Republic of the Union of Myanmar

FY2019 Ex-Post Evaluation of Japanese Grant Aid Project

The Project for Rehabilitation of Baluchaung No.2 Hydropower Plant

External Evaluator: Hajime Sonoda, Global Group 21 Japan, Inc.

0. Summary

The Project for Rehabilitation of Baluchaung No.2 Hydropower Plant (hereinafter referred to as "the Project") was implemented in order to maintain the operating reliability and safety of the power plant for its long-term continuous operation through rehabilitation, thereby contributing to stable power supply in Republic of the Union of Myanmar (hereinafter referred to as "Myanmar"). At the time of ex-ante evaluation and the time of ex-post evaluation, both of rehabilitating the existing power stations and constructing new ones are particularly important issues in the electric power sector for Myanmar. Therefore, the Project is highly consistent with the national development policies and needs of Myanmar. Moreover, the Project was highly relevant to Japan's ODA policy at the time of planning which set its support for development of infrastructure and related systems for sustainable economic growth as one of the pillars of assistance. Therefore, the relevance of the Project is high. Although the project cost remains as planned, the project period was longer than planned and some outputs of the Project were added during its implementation. Therefore, the efficiency of the Project is moderate. After the termination of the rehabilitation work by the Project, the number of unplanned outages at Baluchaung No.2 Hydropower Plant has decreased, it has been performing the continuous operation for a long time, and the plant has recovered its maximum output. Annual power generation at the plant has increased by approximately 20% compared to the ex-rehabilitation period. The Project has highly achieved its objectives and made original impact in respect of the national power supply. Therefore, the effectiveness and impact of the Project are high. As no problems are observed with the institutional, technical and financial aspects of the operation and maintenance of the Project, the sustainability of the Project is high.

Considering all the above points, the Project is evaluated to be highly satisfactory.

1. Project Description

Project Location

Baluchaung No.2 Hydropower Plant

1.1 Background

In Myanmar, there has been power shortage since the late-1980's because the electricity demand has been higher than its supply. Its capacity of power generation was boosted by the development of the large-scale hydropower plants in the 2000's. However, the available power output was estimated to be less than 50% of the total installed capacity due to energy export to China, lack of fuel for thermal power plants and output decline by aging of the existing power plants, etc. Meanwhile, as the electricity demand was steadily increasing in line with its GDP growth, there was a critical shortage in the electricity supply for its demand. As a result, planned outages were carried out in Yangon, the largest demand city in the country. Responding to the high electricity demand that was expected to increase rapidly, promoting hydropower as a base load power supply was raised as an urgent issue in the power policy for resolving the planned outages. It was also set as a short-term objective to secure power generated by hydropower.

Baluchaung No.2 Hydropower Plant (total plant capacity 168 MW=28 MW x 6 units), which was constructed as the first hydropower plant in Myanmar, is situated on Baluchaung River in Lawpita, Kayah State, approximately 300 kilometers northeast from the capital Yangon. However, due to its long-term continuous operation, specifically over 52 years for Units No.1-3 and 38 years for Units No.4-6, it became serious problems that the plant equipment was heavily damaged and deteriorated.

In 1994, the rehabilitation work on the water turbine generators of Units No.1-3 was implemented under the Japanese's ODA Loan Project. However, the water turbine generators, main transformers, substation equipment, control equipment, etc. of Units No.4-6 have never

been full-scale rehabilitated. Under such circumstances, the Government of Myanmar requested the Government of Japan a grant aid project for the Rehabilitation of Baluchaung No.2 Hydropower Plant. The basic design study was carried out by JICA in 2001. As the result of the study, the rehabilitation works was planned in three stages and the first stage of rehabilitation work was carried out in 2002. However, the next stages of the rehabilitation works have been suspended due to domestic situation in Myanmar. After such interferences, JICA conducted the preparatory survey for the Project in 2012-2013. The survey reviewed the second and third stages of the rehabilitation plans by examining the necessary and reasonable rehabilitation works, ascertaining its effects and determining the appropriateness of implementation as a grant aid project. Based on the results of the survey, the Exchange of Notes and Grant Agreement for the Project was signed in March 2013.

1.2 Project Outline

Through the rehabilitation of Baluchaung No.2 Hydropower Plant, the Project aims to maintain operating reliability and safety in order to facilitate the long-term continuous operation of the plant, and thereby contribute to stable power supply in Myanmar.

Grant Limit / Actual Grant Amount	6,669 million yen / 6,669 million yen
Exchange of Notes Date/ Grant Agreement Date	March 2013 / March 2013
Executing Agency	Responsible ministry: Ministry of Electric Power (MOEP) (Currently the Ministry of Electricity and Energy) Implementing agency: Hydropower Generation Enterprise (HPGE) (Currently the Electric Power Generation Enterprise (EPGE))
Project Completion	May 2017
Target Area	Lawpita in Kayah State
Main Contractors	Hitachi Mitsubishi Hydro Corporation (Lot 1), Marubeni Corporation (Lot 2)
Main Consultant	Nippon Koei Co., Ltd. and Tokyo Electric Power Company Holdings Inc. (Consortium)

Basic Design / Preparatory Survey	June 2012-March 2013
Related Projects	The Project for Rehabilitation of Baluchaung No. 2 Hydropower Plant (2002)

2 Outline of the Evaluation Study

2.1 External Evaluator

Hajime Sonoda, Global Group 21 Japan, Inc.

