204,530
	Total	**15,744,168**	**26,453,741**	**715,204,530**
V	**Debt Service**			
	Interest			
	Loan Repayment	21,813,044	21,813,044	21,813,044
	Total	**21,813,044**	**21,813,044**	**21,813,044**
VI	**Variation in Working Capital**			
	Cash Increase (Decrease)			
	Other Than Cash Increase (Decrease)	-23,088,489	10,884,446	-33,463,364
	Net Increase (Decrease)	-23,088,489	10,884,446	-33,463,364
	Total Applecation of Fund	**14,468,723**	**59,151,231**	**703,554,210**

Source: EPGE

The cash flow statement of EPGE uniquely presents the inflow (items I to III in the table) and outflow (items IV to VI in the table), and the total of both flows is equal. Therefore, within the cashflow statement, there is no change of cash and cash equivalents. In the table, cash flow of "operating activity" corresponds to item I in the table. The earning before tax is not declared in the statement, and only depreciation cost is accounted as inflow. Investment activity is stated in item IV, and financial activity may correspond to items II, III, and V. Change in cash and cash equivalents is in item VI.

5.4. Experience of Implementation Agency

(1) Experience in Design and Construction

The gas-fired power plants under EPGE control are Hlawga, Ywama, Ahlone, Thaketa, and Thilawa in Yangon Region, and seven plants outside Yangon Region which include the Myanaung PS.

According to the hearing from EPGE, these gas-fired power plants were constructed under an engineering procurement construction (EPC) contract. Under the EPC contract, the employer (i.e., EPGE) specifies the necessary function and output of the plant. Designing, procurement, manufacturing, and installation/construction are undertaken by the contractors under their

responsibilities.

EPGE has no experience in designing, procurement and installation of GEGs. It is prerequisite for EPGE to contract well-experienced local contractor for installation and get engineers/specialists from heavy transporter, installation company and manufacturer of GEGs to provide technical guidance services in the handling of heavy equipment, installation and assembling of GEGs.

(2) Experience in Transportation

EPGE has experience in inland transportation for the construction of existing gas-fired power plants, and has managed traffic control during transportation, and handling of house feeding cables crossing over the roads.

(3) Experience in Operation and Maintenance

The gas-fired power plants owned by EPGE are directly managed by EPGE and its staff. The thermal power plants of Kyunchaung, Myanaung, and Thaton were constructed in the 1970s and were operated for more than 40 years. However, it is noted that the gas-fired power plants which are directly operated by EPGE are all gas turbine type power plants. EPGE has no experience in the operation and maintenance of gas engine generators (GEGs) as GEGs in Myanmar are all operated and maintained by IPPs. To introduce new GEGs in the Myanaung PS, it is indispensable to train and provide seminar for EPGE staff as capacity building for proper operation and maintenance of GEGs.

5.5. Needs of Technical Supports

In the past, large-scale diesel engine generators (DEG) were installed at capital cities of divisions and states in particular as the generation source during the dry season. Along with the grid extension, most of these capital cities have been connected to the national grid. The aged DEGs were retired and removed from the balance sheet. The experienced engineers and skilled workers who maintained these DEGs also retired.

The proposed GEGs are of a new type and are also large scale. Seminar and training for operation and maintenance are indispensable. The executing agency, EPGE, strongly requests for a complete seminar and training to be provided. Since the construction works of the Baluchaung No. 2 (Lawpita) Power Station in the 1950s, EPGE has accumulated, through civil construction works and installation of E&M works and transmission and substation works, technology and skills for construction and operation and maintenance. In Myanmar, primary education has been diffused nationwide since long time ago, and attitude of the people towards work is earnest. The JICA Survey Team sincerely recommend that the Technical Guidance Services be positively provided so that the Myanmar engineers and workers can acquire new technology on this occasion.

5.6. Contents of Technical Guidance Services

Technical Guidance Services (TGS) are required to facilitate the appropriate installation, operation and maintenance of the GEGs over the planned lifetime of 30 years. These TGS would be required in the following works:

T1 Renovation works of the powerhouse to reduce the noise leak to outside the building, including air outlet of low-noise leak structure;

T2 Installation works of the GEGs including the auxiliary equipment and cabling and piping works;

T3 Commissioning tests and reliability run operation;

T4 Seminar and on-the-job training (OJT) in the operation and maintenance of the GEGs and logging of O&M records and activities, including overseas training at the appropriate overseas training facility of the manufacturer. The seminar and OJT will include:

- Handling of heavy GEGs for installation inside the powerhouse
- Seminar on structure of GEG and parts
- Piping works, cabling works, duct works, etc. probably by a local contractor
- Logging of operation and management, record preparation and filing
- Inspection and maintenance and their logging and filing
- Replacement of spark plug, etc. and oiling and logging
- Overhaul and maintenance
- Stock management of spare parts and consumables, placing order and inspection upon delivery

T5 First overhaul of the GEGs required probably after two years of operation from the commissioning;

T6 Stock management of spare parts and consumables including their procurement

EPGE sincerely requested that the TGS above be provided by the Japanese side to complete the "Myanaung GEGs" in consideration of:

- The TGS and its cost are inseparable from the ones required for the undertakings of the Japan side, in order to achieve the objective to generate electricity over the 30-year lifetime;
- The TGS require specialists from the manufacturer of the GEGs and use of its training facility;
- It may be better to arrange the TGS contract in Japan since the main contractor for supply of the GEGs would be from Japan.

The JICA Survey Team concur to the sincere request of EPGE and strongly recommend that the Japan side thoroughly respond by mobilizing the available facilities.

CHAPTER 6 CONDITIONS FOR PROJECT IMPLEMENTATION

6.1. Undertakings of the Myanmar Side

M1 Timely arrangement of the required budget for the undertakings of the Myanmar side hereof, in the national budget for 2018/19 and for O&M thereafter;

M2 Execution of initial environmental examination (IEE) of the Myanaung GEGs and obtaining approval from the relevant agency;

M3 Obtaining approval for tax exemption on custom duties with respect to the import and import of the GEGs including all the auxiliary equipment and relevant materials, and tax exemption on corporate income tax, withholding tax, personal income tax for the services required for the Technical Guidance Services (TGS) by the foreign personnel of the procurement agent and the consultant for the detailed design and the contractor for the equipment supply and TGS;

M4 Removal of unnecessary concrete structure existing on the foundation of mass concrete and filling of voids with concrete as advised in the design stage.

M5 Cleaning inside the cable ducts and repairing of concrete cracks as required.

M6 Renovation works of the powerhouse for reducing the noise leakage to outside the powerhouse. The openings and apertures of the powerhouse building may be closed to reduce noise leakage. Ventilation system is not required specifically except for air-releasing outlet since the generator will be cooled by blowing outside fresh air. The air outlet may be placed on the roof or at high position of the gable with noise absorbing special structures since the warmed air after engine cooling will rise towards the ceiling. The air temperature rise in the powerhouse will be limited owing to the air circulation for engine cooling.

M7 Setting of the GEGs onto the existing concrete foundation including placing supports to GEGs to prevent overturning by earthquake forces; wiring of power cables, control/communication cables and piping works for fuel gas supply and others;

M8 Nomination and dispatching of staff for operation and maintenance (O&M) of the GEGs, right from the unloading of the GEGs from the barge at the shore of the Ayeyarwady River and throughout the installation works and O&M period;

M9 Supply of natural gas at 7 mmscfd with calorific value of GCV 710 Btu/scf at the minimum throughout the operation period of 30 years (after the start of reduction of the Yadana gas production, the imported LNG will be supplied to the Myanaung PS by MOGE);

M10 Procurement of spare parts and consumables required for O&M of the GEGs after the ones provided by the Japan side have been used up;

M11 Maintaining performance of related equipment such as the existing two transformers and auxiliary equipment supplied together with the GEGs, and replacing these when the replacement is judged required;

M12 Providing seminar and training continuously to the O&M staff including newly assigned personnel.

M13 When GEG is transported from the landing point on the right bank of the Ayeyarwady River to the Myanaung PS, there are many house connection cables crossing over the road. During the road transport, the electricity supply may be shut down temporarily so that the cables can be lifted to allow the passing of GEG on trailer.

M14 Appropriate management of asbestos boards used in the powerhouse building. As far as the boards remain under original condition without physical damages, there may be no risk.

6.2. Necessary Administrative Procedure

(1) Necessary Administrative Measures

In order to implement the project, necessary administrative measures that need to be done by the Myanmar government are as follows:

Table 6.2.1 List of Necessary Administrative Measures by the Myanmar Government

No.	Item	Responsible Agency	Regulatory Agency
1	Approval of IEE and conducting environmental monitoring	EPGE	MONREC
2	Permission of use of road for GEGs transportation	EPGE	Municipality
3	Permission of electricity shutdown during GEGs transportation	EPGE	Municipality
4	Permission of use of electricity, water for installation of GEGs	EPGE	EPGE
5	Assistance in customs clearance	EPGE	MOPF
6	Approval of tax exemption	EPGE	MOPF
7	Permission of modification works of landing point of Ayeyarwady river	EPGE	Municipality
8	Permission of construction and operation shutdown of existing GT during construction	EPGE	EPGE/MOEE

Source: JICA Survey Team

(2) Necessary Budgetary Measures

In order to implement the project, the necessary budgetary measures undertaken by the Myanmar government are as follows:

Table 6.2.2 Necessary Budgetary Measures

No.	Item	Responsible Agency
1	Implementation of IEE, and conducting environmental monitoring	EPGE
2	Traffic control and clearance of road for GEGs transportation	EPGE
3	Provision of office, accommodation, guards, and telecommunication for supervisors	EPGE
4	Use of electricity, water, compressed air, and OHT crane for installation and or maintenance of GEGs	EPGE
5	Provision of temporary warehouse and moving equipment to the warehouse	EPGE
6	Clearance of foundation in the powerhouse	EPGE
7	Repair of foundation concrete	EPGE
8	Renovation works of powerhouse to reduce noise leakage	EPGE
9	Provision of resident staffs for installation and commission of GEGs	EPGE
10	Other costs which are not covered by grant, (contingency)	EPGE
11	Budget of operation and maintenance cost	EPGE
12	Provision of consumables and spare parts for operation of GEGs	EPGE

Source: JICA Survey Team

If ODA project is realized, EPGE is the responsible agency to draft the budget. The draft budget will be circulated for approval to DEPP, MOEE, Economic Committee (EC), Development Assistance Cooperative Unit (DACU), Cabinet, and finally to the Parliament.

(3) IEE

In Myanmar, the power generation project under 50 MW in power output falls into the IEE category if the environmental impact is anticipated to be limited. In Myanmar, local consultants must be certified by MONREC for carrying out EIA. The certification is not necessary for conducting IEE.

If the power producer undertakes the environmental survey, the producer has to submit the project outline report to the Environmental Conservation Department (ECD) of MONREC. ECD determines if the project needs IEE or EIA based on the report. In general, IEE takes three months, and the producer submits the IEE report to ECD. ECD scrutinizes the report and approves it within 60 working days if there are no issues.

According to ECD, the project of upgrading Myanaung PS is simply to replace the existing power generator and environmental impact is expected to be limited. Therefore, ECD approval may be necessary before GEGs arrival to the Myanaung PS.

6.3. Tax Exemption

Tax exemption applicable to the project includes income tax and customs duties. EPGE has to issue the application for the tax exemption to MOPF. The expected items of tax exemption are as follows:

Table 6.3.1 Necessary Tax Exemption

No.	Item
1	Exemption from income tax with respect to the ODA and its accruing interest
2	Exemption from income tax on the income of the companies engaged in the implementation of the projects
3	Exemption from personal income tax for employees working for companies and engaged in implementation of the projects
4	Exemption from customs duties with respect to the import and re-export of materials and equipment owned by the companies engaged in the implementation of the projects
5	Exemption from withholding tax and personal income tax on the companies and employees engaged in the implementation of the projects

Source: JICA Survey Team

MOEE will apply to MOPF for tax exemption, which will be finally approved by the cabinet decision. The procedure from the application by MOEE for tax exemption till the approval will be as listed below:

1) MOEE will submit application documents for tax exemption to the Ministry of Planning & Finance (MOPF);

2) After approval by MOPF, it will be noticed to MOEE;

3) MOEE will apply for the cabinet decision;

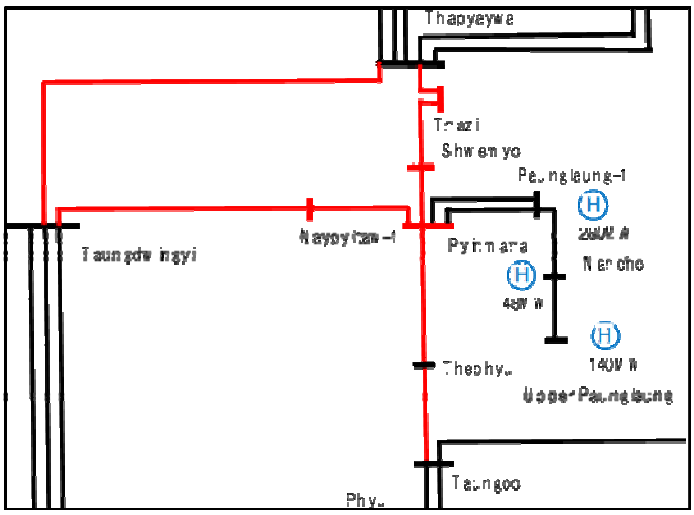
4) The cabinet decision will effect the final approval of the tax exemption.

The procedures of 1) to 4) above will require about one month period subject to the timing of cabinet schedule.

CHAPTER 7 ISSUES AND RECOMMENDATIONS ON POWER SECTOR IN MYANMAR

7.1. Measures and Recommendations on Transmitting Bulk Power from North to Yangon

Looking at the current 230 kV system, the outstanding obstacle in transmitting electricity from the North to the Yangon area is in the sections shown in Figure 7.1.1. Under the five-year plan, reinforcement of the 230-kV system seems to have been implemented and promoted by the Department of Electric Power Transmission and System Control (DPTSC). However, there appear some sections left behind from such reinforcement. In order to minimize the damage which may be caused by an accident of the 500-kV transmission line as described in Chapter 3, it is urgently necessary to reinforce the 230-kV transmission line in the section shown in Figure 7.1.1.

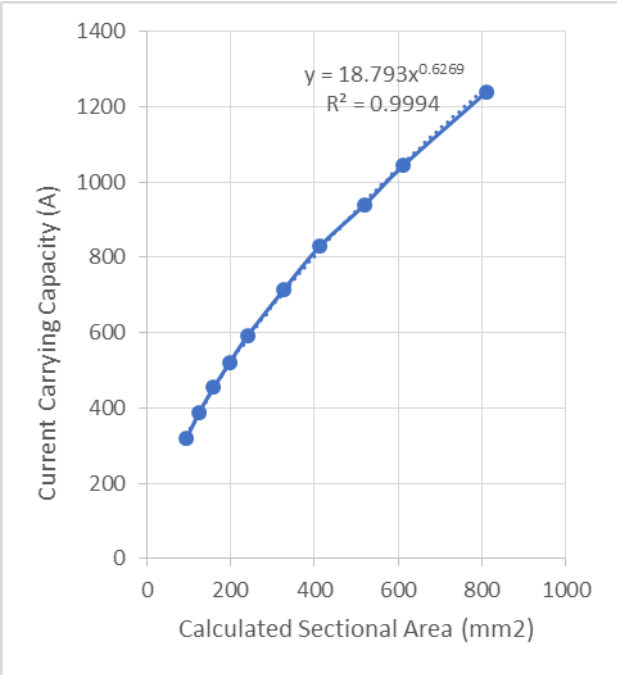


Source: JICA Survey Team

Figure 7.1.1 230 kV System of Pyinmana and its Surrounding Area

In Myanmar, only three sizes of 795 MCM, 605 MCM, and 300 mm^2 of Aluminium Conductor Steel Reinforced (ACSR) are used as conductors of the existing 230 kV transmission lines. The conductor of 300 mm^2 is used only for one section between Paunglaung and Pyinmana. The allowable temperature of ACSR is 90ºC. Figure 7.1.2 is prepared based on the Electric Wire Handbook of Hitachi Cable and shows the allowable current. The allowable current is calculated under the following conditions:

Ambient temperature	40 ºC
Allowable temperature rise of conductor	50 ºC
Solar radiation energy	0.1 W/cm^2
Wind speed	0.5 m/sec
Surface coefficient of conductor	0.9



Source: Electric Wire Handbook of Hitachi Cable

Figure 7.1.2 Allowable Current of ACSR

The expression of the plotted curve above may be approximated as follows:

(Allowable current of ACSR, A) = 18.793 x (Calculated cross section of conductor, mm^2)$^{0.6269}$

In this case, the correlation coefficient R^2 is 0.9994, which shows very good approximation.

