REPUBLIC OF INDONESIA

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PREPARATORY SURVEY ON
WEST JAVA HYDROPOWER PLANTS REHABILITATION, OPERATION AND MAINTENANCE PROJECT
(PPP INFRASTRUCTURE PROJECT)

FINAL REPORT

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CHODAI CO., LTD.

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Summary

Chodai Co., Ltd. (hereinafter referred to as "the Company", "we") is considering a project to rehabilitate and operate (RO) hydroelectric plants owned by the P company, a subsidiary of Indonesia's state-owned power company Perusahaan Listrik Negara (PLN). The prospective power plants are the “A” Power Plant, and “B”-“C” Power Plant located in the suburbs of Bandung City, West Java. Both of these power plants were in operation from the 1920s to the 1950s, and have significantly deteriorated and become obsolete since then. The main purpose of this survey is to check and analyze the current status of the prospective power plants, create a rehabilitation plan, estimate the project cost, and conduct a financial analysis, as well as to examine business and finance schemes, and discuss and coordinate with the parties concerned on the Indonesian side, including the P company, toward the realization of the project.

In Chapter 2, based on the materials provided by the P company and the field surveys, we will check and evaluate the equipment and parts of the power plants under consideration, their operating environment, and operational status. “A” Power Plant is a pondage type power plant consisting of three units of approximately 6.6 MW each. Units 1 and 2 were commissioned in 1925, and Unit 3 in 1934. The main equipment of the turbine generator was rehabilitated in 1995, but it is necessary to check the integrity of the equipment in an overhaul. The plant factor for the past eight years (2014 to 2021) has been about 42%. The optimum plant factor for a pondage type power plant is around 45 to 50%, of which “A” Power Plant falls slightly below. The “B” Power Plant is a 1.05 MW pondage type power plant, downstream of which is the “C” Power Plant, a 0.7 MW run-of-river type power plant. Both power plants have not undergone large-scale rehabilitation since they became operational in 1923, and need to be upgraded to modern facilities, which includes automation. The plant factor of the “B” Power Plant has been 28% over the past eight years; however, in 2019 and 2020, it was extremely low, at the order of 10% level. This is so due to the fact that the output is limited, because of factors such as reduced efficiency of turbines and abnormal shaft bearing temperatures. On the other hand, the “C” Power Plant had a high plant factor of 51% during the same period.

Chapter 3 provides an overview of the power demand and power mix in Indonesia, and sorts out challenges and needs for future development of power sources. We will also collect information on the P company that owns the power plants under examination. Over the 10 years from 2021, domestic power demand is expected to grow at an average annual rate of 4.9%, so there are plans to build 40.6 GW of new supply. 10.4 GW (about one fourth) will potentially be covered by the hydroelectric power. Hydroelectric power is characterized by higher initial costs than thermal power. To reduce these costs, it is important to plan power generation facilities based on appropriate preliminary surveys and basic and detailed designs. The P company owns and operates 23 hydroelectric plants in Indonesia, some of which are well past their useful lives. Achieving the goal of carbon neutrality by 2060 requires not only building new plants, but also enhancing the power output and improving the operational efficiency of aging and obsolete

power plants.

Chapter 4 examines the advantages of Japanese manufacturers based on the local challenges and needs explained in Chapter 3. When it comes to major equipment such as turbines and generators, Japanese manufacturers are significantly inferior to Chinese, Indian, and other overseas manufacturers in terms of costs. Cost reduction is the top priority; however, it is important to provide an added value that leverages the strengths and characteristics of Japanese manufacturers. One of these added values is after-sales service. In particular, after the warranty period has passed, there is no support for failures or accidents, and in many on-site cases where performance deteriorates from an early stage, a maintenance system is an important tool. At the same time, by collaborating with domestic and overseas companies and utilizing their overseas bases, it is possible to expand the use of the local products and contribute to cost reduction.

Chapter 5 examines the scope of rehabilitation for the power plants under consideration by taking into account the degree of deterioration and degradation found in the field survey. At the "A" Power Plant (in 1995, the stator winding and other equipment were partially upgraded), we are considering a "partial replacement" that reuses the existing generator and replaces equipment that contributes to the recovery of turbine efficiency, such as a turbine runner, and a "full replacement" of the turbine and the generator. The maximum output can be increased by 200 kW with the partial replacement, and by 500 kW with the full replacement compared to the current level. For the "B"-"C" Power Plant, which has not been renewed for about 90 years since it became operational, only the "full replacement" plan will be considered. The full replacement plan can increase the maximum output by 100 kW at "B" Power Plant and 90 kW at "C" Power Plant.

In Chapter 6, we will estimate the costs required for rehabilitation, operation and maintenance (O&M), as well as the increased power generation after rehabilitation. First, regarding the replacement proposal explained in Chapter 5, we will estimate the project cost using two patterns based on the Ministry of Economy, Trade and Industry's Agency for Natural Resources and Energy's "Guidance for Calculating Hydroelectric Power Planned Construction Costs" (March 2013) (hereinafter referred to as "Guidance") and the manufacturer's reference quotation. Partial replacement plan of the "A" Power Plant costs JPY 22,000/kW for any pattern, and the full replacement costs JPY 85,000/kW based on the "Guidance". The cost required for the full replacement of the "B" Power Plant is JPY 209,000/kW based on the "Guidance" and JPY 126,000/kW based on the reference quotation. For the full replacement of "C" Power Plant, the costs are JPY 322,000/kW and JPY 243,000/kW, respectively. There is room for cost reductions through domestic procurement of substation equipment. The average annual inspection cost is about JPY 15 million for "A" Power Plant, about JPY 6 million for "B" Power Plant, and about JPY 2 million for "C" Power Plant. Moreover, compared to the past eight years (2014 to 2021), "A" Power Plant is projected to see a 9% increase in the amount of electricity generation from the partial replacement and a 10% increase from the full replacement; in “B” Power Plant a 65% increase from full replacement; and “C” Power Plant a 26% increase from the full replacement.

Chapter 7 examines the business schemes for this project. For this project, a special purpose company (SPC) funded by Chodai Co., Ltd., PT AMCO Hydro Indonesia, etc. will conclude an RO contract with the P company. The SPC will rehabilitate the power plants under consideration owned by the P company and operate and maintain them thereafter. The P company will sell the entire amount of power generated to the PLN based on a power purchase agreement (PPA) and pay a portion of the income from these power sales to the SPC. The “A” Power Plant and “B”-“C” Power Plant will be part of one PPA. . The latest PPA is until the end of 2022, and if the P company and the PLN agree, there will be no legal restrictions on raising the selling price of electricity in response to the increase in installed capacity through rehabilitation.

Chapter 8 explains regarding the interviews we conducted with relevant parties to examine the procurement of equity and debt and the acquisition of guarantees. Initial discussions were held with the S company as a potential investor from Japan, and local the I company as a potential lender, as well as a government guarantee agency. We will continue discussions with all companies and institutions.