2.2 Duration of the Evaluation Study

The ex-post evaluation study for the Project was conducted over the following period.

Duration of the Study: July 2019 - July 2020

Duration of the Field Survey: September 16 - October 9 in 2019, December 12 - December 19 in 2019

3 Results of the Evaluation (Overall Rating: A[1])

3.1 Relevance (Rating:③[2])

3.1.1 Consistency with the Development Plan of Myanmar

At the time of planning, Myanmar identified, as urgent issues, solving the regular power cuts as a short-term target and boosting the power generation as a medium-long term target on the power policy, requiring foreign aids to the power sector as its priorities. Both of rehabilitating the existing power stations and constructing new ones were highly prioritized among its short-term targets. According to *Myanmar Sustainable Development Plan 2018-2030* by the Ministry of Planning and Finance in 2018, it stated "prioritizing the rapid development of fundamental economic infrastructure, such as electricity generation, roads and ports, and establishing a data ID card system, a digital government strategy, and an e-government system" as one of the main policies. It also mentioned "Natural Resources & the Environment for Posterity of the Nation" as one of the goals, setting "providing affordable and reliable energy to populations and industries via an appropriate energy generation mix" as one of its strategies. Therefore, at the both times of ex-ante and ex-post evaluation, the Project was highly relevant to the development plan of Myanmar.

[1] A: Highly satisfactory; B: Satisfactory; C: Partially satisfactory; D: Unsatisfactory

[2] ③: High; ②: Fair; ①: Low

3.1.2 Consistency with the Development Needs of Myanmar

The stable hydropower was among the highest priority on the power policy as described in "1.1 Background" above at the time of planning. Although Baluchaung No.2 Hydropower Plant successfully continued to provide stable power supply through both rainy and dry seasons ever since the beginning of its operation in 1960, deteriorations and aging of the equipment have been recognized and the risk of serious accidents have increased due to this long-year operation. It was urgently necessary to recover the machinery function to the full via thorough rehabilitation of the deteriorated equipment for further stable operation.

At the time of ex-post evaluation, the Government of Myanmar approved *Power Development Plan (2014)* which was formulated with assistance of JICA. It was a development plan of the power sources and its distribution network up to 2030, setting importance to the hydropower as the base load power supply. Meanwhile, according to EPGE, the electricity demand in Myanmar is steadily increasing every year and is expected to reach 4,000MW by 2020. But the supply capacity has fallen short as the demand kept increasing. Power cuts also happen regularly in the major demand area such as Yangon and Mandalay. Baluchaung No.2 Hydropower Plant has operated as the base load power supply all year round, utilizing abundant water resources, and supplied approximately 6% of all Myanmar's power generation in 2018. It also works as a black-start operation for restarting the national power transmission grid in case of its fault. Therefore, necessity of the power plant is acknowledged at the time of ex-post evaluation.

In light of the above, the Project was consistent with the development needs of Myanmar at the both times of ex-ante and ex-post evaluation.

3.1.3 Consistency with Japan's ODA Policies

In April 2012, the Government of Japan set one of the priority areas of assistant on "Development of infrastructure and related systems necessary for the sustainable economic development". JICA commenced a series of Technical Cooperation and Grant Aid accordingly, including the Project in the power sector in 2012. The first three (3) units (Units No.1-3) of the total six (6) power units of Baluchaung No.2 Hydropower Plant were commissioned under Japan's post-war reparations grant and were overhauled by its ODA Loan in 1987 after the 25 years operation period[3]. Further rehabilitation was planned in three stages by the Japanese Grant Aid in 2001 and the first stage of the rehabilitation work was

[3] Overhaul refers to the work of breaking machine products down to their parts, cleaning and reassembling them so that the machines are restored to the initial performance condition.

carried out. However, the next stages of this rehabilitation works have been suspended due to the Myanmar domestic circumstances. Therefore, the Project is consistent with the Government of Japan's ODA policies.

Based on the above, the Project has been highly relevant to Myanmar's development plan and development needs as well as Japan's ODA policies and, therefore, relevance of the Project is high.

3.2 Efficiency (Rating:②)

3.2.1 Project Outputs

In the Project, rehabilitation work was carried out on the generating equipment, substation equipment and penstock equipment at Baluchaung No.2 Hydropower Plant. The planned and actual outputs of the Project are as shown in Table 1.

Table 1 Planned and Actual Outputs

	Plan	Actual
Generating Equipment	Stator Coil of Generator, Control Panels for Generator, Inlet Valve, Turbine Runner, etc.	Generally, as planned. The additional outputs were the followings: − Repair of water turbine needle shaft packing and procurement of its packing of Unit No.3 − Procurement of CF brake for the windlass of ceiling crane
Substation Equipment	Main Transformers, House Transformers, 132kV Circuit Breakers, Emergency Power Supply, etc.	− Procurement of materials for rehabilitation of generator rotor field coil − Procurement of materials for generator rehabilitation − Procurement of tire coupling of Unit No.1, flow switch for generator air cooler of Unit No.6
Penstock Equipment	Penstock liner, etc.	− Procurement of water turbine lower nozzles, governor load control motors, flow control valves for oil lifter, and generator shaft bearings − Procurement of generator cubicles (Units 5, 6) − Procurement of status display unit, voltage detection circuit and measuring instruments for control room − Procurement of spare parts for main transformers and emergency power supply system
Consulting services	Detailed design, supervision, and training for improving maintenance capacity (soft component)	As planned.