According to this equation, the conductor of 795 MCM is assumed as the ACSR code name Drake and its calculated sectional area is 403.0 mm^2, the allowable current is 807 A, its capacity is 273 MW; 605 MCM is its peacock, the calculated cross section is 306.7 mm^2, 680 A, 230 MW. Following the practice of DPTSC, the allowable capacity is determined with the power factor at 85%, which is on the safety side.

On the other hand, DPTSC seems to use 900 A for 795 MCM conductor, 305 MW of allowable capacity; and 760 A and 257 MW for 605 MCM conductor. It is difficult to evaluate because details of calculation conditions are unknown. It is recommended with emphasis on safety to use 807 A and 273 MW for 795 MCM conductor; and 680 A and 230 MW for 605 MCM conductor.

Table 7.1.1 shows the power flow at 19:00 on May 23, 2017 when the maximum load to date was recorded. The most critical sections of the transmission network shown in Figure 7.1.1 use double conductors per phase. Though the power flow itself showed high values, these were much lower than the allowable current (capacity).

Table 7.1.1 Power Flow at 19:00 on May 23, 2017

Transmission Line		Conductor	Allowable Capacity (MW)	Power Flow (MW)	% Load
From	To				
Thapyewa	Taungdwingyi	2x605	460	282.9	61.5%
Thapyewa	Thazi	2x605	460	193.1	42.0%
Thazi	Shwemyo	1x795	273	131.5	48.2%
Shwemyo	Pyinmana	1x795	273	130.5	47.8%
Pyinmana	Thephyu	2x605	460	202.2	44.0%
Pyinmana	Naypyitaw	2x605	460	170.0	37.0%
Naypyitaw	Taungdwingyi	2x605	460	133.0	28.9%
Thephyu	Taungoo	2x605	460	183.4	39.9%
Myaungtagar	Hlaingthaya	1x605	230	202.3	88.0%

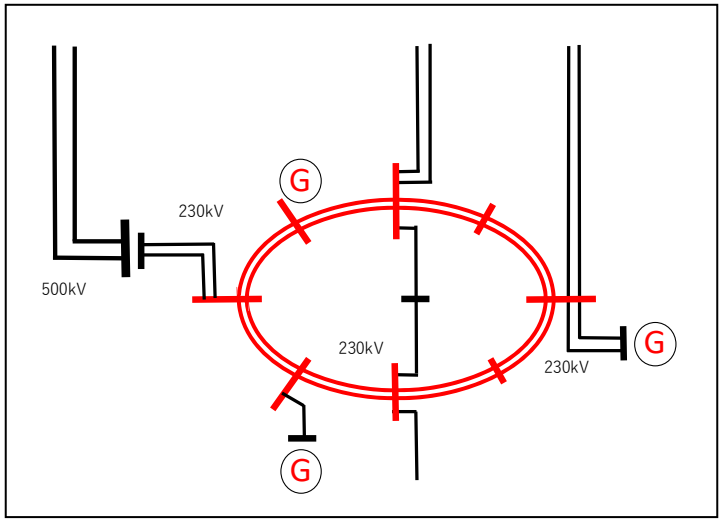
Source：DPTSC

However, although not shown in Figure 7.1.1 (but shown in Figure 7.2.2), it should be noted that the Myaungtagar-Hlaingtharyar Line is 605 MCM single conductor per phase and would be almost overloaded every day. All of the transmission lines shown in Table 7.1.1 are single circuit, and would be sensitive to the accident of the other transmission lines. For example, if the Thapyewa-Taungdwingyi Line fails, its power flow of 280 MW will flow into the Thapyewa-Thazi-Shwemyo-Pyinmana Line, possibly overloading at 130–140% or more. In addition, the 132 kV transmission network for the regional power supply will also be greatly affected.

Therefore, it needs checking whether the N-1 criteria is satisfied for the existing 230kV and 132kV transmission system including those lines currently under construction. An augmentation plan may be prepared and should urgently be implemented. Since this plan aims to minimize people's unrest and anxiety due to serious accident that may take place in the future, it would be economically appropriate to predict accident based on the current demand or 2020 demand forecast. When applying the N-1 criteria, as for the double circuit transmission line, it is considered sufficient to assume single circuit failure, because the probability of occurrences of accident in duplicate on the double circuit lines is considered significantly low.

7.2. Measures and Recommendations on Reinforcement of Power Supply in Yangon

In order to mitigate the situation discussed in Sub-section 3.5.2, the JICA Survey Team proposes to construct the Ring Main System with double circuit as illustrated in Figure 7.2.1 by utilizing the existing 230 kV facilities.



Source: JICA Survey Team

Figure 7.2.1 Illustration of the Ring Main System

Upon commissioning of the Ring Main System, it will be possible promptly to switch the power supply route in case of supply failure due to accidents on the transmission lines and/or substations. Almost normal operation may be continued. In the implementation, there would be problems such as land acquisition and adoption of 230 kV underground cable. Adoption of gas insulated switchgear (GIS) for new substations should be considered.

In addition, the Ring Main System proposed here covers the essential part of the electricity supply in the Yangon area in the future. It is, therefore, important to plan these in advance of the ordinary grid reinforcement.

Furthermore, considering the future demand increase, the JICA Survey Team proposes to study on switching the voltage configuration from present 66 kV-33 k -11/6.6 kV to the future 132 kV-20 kV in the planning. It is difficult to deal with the future demand increase with the current voltage configuration, so there would be a limit in reducing the power losses. The distribution system in the Yangon area is still relatively small. Early undertaking of the implementation will minimize the possible disruption and expenses associated with switching voltage configuration.

Additional investigation was conducted based on the information "the development plan of transmission network of Yangon area by ADB assistance is underway" obtained at the final stage of this survey. ADB's plan is composed of the following new construction, expansion, enhancement plans. A loan agreement for USD 80 million was signed on April 26, 2016.

(1) New double circuit 230/66 kV and 8.5 km long overhead transmission line between Thida substation and Thaketa substation.

(2) Single circuit 230 kV overhead transmission line between Thaketa substation and 66 kV Kyaikasan substation, including the expansion of the 230 kV Thaketa substation, the expansion and upgrading of the Kyaikasan substation into a 230/66/11 kV substation.

(3) Construction of a new 230/66/11 kV, 2x150 MVA South Okkalappa substation.

(4) Construction of a new 230/33/11 kV, 2x150 MVA, West University substation.

The plan above will be implemented and will constitute the Ring of Ahlone-Thida-Thaketa-South Okkalappa -Hlawga-Myaungtagar- Hlaingtharyar-Ahlone. The existing Kyaikasan substation is on the premises of Kyaikasan play ground. South Okkalappa substation is built in the middle of Thaketa – Hlawga existing transmission line. The West University substation in (4) above is for connecting the 500-kV substation under planning with the existing 230kV system in Yangon area. The Kyaikasan and West University substations are not related to the configuration of the Ring. Also, it is judged that the transmission line between Ahlone and Thida and the construction of Thida substation are planned to be done by DPTSC. The information is not provided and details of the plan are unknown.

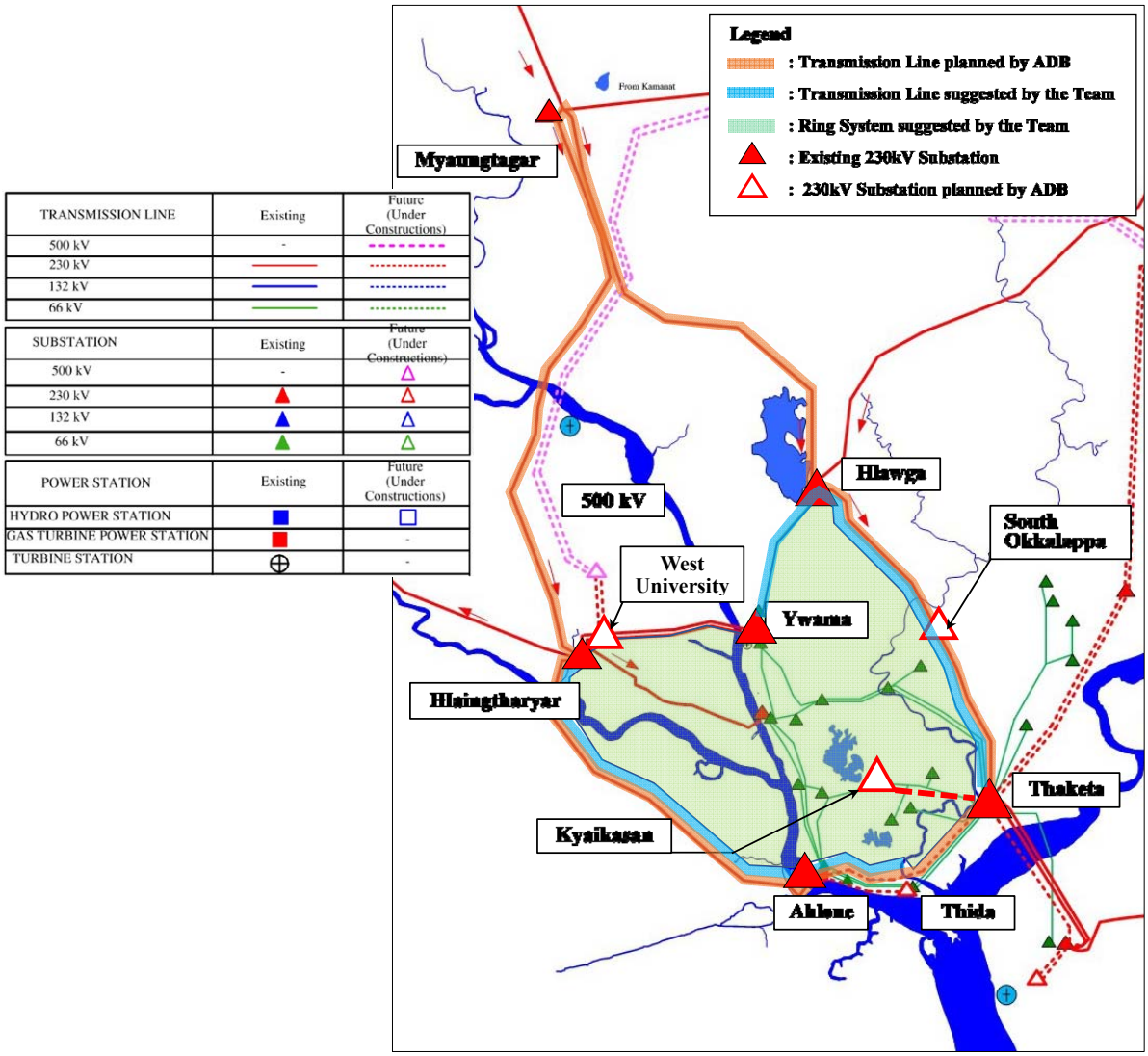
Table 7.2.1 shows the transmission lines that make up the Ring System financed by ADB. In addition, Figure 7.2.2 shows the location diagram of planned transmission lines and substations

Table 7.2.1 Transmission Lines Forming Outer Ring System with ADB Loan

	230kV Transmission Line		Length	CCT	ACSR	Fund
1	Ahlone	Thida	-	-	-	DPTSC
2	Thida	Thaketa	8.5	2	-	ADB
3	Thaketa	South Okkalappa	-	1	795	Existing
4	South Okkalappa	Hlawga	-	1	795	Existing
5	Hlawga	Myaungtagar	25.9	1	2x605	Existing
6	Myaungtagar	Hlaingtgaryar	40.2	1	605	Existing
7	Hlaingtgaryar	Ahlone	22.4	1	2x605	Existing

Source: DPTSC and ADB's Report

Remark: "-" means no information



Source：Original map by DPTSC

Figure 7.2.2 Location Diagram of Planned 230 kV Transmission Facilities

In the ADB plan shown in the table and figure, the following are issues. The data of the existing transmission lines was provided by DPTSC. The input data for the computer program of system analysis is provided but the details of the transmission lines are unknown. Therefore, the issues will be discussed based on fragmentary transmission line data and the following estimates:

- Transformer capacity of 500/230kV substation in Yangon: 2x500 MVA
- Conductor size of Hlaingtharyar-Ywama Line: 2x795 MCM (642 MVA)
- Conductor size of Hlaingtharyar-Ahlone Line: 2x605 MCM (542 MVA)

(a) The whole amount (maximum 1,000 MVA) of electricity transmit by the 500kV transmission line will be sent to the Hlaingtharyar substation. The electricity generated at the Ywama power station (245 MW, 288 MVA) will be added there. Up to 1,288 MVA of electricity will

be sent to the Hlaingtharyar substation.

(b) On the other hand, the allowable transmission capacity of the Hlaingtharyar-Ywama line is 2x642=1,284 MVA, which is lightly less than the estimated maximum power transmitted to the Hlaingtharyar substation. The line will be extremely overloaded in case of one line failure.

(c) Electricity is supplied from Hlaingtharyar to the Ring System via two transmission lines i.e. Hlaingtharyar-Ahlone line and Hlaingtharyar-Myaungthagar line. The allowable transmission capacity of the lines is 542 MVA and 271 MVA respectively, totaling 813 MVA. Even if the transformer capacity 200 MVA of the Hlaingtharyar substation is added, it will be 1,013 MVA. This is obviously less than the total power sent from West University substation, and the transmission lines for sending out may always be overloaded. Furthermore, in case of one line failure, the remaining lines become extremely overloaded.

(d) The ADB Outer Ring System is of eggplant-shape that uses existing transmission lines as much as possible. However, it does not necessarily cover only heavily loaded area.

From the above, the JICA Survey Team proposes to create the Heart-shaped Ring System by simply adding "Ywama-Hlawga double circuit overhead transmission line", which surrounds the most loaded area. It is the Ring System of Ahlone-Thida-Thaketa-South Okkalappa-Hlawga-Ywama-West University-Hlaingtharyar-Ahlone. Besides, it does not affect the facilities planned with ADB loan. However, it is necessary to add and /or modify part of the design of the substations according to the additional proposal as described below:

The proposed Heart Ring System is to become a key to the power supply in Yangon area in the future. Therefore, the JICA Survey Team propose that additional plans be implemented to further improve it to the real Ring Main System. These plans are to cope with the above-mentioned four issues.

(a) Construction of single circuit or double circuit Hlaingtharyar-Ahlone overhead transmission line.

(b) Construction of single circuit overhead Hlawga-South Okkalappa-Thaketa transmission line. For South Okkalappa-Thaketa transmission line, if there is difficulty in land acquisition, adoption of underground transmission line should be considered.

(c) The progress of the construction of Ahlone-Thida transmission line and Thida substation should be confirmed. For the line, if single circuit line is currently planned, another single circuit line should be considered. If there is difficulty in land acquisition, adoption of underground cable line should be considered.

Although it does not relate to the c proposed Heart Ring System, when considering the 500 kV system accident as described in Section 7.1, the JICA Survey Team propose the addition of the following reinforcing plan for ensuring the power supply in Yangon area.

(d) Construction of single circuit overhead Myaungtagar-Hlaingtharyar transmission line. Currently the existing transmission line in this section is already operating close to overload at all time under normal operation condition.