In Chapter 9, we estimate returns using multiple scenarios for the replacement plan considered in Chapter 5. The results are shown in the table below. At the “A” Power Plant, returns can be expected even at the current selling price of electricity in the case of a partial replacement. In the case of full replacement, the selling price of electricity must be raised to IDR 750/kWh in order to secure an equity internal rate of return (EIRR) of 15%. The “B”-“C” Power Plant is similarly unviable at the current selling price of electricity, and the selling price of electricity must be raised significantly in order to secure an EIRR of 15%.

Expected returns from this project (real price basis)

Power plant	Replace-ment Details	Tariff	Project cost basis	CapEx (Billion IDR)	PIRR	EIRR
“A”	Partial	Current	"Guidance"	56.3	10.40%	10.81%
	Partial	Current	Manufacturer's quotation	54.5	10.84%	11.43%
	Full	Current	"Guidance"	201.1	▲5.25%	▲7.93%
	Full	Adjusted	"Guidance"	207	13.81%	15.75%
“B”-”C”	Full	Current	"Guidance"	115.5	▲13.69%	▲17.08%
	Full	Current	Manufacturer's quotation	74.5	▲10.27%	▲13.38%
	Full	Adjusted	"Guidance"	119.6	13.37%	15.08%
	Full	Adjusted	Manufacturer's quotation	77	13.95%	15.93%

Chapter 10 sorts out the process for concluding an RO contract, laws and regulations, permits and licenses related to this project, and shows the project implementation schedule. In this project, there is a strong possibility that the P company will procure RO through public tender. There are no restrictions on foreign investment in the RO project; however, the investment amount must be at least IDR 20 billion, excluding the value of land and buildings, and the issued, and the paid-in capital must be at least IDR 10 billion. It is projected that the period from the start of the RO procurement process to the start of operation will be a little over two years.

In Chapter 11, we will calculate the effect of this project on reducing CO_2 emissions and improving the environment. The CO_2 emissions from the hydroelectric power generation are insignificant to begin with, and assuming that other power sources can be replaced by an increase in power generation due to increased output and operational efficiency, the “A” Power Plant is expected to reduce CO_2 emissions by 3,815 tons per year, and the “B”-“C” Power Plant by 3,698 tons, for a total reduction of 7,513 tons of CO_2 emissions. Moreover, unlike building new plants, this is a rehabilitation project. Therefore, it will not cause any environmental and social impacts.

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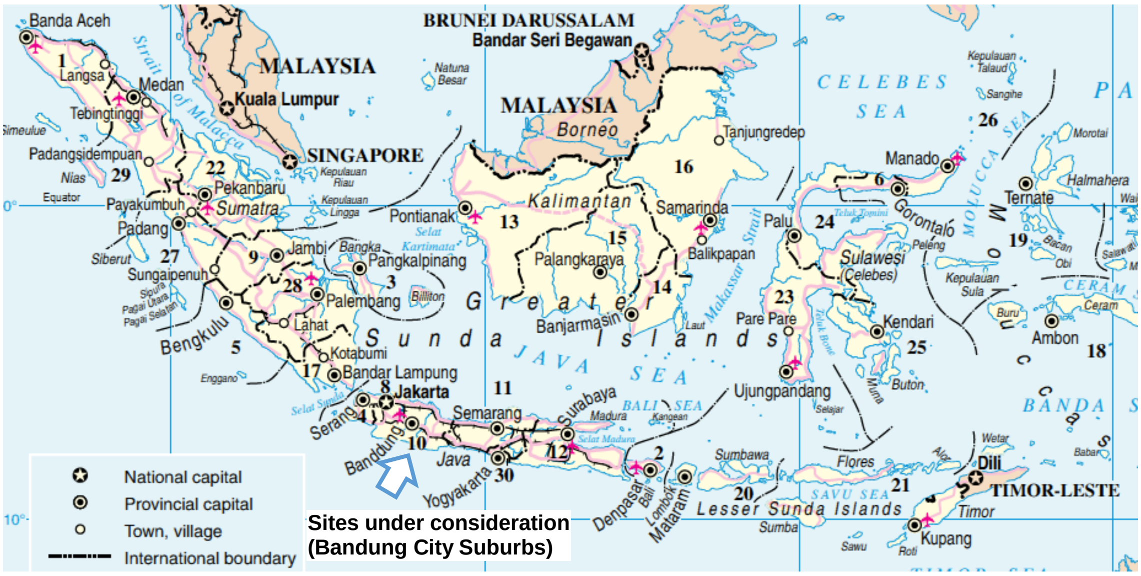
Abbreviations

Abbreviations	English/Indonesian
BOT	Build-Operate-Transfer
CapEx	Capital Expenditure
CFD	Computational Fluid Dynamics
EIRR	Equity Internal Rate of Return
F/S	Feasibility Study
FIT	Feed-in Tariff
IDR	Indonesia Rupiah
IEC	International Electro-technical Commission
IPP	Independent Power Producer
JEC	Japanese Electro-technical Committee
O&M	Operations and Maintenance
PIRR	Project Internal Rate of Return
PLC	Programmable Logic Controller
PLN	Perusahaan Listrik Negara
PPA	Power Purchase Agreement
RO	Rehabilitate-Operate
RTM	Right to Match
RUPTL	Rencana Usaha Penyediaan Tenaga Listrik
SCADA	Supervisory Control and Data Acquisition
SPC	Special Purpose Company

Map



Source: United Nations website

Note

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The exchange rate is 1 JPY = 110 IDR (August 9, 2022; www.exchangerates.org.uk).

Chapter 1 Survey overview

Electricity demand in Indonesia is growing at an average annual rate of about 7% to 8%. Based on the global trend toward decarbonization, the "National Energy Policy (Kebijakan Energi Nasional)" (which sets out a framework of energy policy up to 2050) plans to increase the ratio of renewable energy to 23% by 2025 on a primary energy basis. Based on this, the state-owned power company Perusahaan Listrik Negara (PLN) plans to increase installed capacity by 40.6 GW over the next 10 years in the General Power Supply Plan (RUPTL) 2021-2030. Approximately one-fourth of this, or 10.4 GW, will be generated by hydroelectric power, and the stable supply of electricity by hydroelectric power will continue to be important.

On the other hand, the PLN Group alone has 152 hydroelectric plants nationwide. The power plants, many of which were designed more than 50 years ago, are difficult to operate efficiently. The issue is not only new plants but also improving the operational efficiency of existing facilities.

For this project, a special purpose company (SPC) funded by Chodai Co., Ltd. (hereinafter referred to as "Chodai") will sign a rehabilitate-operate (RO) contract with the P company, a PLN-affiliated independent power producer (IPP). The special purpose company will rehabilitate the facilities of the two existing hydroelectric plants (replace power generation turbines with more efficient ones, etc.) and operate and maintain those plants (O&M). This will improve output and power generation efficiency, reduce the risk of blackouts due to major power generator failures, and contribute to clean and stable power supply in Indonesia. Among the hydroelectric power plants owned by the PLN Group, the target of this project will be two hydroelectric plants (“A” 19.56 MW, “B”-“C” 3.85 MW) located on the outskirts of Bandung City, West Java, which are relatively close to high power demand areas and have been in operation since the 1920s to 1950s.