Source: Information provided by JICA

The Project was carried out based on the basic design policies of the Detailed Design (D/D) by the Preparatory Survey (2013) such as “conducting the necessary and sufficient rehabilitation for preventing a serious fault and keeping the power plant in service consecutively”, “adopting technical specifications by taking into consideration of technical level of operation and maintenance staff whenever the restoration to the original condition is difficult”, and “designing the layout and installation method of the equipment to minimize impacts on the existing equipment”.

At the time of the Preparatory Survey, only the limited time was available for stopping and disassembling the equipment to examine the scope of rehabilitation since it would not allow to stop the machinery for a long time due to severe power shortages. During the implementation phase of replacing parts, there were sufficient time for breaking down and examining the equipment in detail. As a result, the necessity of some additional rehabilitation works, which were not found by the Preparatory Survey, were recognized. After multiple amendments of the contracts, some materials were procured as additional outputs, using surplus budgets of the Project (as described hereinbelow). Also, some important spare parts (transformers, etc.) for continuous generation were additionally procured. These changes were appropriate since those additional outputs were decided according to the project objective and planning policies. According to EPGE, the scope of the Project (including amendments in the implementation phase), quality of the equipment, the scope and methods of the soft component were appropriate. The activities shouldered by the Government of Myanmar, such as tax exemptions for imported equipment and materials, preparation of accommodations and offices for Japanese personal and assistance for them to obtain a visa were implemented in proper time. Concerning the project scope, the following points which affect effectiveness and sustainability of the Project can be raised;

- Before the implementation of the Project, the generators have experienced outages caused by blocked pipes of the generator cooling system (when warnings of temperature increase arose, unplanned outages for 1-2 hours were required for deep cleaning of the pipes). However, appropriate measures such as installation of auto strainer to treat cooling water containing impurities, which was recognized as the main reasons of this problems, were not included in the final requests by the Government of Myanmar, and they were not considered as the project scope. Therefore, even after the completion of the Project, unplanned outages are observed due to blocked pipes of the generator cooling system.

- The existing excitation systems (devices for adjusting voltage in each generator) were

so outdated that the necessary parts were no longer available in the market. Therefore, they were upgraded to new systems. On the other hand, since the power plant staff have a thorough knowledge of maintaining the governors (devices for adjusting frequency in each generator) from their over 50-year experiences from the beginning of operation, it was decided to maintain these original governors by making a few minor parts replaced. According to the examinations implemented by EPGE in 2018, however, it could not control a frequency enough in Units No.1-3. They think that this is due to insufficient output from the control motors of the governors. Incidentally, this sort of problem is not occurring in Units No.4-6, in which the control motors have larger output.

- After the completion of the Project, whenever they conduct a "black starting" at Unit No.4-6, a work of supplying the initial power required to start other power stations in case the whole transmission grid stopped, it became obvious at the transformer substations that its startup operation did not work out smoothly because the protector started working simultaneously. Although reasons for this phenomenon has not been found out, EPGE thinks it necessary to adjust the excitation system or readjust the protective equipment on the substations, as a new type excitation system has been combined with old type governor. In order to avoid these issues, EPGE developed its own methods that, whenever they conduct a black starting at the Baluchaung No.2 Hydropower Plant, they start operations at Unit No.4-6 by disconnecting once from the distribution network and then reconnect to it after generation has settled down.[4]

Out of the above issues, any measures for improving the quality of cooling water were not considered as this was not originally requested. In addition, there was a possibility to cope with those issue by proper maintenance such as systematically stopping the machinery for cleaning before warning would be given. Concerning the decision to maintain the old governors while upgrading the excitation systems, it might have had different conclusion if more detailed technical examinations were conducted. All the measures were examined according to the above policies from the viewpoints of keeping the project cost and its period within an appropriate scope. Therefore, it cannot be said that defining the project scope as described above was inappropriate.

[4] Having recorded this phenomenon when they put on a black starting in May 2018, EPGE discussed this matter with the consultant of the Project. However, it was necessary to collect additional records to clarify the cause. Meanwhile, when this phenomenon occurs during a black starting, it caused about 30-minute delay for power plants in the country to resume their operation, causing extended power interruption, and it is necessary to speed up the recovery process by adopting the new method described above. Therefore, no records of this phenomenon have been taken after May 2018.


Baluchaung No.2 Hydropower Plant: generating equipment (left), substation equipment (right)


Baluchaung No.2 Hydropower Plant: mechanical governor interior (left), control room (right)

3.2.2 Project Inputs

3.2.2.1 Project Cost

The total project cost was planned as 6,686 million yen (comprising 6,669 million yen on the Japanese side and 17 million yen on the Myanmar side). The cost of originally planned outputs on the Japanese side was reduced by approximately 7% as a result of competitive tender. As the additional outputs are included, however, the project cost reached 6,647 million yen (100% of the planned amount). The total project cost including the cost on the Myanmar side (actual cost 31 million yen) was 6,678 million yen (100% of the planned amount), which was almost as planned.