The Ring Main System is a facility that should secure the continuous electricity supply to the center of Yangon also in the distant future. It will be very difficult to renew the Ring once it is constructed, including the ADB-planned facilities. The Team, therefore, propose the transmission lines should have sufficient transmission capacity; i.e. 1,000 MVA to 1,500 MVA per circuit.

7.3. Needs of Coal Thermals and Recommendation of Information Sharing Campaign

First, the existing development plans and latest data of the energy and power sector will be reviewed. Based on the review, issues of the power sector will be examined. Then the direction of the countermeasures and possible approaches to cope with the issues will be studied and the fields expected on the Japanese official development assistance (ODA) will be pursued for possible cooperation and support to the power sector in Myanmar.

7.3.1 Review of Existing Development Plans and Latest Sector Information

7.3.1.1 Myanmar National Electricity Master Plan 2014

The Myanmar National Electricity Master Plan 2014 (MP-2014) was made public at the seminar held by the then Ministry of Electric Power (MOEP) in July 2014 as the Outline of National Electricity Master Plan – Vision as of 2030. MP-2014 was studied by Newjec and Kansai Power Corporation under the Preparatory Study for Power Sector Development Planning in Myanmar, 2014.

Natural Gas-fired Thermals

(1) Of the domestic production of natural gas, 200-300 billion British thermal unit per day (BBtud) or 13% is allocated to the power sector, 7% to the industry, and the rest of 80% to export.

(2) The gas demand of the power sector amounts to double the quota above.

(3) To fill the gap between the gas demand and the quota of domestic gas to the power sector, imported oil (HSD) or liquefied natural gas (LNG)-fired gas turbine combined cycle (GTCC) of 700 MW in total will be constructed by 2020 under the Fast Track.

(4) On the medium-term after 2020 till 2030, GTCC of 2,789 MW in total will be required. These will be fueled by imported LNG.

Hydros

(1) Of the gross hydropower potential at 108,000 MW, the total of the three categories, i.e., “Developed”, “Primary”, and “Possible” amounts to 48,500 MW. The rest is grouped under “Challenge” which may correspond to “Technical Potential”. Of the 48,500 MW, 3,000 MW have been developed. Of the rest of 45,500 MW, 42,100 MW or 92.5% were proposed for

development by the independent power producers (IPPs) from China and Thailand. Of the electricity produced by these IPP hydros, one-half will be allocated to respective home countries. The dry season outputs of these hydros are estimated to lower to 50% of the installed capacity.

(2) Of these IPP hydros planned, 8,700 MW were suspended due to various reasons. The rest of 36,800 MW may be considered as the "Economic Potential". Of these, those projects located on the main stream and have an installed capacity of greater than 1,000 MW are classified as large hydros. This amounts to 26,900 MW in total. The medium and small hydros of less than 1,000 MW amount to 9,900 MW.

(3) Large hydros of 26,900 MW in total on the main streams have the following issues, and therefore, it is considered that their development would face difficulty:

- Long lead time until commissioning;
- Environmental and social impacts; and
- Needs of constructing long high-voltage transmission lines.

Coal Thermals

(1) The first coal thermal plant in Myanmar is Tigyit and was constructed in 2004 with installed capacity of 120 MW. Its output did not reach 120 MW. It frequently stopped operation and finally was tentatively closed in November 2014. Air and water pollutions of the Tigyit are significant threats to agriculture and health of the people around and caused serious hazards to the environment. Many villagers suffered from skin eruptions[27]. Tigyit is not equipped with environmental devices and serious environmental hazards were reported. The environmental pollution in Tigyit triggered the opposition to coal thermals in Myanmar. It is reported that boilers and stream turbines were replaced and environmental devices were attached and test operation was executed for three months by July 2017. Most of the nation's population participated in the opposition movement against other coal thermals in Myanmar. For example, Toyo-Thai planned a coal thermal in Ye, Mon Region and concluded the memorandum of understanding (MOU) with the previous government. However, it faced strong opposition from the people and the Mon Governor finally declared the withdrawal of the Ye Coal Thermal in July 2017. In addition to Tigyit, there is another coal thermal of 8 MW in Kauthaung, the southern-most place of Myanmar. Also, Siam Cement in Mon Region owns coal thermals of 30 MW for self-supply. Coals were transported via canal from the port nearby.

(2) Coals in Myanmar have calorific value of 3,000～6,500 kcal/kg. Kalewa in Sagaing Region and Mainghkok in Shan Region produce sub-bituminous coal (see Figure 7.3.5 for the coal

[27] Myanmar Times 28 April 2016

classification). The Ministry of Mines has a plan to produce coal at 5.6 mt by 2030, of which 4 mt[28] is allocated to the power sector.

(3) It is planned that coal thermals of 7,800 MW will be required iby2030 and coals of about 24 mt will be required. Coal import worth six times as much as the domestic coal production will be required.

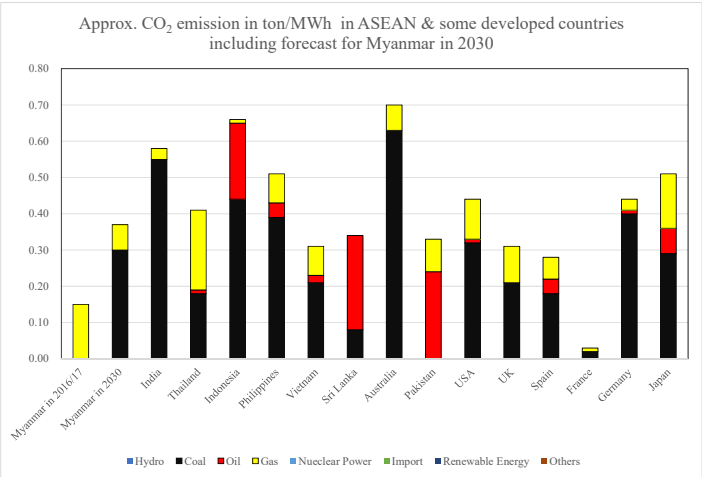
(4) The advantages of coal thermals are low cost and stable supply of base power throughout the year; and stable import could be expected because of various exporting countries. Environmental hazards became the big problems of Tigyit. However, if appropriate environmental devices for dust removal, desulfurization, and denitration are attached as what is done in Japan and in developed countries, environmental emission regulations can be met. On the other hand, the disadvantage is in the fact that carbon dioxide (CO_2) emission level is high at about 1 ton/MWh, being greater than double the one of gas thermals. The policy to construct new coal thermals that accompany an increase in the CO_2 emission level would not be in line with the international agreement of the Twenty-first session of the Conference of the Parties (COP 21) held in December 2015.

(5) In Myanmar, it is planned even in 2030, hydros will share 47%, coal thermals 33%, and gas thermals 20%. In Myanmar, hydros were invested with priority since the 1990s and gas thermals were put into the investment stream since 2000. Construction of coal thermals in full swing will start from now on. The order of generation expansion starts with hydros which emits little CO_2, followed by gas thermals, and finally coal thermals. The policy to target appropriate generation mix is reasonable in terms of energy and reliability of the power supply and meets the national interest.

(6) Accompanying the introduction of coal thermals, the CO_2 emission level per MWh will rise. To suppress the rise, it is important to develop hydros in parallel with coal thermals in accordance with the Balanced Scenario of Electricity MP-2014. It is required for the Government of Myanmar (GOM) to sufficiently supply low-cost base power while suppressing the CO_2 emission level as much as possible following the international agreement of COP21.

(7) Figure 7.3.1 presents the trial calculation of the average CO_2 emission level per MWh of electricity generation in the 15 countries of the Association of Southeast Asian Nations (ASEAN) and some developed countries. The CO_2 emission level in Myanmar under the Balanced Scenario in 2030 would reach around 0.37 ton/MWh. This level of CO_2 emission is close to the current average of the 15 countries at 0.40 ton/MWh. It is planned in the Electricity MP-2014 that the development of hydros will be sustainably continued.

[28] This corresponds to the fuel of 600 MW x 1.5 units.



Source: Compiled by the JICA Survey Team with assumed generation efficiency and unit emission and based on generation mix by: India to Pakistan: "Power Situation and Policy in Asia and Oceania Countries", May 2015, JETRO
USA to Japan: METI, http://www.enecho.meti.go.jp/about/pamphlet/pdf/energy_in_japan2016.pdf
Unit emission was tentatively assumed to be zero for hydro, nuclear, import, RE and others.

Figure 7.3.1 CO_2 Emission Level per MWh of 15 Countries of the ASEAN and Some Developed Countries

National Grid

(1) In Myanmar, large-scale hydros are situated in the north while the load center of Yangon is situated in the south. Main gas thermals firing imported LNG would be located rather close to Yangon. Putting aside the two mine-mouth coal thermals, those coal thermals firing imported coals would be situated in the southern peninsula. However, according to Electricity MP-2014, the power flow of more than 3,000 MW in 2030 would be from north to the Yangon area. Accordingly, the 500 kV transmission lines currently under construction would not be sufficient and 500 kV lines of the Second Phase is judged necessary and planned. The gross investment on transmission expansion from 2016 to 2030 would amount to USD 5.75 billion.

7.3.1.2 Myanmar Energy Master Plan 2015

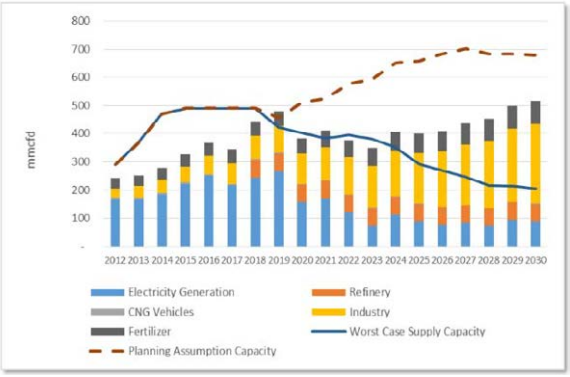
(1) The share of the primary energy in 2015 by hydro was 5% and by coal at 2%. It is forecasted that there will be an increase to 11% by hydro and 20% by coal in 2030 (Figure, E9 and E10, Myanmar Energy Master Plan, ADB, December 2015). On the other hand, biomass (mainly firewood and charcoal) is being used for home cooking which shared 55% in 2015. This will, however, rapidly drop to 33% by 2030 as a result of rural electrification.

(2) Of the final energy demand, home cooking demand remarkably decreased from 58% in 2012 to 34% in 2030[29]. On the other hand, industrial demand will sharply increase from 6% to 26%. Transport demand will increase as well from 11% to 17%.

(3) According to the worst case forecast of gas supply-demand balance, the supply shortage would

[29] Figure E3

become apparent in 2018 onwards and the supply-demand gap will continue its expansion towards 2030. To meet the growing gas demand, commissioning of new gas field M3 in 2019 and LNG import from 2020 will be required. According to Figure 7.3.2, gas consumption of the power sector would start to drop sharp from 2020. Instead, it allocates the reduction in the power sector to the industrial sector. This figure may have deducted the imported LNG from the gas demand of the power sector.



Source: Myanmar Energy Master Plan, ADB, Dec. 2015, p. xi

Figure 7.3.2 Supply and Demand of Natural Gas by Sector

7.3.1.3 Presentation Material "Power Development Opportunities in Myanmar" at Myanmar Investment Forum 2017

The Myanmar Investment Forum 2017 was held in Nay Pyi Taw on 6-7 June 2017. The Chief Engineer of the Electric Power Generation Enterprise (EPGE) introduced the present status and investment projects as "Power Development Opportunities in Myanmar".

(1) Coals are administered in Myanmar by the Ministry of Natural Resources and Environmental Conservation. Renewable energy is jointly administered by the Ministry of Education; Ministry of Agriculture, Livestock and Irrigation; Ministry of Electricity and Energy; Ministry of Natural Resources and Environmental Conservation; Myanmar Engineering Society; and Renewable Energy Association Myanmar.

(2) Energy Strategy of Myanmar

- In the extraction and utilization of natural resources, foreign and local investments are encouraged while the environmental impacts shall be minimized.
- By observing the ASEAN and international energy pricing policy for defining the energy pricing, power purchase agreement (PPA) for independent power producer (IPP) and wholesale price for electricity supply enterprise (ESE) will be determined at reasonable levels while ensuring the stable electricity supply and fair retail price for consumers.
- Privatization of the power sector will be progressed.
- To generate more electricity, not only hydros, renewables, and thermals but also other

energy resources should be utilized.

- To reinforce the reserved power.

(3) The gross electricity consumption amounted to 15,355 GWh in 2015-16 and the per capita consumption reached 300 kWh/yr. The sector share was 49% by domestic, 30% by industry, 19% by commercial, and 2% by others. All of the 422 townships in Myanmar have been electrified. Of the 63,859 villages, 50% were electrified. Of the 10.9 million households, 38% were electrified.

(4) Generation share in 2016-17 was 55% by hydros, 45% by gas thermals, and less than 1% by others.

(5) The total length of transmission lines of 66 kV and above reached 11,364 km, and the gross capacity of substations reached 10,308 MVA.

(6) The share of installed capacity of power stations by ownership was 60% by state, 18% by joint venture/build-operate-transfer (JV/BOT), 12% by IPP/BOT, 10% by IPP/rental. In terms of generation in 2016-17, the share was 52% by state and the rest of 48% by private. The private sector generated with higher energy share than the capacity share of the generating facilities. With the background of this high share would be the duty of GOM to buy up all the electricity that is generated by IPP in accordance with the PPA based on take or pay.

(7) Generation projects under construction were 1,691.6 MW by hydros, 649 MW by gas thermals, and 470 MW by solar. It is very remarkable that the solar power is under construction with a capacity comparable to gas thermals.

(8) Transmission lines of 66 kV and above were under construction for a total length of 1,329 km. Substations are under construction at 38 sites. Facilities of 3,655 MVA in total are under installation.

(9) Two of the hydro power stations, with 53 MW in total capacity are under rehabilitation with Japanese yen loans and 528 MW are awaiting rehabilitation. At the Thaketa gas thermal, 57 MW are under rehabilitation with Japanese yen loan. The solar power will be installed at three places with 90 MW in total capacity on the existing reservoirs of hydropower.

(10) The power demand in 2030 will be 14,500 MW in high case and 9,100 MW in low case. In the balanced scenario to meet this demand, it is planned to increase the total generation capacity at 23,600 MW. Its generation mix is 38% by hydros, 20% by gas thermals, 33% by coal thermals, and 9% by renewables.

(11) GOM targets to achieve an electrification level of 100% by 2030. Of the total households, 99% will be electrified by the grid extension while the rest or 1% by distributed generation sources. The investment for electrification is estimated to be USD 40 billion. Of these, the connection costs were estimated to be about USD 5.4 billion for about 6.80 million households. Within the

planning period of the First Five-year Plan (2015-2019), electrification of 1.70 million households are planned. The World Bank loan amounting to USD 400 million is provided. However, USD 270 million is still further required.

(12) According to the Long Run Generation Expansion Plan, the total capacity of hydro facilities in 2030 is planned to be 8,896 MW. On the other hand, hydros introduced as investment opportunities amounted to 35,712 MW in total. This corresponds to 4.0 times the capacity required by 2030. Hydros of 35,712 MW in total would better be considered as the catalogue for possible investment rather than of the investment plan.

(13) In the similar manner, the Long Run Generation Expansion Plan includes coal thermals of 7,940 MW in 2030. On the other hand, the total capacity of the envisaged coal thermals amounts to 9,825 MW. This is 124% of the required inputs of new coal thermals. This 124% level may be appropriate as envisaged projects are for implementation planning.

(14) According to the Long Run Generation Expansion Plan, gas thermals are planned at 4,758 MW in 2030. The existing gas thermals in 2015-16 have a total capacity of 1,623 MW. It is planned to implement new gas thermals by 168 MW by the state, 601 MW by JV/BOT, and 769 MW in total. The sum of the two will remain at 2,392 MW. Further new gas thermals will be required by 2,366 MW.