The main purpose of this survey is to check and analyze the current status of the prospective power plants, create a rehabilitation plan, estimate the project cost, and conduct a financial analysis, as well as to examine business and finance schemes, and discuss and coordinate with the parties concerned on the Indonesian side, including the P company, toward the realization of the project. We will also examine the need for rehabilitation of the hydroelectric plants in Indonesia and the advantages of Japanese manufacturers for the rehabilitation.

Chapter 2 Checking and analysis of the current situation of the prospective sites

2.1 Power plant facility overview and operating environment

This project will target the “A” Power Plant and the “B”-“C” Power Plant located on the outskirts of Bandung City, West Java, Indonesia.

2.1.1. “A” Power Plant facility overview and operating environment

“A” Power Plant is located in the south of Bandung city. The plant is located downstream of the “D” Power Plant, which uses the effluent from the Dam1 and Dam2 that were constructed on a lake for irrigation purposes. It is a pondage type power plant that adjusts load fluctuations for one day using the water discharged from the power generation. Three power plants “D” Power Plant, “A” Power Plant, and “E” Power Plant are constructed with the cascade method[1] on the same river basin. Units 1 and 2 of “A” Power Plant became operational in 1925, and Unit 3 in 1934. The main equipment of the turbine generator was rehabilitated in 1995. Based on the documents and the materials provided by the P company and the equipment nameplate, the overview of the equipment Table 2-1 is shown below. Moreover, 208 m is mentioned, which is considered to be the standard effective head.

Table 2-1 “A” Power Plant facility overview

		Original		After rehabilitation
		Units 1 and 2	Unit 3	Units 1 to 3
Rated output (kW)		6,520	6,520	6,520
First year of operation		Year 1925	Year 1934	Year 1995
Turbine	Turbine type	Vertical shaft Francis	Vertical shaft Francis	Vertical shaft Francis
	Number of units	2 units	1 unit	3 units
	Turbine power output[2] [3](kW)	6,600 (9,000PK)	6,600 (9,000PK)	6,600
	Effective head (m)	208	208	208
	Discharge (m^3/s)	3.9	3.65	3.65
	Turbine efficiency (%)	83	89	90

[1] A cascade is a configuration form of power plants that are connected in a row.
[2] The number of significant digits for the turbine output is set to two digits, so it does not match the value after unit conversion.
[3] PK is a Dutch horsepower notation, 1 PK =1 PS =735.5 W.

Generator	Generator type	Synchronous generators	Synchronous generators	Synchronous generators
	Capacity (kVA)	8,000	8,000	7,250
	Voltage (kV)	6.3	6.3	6.3

The “A” Power Plant is located at the bottom of a steep valley with a width of 450 m, an elevation difference of about 100 m to the office on the right bank, and an elevation difference of about 210 m to the head pond on the left bank. There is no approach road to the power plant, and the only route for carrying maintenance personnel and materials in and out is a winch (hoisting machine) that has been in use for over 90 years. The generated power is transmitted to the PLN “A” substation next to the office through transmission lines in the cable pit installed parallel to the winch.

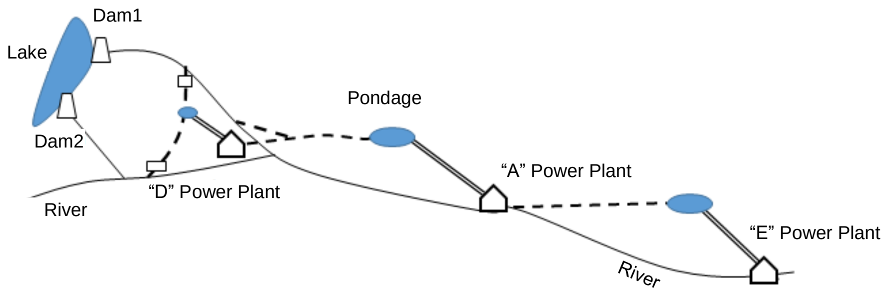


Fig. 2-1 Overview of “A” river basin

2.1.2. Facility overview and operating environments of “B”-“C” Power Plant

”B” Power Plant is located in a residential area north of Bandung City, and “C” Power Plant is located downstream of “B” Power Plant. The “B” Power Plant is a pondage type power plant that utilizes effluent from the Dam, while the “C” Power Plant [4] is a run-of-river type power plant that utilizes all of the “B” Power Plant's discharge and a portion of other river discharges. Both power plants have been operational since 1923 and have continued without major renovations. However, the facility itself have become obsolete and need upgradation to a modern facility, which includes automation. Moreover, although its start date is unknown, the drinking water factory (or water purification facility) takes in 0.3 m^3/s x 2 waterways from the upstream of the intake weir of the “B” Power Plant.

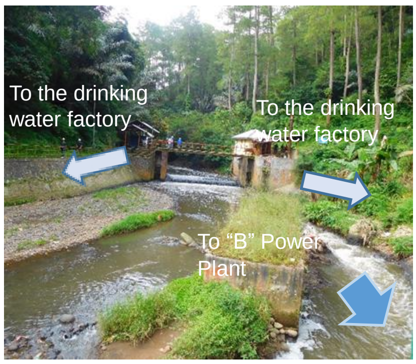


Fig. 2-2 Intake of “B” Power Plant

[4]The “C” Power Plant is considered as a part of the “B” Power Plant.

Based on the documents and the materials provided by the P company and the equipment nameplate, the overview of the equipment is Table 2-2 shown below.

Table 2-2 Overview of facilities at “B” Power Plant and “C” Power Plant

		Original	
		“B” Power Plant	“C” Power Plant
Rated output (kW)		1,050	700
First year of operation		Year 1923	Year 1923
Turbine	Turbine type	Horizontal shaft Francis	Horizontal shaft Francis
	Number of units	3 units	1 unit
	Turbine power output[5] (kW)	1,100 (1,500PK)	750 (1000PK)[6]
	Effective head (m)[7]	104	44
	Discharge (m^3/s)	1.36	2.25
Generator	Generator type	Synchronous generators	Synchronous generators
	Capacity (kVA)	1,500	1,000
	Voltage (kV)	6.3	6.3

There is no problem with the loading and unloading of equipment at “B” Power Plant. On the other hand, at “C” Power Plant, which is located in an urban area, the access road for equipment and materials is narrow and winding. In particular, there is no road from the middle of the penstock, and there are stairs, which is a big obstacle for the rehabilitation work.