3.2.2.2 Project Period

The overall project period including the Detailed Design (D/D) and the tender procedure was planned as approximately 35 months from April 2013 to February 2016. The main

rehabilitation work was completed in February 2016, 35 months after signing of the consultant agreement in April 2014. Due to the extra times required for additional repair and procurement of the parts, the whole work was completed in May 2017. Thus, the actual project period was 50 months (143% compared to the plan).

The project cost was almost as planned meanwhile the project period exceeded the plan. Therefore, efficiency of the Project is moderate.

3.3 Effectiveness and Impacts[5] (Rating: ③)

3.3.1 Effectiveness

The expected outcomes by the Project is to maintain the operating reliability and safety of Baluchaung No.2 Hydropower Plant for a long-term continuous operation. For quantitative effects, the indicators are; 1) reduction of unplanned outages, and 2) increase of maximum output. With the focus on these quantitative indicators, the analysis of any changes in the operating performance of the power plant before and after the Project is shown in Table 2. Other effects are also analyzed as qualitative effects.

3.3.1.1 Quantitative Effects

In the Project, the rehabilitation works were carried out on the six generators, substation equipment and penstocks at Baluchaung No.2 Hydropower Plant between July 2014 and February 2016. Changes in the operating performance of the power plant before (2011~2013) and after (2017~2018) the Project are shown in Table 2.

[5] Impact is taken into consideration in rating of effectiveness.

Table 2 Changes in Indicators Before and After the Project

	Target at the time of planning	Before the Rehabilitation				After the Rehabilitation			Ratio
		2011	2012	2013	Average ①	2017	2018	Average ②	②/①
Unplanned outages (Note) (times/year per unit)	3.0	5.2	6.8	4.3	5.4	3.5	3.7	3.6	66%
Cooling system failures/troubles	None	4.7	6.8	4.2	5.1	3.3	3.0	3.2	62%
Other equipment failures/troubles	None	0.5	0.0	0.1	0.3	0.2	0.7	0.4	125%
Maximum output (power plant, MW)	None	157.5	157.0	152.0	155.5	166.9	167.8	167.4	121%
Generator on Unit No.1(MW)	28.0	24.0	22.0	22.0	22.7	28.0	27.0	27.5	108%
(Reference information) Annual Power Generation (GWh per power plant)	None	806	1,079	1,003	963	1,066	1,262	1,164	121%

Source: Compiled by the evaluator based on responses to a questionnaire by EPGE
Note: The number of unplanned outages in the table only shows outages caused by failures/troubles in generation equipment. Unplanned outages may also be caused by factors such as; troubles in transmission equipment outside of the power plant, shortage of water resources and so on. The objective of the Project was to reduce outages caused by failures/troubles in generator equipment. It should be noted that, the annual power generation (reference information) shows the contribution of Baluchaung No.2 Hydropower Plant to power supply in the entire country.

(1) Reduction of unplanned outages

As for unplanned outages (the number of the annual outage per one generator) caused by generator equipment failures or troubles, it was targeted by the Project to reduce the number to 3.0 times a year[6]. In reality, the number of unplanned outages was reduced from 5.4 times in the ex-rehabilitation to 3.6 times in the post-rehabilitation. Although the target of 3.0 times of annual outages was not achieved, the number of unplanned outages was reduced to approximately two-thirds. Therefore, the degree of achievement of the target is judged to be moderate[7].

Almost all of these unplanned outages were caused by failures or troubles in the cooling systems, mainly arising from cooling water leaks from deteriorated pipes and its blockages[8]. Unplanned outages caused by pipe leaks were prevented by replacing the

[6] According to the ex-ante evaluation of the Project, 15 unplanned outages per unit in 2011 was recognized as benchmark, and the target was set to reduce this figure to 3.0 outages per unit. However, as the definition (scope of its causes) of the unplanned outages as the aforementioned benchmark is not clear, the data newly obtained this time were considered as the benchmark. The consultant of the Project confirmed that the target on reducing unplanned outage was for any outrages caused by generation equipment. Based on the above, according to the performance of unplanned outages by failures or troubles in generation equipment which was shared by EPGE in the ex-post evaluation, the degree of target achievement was analyzed, assuming that 5.2 times/year (2011) as benchmark, 3.0 times/year as target and 3.6 timers/year as actual record in 2011.

[7] The degree of achievement is calculated as 73% based on the following calculation: "Realized reduction in the number of unplanned outages (5.2 times－3.6 times = 1.6 times)" ÷ "Planned reduction in number of unplanned outages (5.2 times – 3.0 times = 2.2 times)."

[8] Water from Baluchaung River which is the source of power generation and flows down from Movi Dam is used for cooling water. Any household trash by riverside residents into the water are increasingly causing pipe blockages.

cooling system in the Project. However, because no measures were taken to treat cooling water containing impurities recognized as the main cause of pipe blockages (see 3.2.1 Project Outputs), pipe blockages have continued to occur after the rehabilitation. Although pipe blockages are not serious enough to cause damage to generator equipment, the generator has to be stopped for one or two hours whenever it happens, giving an impact on power generation.