(15) The production and quota of natural gas fields are presented in Table 7.3.1.

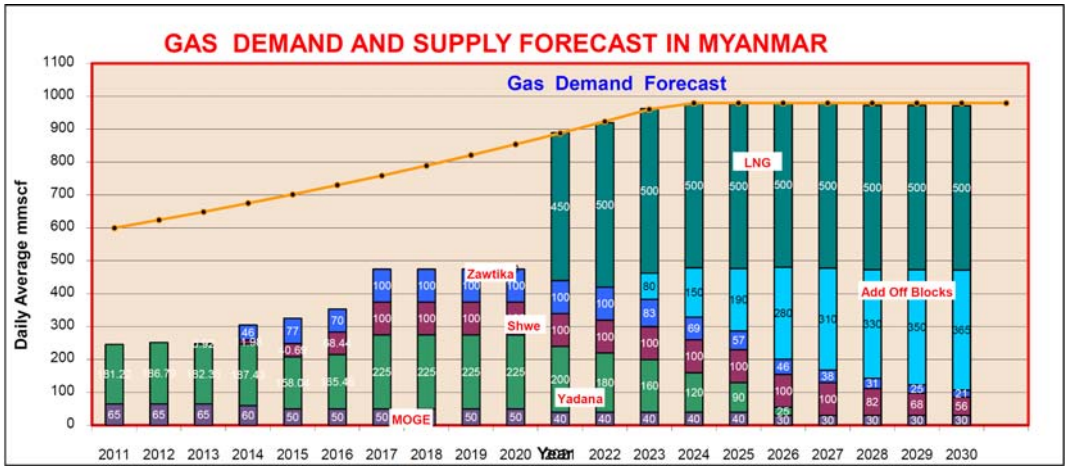
Table 7.3.1 Production and Quota of Natural Gasfields in Myanmar

Unit: MMscfd

No.	Gas Field	Production	Dometic	Export	Remarks
1	Yadana	850	200	650	
2	Yetagun	250	0	250	
3	Shwe	550	100	450	Domestic supply may be increased to 150 by reallocation.
4	Zawtika	330	80	250	
Total		1,980	380	1,600	

Source: Prepared by the JICA Survey Team based on the Power Development Opportunity

Of these, as shown in Figure 7.3.3, the production of Yadana gasfields will start to decline from 2021 while Zawtika from 2023.



Source: Power Development Opportunities in Myanmar, EPGE, June 2017

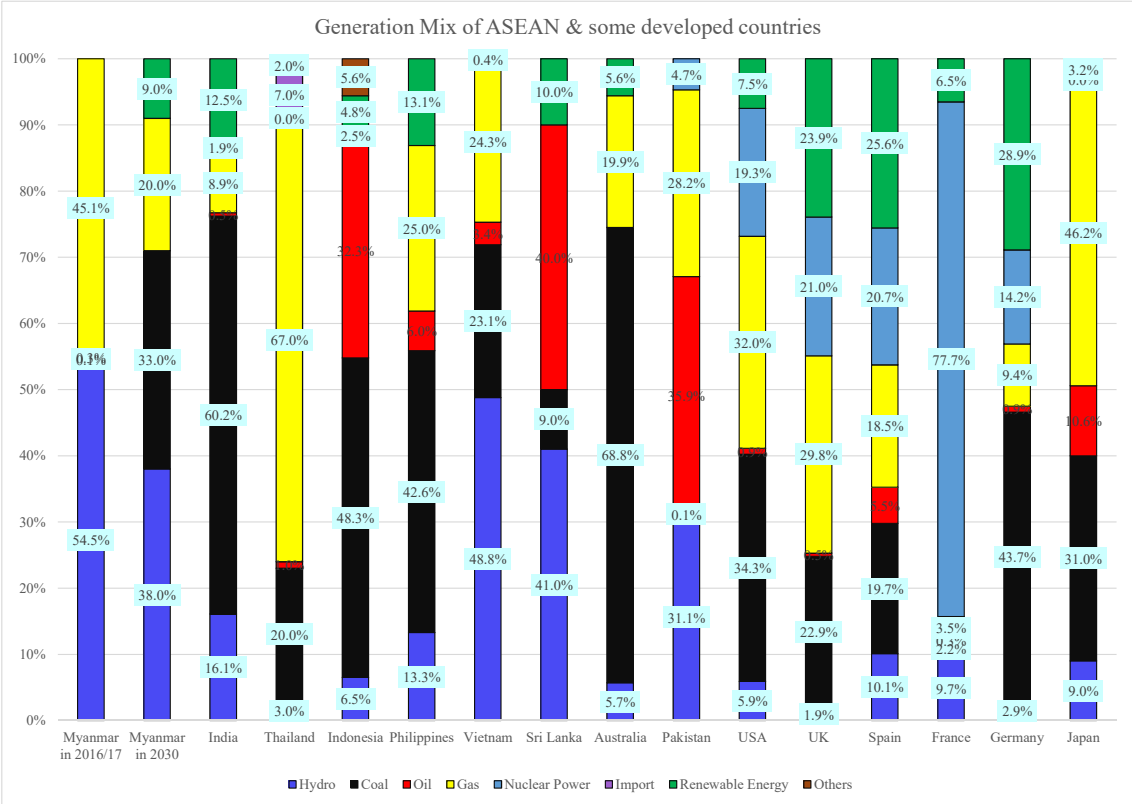
Figure 7.3.3 Supply-Demand Forecast of Natural Gas

While domestic gas production will decline, the gas demand will sharply increase. Accordingly, it is planned in Figure 7.3.3 to start LNG import from 2021. As one of the countermeasures to facilitate urgent import of LNG, Floating Storage and Regasification Unit (FSRU) is being studied. The Pre-Feasibility Study of FSRU was supported by the World Bank and was completed. Tender will be noticed for feasibility study (FS) and Supply of FSRU.

7.3.1.4 Generation Mix of the ASEAN Countries

Figure 7.3.4 shows generation mix of 15 countries of the ASEAN and some developed countries. The following may be observed from the figure below:

(1) According to the generation mix of the 15 countries, there are countries whose generation mix is greatly shared by certain source(s) of energy. In France, 78% was by nuclear probably for the energy security and low costs. In Australia, the share by mine-mouth coal thermals amounted to 69%. At the same time, the domestic LNG is given priority for export while power generation by gas thermals remained at 20%. Also in India, coal thermals firing domestic coals shared 60%. In Thailand, construction of new coal thermals got stacked due to environmental issues. As the result, the gas thermals firing domestic gas from the Gulf of Thailand and the gas imported from Myanmar shared as high as 67%. Hydro share in Myanmar is also significantly high at 55%.



Source: Compiled by the JICA Survey Team with assumed generation efficiency and unit emission based on generation mix by: India to Pakistan: "Power Situation and Policy in Asia and Oceania Countries", May 2015, JETRO
USA to Japan: METI, http://www.enecho.meti.go.jp/about/pamphlet/pdf/energy_in_japan2016.pdf

Figure 7.3.4 Generation Mix of 15 Countries of the ASEAN and Some Developed Countries

(2) Next, countries whose generation mix by three to five sources were observed. In Myanmar in 2030, it approaches towards best mix in accordance with the Balanced Scenario of Electricity MP-2014. In Indonesia, coal thermals with 48% share and oil thermals with 32% from the two major generation sources. In addition, hydropower with 7% and geothermal with 5% are also domestic and renewable energy sources. Thus, Indonesia maintains high level of energy security. In the Philippines, the generation share is 13% by hydros, 43% by coal thermals, 6% by oil thermals, 25% by gas thermals, 13% by geo-thermals, etc. Thus, the Philippines maintained a variety of generation mix between the domestic and imported energy resources. In Sri Lanka, the generation mix is 41% by hydros, 40% by oil thermals, forming two major sources of generation. However, coal thermals and renewables shared 19% in total.

In Pakistan, the share is 31% by hydros, 36% by oil thermals, and 28% by gas thermals, which formed the three major sources of generation with a total share of 95%. The high share of oil thermal may probably be the result from priority supply of oils from the Gulf countries. In the United Kingdom (UK), the United States of America (USA), and Spain, the generation share is distributed to three to five sources. In Germany, there remain aged coal thermals from the time of old East Germany and coal thermals shared 44%. However, Germany promoted solar power policy and the share of renewables amounted to 29%. The policy invited the sharp rise in the

electricity tariff. In Japan, all the nuclear power stations were shut down after the Fukushima accident, gas thermals rapidly increased its share to 46% and coal thermals also shared 31%.

(3) Next, the share of coal thermals in Asia and Oceania countries is observed. In general, the share ranges from 40% to 60%. It is exceptionally low in Myanmar and Pakistan at 0.1%. Instead, in Myanmar, hydros and gas thermals supplied most of the electricity. On the other hand, in Pakistan, oil thermals showed higher share at 35.9%. After these two countries, countries with low share of coal thermals are Sri Lanka at 9% and Viet Nam at 23.1%. In Viet Nam, hydros shared 48.8% being high after Myanmar. However, Viet Nam has the energy policy to gradually reduce the hydro share, supply of which is subject to rainfall. The hydro share will be significantly lowered to 11.8% by 2030 and the generation mix will be shifted to coal thermals.

(4) In developed countries except for France whose generation is dominated by nuclear power, the share of coal thermals is above 20%. In UK and Spain, it is rather low at around 20%. In Japan, USA, Germany, and Australia, the share is higher than 30%. (In Japan, the coal share has increased after the Fukushima accident in 2011.)

(5) In Myanmar, the coal share in 2030 is planned to be 33%. This is lower than the general share of 40～60% in Asia and Oceania countries. However, the coal share in Thailand remained at 20%. The planned share of Myanmar in 2030 will exceed the current level of Thailand. On the other hand, while the current coal share in Viet Nam is 23%, the generation mix will be shifted to coal thermals by lowering the hydro share. The planned shift to coal thermals in Myanmar and Viet Nam would show that coal thermals are the inevitable choice to meet the increasing power demand accompanying the remarkable economic growth.

(6) According to the World Energy Outlook 2016, the International Energy Agency (IEA), describes "Coal as a rock in a hard place" on page 27 as quoted below.

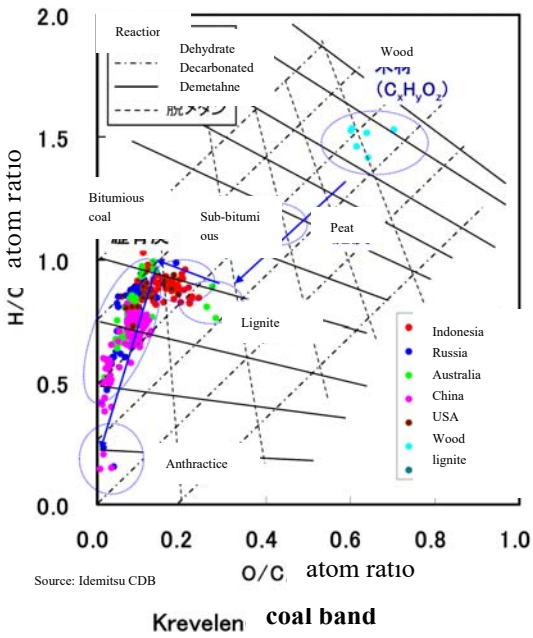
> *"With no global upturn in demand in sight for coal, the search for market equilibrium depends on cuts to supply capacity, mainly in China and the United States. There are stark regional contrasts in the coal demand outlook. Some higher income economies, often with flat or declining overall energy needs, make large strides in displacing coal with lower carbon alternatives. Coal demand in the European Union and the United States (which together account for around one-sixth of today's global coal use) falls by over 60% and 40%, respectively, over the period to 2040. Meanwhile, <u>lower income economies, notably India and countries in Southeast Asia, need to mobilise multiple sources of energy to meet the fast growth in consumption; as such they cannot afford, for the moment, to neglect a low cost source of energy even as they pursue others in parallel</u>. China is in the process of moving from the latter group of countries to the former, resulting in a decline of almost 15% in its coal demand over the Outlook period. China is also instrumental to the way that the coal market finds a new equilibrium, after the abrupt end to the coal boom of the 2000s. China is administering a number of measures to cut mining capacity, a move that*

has already pushed coal prices higher in 2016 (after four straight years of decline). If, however, the social costs of this transition prove too high, China could ease the pace of supply cuts, raising the possibility of China becoming a coal exporter in order to get rid of surplus output: this would prolong the slump in the international market. Alongside measures to increase coal-plant efficiency and reduce pollutant emissions, the long-term future of coal is increasingly tied to the commercial availability of carbon capture and storage, as only abated coal use is compatible with deep decarbonisation."

7.3.1.5 Overview of Coal Thermals

Introduction of coal thermals in Myanmar is indispensable to meet the growing power demand in the medium to long term with the reasonable level of the electricity. Preceding the study on issues and countermeasures of the power sector, the basic information on coal thermals is outlined below.

(1) Quality of Coals: The main coals available in Myanmar are sub-bituminous coals as shown in Figure 7.3.5.



Source: Basic of Coal, Idemitsu, Basic Course of Coal, JCOAL 2012, slide #4

Figure 7.3.5 Classification of Coals by Carbon Contents and Heat Value

(2) Environmental Technology of Coal Thermals

Coal thermals supported the rapid economic growth in Japan after the World War II. After the air pollution became public issues in the 1960s, emission of particulate matter (PM), nitrogen oxides (NOx), and sulfur oxide (SOx) was managed to clear the environmental standards through technology development of environmental devices in the 1970s. As a result, Japanese technology for environmental devices achieved a marked progress. Also, what supports the Ultra Super-Critical (USC) technology is the material developing technology of Japan which

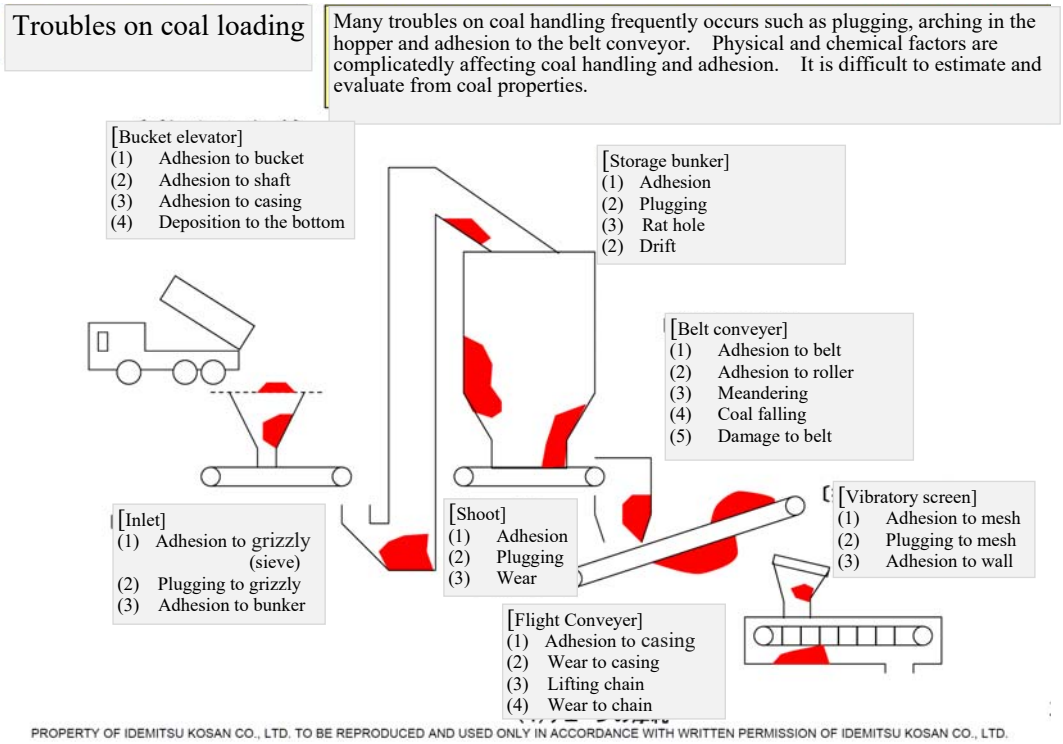
ranked top level in the world, that is, the material to maintain durability under USC high temperature and pressure. The thermal efficiency of coal thermals also maintains the world top level. However, kW price increased as a result of pursuing high level environmental devices and high efficiency.