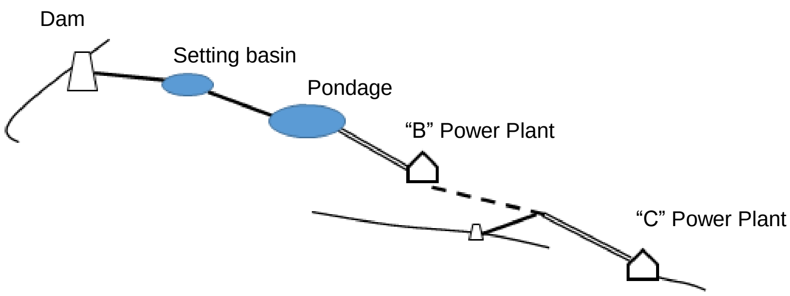


Fig. 2-3 Overview of the “B” river basin

2.2 Current status and evaluation of power generation facilities

5 The number of significant digits for the turbine output is set to two digits, so it does not match the value after unit conversion.
6 The turbine efficiency calculated from the effective head and the water consumption of the “C” Power Plant is 0.536, and the turbine output is thought to be 750 (kW), instead of 750 (PK).
7 The P company does not have detailed data on the effective head.

Based on the information collected during the field survey and the operation status of the main equipment of the power plant, we conducted an integrity evaluation of the equipment at each power plant.

2.2.1. Current Status and Evaluation of “A” Power Plant

A summary of the results of the field survey and evaluation of the “A” Power Plant is shown in Table 2-3.

Table 2-3 Field survey results and evaluation of “A” Power Plant

Equipment	Main parts	Survey results	Evaluation
Turbine	Runner, Guide vane, Sheet liner	In 1995, the turbine efficiency was increased to 90%, thereby increasing the runner performance. Since the backup runner has never been used, the runner has been in use for about 20 years. Although there is no cavitation or abnormal vibration, it is presumed that there is water leakage from the upper cover and oil leakage from the surrounding area, and the efficiency is declining.	According to the recent records, the guide vanes and the sheet liners of Unit 3 and Unit 1 were replaced in 2017 and 2018, respectively; however, no overhaul was carried out to disassemble and inspect the entire turbine generator. It is necessary to conduct an overhaul, replace any worn out parts such as runners, and check the equipment's integrity periodically, such as by performing non-destructive inspections of highly stressed parts.
	Pressure regulation valve	It is in a good working condition. However, the designed maximum water pressure rise value is unknown.	Removal is difficult due to the low specific speed (62) turbine. Can be used continuously.
	Inlet valve	Has been upgraded in 1995. It is working fine.	To check the integrity of the equipment, it is necessary to conduct a non-destructive inspection during an overhaul.
	Speed Governor	It has been upgraded to an analog governor developed by the PLN.	It is time to upgrade to a digital governor.

	Oil pressure supply system	Aging of measurement and control equipment is conspicuous.	It is time to upgrade the measurement and control equipment.
Generator	Machine body	Major parts such as the stator winding were upgraded in 1995. The insulation type was changed from B to F, and the power factor was changed from 80% to 90%.	This is the time when the stator windings begin to deteriorate, and it is necessary to conduct periodic insulation diagnostic tests to determine the lifespan of the windings.
	Exciter	It was upgraded to a static (thyristor type) exciter in 1995, and the exciter panel was upgraded in 2016.	Can be used continuously.
	Bearing	The bearing temperature is within the permissible range, and it remains in good condition.	Can be used continuously.
Control Device	Control panel Protection panel	The deterioration of the instruments on the control panel and the protection panel is conspicuous, and their reliability is declining.	It is time to upgrade the monitoring and control equipment.

2.2.2. Current Status and Evaluation of “B” Power Plant

A summary of the results of the field survey and evaluation of the “B” Power Plant is shown in Table 2-4.

Table 2-4 Field survey results and evaluation of “B” Power Plant

Equipment	Main parts	Survey results	Evaluation
Turbine	Casing, Runner, Guide vane	The turbine casing is presumably made of gray cast iron (FC). When a turbine made from this material is used for more than 90 years, the overall strength of the turbine decreases due to wear and corrosion, making it obsolete. Moreover, the runners are deformed and defective due to welding repairs.	Turbine casings and runners have already reached their limits of use.
	Inlet valve	Installed outside the building, it is manually opened and closed from the inside via chain gears.	It needs to be made automated and chainless.
	Speed Governor	It is a mechanical governor and speed detection is with a belt. Moreover, the turbine is started manually.	It is time to upgrade the mechanical governor to a digital one. Automating the start/stop of the turbine is also necessary.
Generator	Machine body	The stator windings are compound-insulated and have already reached the end of their service life.	It needs to be upgraded to a new insulation system.
	Bearings	Since the bearing temperature rises abnormally, wear on the bearings and a change in thrust amount are likely.	It is necessary to replace the bearing metal and measure the amount of thrust.
ControlDevice	Control panel Protection panel	Damage to gauges, etc. is visible, and they have markedly deteriorated.	It is time to upgrade the monitoring and control equipment.

2.2.3. Current status and evaluation of “C” Power Plant

A summary of the results of the field survey and evaluation of the “C” Power Plant is shown in Table 2-5.

Table 2-5 Field survey results and evaluation of “C” Power Plant

Equipment	Main parts	Survey results	Evaluation
Turbine	Casing, Runner, Guide vane	The turbine casing is presumably made of gray cast iron (FC). When a turbine made from this material is used for more than 90 years, the overall strength of the turbine decreases due to wear and corrosion, making it obsolete.	Turbine casings and runners have already reached their limits of use.
	Inlet valve	Installed outside the building, it is manually opened and closed from the inside via chain gears.	It needs to be made automated and chainless.
	Speed Governor	It is a mechanical governor and speed detection is with a belt. Moreover, the turbine is started manually.	Automation is required.
Generator	Machine body	The stator windings are compound-insulated and have already reached the end of their service life.	It needs to be upgraded to a new insulation system.
Control Device	Control panel Protection panel	Damage to gauges, etc. is visible, and they have markedly deteriorated.	It is time to upgrade the monitoring and control equipment.

2.3 Operation status of the power plant

After sorting out the past amount of power generated and plant factor of each power plant under consideration and analyzing the amount of water used, the performance of the turbine will be evaluated.

2.3.1. Power Generation Results

The amount of power generated[8] and the plant factor for each power plant under consideration from 2014 to 2021 has been summarized.

2.3.1.1. Power generation performance at "A" Power Plant

The average amount of power generated at the "A" Power Plant from 2014 to 2021 is 70,491 MWh, the average power[9] is 8,047 kW, and the plant factor[10] is about 42%. Empirically, a power plant with a large adjustment coefficient has an optimal plant factor of about 45 to 50%, which is lower than that of a run-of-river type plant. Since the "A" Power Plant is a pondage type hydropower plant, it is equivalent to a power plant with a large adjustment coefficient.