The number of unplanned outages caused by factors outside of the generator equipment slightly increased after the rehabilitation (0.3 times→0.4 times). In the first two years after the rehabilitation (2017-2018), the overall power plant experienced five outages, one of which was caused by an external factor (the damages by a snake on the transformer substation equipment), the others arose from problems out of the scope of the Project. Concerning the equipment which were rehabilitated by the Project, no failures or problems had arisen by the time of ex-post evaluation, and it is thought that more unplanned outages would have occurred if they were not rehabilitated. Therefore, this slight increase does not signify any failure in the rehabilitation conducted under the Project.

An unplanned outage was caused at the generator of Unit No.6 in 2018 due to a short circuit fault by a snake on the transformer substation equipment. The system successfully resumed operation in a short time (25 hours) by utilizing the emergency transformer procured by the Project. Without this emergency transformer, it would have needed to borrow one from another power plant or substation, resulting in a long-term outage.

In light of the above, the Project contributed to reducing unplanned outages and to operating continuously at Baluchaung No.2 Hydropower Plant[9].

(2) Maximum output

The maximum output of the generator on Unit No.1 at Baluchaung No.2 Hydropower Plant fell to 24MW in 2011 due to deterioration. The Project aimed to restore its rated maximum output up to 28MW. Although the maximum output of the generator on Unit No.1 fell to 22MW in 2013, this was restored after the Project up to 28MW as planned (it reached to 28MW in 2015 immediately after the rehabilitation work). The maximum output was only 27MW in 2018 but there has not been any particular trouble at Unit No.1 since the rehabilitation. Therefore, this slight drop should not have been related to the generator issues.

[9] Concerning the time length of unplanned outages (total time per unit/per year), it was impossible to collect chronological data according to causes in power plant equipment, in transmission equipment outside of the power plant, and other causes. But there was a major overall reduction from 141.6 hours in the ex-rehabilitation to 34.5 hours in the post- rehabilitation (Down to 24% compared to the ex-rehabilitation).

Moreover, as a result of the rehabilitation, maximum output of the overall power plant increased by approximately 12MW, 21% higher than before the rehabilitation, and it reached the highest record 167.8MW (99.9% of the rated maximum output 168MW) in 2018.

In light of the above, it can be determined as a result of the Project that the maximum output of Baluchaung No.2 Hydropower Plant was restored as planned. This shows a high degree in the achievement of the project purpose.

(3) Power Generation (Reference Information)

The annual power generation at Baluchaung No.2 Hydropower Plant increased from 963GWh of the ex-rehabilitation up to 1,164GWh of the post-rehabilitation (121% of the before-rehabilitation level). The annual power generation in 2018 reached to 1,260GWh, which is 86% of the plant's maximum capacity of 1,472GWh (168MW x 6 units x 24 hours x 365 days), indicating that the plant operated at almost full capacity. It can be considered that the reduction of unplanned outages, namely an increase of operating hours, as well as the increase of maximum output by the Project have contributed to the above improvement[10].

3.3.1.2 Qualitative Effects

The soft component of the Project was carried out for the power plant staff, by providing trainings and manual on operation and maintenance of electro-mechanical equipment and hydrostatic penstock pipes. This resulted in implementing the manual-based operation and maintenance (preventive maintenance) and keeping its operation and maintenance records. At the time of ex-post evaluation, it was confirmed that these activities are still continuing.

According to EPGE, the reliability and safety levels of the facilities/equipment have generally improved by the Project (no accidents reported after the Project was completed) and this has helped in releasing the psychological stress felt by the power plant staff. They mentioned that their work has become less stressful than those previous days when they usually had concern on how soon the machines would be broken down.

In light of the above, it can be summarized that, after the rehabilitation by the Project, longer continuous operation has been achieved at Baluchaung No.2 Hydropower Plant with less unplanned outages. In addition, power generation has increased by 20% compared to the ex-rehabilitation by recovering maximum output. Also considering a high degree in the achievement of project purpose with regard to unplanned outages and maximum output, the

[10] The annual operating time per generator at the power plant increased from 7,630 hours in the ex-rehabilitation to 8,250 hours in the post-rehabilitation (Up 108% of the ex-rehabilitation).

effectiveness of the Project is high.

3.3.2 Impacts

3.3.2.1 Intended Impacts

(1) Contribution to the national power supply

Based on the EPGE data, the Myanmar's maximum output doubled from 1,588MW in 2011 to 3,189MW in 2017, while it is predicted to reach 4,000MW in 2020. The power generation also doubled from 10,312GWh in 2011 to 20,141GWh in 2017. Power shortage occurs by high electricity demand for air conditioners in summer from March to May and planned outages are set in Yangon and other demand area. While, since the 2000s, many hydropower plants have been constructed by the Chinese funds and commenced its operation in the northern part of the country. However, its power generation is constrained during a dry season from March to May due to reduced water flow there.