In China, many coal thermals, factories, and home heaters in the winter emit pollutants to the air. The total volume of pollutants exceeds the permissible level thus causing serious air pollution in Beijing.

(3) Handling of Coals

The 660 MW class coal thermals are of the preferred scale and relatively easy to handle. There are many plants of this class in Japan. China also started to have a plant for export of this scale. In Pakistan, four units of China-supplied coal thermals will shortly start their operation. The Hongsa coal thermal in Laos is also of this scale and was supplied by China. Monitoring of these coal thermals will be the forerunning examples for Myanmar. There are cases in the past that various difficulties and obstacles were experienced on the coal thermals supplied by China. It is very important to completely understand the hazards in that way it will avoid any opposition as experienced in Thailand.

Coal is solid. When it is used as fuel, various troubles would take place such as adherence to, clogging of and erosion of coal-feeding pipes, rat holes in bunker, damage by erosion, meandering of belt-conveyer, coal-falling, clogging of screen mesh, etc.



Source: Basic of Coal, Idemitsu, Basic Course of Coal, JCOAL 2012, slide #32

Figure 7.3.6 Places of Troubles Often Occurred During Coal Handlings

(4) Efficiency Improvement of Coal Thermals: SC and USC

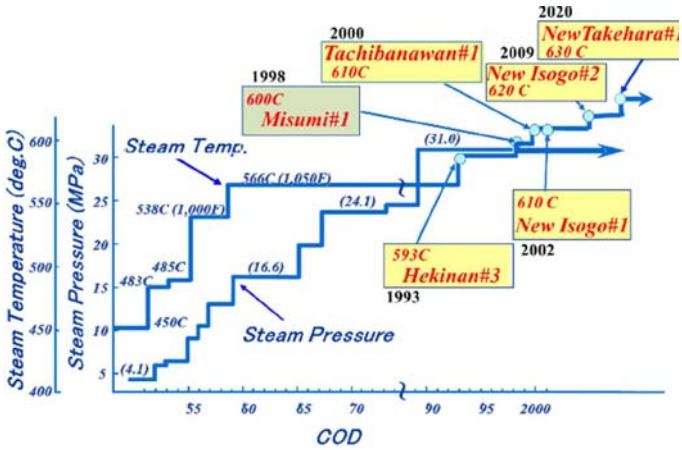
Historical development of coal thermal technology from Sub-Critical (Sub-C), Super-Critical (SC) to Ultra-Super Critical (USC) is illustrated in Figure 7.3.7.

When the plant management is undertaken through BOT including Japanese power company, even coal thermals of USC may be operated and maintained without major problems owing to the participation of engineers who have a lot of experience in the operation and maintenance (O&M) of similar plants. However, there remains an issue as to whether the country can continue the O&M after the transfer of BOT projects. In the case of GOM, the conventional method would be favored over the BOT or build-own-operate (BOO) if public loans are provided, in order to facilitate transfer and learning of technology for inspection and maintenance. In that case, it is desired and recommended for Myanmar to first acquire the basic technology through O&M of Sub-C coal thermals. After mastering the basic coal technology, it is advised to proceed to the USC coal thermals.

Because of high steam pressure and temperature rise, more impurities would be deposited inside the steam pipes. To cope with the impurities deposition, a device to improve the purity of boiler water (desalinization device) is attached to the circulating system of the boiler water. In the steam drum of Sub-C coal thermal, steam and water are separated; and concentrated impurities are included in the water. The impurities can then be removed by draining part of the water out of the boiler system.

The overheating pipes of SC and USC boilers are always exposed to high temperature of 566 ℃ (SC) and 600 ℃ (USC) . A little change in the steam temperature (within ±3～4 ℃, +7 ℃ is the abnormal value in monitoring) will expedite the degradation of steaming pipes by Low Cycle Fatigue, which may lead to fatal failure.

High Cycle Fatigue is the mechanical fatigue of metals caused by physical vibration. The materials of steaming pipes are not crystal but with particle boundary. Viewing microscopically, there is a contact between particles. Low Cycle Fatigue (heat fatigue) is caused by the contact between the particles which repeat expansion and contraction along with temperature changes and gradually weakens. SC and USC have higher steam conditions beyond the critical point. Then much more strict management of operation conditions (purity of the boiler water, sticking to the steam temperature specified) will be required.



Source: CCT Handbook for Power Generation, © Japan Coal Energy Center (JCOAL), February 2017

Figure 7.3.7 Development in Japan of Steam Boiler Temperature and Pressure

(5) Antecedents of Coal Thermals in ASEAN Countries

(a) **Thailand**: According to the "Power Situation and Policy of Asia and Oceania Countries", JETRO, May 2015, in Japanese, better past experiences are introduced on the introduction of coal thermals in Thailand. These are partly quoted below.

Coal thermal started power generation in 1984 with ADB support, fueling the lignite produced in the Mae Moh area. The station emits SOx at 1.60 million ton/yr. The gas emission caused health hazard, paddy withering, water pollution, etc., which became the problems among the people around. In the station, appropriate environmental devices were not attached. When mobile clinic visited the site in 1988, 8,214 patients were observed including 3,463 patients with respiratory illness.

- ellipsis -

BLCP Coal Thermal of IPP led by Hong Kong started power generation in 2006 in Rayong Province (about 130 km to the southeast of Bangkok). At the construction site, not only the people around the site but also international NGOs like Green Peace spread the opposition movement from the viewpoint of fear caused by mineral pollution from coal and global warming. Gheco Coal Thermal (660 MW) was constructed by local IPP in Rayong Province in 2012. The local Association for Anti-Global Warming and organizations bring the authority, who issued approval for construction, to the Rayong Local Court in April 2014.

As to the H (Hinkurutto, 1,400 MW) and B (Bonoc 734 MW) coal thermals, the opposition by the people around the site, who worried about the coal hazard and impacts on marine resources, was so strong and GOT gave up the plan. Thereafter, the leader of the opposition group was shot dead. The National Power Coal Thermal (540 MW) in Chachoengsao Province targeted commissioning in 2014. However, the opposition by the people around the site was very strong. The EIA was disapproved in 2013.

It is well recognized among the government officers and business leaders that the coal thermals are very important to lower the excessive dependence on the gas thermals and achieve the best mix of the generation sources. It is considered that the environmental pollutions can be overcome. However, the negative images of coal thermals that have deeply permeated into the mind of the people could not be swept off instantly.

(b) **Laos**: The Thailand power company, Ratch-led IPP, constructed Hongsa coal thermals (1,878 MW) in Laos on the west bank of the Mekong River. The plant was commissioned in 2016.

(c) **Viet Nam**: There is anthracitic (smokeless) coal mine in the northern Viet Nam. Viet Nam has experience in coal thermals. They have rich experience in operating 300 MW class coal thermals of Sub-C pressure. In the recent years, USC coal thermals of 600 MW firing imported coals were commissioned one after another. The Bac Lieu Coal Thermal was scheduled with JICA's yen loan. However, due to the opposition raised in the site followed by the change of Prime Minister, the project was suspended.

(d) **Malaysia**: Sumitomo Corporation was awarded with No. 5 Unit (1,000 MW x 1 unit) of Manjung Coal Thermal of USC technology. It is scheduled to be commissioned in autumn of 2017. The contract price is JPY 130 billion. Boiler will be supplied by Mitsubishi Heavy Industry (MHI) and steam turbine by Daelim. The Manjung Coal Thermal has been in operation with 700 MW x 3 units and 1,000 MW x 1 unit.

(e) **Myanmar**: Toyo-Thai (TTCL) planned a coal thermal in Ye, Mon Region and concluded a MOU with the previous government. However, it faced strong opposition from the people and the Mon Governor finally declared withdrawal of the Ye Coal Thermal in July 2017.

(f) **Bangladesh**: Matarbari Coal Thermal has an installed capacity of 600 MW x 2 units＝1,200 MW. There is no suitable site for deep seaport in Bangladesh and the site was selected in the Matarbari Island situated about 70 km to the south of Chittagong. The Japanese yen loan was provided at JPY 500 billion including port construction. In July 2017, the contract was concluded with the Japanese consortium of Sumitomo-Toshiba-IHI. The construction period is seven years and the project commissioning is scheduled to be in July 2024. In Bangladesh, generation share is dominant with gas thermals as high as 80% which fire the domestic natural gas. However, gas production started declining and would be exhausted within a ten-year period. Accordingly, it is required to identify another source of energy. There are no hydropower resources in Bangladesh which has no mountain and head for hydropower. The power policy, therefore, plans to introduce thermals fueled by imported coal and imported LNG.

7.3.2 Issues of Power Sector

7.3.2.1 Summary of Review of Existing Development Plans and Latest Sector Information

(1) **Power Masterplan 2014**: The generation mix of Myanmar in 2020 by Balanced Scenario is presented in Table 7.3.2. Also presented in the table are the required capacities to be extended compared to the existing ones in 2016-17. It will be required to extend hydros by about 5,600 MW, gas thermals by 2,800MW, coal thermals by 7,800 MW and renewables by 2,000MW. To implement such great scale of capacities, financial arrangement, private sector participation and proper addressing to the environmental impacts will be very important.

Table 7.3.2 Generation Mix in 2030 and Required Developments by Fuel

Unit: MW

Timing	Hydros	Gas	Coal	Diesel	Renewables	Total
2016-2017	3,255.18	1,919.9	120	94.3	-	5,389.37
2030 (Balanced Scenario)	8,896 (38%)	4,758 (20%)	7,940 (33%)	-	2,000 (9%)	23,594 (100)
Required extension	5,640.82	2,838.1	7,820	-	2,000	18,298.93

Note: Figures in parentheses show the share to the total capacity.
Source: Prepared by the JICA Survey Team based on the existing development plans.

(2) **Energy Masterplan 2015**: The hydro share in the total primary energy demand in 2015 is 5% and coal 2%. It is forecast to grow to 11% and 20% respectively by 2030. As to the gas supply-demand balance, it is forecasted the supply shortage will become apparent in 2018 onward and the LNG import will be required from 2020.

(3) **Power Development Opportunities in Myanmar**: The Ministry of Natural Resources and Environmental Conservation (MONREC) administers the coal resources. The generation mix in 2016-17 was hydros at 55%, gas at 45% and others less than 1%. Generation projects under construction were hydros at 1,691.6 MW, gas at 649 MW, solar at 470 MW. The power sector targets the achievement of 100% electrification by 2030.

(4) **Generation Mix in Asia and Some Developed Countries**: In some Asia and Oceania countries, the coal thermal share was in the general range of 40%～60%. In Myanmar it is planned to raise the coal thermal share to 33% by 2030. However, this level is still rather low compared to the general share of 40-60% in some Asia and Oceania countries. IEA describes in its World Energy Outlook 2016 "*Coal demand in the European Union and the United States falls by over 60% and 40% respectively over the period to 2040), lower income economies, notably India and countries in Southeast Asia, need to mobilise multiple sources of energy to meet the fast growth in consumption; as such they cannot afford, for the moment, to neglect a low cost source of energy even as they pursue others in parallel.*"

(5) **Overview of Coal Thermals**: Coal thermal technologies are classified by its steam temperature and pressure as Sub-Critical (Sub-C), Super-Critical (SC) and Ultra-Super Critical (USC). Of these, SC and USC will be exposed to super-critically high temperatures, even

small changes in the steam temperature has a risk to lead to fatal fault. Mae Moh coal thermal constructed in the Thailand in 1980s caused serious environmental impact. This triggered the practical ban of construction of new coal thermals in Thailand. It is not easy to sweep off the negative images of coal thermals deeply permeated into the mind of the people.

7.3.2.2 Issues of Power Sector in Myanmar[30]

(1) **Retail price lower than costs and subsidies**: It is not easy to raise the retail price of electricity. GOM subsidized electricity price in 2016-17 by MMK 23/kWh. It amounted to about MMK 420 billion or about JPY 34.0 billion. Purchase price of solar power, which will start generation in 2018, is MMK 175/kWh. This rate is higher than the average retail price of MMK 35～150/kWh. The average CO_2 emission level per kWh of Myanmar is the world lowest level. It would be necessary that the renewable energy policy be reviewed for short to medium term in particular.

(2) **Shortage of developing fund**: Hard currencies will be required to make payments to foreign JV/BOT generation projects. However, foreign currencies are short; therefore, payment may face difficulty. The gas export payment will be received in hard currencies. LNG import will need payment in hard currency. The payment for LNG import would be managed within the account of gas export-import. It would be effective to lower the generation costs if GOM obtains long term and low interest rate loans from international financing agencies and provides the fund to low-cost base power (hydros and coal thermals).

IPPs would often request Government Guarantee for payments. This issue also could be mitigated with the state-led generation projects with public loans. Invitation to IPP projects without Government Guarantee may be responded only by domestic investors. However, domestic IPPs alone could not invest on whole of the projects required.

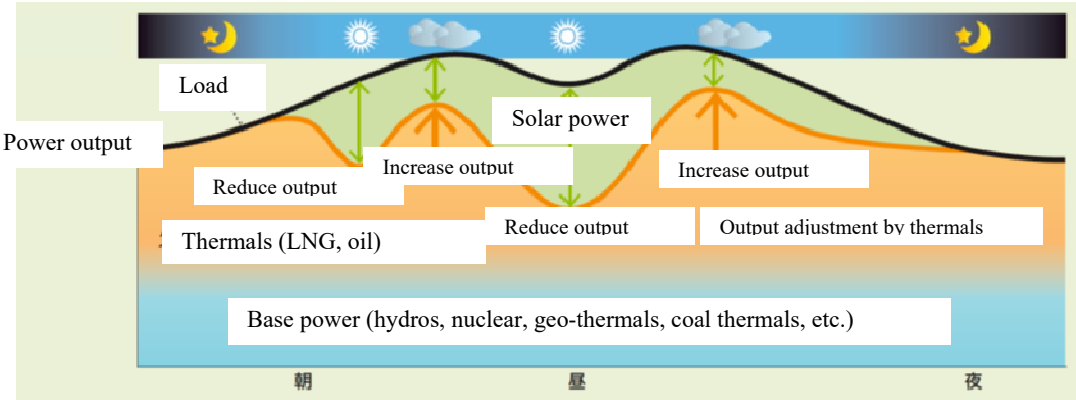
(3) **Costs required to backup renewables**: The national grid of Myanmar may have technical issues to stably absorb as much renewables as 9% of the gross generation capacity. There is the target to introduce renewables towards 2030. However, its promotion policy has not been established[31].

The production cost of renewables like solar power is in general rather high compared with hydros and gas thermals. Therefore, in some countries, Feed-in Tariff (FIT) is introduced to provide price incentive. In some countries, Port-Folio is introduced to require power companies to have certain share of renewables in their total generation. However, renewables require EPGE to maintain the generation capacity to back up the solar power connected to the national grid during cloudy time and nighttime (Figure 7.3.8). EPGE owes the duty to always supply power to the consumers. This supply duty will require EPGE to construct and maintain the same amount of generation capacity in duplication with the solar power capacity. In other words, EPGE or GOM

30 The issues the JICA Survey Team recognized will be introduced. These are based on the hearing and discussion to the officers of the power sector in mid-June to early July 2017. News articles of Myanmar Times "Only high-tech firms for hydro, coal power, Chan Mya Htwe" dated 30 June 2017 was also used as reference.

31 Myanmar Times, dated 30 June 2017.

will require to buy solar power at subsidized price on one hand and need capital costs for the backup facility on the other hand. This will lead to the rise in the average generation costs. It is planned to introduce such renewables as much as 2,000 MW by 2030 (Electricity MP-2014). In Minbu, Magwe Region, the first phase of 40 MW of the solar plant (170 MW) will be commissioned in mid-2018. The Green Earth Power of Thailand will manage the project under BOT contract for a 30-year period. The power purchase agreement (PPA) is US¢ 12.75/kWh (MMK 175).