2.3.1.2. Power Generation Results of "B" Power Plant

The average amount of power generation at the "B" Power Plant from 2014 to 2021 is 8,030 MWh, and the average power is 917 kW. The plant factor was extremely low for the unit in 2019 and 2020 at the order of 10% level, and the eight-year average is at the low level of about 28%. This plant factor is extremely low, although it is a reservoir-type hydropower plant.

In the vibration measurement survey, it was found that the power plant did not reach the maximum output, even when the guide vanes were 100% open. Also, when the output was increased to around 650 kW (60% output), the temperature of the shaft bearings rose up to near the limit values and the power plant could not provide maximum output. The direct cause of the low-plant factor is the limited output due to factors such as reduced efficiency of turbines and abnormal shaft bearing temperatures.

[8] Power generation performance is based on the operating data of the P company.
[9] Average power (kW) = Amount of generated power (MWh) x 1000/(365 x 24)
[10] Plant factor (%) = Amount of generated power (MWh)/{Rated output 6.52 (MW) x 3 units x 365 x 24}

2.3.1.3. "C" Power Plant Power Generation Results

The average amount of power generation at the "C" Power Plant from 2014 to 2021 is 3,516 MWh, average power is 360 kW, the plant factor is high at 51%, and the water flow is relatively good.

2.3.2. Power plant water consumption

The river duration curve is based on rainfall and river water level data in the "A" and "B" catchment areas, as there is no data on actual water discharge measurement This curve is the average river discharge over the past 10 years (2009 to 2018) logically predicted by a hydrological analysis model (Hec-HMS). The correlation between the measured data by discharge observation and the hydrological analysis model has not been verified. Therefore, the precision of this discharge remains a problem.

Intake discharge is the discharge from the P company measuring the water level of the intake channel and converting it using the water level/discharge conversion curve. The intake discharge curve is the average daily discharge for the past 8 years (2014 to 2021), arranged in descending order.

The annual possible discharge for power generation differs depending on whether the river duration curve or the intake discharge curve is used. For calculating the project scale, the intake discharge curve will be used in this study, as there might be an overestimation if the river duration curve is used.

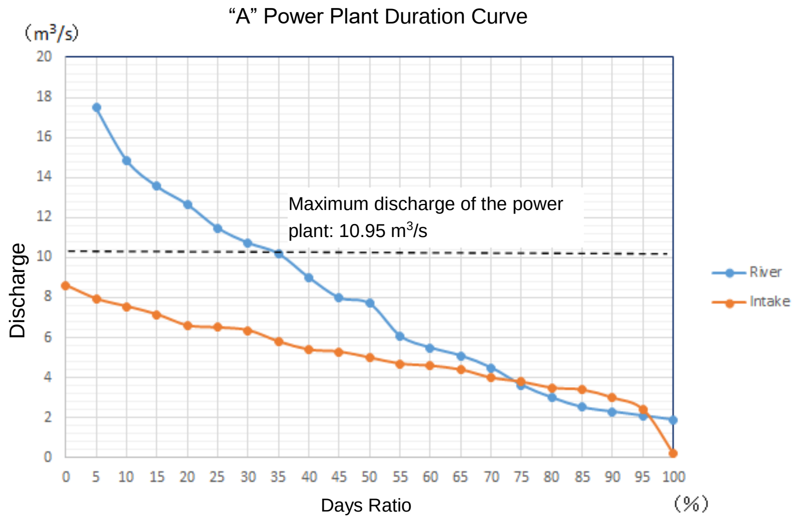


Fig. 2-4 "A" Power Plant - Duration curve

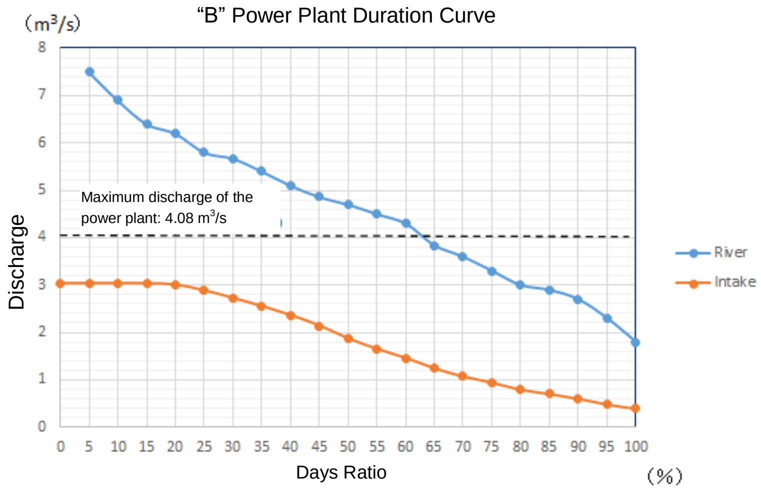


Fig. 2-5 "B" Power Plant - Duration curve

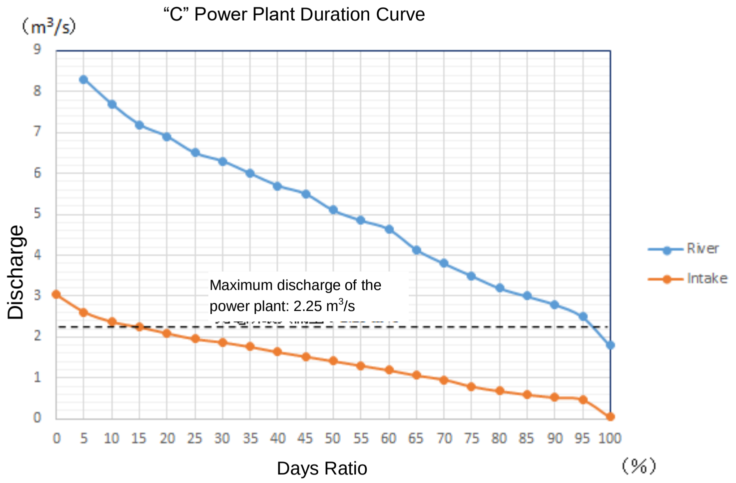


Fig. 2-6 "C" Power Plant - Duration curve

2.3.3. Turbine performance evaluation

The current efficiency of Units 2 and 3 was calculated (estimated) from discharge measurement data. A comparison of the total efficiency η converted to the standard head (208 m) and the turbine efficiency η_T is shown in Fig. 2-7 and Fig. 2-8.

The original efficiency (presumption) in the table is based on the turbine efficiency in the equipment outline, and was formulated for the study of this project while considering recent turbine performance improvement technologies. Reference was made to the "Guidebook for Small and Medium-sized Hydroelectric Power (Fifth Revised Edition)"[11], "Hydro Valley Planning

[11] New Energy Foundation: "Guidebook for Small and Medium-sized Hydroelectric Power (Fifth Revised Edition)" (May 2019)

Guidebook"[12], "Hydropower Development Guide Manual"[13], etc. In the future, it will also be used for trial calculations of the output scale.