(Unit: GWh)

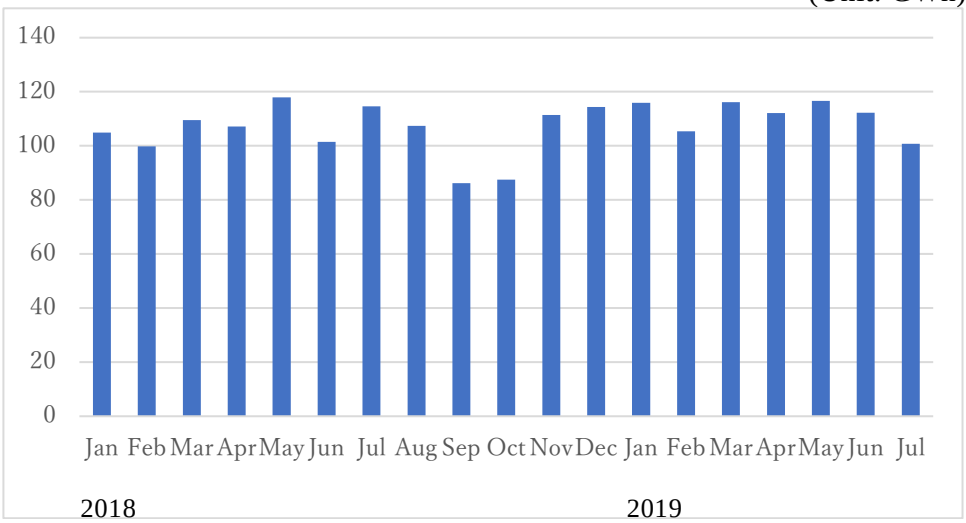

Figure 1 Amount of Energy Generated at Baluchaung No.2 Hydropower Plant

Source: Materials provided by EPGE

Baluchaung No.2 Hydropower Plant accounts for 5.2% of the Myanmar's electric power (MW) and 5.3% of its power generation (GWh) in 2017. Unlike hydropower plants in the northern part of the country, this plant generates power throughout the year including a dry season by utilizing abundant water resources from Moevi Dam (see Figure 1). The Project's direct contribution to the national power supply is regarded as increasing the maximum output up to approximately 12 MW which is 0.4% of the nationwide demand

in 2017 and increasing the power generation up to 202 GWh which is 0.1% of the nationwide demand in 2017. It can be determined that the anticipation for the Project in contributing to the national power supply has been realized, recognizing the full utilization of the plant.

(2) Contribution to black starting

Baluchaung No.2 Hydropower Plant has the duty of a “black starting”, a work of supplying the initial power required to start other power stations in case the whole transmission grid stopped. In that case, the stable frequency by individual power plants (generation unit) is required. As a result of the Project, the frequency of each generator became more stable, especially in Units No.4-6, and the plant can conduct a black starting more smoothly than before. On the other hand, because of the phenomenon that the protector trips at the transformer substations, an irregular operation is currently required such as disconnecting once from the transmission grid whenever they conduct a black starting (see 3.2.1 Outputs).

(3) Contribution to Baluchaung No.3 Hydropower Plant

Water from Baluchaung No.2 Hydropower Plant is utilized to generate further power at the Baluchaung No.3 Hydropower Plant (52MW) downstream. The fact that the Project has realized longer continuous operation at Baluchaung No.2 Hydropower Plant is considered to have contributed to the utilization of Baluchaung No.3 Hydropower Plant as well. However, EPGE has not developed any guidelines nor methods for the linked operation of Baluchaung No.1, No. 2, and No. 3 Hydropower Plants which generate electricity by using the same water source. Additionally, there is no practical operation plan based on the water resource conditions. These remain as issues for future analysis.

(4) Ripple Effects on Technical Aspects

The staff who worked for many years at Baluchaung No.2 Hydropower Plant and obtained experience through the Project have been promoted to senior positions at other hydropower plants. Moreover, EPGE has shared the manual and formats (maintenance inspection forms and repair log forms) prepared by the Project with other hydropower plants.

3.3.2.2 Other Positive and Negative Impacts

At the time of planning, no major environmental impacts of the Project were anticipated. The transformer insulating oil (PCB waste) and asbestos waste taken out by the Project has

been sealed and placed in storage as planned, so, there are no major environmental impacts. No other environmental impacts have been confirmed.

In light of the above, the Project has mostly achieved its objectives. Therefore, the effectiveness/impacts of the Project are high.

3.4 Sustainability (Rating: ③)

3.4.1 Institutional/Organizational Aspects of Operation and Maintenance

Baluchaung No.2 Hydropower Plant is under jurisdiction of EPGE and its organizational structure is as shown in Figure 2. Its organizational structure and job descriptions are well established based on many years of their operating experience and there are no particular problems in this regard. The Government of Myanmar currently restricts new hiring in all the government agencies based on its policy of reducing the number of civil servants by a third.