Source: Energy in 2016 of Japan, Q13, Agency for Natural Resources and Energy, Japan

Figure 7.3.8 Can We Manage Grid Only with Renewables?

Unit construction cost of large-scale solar system of 10s MW class is assumed at USD 2/kW, about USD 4 billion in total will be required to implement 2,000 MW solar as planned in the MP-2014. Assuming both foreign and domestic private sectors can mobilize such big fund, the investment will be recovered by the payments to IPPs out of the power revenue plus subsidy of GOM. However, such power tariff and subsidy will have to finally be borne by the people or consumers.

The national power account requires subsidies of MMK 420 billion at present. There may be a question if the challenge to pursue the renewable policy under the current economic situation meets the national interests. Review and discussion on the policy may be necessary. It may be suggested that the policy be reviewed including the following:

(a) From the viewpoint of CO_2 reduction, hydros are renewable and may be classified as renewable energy. Hydros are classified as renewables in the Philippines.

(b) It might be an option to give priority, during the short MP period till 2030, to secure the low-cost base power (hydros and coal thermals) and stable supply. Hydros will reduce the average CO_2 emission level.

(c) Renewables like solar power, wind power could be utilized as distributed power source of isolated mini-grid or home electrification in remote mountainous regions.

(4) **Issue of coal thermals-Information sharing on the mitigation effects of environmental impacts**: As presented in Electricity MP 2014, it is indispensable to introduce low-cost hydros and coal thermals and expansion of related transmission and substation system. Securing a long-term stable supply-demand balance and maintaining the appropriate price level would control the economic growth of Myanmar.

On the other hand, many have deep concern on the environmental and social impacts of large hydros and coal thermals. In the developed countries, advanced coal thermals are equipped with the latest environmental devices, all of PM, NOx and SOx strictly meet the environmental standards of respective countries. However, the first coal thermal in Tigyit installed in 2004 by China was not equipped with these environmental devices. It is reported that serious environmental impacts were caused on the surrounding environment[32.] In Myanmar, relevant information were provided to the people to date; some of them were dispatched to Japan for inspection of the actual situation around the coal thermals in Japan. Those who attended such inspection well understood the fact that environmental impacts as observed around Tigyit were not present around the coal thermals of Japan. It is inferred that many of the people still have or feel serious concerns due to insufficient information sharing.

GOM stopped the operation of Tigyit in 2014, and invited IPPs in replacing boilers and steam turbines and adding environmental devices. The Wuxi Huagaung Electric Power Engineering, China was awarded and concluded the BOT Contract in October 2015. The renovation works and test operation were reportedly completed by July 2017. It has not been verified if the monitored figures of emission to the environment during the test operation are correct. It is important to train the monitoring experts on the side of Environmental Administration in Myanmar.

It will require a long time to hold public hearings and provide correct and sufficient information to the people. Implementation of low-cost base power will require long lead time. However, long lead time is required and it is very important to overcome the issue by providing the correct information to the people.

Issue of coal thermals in Myanmar: In the Myanmar power sector, the subsidy to the power tariff amounted to MMK 420 billion (JPY 34.0 billion). In parallel with the raising of power tariff, it is essentially required to increase the low-cost base power. One of the base powers is coal thermal. In Myanmar, the main coal sources and planned scale are listed below:

- Kengtong, Shan, 660 MW
- Kalewa, Sagaing, 600 MW
- Imported coals, 8,565 MW (gross installed capacity required until 2030)

[32] Poison Cloud

The critical issue common to the above is the negative feeling of the people, which originated from the serious environmental impacts around the Tigyit Coal Thermal. In other words, insufficient information sharing on the actual mitigation effects of the latest environmental devices attached to coal thermals in the developed countries created negative impact to the people.

(5) **Promotion of site selection for coal thermals**: In the case of coal thermals firing imported coals, there would be three technical issues as listed below:

- Wide land of about 50 ha with good drainage for storing coals for a two-month operation (annual coal volume of about 4.5 million tons for 600 MW x 2 units). For 8,565 MW required until 2030, the land required will be some 400 ha in total;
- Deep seaport of 13 m in depth is desirable to import coals by large ships;
- Regulation of the gross (total) emission amount in certain urban area; and
- High voltage transmission lines are required to transmit the power generated to the load center in Yangon.

The four issues above will be all the pre-conditions in selecting the site of coal thermals.

(6) **Privatization of generation business**: Electricity Law was enacted towards privatization of the generation business. However, the draft Grid Code, Tariff Regulation Law, and Renewable Energy Policy are not in force.

7.3.3 Possible Direction of the Power Sector Policy of Myanmar

(1) **Urgent Reinforcement of Dry Season Generation Capacity by LNG-fired Thermals**: The generation mix of Myanmar is 55% hydro + 45% gas thermals. Since the output of hydros will drop in the dry season, it is reported that the dry season power is in short by about 250 MW. To cope with the power shortage, GOM urgently introduced small gas engine generators (GEGs) on a rental basis. The gross installed capacity of the IPP rental amounted to 10% of the gross capacity of the national grid. As a result of this urgent measure, GOM is involved in the following two issues: The first is the high purchase price because of the short rental contract. The second is GOM is obliged to buy the electricity from IPP rentals in accordance with the contract of Take or Pay basis, which forces releasing part of the inflow of hydro dams through spillways instead of power generation during the rainy season. Since the power shortage in the dry season has not been solved, GOM is obliged to maintain these IPP rental contracts bearing the abovementioned two issues.

To cope with the issues above on short term, (a) urgent import of LNG by Floating Storage and Regasification Unit (FSRU) be realized by 2021 (pre-FS is completed with support from the World Bank); (b) in parallel, large-scale GT fueled by imported LNG be introduced which may

later be combined-cycled one after another in accordance with the growth of the power demand. To achieve the early introduction, these GTCCs may better be undertaken by IPP to minimize the lead time. To lower the generation costs of IPP, it is desired to have public financial support.

(2) **Medium to Long-term Reinforcement by Hydros and Coal Thermals**: In Myanmar, finance for generation and grid expansion is not enough; foreign currencies for payments to IPPs are also in short; government guarantee to IPP is difficult and not practiced. The developing finance is absolutely in short. On the other hand, economic development is rapidly progressing following the liberation policy of foreign trade and investment since 2011. Power demand is growing at the rate exceeding 10% per annum. As a result, GOM has been obliged to depend on small GEGs of IPP rental. The PPA price rose and the subsidy to power tariff amounted to MMK 340 billion (JPY 34 billion).

Therefore, in addition to the short-term measures in the paragraph above, medium- to long-term measures are required to cope with the financial issue, that is, it is naturally required to implement low-cost base power (hydros and coal thermals) in the planned manner. To further lower the average generation costs, it would be necessary and desirable that GOM lead some projects and obtain long-term public loans of low interest rate.

(3) **Privatization:** Privatization of generation business may promote progress in the LNG-fired gas thermals by IPP of which capital cost is relatively low and recovered in short time. On the other hand, hydros require high capital costs, need long lead time, and therefore incur risks in recovering initial capital investment. The feasibility study (FS) may be undertaken by GOM with assistance from JICA to shorten the lead time. In parallel with the FS, environmental and social considerations should desirably be executed thoroughly also to shorten the lead time. Thereafter in the planning stage, some of the projects may desirably be led by GOM to promote capacity building and succession of technology to the young generation. Those hydros further required in the long run generation expansion sequence may be undertaken by IPP mobilizing the capital of the private sector. If both state and private schemes are implemented in parallel, sharing the role and finance may be realized. Large-scale coal thermals would be first introduced into Myanmar. It would be wise and prudent that coal thermals be led by GOM in the initial stage to introduce the complicated technology and know-how for operation and maintenance (see paragraph (4) Efficiency Improvement of Coal Thermals: SC and USC on page 7-20 herein) also the O&M staff accumulate the experience to realize the human resources development.

Putting aside the new generation projects by IPP, privatization of state-owned power stations would not be late even if it is done after the per capita gross domestic product (GDP) reaches USD 3,000. There may be certain limits even on the money and business knowhow or manpower of the private sector. It may be prudent that privatization be concentrated for the time being on the new IPP business. Per capita GDP of Myanmar was USD 1,275 in 2016 and gross national income (GNI) was USD 1,190. If the Myanmar economy continues its growth at 10% over the ten-year period in the future, GDP would exceed USD 3,000.

(4) **Information Sharing**: Construction of base power stations (hydros and coal thermals) and related transmission and substation facilities is essentially required. On the other hand, the people are deeply concerned with the environmental and social impacts of the large-scale hydros and coal thermals. It would require a long time to hold public hearing nationwide and provide correct information. A stable power supply at reasonable price will foster the economic growth in Myanmar. Therefore, information sharing with the people will be very important to promote steady implementation of low-cost base power (hydros and coal thermals) and secure the required generation capacity at low costs.

(5) **Export of Secondary Hydropower during the Rainy Season:** In the future when coal thermals and gas thermals are introduced as scheduled, the total of the dry season outputs of hydros and thermal outputs would exceed the level of the grid load plus reserve power. In the rainy season, it would be possible for hydros to generate secondary energy. This secondary energy of hydros may be transmitted towards Yangon in the south. It would be possible to export the secondary energy from Yangon to Bangkok located about 600 km to the southeast. The Thai Grid has gas thermals as high as 67% of the grid generation capacity. Even the energy import during the rainy season would only facilitate the Thai Grid to stop some of its gas thermals and save consumption of gas fuels. The energy that may be exported from Myanmar is of hydros and has very low emission level of CO_2. Therefore, the export will have the merits for the Thai side as fuel saving effect and CO_2 emission reduction effect. The export would be a good deal benefitting both countries.

7.3.4 Cooperation Expected to Japanese ODA in the Power Sector

7.3.4.1 Power Policy and Issue of Information Sharing

In establishing the power sector policy in Myanmar, it would be necessary to collect various information concerned and study on the various policy approaches:

- Confirmation of potential of domestic energy resources (hydros, natural gas, coals, and renewables), information on available experts and technology for each resource development, study on the technical and environmental issues for development, study on the basic plan for development, study on the priority order for development among the energy resources and on the best mix.
- Information on the supply stability in the world and Asian market in particular, price trend, and direction of latest technology development.

If the policy is implemented under insufficient information collection and analysis, it may lead to some problems. In case serious problem takes place, people facing this problem would raise their claims. If it is serious and becomes a social problem, the government would review the policy and would be obliged to take mitigation measures to address the problem. If the policy preparation and implementation are delayed, it would lead to power shortage and/or price rising. The government and

policy are always required to be at their best.

As general discussion, the process of policy preparation and implementation may be of top-down approach. On the other hand, the following two methods are practiced in the modern democratic countries in order for the people to express their will by gathering their needs and reflect these to local and central government policy. The first is the will expression through national election. The second may be for the private sector to propose certain policy and apply for a petition to the government by adopting the policy, or campaign to change or abolish certain existing policy. These may be the bottom-up approach.

Public relation by the government is of top-down approach. Its objective is to explain to or provide information on a certain policy to the people. It may be utilized as justification of a certain policy. However, the original purpose of public relation (PR) is to explain to the people thoroughly by providing sufficient information to deepen their understanding, thus, this will help to implement the target policy. For example, coal thermals of developed countries have cleared their environmental regulations. No environmental hazards are taking place unlike the case of Mae Moh and Tigyit. The PR first provide sufficient and correct information to the people, finally achieving the policy target to realize a stable supply of low-cost electricity.

Observing such information dissemination on the coal thermals, when judged necessarily, it is important for the government to consider direct delivery of sufficient and correct information to the people.

In Japan, after the accidents at the Fukushima No. 1 Nuclear Power Station in 2011, all of the nuclear power stations stopped their operations. According to various censuses of people's perception to the nuclear power, those who consider that nuclear power is dangerous and its share should gradually be decreased or demolished, shared the majority. The nuclear share in the overall generation mix in Japan was 28.6% in 2010. It dropped to zero after the accident. The government plans to restore the share to 20-22% by 2030. New regulating standards are established. In accordance with the new standards, each nuclear plant applied for resumption of the operation is being examined. Of the 60 nuclear plants in total, 15 plants are to be abolished, seven plants were approved for the installation changes of the nuclear reactor, 14 plants are undergoing examination of their compatibility to the new standards, and 19 plants are yet to apply for the compatibility examination. Only five plants resumed operation to date[33].

In Thailand, as introduced in Sub-section 7.3.1.5 Overview of Coal Thermals, Item (5) Antecedents of Coal Thermals in ASEAN Countries, the Mae Moh Coal Thermal constructed in the 1980s was not equipped with environmental devices. As a result, serious environmental hazards took place. Since then, people tend to present extremely negative response to coal thermals. Then, the government gave up in 2003 the construction of two coal thermals. In 2013, the environmental impact assessment (EIA) of other coal thermal was disapproved. New coal thermal could not be constructed thereafter. As a

[33] Current Situation of Nuclear Power Stations in Japan, Agency for Natural Resources and Energy (in Japanese) http://www.enecho.meti.go.jp/category/electricity_and_gas/nuclear/001/pdf/001_02_001.pdf

result, gas thermal share jumped up to 67%, thus creating heavy dependence on gas thermal which is very rare in the world.

In Myanmar, Tigyit Coal Thermal was built in 2004. It was not equipped with environmental devices upon commissioning. People opposed the plans also of other coal thermals which were proposed with environmental devices. GOM publicly invited IPP for renovation of Tigyit Coal Thermal. The renovation was undertaken and three-month test operation is completed to date. One-year reliability run is ongoing. Scheduled input of coal thermals is recognized as indispensable. The policy response to this environmental issue may affect the future energy supply in Myanmar. The power policy stands on the critical ridge between the success and failure sides of the socioeconomic development of Myanmar.

The power policy will be prepared based on various information and through various analysis and planning works. Some parts of their processes and issues are introduced below:

(1) Demand Forecast: Demand forecast by sector and by region. Since the liberalization of foreign trade and investment in 2011, foreign direct investment (FDI) flows into Myanmar and the economic growth was expedited. As a result, the power demand continuously grows higher than 10%. GOM prepared the Electricity MP-2014 which is being updated with the support from JICA. The demand in 2030 would be 9,100 MW even with Low Case and 14,542 MW with High Case. The gross installed capacity at 5,029 MW in 2015-2016 will require the expansion to 23,595 MW in the 15-year period up to 2030. To achieve such great amount of capacity expansion, a very strong policy guide is indispensable.

(2) Generation Expansion Plan: Myanmar has domestic energy resources of hydropower, natural gas, coals, and renewable energy such as solar power, wind power, biomass, etc. GOM prepared the Electricity MP-2014 and set the generation mix in 2030 to be 38% by hydropower, 20% by gas, 33% by coal, and 9% by renewables.

    GOM is required to prepare the power policy which will achieve the generation expansion to 23,595 MW in total in accordance with the generation mix above. However, domestic gas production is limited and cannot meet by far the forecast demand in 2030. LNG import will be required from 2021. Coal import will also be required shortly. Renewable energy is clean and emits little CO_2. However, it is relatively costly and in addition it will require backup capacity of the same scale in the national grid. Hydros require long lead time until commissioning. In the case of dam type hydro, people's resettlement would be required and it would impact on the aquatic ecosystem. In the case of coal thermals, appropriate environmental devices are indispensable. Otherwise, environmental hazards such as PM, acidic rainfalls, etc., would take place. If serious social impacts and environmental impacts are caused in the initial stage of introduction and if the government fails to take appropriate and timely countermeasures, serious mistrust may be grown among the people to the government and IPP promoters.

To overcome these various issues and to develop low-cost generation projects in the required scale for stable power supply, a policy guide is urgently required.