The figure shows that the drop in efficiency at the rated discharge (3.65 m^3/s) is small, but the drop in efficiency of the partial load side is large. However, the decrease in efficiency at partial loads may be due to the large discharge error due to the small number of measurement points. Moreover, considering that there is no record of using a backup runner, the efficiency is projected to decrease by about 10% in about 20 years, or about 0.4 to 0.6% per year.

[12] Hydro Valley Plan Guidebook, Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry (March 2005)

[13] Japan International Cooperation Agency, Electric Power Development Company, and Kaihatsu Sekkei Consultants, Inc.: "Hydroelectric Power Development Guide Manual" (March 2011)

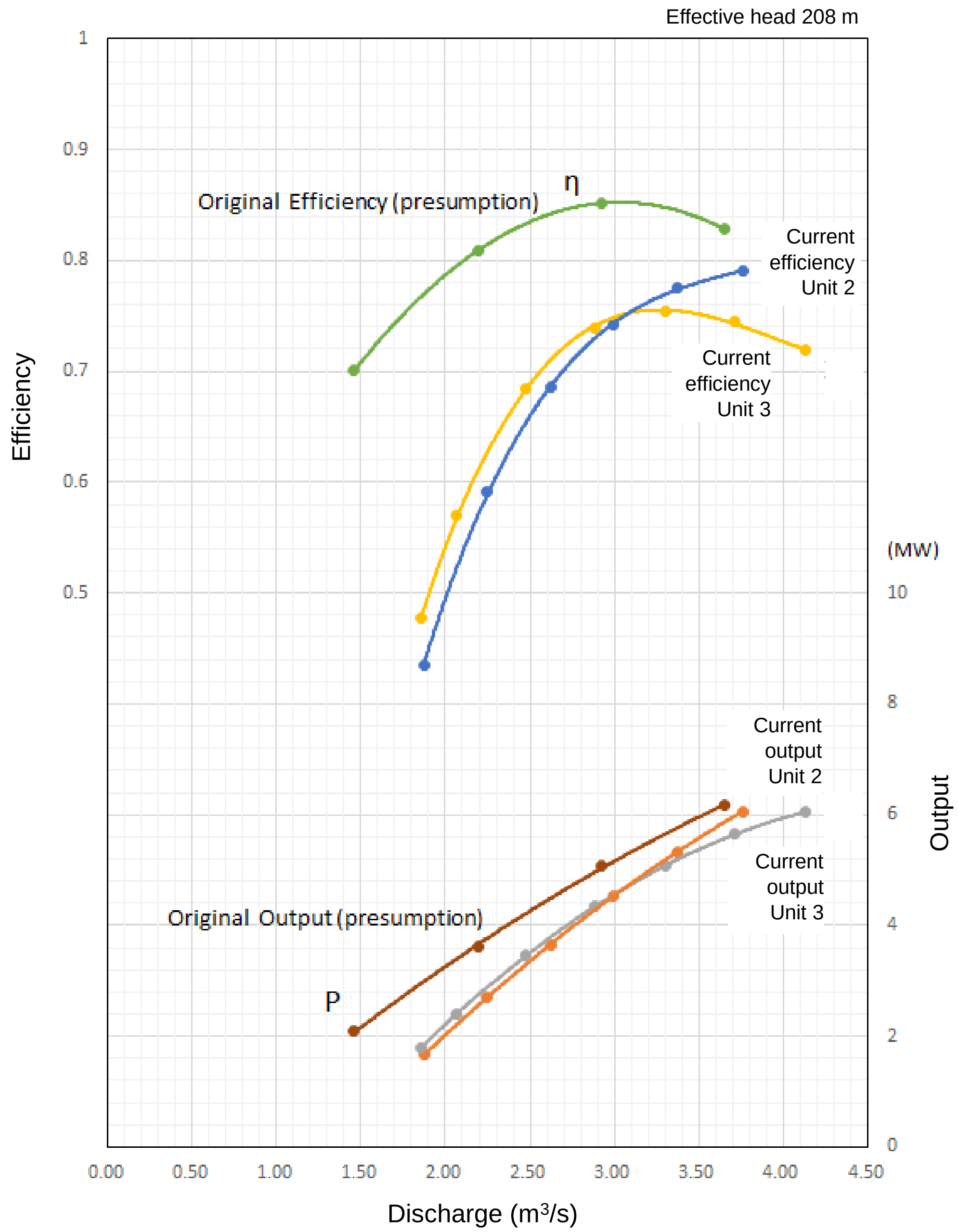


Fig. 2-7 Existing turbine characteristics (overall efficiency) estimated from discharge measurement results