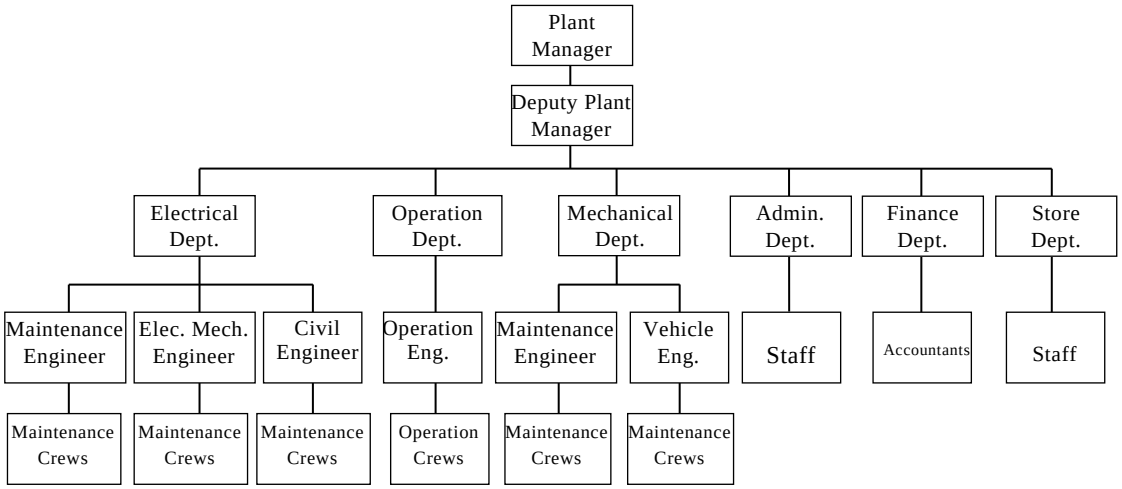

Figure 2 Organization Chart of Baluchaung No.2 Hydropower Plant

Source: Materials provided by EPGE

The staff number at Baluchaung No.2 Hydropower Plant in 2012 was 159 out of the regular staff number of 165. Based on the above policy, however, they laid off some staff while keeping experienced ones. The staff number at the time of ex-post evaluation was 114. They hired contract workers for non-skilled job rather than keeping full-time employees. According to the Plant, although the current workforce is not entirely adequate, it is enough for daily operation without any issues. However, in cases when experienced senior operators are absent for some reason, or when a major problem occurs, extra assistance is in need. Baluchaung No. 1 and No. 3 Hydropower Plants are located close to Baluchaung No.2

Hydropower Plant, so that they help each other in emergencies. Moreover, as institutional approach to such issues, the EPGE headquarters selects and dispatches its experienced staff with specific knowledge and skills to other plants whenever issues arise there.

In light of the above, there are no major issues regarding the institutional/organizational aspects of the project operation and maintenance.

3.4.2 Technical Aspects of Operation and Maintenance

As the average years of work experience of the operation and maintenance staff is about 20 years at Baluchaung No.2 Hydropower Plant, they gained a lot of knowledge and experience concerning operation and maintenance of the Plant. Out of the 55 operation and maintenance staff, three members have 30 years or more continuous experiences, 27 have between 20-29 years experiences, 18 have between 10-19 years experiences, and seven have less than 10 years experiences.

The manual and formats prepared by the Project's soft component are all being used. According to the participants in the staff trainings, the lectures and practical trainings of the soft component were the places to develop comprehensive knowledge of hydropower plant operation and maintenance. Almost all the training participants have remained in their current jobs, while two members have been transferred to other plants for a higher position.

Each power plant submits its spare parts list to the EPGE headquarters every month. It appears that the spare parts stock including those procured in the Project are well managed. According to Baluchaung No.2 Hydropower Plant, there are adequate quantity of the spare parts for maintaining power generation except for a few important ones. They applied to the EPSG headquarters for those parts[11]. In case the Plant is out of the spare parts stock, they can obtain from another plants or transmission and distribution companies (Department of Power Transmission and System Control) through the EPGE headquarters, although it requires some time. If genuine parts cannot be obtained, they are possibly manufactured in Myanmar. Manufacture information such as equipment drawings and user manuals are appropriately stored.

In light of the above, there are no major issues regarding the technical aspects of operation and maintenance.

[11] Every year, each power plant submits a necessary spare parts list and the reasons for their necessity to the EPGE headquarters. The headquarters conducts technical review of the contents and applies for a budget to the Ministry of Finance. The Ministry of Finance approves within the available budgets, however, according to EPGE, some items were not approved in 2017 and 2018. Since the governmental policy for 2019 is to give priority to budget allocations for infrastructure, it is anticipated that almost all the budget requests will be approved for this year.

3.4.3 Financial Aspects of Operation and Maintenance

According to EPGE, the income/expenditure balance of Baluchaung No.2 Hydropower Plant is as follows. The Plant's balance is in the black and the budget for continuous operation is secured.

Table 3 Baluchaung No.2 Hydropower Plant Income and Expenditure Balance

(Unit: million MMK)

	FY2016	FY2017	FY2018 first half
Income from electricity	45,037	59,267	35,137
Other income	2,280	2,502	29
Total Income	47,318	61,770	35,166
Salary	471	453	251
Maintenance	158	91	33
Consumables	57	54	31
Others (including depreciation costs)	3,181	3,445	1,757
Tax	2,147	2,825	1,675
Total Expenditure	6,015	6,867	3,746
Balance	41,302	54,902	31,420

Source: Information provided by EPGE

Previously, the electricity charges in Myanmar have been set at the lowest level even among the ASEAN nations, and the Government has borne the large cost loss margin. The transmission and distribution companies had been maintaining profitability with the wholesale prices of electric power sold by EPGE which had been kept low. However, EPGE had been in red due to this arrangement, and the government subsidies for deficit covering were provided only for EPGE. In July 2019, Ministry of Electricity and Energy (MOEE) revised the electricity charges substantially for the first time in five years, and simultaneously they aimed for a financial stability of EPGE by doubling its wholesale electricity prices. According to MOEE, the income/expenditure balance of EPGE is expected to show a surplus from 2020 onwards.