(3) Transmission and Substation Plan: When a new power station is constructed, reinforcement of the transmission lines will be required from the station to the load center. Hydros, coal thermals, and LNG-fired gas thermals, which will receive gas supply from large-scale onshore LNG base, would mostly be located in the remote place from the load center. From these power stations, 500 kV lines may be required. It is also an option to study the gas pipelines from the onshore LNG base up to the gas thermals situated close to the load center.

(4) Privatization: It will be required to expand the grid generation capacity to 4.7 times by 2030. It would be impossible for GOM alone both in financing and manpower inputs to achieve such big generation expansion. The policy guide is required to promote inflow of private sector money, manpower, and efficiency.

7.3.4.2 Technical Cooperation to National Campaign for Information Sharing on Coal Thermals

For the Myanmar power sector, JICA provided technical cooperation to follow up the Electricity MP-2014 and financial cooperation to 500 kV transmission and substation project. The following future cooperation are expected to the power sector:

- Technical Cooperation to National Campaign for Information Sharing on Coal Thermals;
- Technical Cooperation in the Site Selection of Priority Coal Thermals followed by FS and SEA;
- Technical Cooperation in FS and SEA of State Hydros; and
- Economic Cooperation to Priority Hydros and Coal Thermals.

To realize coal thermals as planned in the Electricity MP-2014, the National Campaign for Information Sharing on Coal Thermals may desirably be conducted by the Ministry of Natural Resources and Environmental Conservation, supported by the Ministry of Electricity and Energy in the technical aspects of the coal thermals, with back support from JICA, to provide further sufficient and correct information on coal thermals to the people nationwide. There might be a discussion, “it would be quicker to let IPP undertake such information campaign compared with the government campaign.” However, information sharing to the people forms the main part of the Environmental Policy Administration concerned with coal utilization. It also forms part of the Power Policy Administration. However, as this may take a long time, if the Ministry of Natural Resources and Environmental Conservation jointly with the Ministry of Electricity and Energy will directly provide information to the people, the information sharing would be promoted and deepened.

The national campaign may include the following activities:

(1) First of all, the Ministry of Electricity and Energy may explain the need for the advanced environmental devices of developed countries and provide correct information on the actual

environmental impacts to the top management and staff of the Ministry of Natural Resources and Environmental Conservation. If necessary, it would be an option that they may inspect by themselves the coal thermals in Japan, Beijing, and Delhi in the winter to experience the difference or the need of regulation of the gross emission in the large cities in particular.

(2) Open seminar on Myanmar Energy Policy: It will be explained that coal thermals are indispensable to realize a stable power supply while managing the electricity price within the reasonable level. At the same time, the generation mix of ASEAN countries and some developed countries will be introduced and the need of improving the one in Myanmar will be explained.

- It will be important for energy security to achieve the best mix of generation sources.
- The best mix of Myanmar for the medium term till 2030 will be by hydros, gas thermals, and coal thermals.
- When the best mix is achieved as planned in the Electricity MP-2014, the average CO_2 emission level of Myanmar will increase compared with the current level. The level, however, will remain close to the current average of the 15 countries of the ASEAN and some developed countries. GOM will further endeavor in continuing development of very low-emission hydros, to regulate or even lower the CO_2 emission level by introducing more renewables in the long term and beyond 2030.

(3) Review of the environmental hazards of Tigyit Coal Thermal, data collection on the situation after the renovation made by mid-2017, site inspection and holding a seminar thereon.

(4) Seminar on environmental devices of coal thermals: Latest technologies in the developed countries for PM removal, desalinization, denitration, their effects, and introduction of samples.

(5) Seminar on improving efficiency: Introduction of technology of Sub-Critical (Sub-C), Super-Critical (SC), and Ultra Super-Critical (USC) steam pressure and temperature. The objective of these technologies is not for mitigation of environmental hazards but for achieving higher efficiency, that is, by firing the same volume of coal, EPGE can generate more electricity or can lower the fuel cost per kWh of electricity. As the result of efficiency improvement, reduction of CO_2 emission level per MWh by several percentage can be introduced. On the other hand, however, steam temperature will be 566 ℃ with SC or 600 ℃ with USC above the critical temperature of steam. Then a temperature change even only within several degrees will cause Low Cycle Fatigue which will promote degradation of the steam generating pipes. The fatigue will incur the risk resulting to fatal failure.

(6) Site inspection of coal thermals in Japan, etc., and actual situation of the air: The participants in the Inspection Tour will observe and feel by themselves that the clean air conditions are maintained around the coal thermal of Sub-C technology. It will be explained that the SC and USC technologies are not for conservation of the air environment but for improving the

efficiency, that is, for generating more electricity from the same volume of coals. The efficiency improvement will have the effect to reduce the CO_2 emission level per MWh.

(7) Seminar on COP21 and Myanmar's strategy for regulating CO_2 emission level: In accordance with the Electricity MP-2014, coal thermals will be introduced at 7,800 MW by 2030. It will be explained that the average CO_2 emission level of Myanmar in 2030 would increase but remain at around 0.37 ton/MWh. This level is similar to the current average level of the 15 countries at 0.40 ton/MWh as shown in Figure 7.3.1.

(8) Seminar on the desirable technology to be introduced in Myanmar, its price, and necessary maintenance technology.

(9) Summary of the seminars above and publication of book on National Campaign for Information Sharing on Coal Thermals.

It is desirable to invite, to the campaign, officers of the Government and Parliament, the people, mass-media, energy companies, students, NGOs, etc. However, the campaign is not the venue to extend opposition. Certain rule to follow the instruction of the chairperson would be necessary. Experts on social issue may better be mobilized. The outlines of the campaign may be repeatedly released each time as news and government PR through television (TV), newspapers, internet, social networking services (SNS), etc. Experts on PR will also be required to participate in these PR activities.

It is expected that proper information on coal thermals would be disseminated to and shared among the people through the national campaign. At appropriate timing, the Coal Policy of the Ministry of Natural Resources and Environmental Conservation may be put up to the Parliament for examination. After the policy gets consent or resolution, further PR and seminar may be held. Thereafter, FS and strategic environmental assessment (SEA) of coal thermals may be started by taking detour of the national campaign arriving at the destination.

7.3.4.3 Technical Cooperation for FS and SEA of Priority Coal Thermal

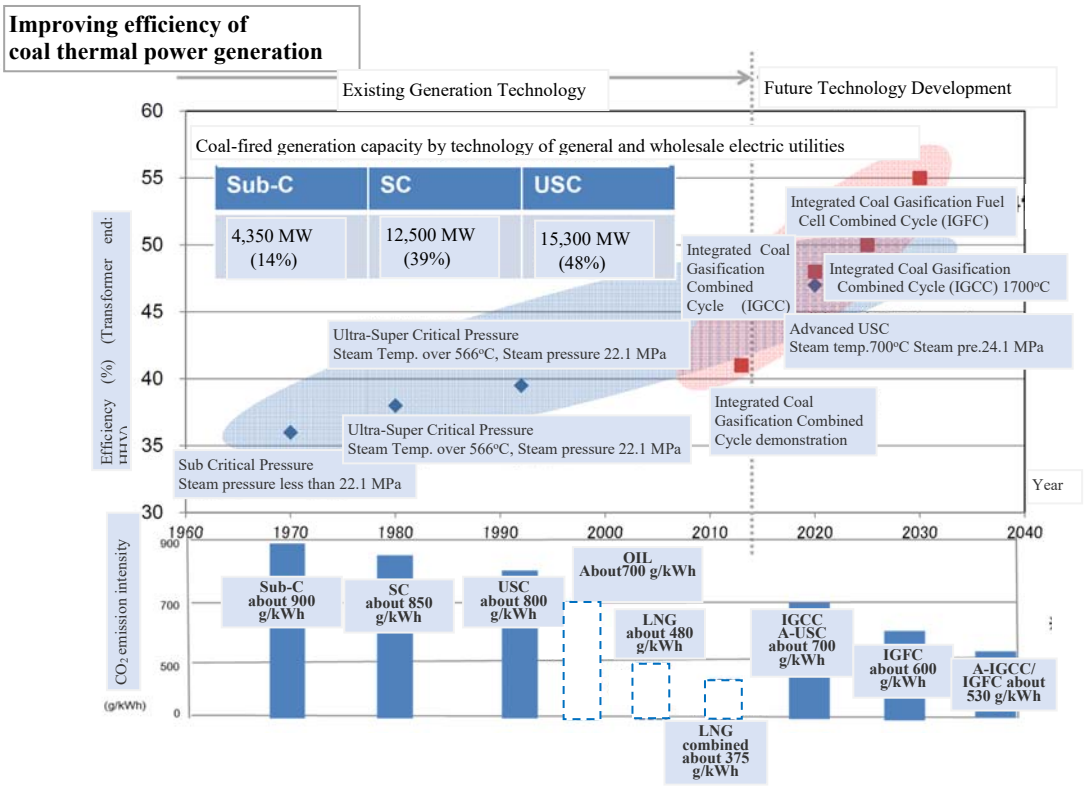
The following approaches may be considered to promote the introduction of coal thermals:

(1) First, FS reports of many coal thermal projects proposed in the past may be reviewed once again including the current situation of their MOA and MOU. Several priority projects may be selected and it will be confirmed if their MOA and/or MOU have been expired.

(2) FS and SEA will be executed on the priority projects selected. In the facility design of FS, it is a must to equip these coal thermals with the latest environmental devices of the developed countries. However, it would be wise and prudent that the technology with higher efficiency by SC or USC will not be pursued at the initial stage of the first advanced coal thermal in Myanmar since this is also equipped with the latest environmental devices of the developed countries.

This is to avoid frequent unexpected troubles to happen or a situation of operation shutdown requiring a long time. Such trouble may take place due to the basic technical issues inherent to coal thermals. The probability and frequency of the troubles will increase along with higher air pressure and temperature from Sub-C to SC to USC. The costly facilities of the latest coal technology may not be fully utilized due to less O&M experience in coal thermals. Instead, the priority may be given for O&M staff to acquire and become very familiar with the technology and knowhow of basic handling of coals. Also, they should master O&M of coal feeding system and high pressure boiler at coal thermal of Sub-C technology. Sub-C is less sensitive to the Low Cycle Fatigue. After mastering the handling technology of coals and O&M of boilers common to coal thermals, latest technology of SC or USC may be introduced. These might be a prudent way.

As shown in Figure 7.3.9, coal thermals of SC and USC in Japan shared 86% of the total. However, coal thermals of Sub-C technology with a total capacity of 4,350 MW still continue their operation without causing any environmental hazards.



Source: Issue of Thermal Power Generation, Agency for Natural Resources and Energy, Japan, March 2015

Figure 7.3.9 Further Improving the Efficiency of Coal Thermals

(3) After completion of FS and SEA, the coal thermal may be implemented as a state or public-private partnership (PPP) project under EPC contract. State or PPP project may be advantageous in getting public finance for long term with low interest rate.

In the case of a state or PPP project, it may incur risks called "Optimistic Bias", that is, estimation risks in the costs and construction period when viewed by the professional in that field. If such

risks are concerned, public financing agency may adjust the estimate with the so-called Public Sector Comparator (PSC) taking into account the risks of significant time extension and cost overrun. Then the least costly mode of implementation may be chosen between the state/PPP and IPP. If appropriate professionals are engaged in the FS, such Optimistic Bias could be minimized.

(4) In the implementation and management of coal thermals by state or PPP, EPGE may first organize the Project Team by selecting young capable engineers so that the team will acquire the technology and knowhow of O&M of coal thermals. It is essential to master and get familiar with all the related works: placing order for coals, monitoring of coal transport from overseas, customs clearance, unloading and storage of coals, pre-processing and feeding of coals, operation, processing of ash, periodical inspection and maintenance of the boilers and steam turbines with auxiliary equipment, placing order for major overhaul, procurement and management of consumables and spare parts.

7.4. Recommendation of Capacity Development through Implementing State Hydro

7.4.1 Issues of the Hydropower Sector

The hydropower development in Myanmar started in the 1950s. In 2000s, hydropower resources are developed by DHPI with high priority. However, in recent years, to cope with the power drop of hydros in the dry season, the budget of GOM shifted to small GEGs by IPP or IPP rental. As a result, there is no new State Hydro. The State Hydros, which utilize the DHPI's construction equipment and engineers and foremen, are nearing to completion. No succeeding projects are scheduled. Experienced engineers are aged and about to retire. It is an issue how to succeed with the technology and knowhow in the design, procurement, and construction. In training the engineers and foremen, it will be best to engage them in the actual design and construction works of the projects so that they can accumulate experience through actual works. This fact has been proven in Myanmar, Indonesia, Viet Nam, Thailand, etc., in the Asian countries. It is desired to have one State Hydro always under implementation, to secure the sustainable capacity building.

Hydropower capacity was 277 MW in 1995. This was increased to 3,255.18 MW or more than ten times in 2016/17. However, since the output drop of hydros in the dry season is large, introduction of large-scale gas thermals is highly required for the time being. As mentioned in Section 7.3, in parallel with the hydropower development on medium to long term, construction of thermals that can sufficiently backup the dry season drop of hydros is becoming an urgent need. As the thermals for such backup, large-scale GTCC fueled by imported LNG would be suitable since it can adjust outputs between the two seasons and even stop operation during the rainy season to save fuel. State-owned GTCC, if implemented, could replace the many small GEGs of IPP rental. Then, it will be possible to stop operation or lower the outputs during the rainy season and to save fuel consumption while utilizing the hydropower at the maximum during the rainy season. This will contribute in lowering the average generation costs.

7.4.2 Capacity Development through State Hydros

The Ministry of Electricity and Energy positions the hydros, natural gas, coals, and renewables as the four major energy resources.

Under the current acute shortage of national revenue, the practical power policy would be:

> "On short term, LNG-fired gas thermals of large scale may be developed by IPPs. This is for the relatively low capital (construction) costs of gas thermals compared with hydros and coal thermals and short lead time of IPP scheme. Thus, the priority in the generation expansion will be given in solving the current shortage of generation capacity in the dry season by IPP gas thermals. On the other hand, low-cost base power by hydros and coal thermals requires long lead time until commissioning. Therefore, the base power will be developed on the medium to long term in accordance with the long run least cost generation expansion sequence."

(1) Preparation and Updating of Long Run Least Cost Generation Expansion Sequence

To commission the base power that has long lead time in the planned manner, the long run least cost generation expansion sequence will be prepared and updated periodically. To back up the output drops of hydros in the dry season, least cost thermals may automatically be identified from within the catalogue of candidate projects and will be included in the sequence. At the same time, hydros if obliged to release part of the inflow through spillway instead of power generation with the reservoir at full supply level (FSL) in the rainy season, will not form the least cost. Therefore, in the least cost sequence, best mix of generation sources will be automatically progressed to facilitate the hydros even if full reservoir can generate secondary energy by lowering outputs and saving fuels of gas thermals. Also, to minimize the long run generation costs, low-cost base power of hydros and coal thermals will be put into the least cost sequence one after another in the necessary and appropriate capacity, towards achieving the best mix. Further, if the negotiation for export of secondary energy during the rainy season with Thailand progresses, it would be possible to include the export option in the catalogue.

It is desirable that the Ministry of Electricity and Energy (MOEE) and DHPI study on the hydro development policy as presented below:

(a) The long run least cost generation expansion sequence will be prepared. In the preparation, if all the economic potentials of hydros without FS are included in the catalogue of the candidate projects, it will lower the reliability or dependability of the sequence because of the uncertain long lead time. After the completion of FS that meets the following conditions, the possible year of commissioning may be assumed by adding necessary years for the detailed design and construction period.

- FS completed or ongoing or will be completed by a certain year.
- Environmental and social impacts are judged acceptable by the Ministry of Natural Resources and Environmental Conservation taking into consideration the mitigation effects of the countermeasures.

(b) long run least cost generation expansion sequence will be updated every year or once in some years, based on the current progress of FS, detailed design, and construction works including newly proposed projects.

(c) Those hydros included in the long run least cost generation expansion sequence will proceed to the design and construction stages.