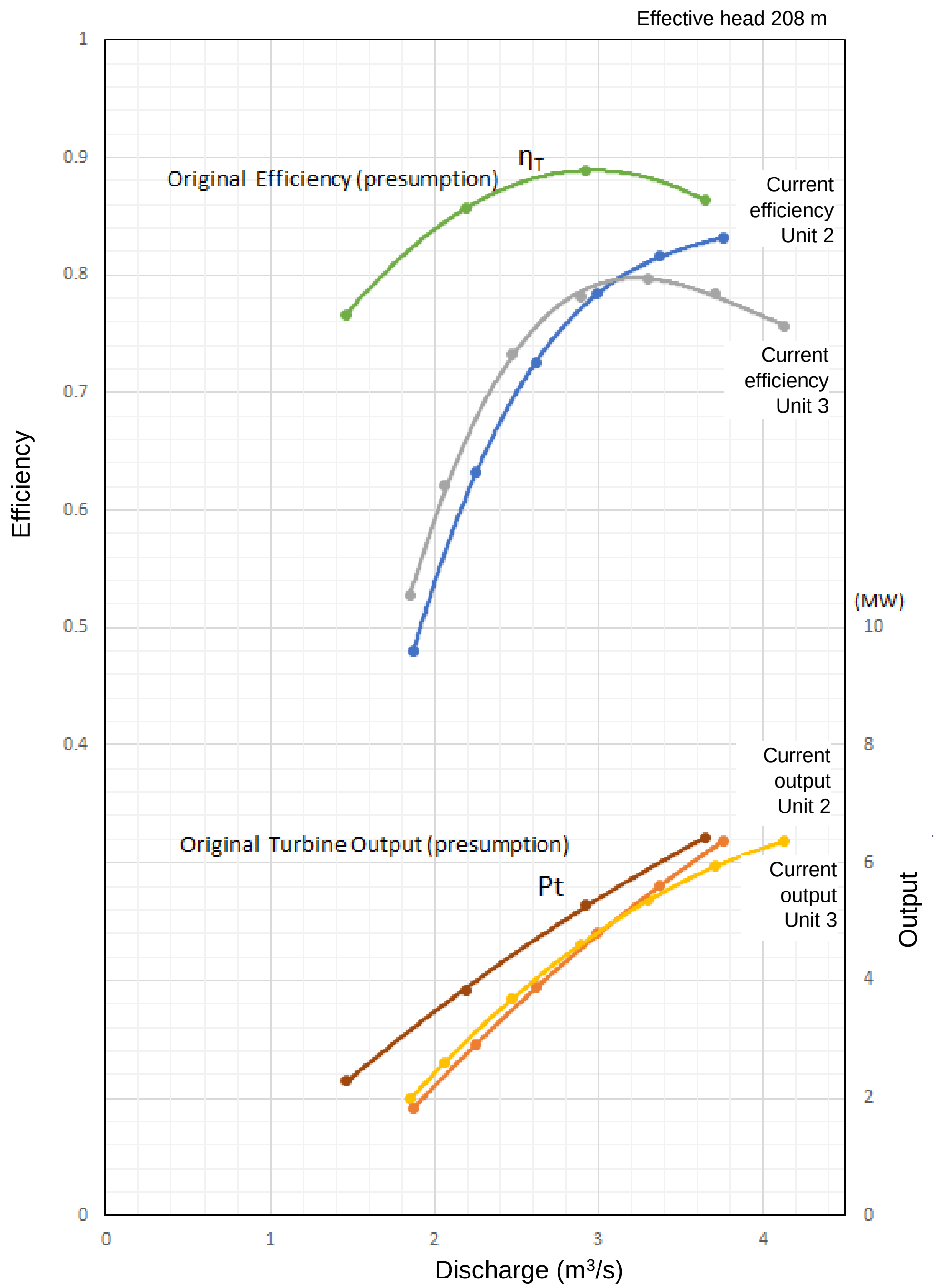


Fig. 2-8 Existing turbine characteristics (turbine efficiency) estimated from discharge measurement results

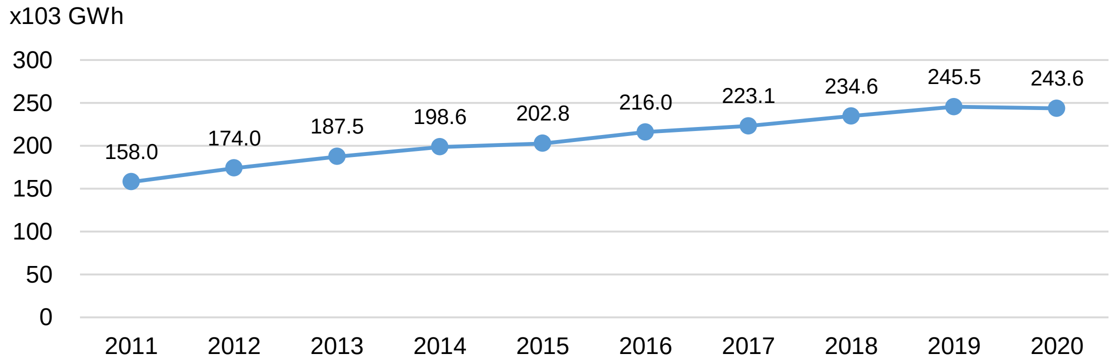
Chapter 3 Market needs, market size, and demand forecast

3.1 Electric power situation in Indonesia

After surveying power demand and the power mix in Indonesia, future power source development policies and their challenges and requirements are sorted out. Further, information on the P company that owns the power plants involved in this project has been organized.

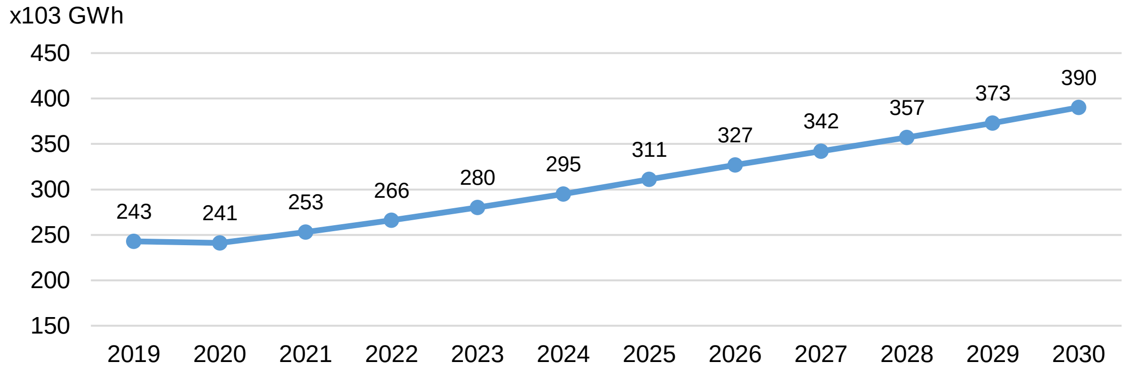
3.1.1. Power demand

Indonesia's domestic power demand is growing at around 7 to 8% annually. To address this increase in the demand, development of new power sources by launching several crash programs is being promoted. In RUPTL 2019-2028, the PLN expected an average annual power demand growth rate of 6.4% over the next 10 years, and planned to increase installed power generation capacity by about 60 GW by 2028. But in response to the COVID-19 pandemic, RUPTL 2021-2030 revised down the average annual power demand growth rate to 4.9% over the 10-year period from 2021 to 2030, and the increase in installed power generation capacity was revised down to 40.6 GW.