In light of the above, there are no major issues regarding the financial aspects of project operation and maintenance.

3.4.4 Operation and Maintenance Status

According to onsite inspection at the time of ex-post evaluation, there have cleaned in the Plant and the facilities are operated well functionally. After the damage by a snake in the substation, some protection plates have been installed to prevent further such infiltrations. The spare parts procured by the Project are appropriately stored in the warehouse.

As instructed in the soft component, all the operation and maintenance logs are recorded and any data has been computerized in the PCs. Since the previous data can be immediately retrieved on the computers, they can respond to any enquiries and submit necessary data to the EPGE headquarters whenever problems arise. However, in order to detect operational abnormalities, no time series analysis is made utilizing the data, while, in the same manner as before, interpretation of the figure is made simply based on past experiences. As also instructed in the soft component, the scheduled preventive maintenance (routine inspection and detailed examination) was successfully introduced. Daily operating records have been taken. Preventive maintenance of generators is carried out at weekends when the power demand is relatively low, stopping one generator for about five hours every week and another generator in the next weekend. According to the records, weekly maintenance has been certainly carried out. There were some cases where operational abnormality was detected through the routine inspection based on the manual and detailed inspections and repairs were conducted[12].

In light of the above, there are no major issues regarding operation and maintenance in the Project. It should be also noted that, although not directly included in the scope of the Project, as stated in 3.2.1 Outputs, it is assumed that the poor quality of cooling water and partial rehabilitation of the governor have an impact on operation of Baluchaung No.2 Hydropower Plant.

To sum up, no major problems have been observed in the institutional, technical, financial aspects and current status of the operation and maintenance system. Therefore, sustainability of the Project effects is high.

4 Conclusion, Recommendations and Lessons Learned

4.1 Conclusion

The Project was implemented in order to maintain the operating reliability and safety of

[12] In August 2018, water leakages were found in a penstock by inspection conducted according to the manual. This was repaired by stopping power generation for a while.

the power plant for its long-term continuous operation through rehabilitation, thereby contributing to stable power supply in Myanmar. At the time of ex-ante evaluation and the time of ex-post evaluation, both of rehabilitating the existing power stations and constructing new ones are particularly important issues in the electric power sector for Myanmar. Therefore, the Project is highly consistent with the national development policies and needs of Myanmar. Moreover, the Project was highly relevant to Japan's ODA policy at the time of planning which set its support for development of infrastructure and related systems for sustainable economic growth as one of the pillars of assistance. Therefore, the relevance of the Project is high. Although the project cost remains as planned, the project period was longer than planned and some outputs of the Project were added during its implementation. Therefore, the efficiency of the Project is moderate. After the termination of the rehabilitation work by the Project, the number of unplanned outages at Baluchaung No.2 Hydropower Plant has decreased, it has been performing the continuous operation for a long time, and the plant has recovered its maximum output. Annual power generation at the plant has increased by approximately 20% compared to the ex-rehabilitation period. The Project has highly achieved its objectives and made original impact in respect of the national power supply. Therefore, the effectiveness and impact of the Project are high. As no problems are observed with the institutional, technical and financial aspects of the operation and maintenance of the Project, the sustainability of the Project is high.

Considering all the above points, the Project is evaluated to be highly satisfactory.

4.2 Recommendations

4.2.1 Recommendations to the Executing Agency (EPGE)

It is recommended to EPGE to examine possible measures to improve the water quality that causes clogging of the air cooler (installation of an auto strainer, etc.), and if it is found feasible, carry out these measures promptly.

4.2.2 Recommendations to JICA

JICA should encourage EPGE to take action on the above recommendation concurrently and monitor the status of its implementation.

4.3 Lessons Learned

Reserving additional fund and extra implementation period for rehabilitation projects

In the Project, although the scope of rehabilitation work was set by the Preparatory

Survey, however, since it was not possible to suspend operation of generators for long at this time, it was not possible to ascertain the need for rehabilitation in detail. After the commencement of the Project, the needs for additional repair work became clear in a process of breaking down the facilities, which were added to the project scope. Procurement for the additional scope was possible by utilizing surplus funds, since the procurement cost for the original scope was lower than the planned cost as a result of competitive tender. The project period was longer than the plans, therefore efficiency of the Project is judged to be fair.

As for any rehabilitation projects for electro-mechanical equipment such as power plant, in general, it is difficult to identify in advance the scope of all the necessary repair works for the equipment being currently in operation. Therefore, it is a reasonable argument that additional rehabilitation works to be added to the project scope at its implementation phases. Considering the above, in order to achieve the project purpose by appropriate rehabilitation, in accordance with the extent to which concrete needs for rehabilitation could have been confirmed at the time of planning, it is necessary to examine the necessity of additional budgets and extra implementation periods to be included in the plan.