(2) Recommendation of Capacity Development through Implementing State Hydro

In addition to IPP hydros, DHPI should lead always one State Hydro desirably with public finance of long term and low interest rate. The objectives of this State Hydro led by DHPI are:1) effective mobilization of DHPI-owned construction machineries and hydropower experts, 2) lowering the generation costs by acquiring international public finance, and 3) sustainable capacity building (CB). In Myanmar, where undeveloped hydropower resources are abundant, State Hydro provides opportunities for the young engineers and workers to accumulate experience through participating in the actual design and construction project. The actual project is the best field for CB. Thus, Myanmar engineers and foremen should lead in the future development of hydropower in Myanmar.

The implementation mode of DHPI-led State Hydro may be chosen from among 1) three party conventional model, 2) surface civil works by direct management by DHPI and underground works by JV of DHPI and foreign contractor, and electro-mechanical works by international tendering, and 3) PPP (also referred to in Myanmar as JV/BOT). The selection criteria may be in three points, i.e., lead time concerned with the environmental impacts, unit generation costs, and effects to CB.

Examples of Assumed PPP: The government equity to SPC may be the pre-FS and FS reports of DHPI; construction machineries and equipment, construction engineers, foremen and skilled workers of DHPI; equity to SPC with back finance; obtaining public finance; or combination of some of these. On the other hand, the equity and role of the private sector may be the capital, FS reports prepared by the private sector, undertaking of underground works and/or E&M works, procurement, project management, and so forth.

Appendix A

Note of Discussion

Data Collection Survey on Urgent Upgrade of Electricity Supply in the Republic of Union of Myanmar
Note of Discussion on the Myanaung Power Station

WHEREAS the JICA Survey Team for Data Collection Survey on Urgent Upgrade of Electricity Supply in the Republic of Union of Myanmar (the JICA Survey Team) reported to the Electric Power Generation Enterprise on the "Urgent Upgrading of Electric Power Supply in the Union of Myanmar" which was proposed based on the study jointly performed to date;

WHEREAS the Electric Power Generation Enterprise, Ministry of Electricity and Energy (EPGE) examined and confirmed the contents of the proposal of the JICA Survey Team;

NOW THEREFORE, both Parties prepared, initialed and signed this Note of Discussion on this 4th day of September, 2017, as presented hereinbelow:

1. The Electric Power Generation Enterprise (EPGE) will be the Executing Agency of "Urgent Upgrading of Electric Power Supply in the Union of Myanmar" which will be supply of Gas Engine Generators (GEGs) for Myanaung Power Station (PS).

2. The GEGs for Myanaung PS will be of 22-24 MW in the total installed capacity of plural units. The total installed capacity will be fixed through the tender as the product of unit capacity and number of units to be offered by each tenderer. The unit capacity would vary in the range of 5 MW at minimum to around 10 MW depending on the tenderers' offer. The potential power of GEGs in Myanaung PS using Yadana gas (7 mmscfd with 710 Btu/scf) is approximately 25 MW.

3. The GEGs will be installed in the existing Powerhouse of the Myanaung PS, fueling the Yadana gas available at 7 mmscfd with Gross Calorific Value (GCV) 710 Btu/scf, or equivalent.

4. The commissioning of the GEGs is expected to be within 16 months at the maximum from the issuing date of Notice to Proceed to the Contractor.

5. The envisaged GEGs would have the following features, possibly subject to some changes through detailed design:

   S1 The GEGs shall generate as much electricity as possible fueling the Yadana gas at

7 mmscfd with GCV 710 Btu/scf, or equivalent.

S2 All the GEGs shall have the dimensions to be installed inside the exiting Powerhouse where three foundations and two machine bays without concrete foundation exist. Another foundation also exists but is occupied by the existing GT of John Brown which will be used as an emergency generator after commissioning of the proposed GEGs.

EPGE prefers unit number of three giving priority to the medium speed machine with high efficiency/good heat rate.

The JICA Survey Team recommends not to limit the unit number to three, but also four numbers should be allowed to secure the competitiveness of the Tender.

Both parties took note on the view of the other parties above.

S3 The GEGs shall be able to be maintained using the existing overhead travelling crane and height of about 9 m above the floor level. The nameplate capacity of the crane is 15 ton, but the current capacity is not known. The Contractor shall execute lifting test before crane handling to secure the lifting capacity for its maximum load.

S4 The GEGs shall be connected to existing two transformers and auxiliary equipment, whereas the capacity of the two transformers are 25 MVA and 24 MVA. The all generators are connected via 11 kV bus before the transformers, but disconnected by disconnection-switch during the operation. A cable connection plan is shown in Figure 1 for a sample case of three GEGs. Possible routes of power cables from the same sample GEGs to the existing transformers are shown in Figure 2.

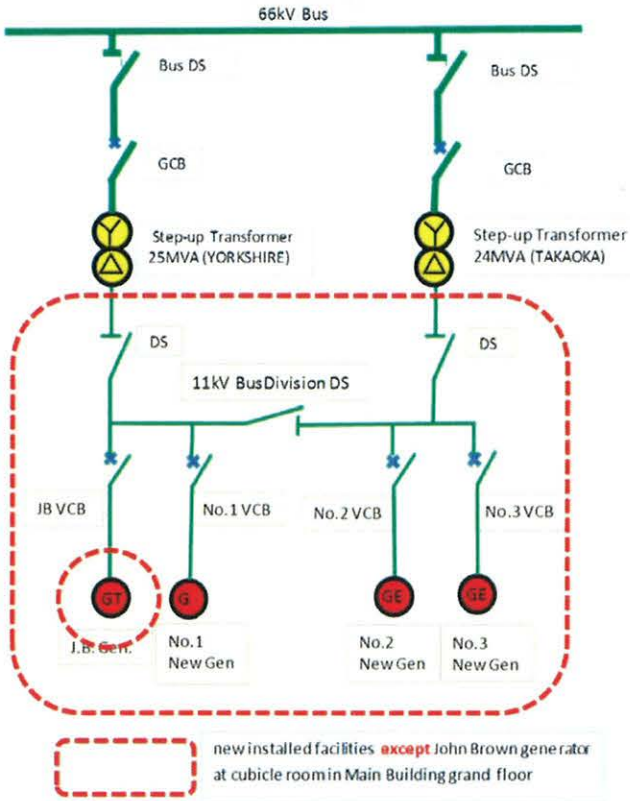


Figure 1 Sample Connection of new GEGs and Existing Transformers & GCBs

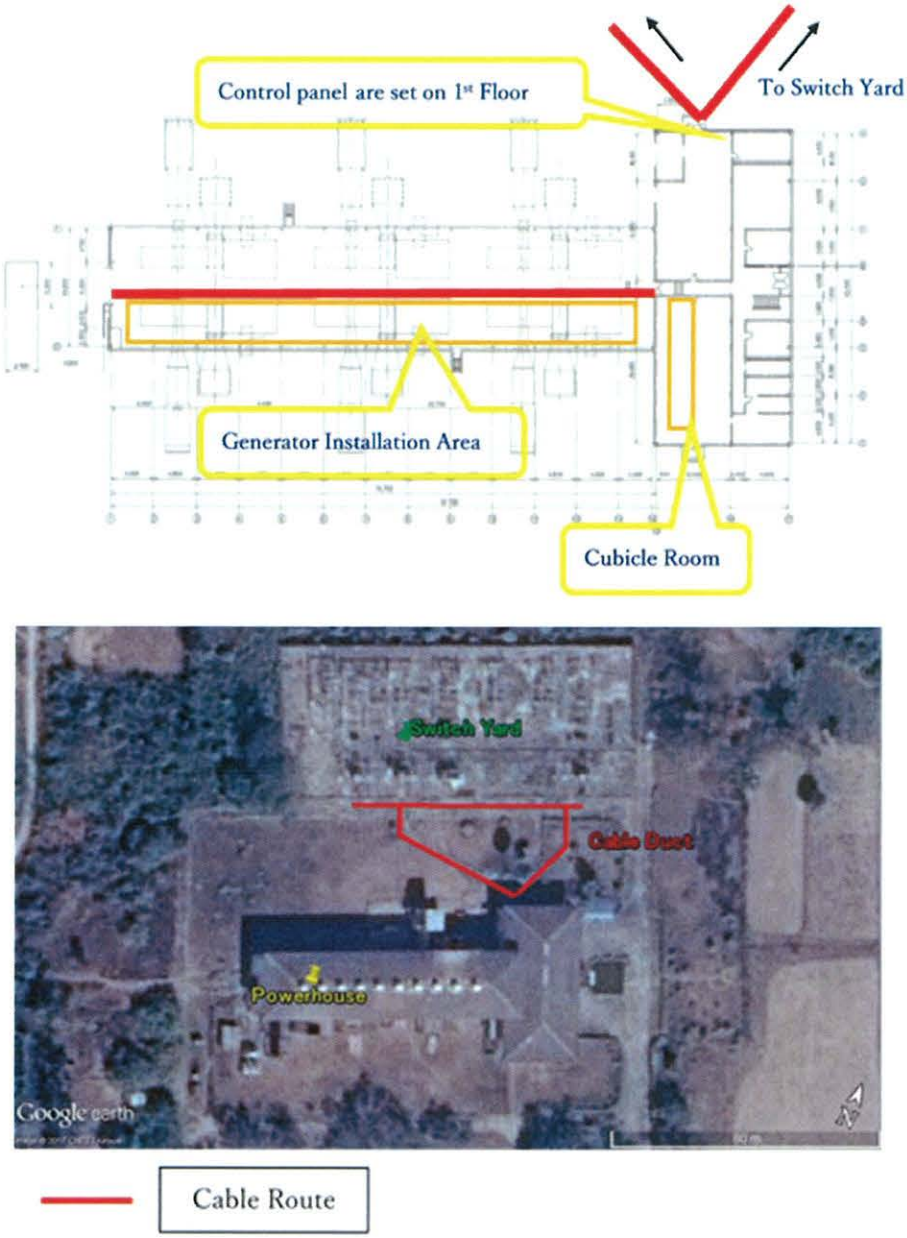


Figure 2 Sample Routes of Power Cables form new GEGs to Existing Transformers

S5 NOx emission level shall be within 200 mg/Nm^3 under O_2 concentration of 15% in accordance with the environmental regulations of the Ministry of Natural Resources and Environmental Conservation.

S6 The noise level shall be within 55 dB for day time from 7:00 to 22:00, and 45 dB for night time from 22:00 to 7:00 at the border of the compound of the Myanaung PS in accordance with the environmental regulations above. If it is judged

necessary, acoustic absorption panels will be fixed to all the walls and ceilings of the Powerhouse. The openings and apertures of the Powerhouse building may be closed to reduce noise leakage.

S7 The GEGs shall be suitable for transportation by barges from the Yangon Port to the shore of the Ayeyarwady River near the Myanaung site, and then transportation by trailers. The maximum height of trailer and GEG shall be around 4.5 m above the road surface. The maximum width shall be 3.0 m. The maximum weight of one heaviest package of GEGs and trailers for transport shall be within 100 ton.

S8 The GEGs shall be able to achieve the heat rate, to be offered at the Tender, for the two years of Guarantee Period, at the minimum, after the Commercial Operation Date (COD) of each GEG.

S9 Consumables required for operation of the GEGs shall be supplied in the quantity required and sufficient for the two-year operation. Spare parts required for operation, maintenance and overhauling of the GEGs shall be supplied in the quantity required and sufficient for the four-year operation.

S10 The spare parts of the GEGs shall be made available to EPGE for purchasing these for 25 years after COD. In case the Maker stops producing the spare parts, it shall be noticed to EPGE at least two years in advance so that EPGE can arrange the budget and procure these in sufficient quantity before the stop.

6. The expected scope of works of the Japanese side and the Myanmar side will be as listed below:

Expected Scope of Works of Japanese Grant

J1 Supply of all the GEGs as featured in Section 1 hereof, including all the auxiliary equipment, spare parts for four-year operation, and consumables required for two-year operation (which is subject to in-depth examination of some consumables which tend to deteriorate in short term);

J2 Ocean freight from the place of the Manufacturer's factory to the Yangon Port;

J3 Inland transportation from the Yangon Port by barges up to the shore of the Ayeyarwady River near the Myanaung PS, and land transportation by trailers therefrom to inside the Powerhouse of the Myanaung PS.

J4 Technical Guidance Services (TGSs) to facilitate the appropriate installation, operation and maintenance of the GEGs for over the planned lifetime of 30 years. These TGSs would include the following scope of works:

a. Technical guidance for installation works of the GEGs including the auxiliary equipment and cabling and piping works;

b. Technical guidance for commissioning tests and reliability run operation;

c. Seminar and OJT in the operation and maintenance of the GEGs and logging of O&M records and activities, including overseas training at the appropriate training facility overseas of the Contractor;

d. Technical guidance for first overhaul of the GEGs required probably upon two-year operation after the commissioning;

e. Technical guidance for stock management of spare parts and consumables including procurement of these.

Expected Scope of Works of the Myanmar side

M1 Timely arrangement of the required budget for the Expected Scope of Works of the Myanmar side hereof, in the national budget for 2018/19 and for O&M thereafter;

M2 Execution of Initial Environmental Examination (IEE) of the Myanaung GEGs and obtaining approval from the relevant agency;

M3 Obtaining approval for tax exemption on custom duties with respect to the import and re-export of the GEGs including all the auxiliary equipment and relevant materials, and tax exemption on corporate income tax, withholding tax, personal income tax for the Services required for Technical Guidance Services (TGSs) by the foreign personnel of the Procurement Agent and the Consultant for the detailed design, etc. and the Contractor for the equipment supply and TGSs;

M4 Removal of unnecessary concrete structure existing on the foundation of mass concrete and filling of voids with concrete as advised in the design stage.

M5 Cleaning inside the cable ducts and repairing of concrete cracks etc. as required.

M6 Renovation works of the Powerhouse for reducing the noise leakage to outside the Powerhouse. The openings and apertures of the Powerhouse building may be closed to reduce noise leakage. Ventilation system is not required specifically except for air-releasing outlet since the generator will be cooled by blowing outside fresh air. The air outlet may be placed on the roof or at high place of the gable with special structures for absorbing noise since the warmed air after engine cooling will rise towards ceiling. The air temperature rise in the Powerhouse will be limited owing to the air circulation for engine cooling.

M7 Setting of the GEGs onto the existing concrete foundation including placing supports to GEGs to prevent overturning by earthquake forces; wiring of power cables, control/communication cables and piping works for fuel gas supply and others;

M8 Nomination and dispatching of Staff for Operation and Maintenance (O&M) of the GEGs, right from the unloading of the GEGs from the barge at the shore of the Ayeyarwady River and throughout the installation works and O&M period;

M9 Supply of natural gas at 7 mmscfd with calorific value of GCV 710 Btu/scf at the minimum throughout the operation period expected for 30 years (after starting reduction in the Yadana gas production, the imported LNG or from other appropriate sources may be supplied to the Myanaung PS by MOGE);

M10 Procurement of spare parts and consumables required for O&M of the GEGs after the ones provided by the Japanese side have been used up;

M11 Maintaining performance of related equipment such as the existing two transformers and auxiliary equipment supplied together with the GEGs, and replacing these when the replacement is judged required;

M12 Providing seminar and training continuously to the O&M staff including newly assigned personnel.

M13 When GEGs are transported from the landing point on the right bank of the Ayeyarwady River to the Myanaung PS, there are many house-connection cables crossing over the road. During the road transport, the electricity supply may be shut down temporarily so that the cables can be lifted up to pass GEGs and trailers.

M14 Appropriate management of Asbestos Boards used in the Powerhouse building.

As far as the boards remain under original conditions without physical damages, there may be no risk for staff health.

Discussed as noted above by and between the two parties below on the date first written above:

Mr. Akio Katayama Team Leader/Generation Planning JICA Survey Team for Data Collection Survey on Urgent Upgrade of Electricity Supply 5. 9. 2017	Mr. Khin Maung Win Managing Director Electric Power Generation Enterprise Ministry of Electricity and Energy 5. 9. 2017

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