Source: The PLN Annual Report

Fig. 3-1 Changes in electricity sales volume of the PLN



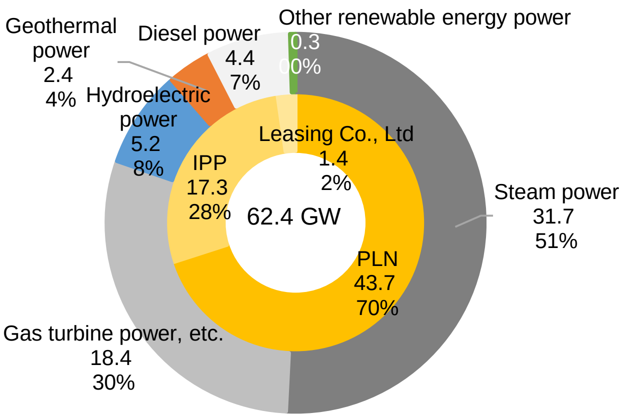
Source: RUPTL 2021-2030

Fig. 3-2Electricity sales forecast for RUPTL 2021-2030

3.1.2. Power source development

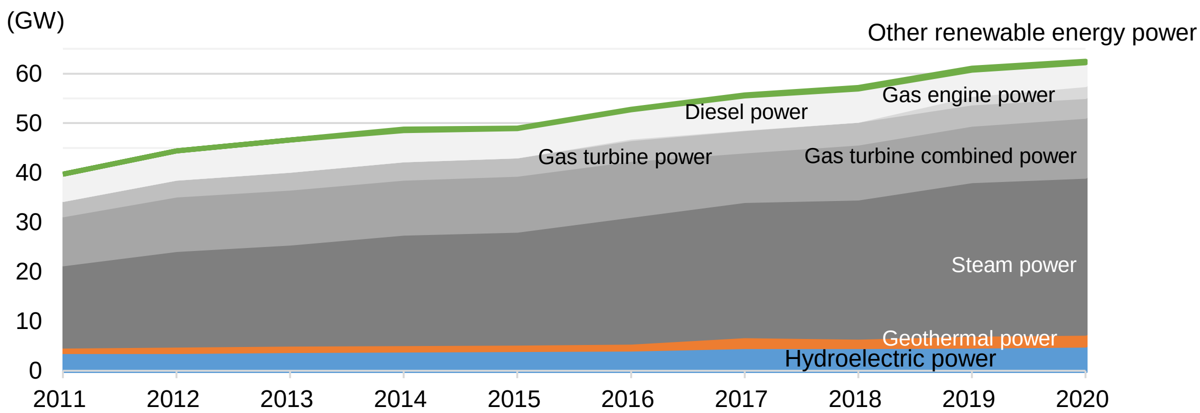
3.1.2.1. Power mix

As of December 2020, the total installed capacity of power plants in Indonesia is 62.4 GW, consisting of PLN 43.7 GW, 17.3 GW private and 1.4 GW leased. By type of power generation, 51% is steam, 30% is gas turbine, gas turbine combined, and gas engine, 7% is diesel, 8% is hydroelectric, 4% is geothermal, and the rest is other renewable energy.



Source: RUPTL 2021-2030

Fig. 3-3 Power mix (as of the end of 2020)

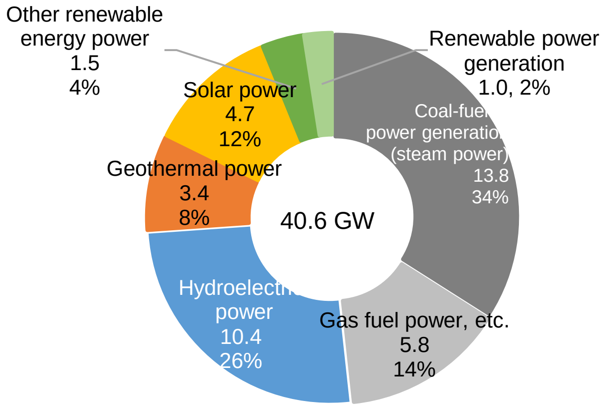


Source: RUPTL 2021-2030

Fig. 3-4 Changes in installed capacity

3.1.2.2. Power plan

As mentioned above, the electricity growth rate in 2020 was only 0.79% due to the COVID-19 pandemic, so considering the uncertainty of demand after the end of the pandemic, RUPTL 2021-2030 assumes an average annual power demand growth rate of 4.9% over the next 10 years, with an additional installed capacity of 40.6 GW. This is lower than the RUPTL 2019-2028 annual average of 6.4%.



Source: RUPTL 2021-2030

Fig. 3-5 Additional installed capacity

However, most of the crash programs[14] are in the build phase and will go live soon. Oversupply is possible in the absence of increased demand due to the COVID-19 pandemic. The PLN said it will take steps to mitigate the risk and impact of oversupply.

Meanwhile, in line with international trends in reducing greenhouse gas emissions, the Indonesian government has set a national reduction target[15] of 29% by 2030 compared to business as usual (BAU[16]), and aims to achieve a maximum reduction of 41% by utilizing international assistance. It announced that it will achieve carbon neutrality by 2060 at the latest.

To achieve the country's goal of "Carbon Neutral 2060," the PLN has committed to an energy mix that uses 23% or more renewable energy from 2025, and has set additional power generation capacity from renewable energy at 16.1 GW. Among the energy mix, hydropower and small hydropower are the largest, at 8.9 GW, equivalent to 22% of the total capacity.

3.1.2.3. Challenges and needs related to power source development

In Indonesia, to respond to the vigorous growth in the electricity demand, the 1985 Electricity Law opened up the power infrastructure business to the private sector, advocating public-private partnerships as policy. Developing electric power infrastructure requires a large amount of funds. Under this policy, power companies preferentially allocate their limited budgets to the construction of distribution systems such as transmission lines and substations, and utilize private funds for power sources. Therefore, expectations for power source development by the private sector are extremely high.

[14] Crash program: Programs call for the construction of 10 GW of non-petroleum fuel power plants in the first five-year period from 2006 to 2010 and the second program in the five-year period from 2015 to 2019.

[15] Nationally Determined Contribution (NDC)

[16] Business as Usual

Although the power source development capacity for the decade from 2021 has been revised downward due to the COVID-19 pandemic, the amount is actually 40.6 GW, which is a large infrastructure investment equivalent to about 60% of the current power generation facilities. Furthermore, when developing power sources, the proportion of renewable energy will be increased in order to achieve "Carbon Neutral 2060". Among them, hydroelectric power generation and small hydroelectric power generation are expected to generate 8.9 GW, which accounts for 22% of the new power development capacity.

While steam power generation and gas turbine power generation have mounting running costs due to fuel costs, civil engineering costs such as from dams and waterways mount for hydroelectric power, resulting in high initial costs. But with proper maintenance, it can be used for a long time, so running costs are low. Appropriate planning for power generation facilities is essential to reduce the initial costs. Basic design and detailed design are important, based on preliminary survey and its analysis and evaluation such as checking precise flow conditions, selection of appropriate power generation equipment based on it, checking geological topography, etc.

Chapter 4 Advantages of Japanese manufacturers

4.1 Building advanced O&M that leverages the advantages of Japanese manufacturers

For main equipment such as turbines and generators, Japanese manufacturers are about double as expensive as overseas manufacturers, mainly in China and India. In particular, the difference in the price of control equipment is large, and Japanese manufacturers are greatly inferior in terms of cost.

Japan is active in the development of small and medium-sized hydroelectric power plants of 30,000 kW or less using the Feed-in Tariff (FIT) system and rehabilitation work aimed at increasing the output of existing turbine generators. The market for small and medium-sized hydroelectric power generation equipment was relatively booming, and when the FIT was first established, there was hope that technological innovation focused on cost reductions would overcome the competition for orders from overseas manufacturers. However, Japanese users have a strong demand for high performance and high quality, and custom-made products are dominant. The entry of foreign manufacturers is hindered due to the difference between overseas standards and Japanese standards, and the high level of required specifications that emphasize quality and functionality. As a result, opportunities for competition with overseas products have decreased, and despite the emphasis on cost reduction, companies are unable to break away from their high cost structure, and are losing ground in price competition.

When expanding into the local market, the initial cost reductions are basically the top priorities. If we can provide high added value that meets local needs, such as with the brand image of Japanese-made equipment and after-sales service, we will be able to take advantage of the strengths and characteristics of Japanese manufacturers. One of those is after-sales service, which is naturally very extensive in Japan. At hydroelectric plants in Indonesia, after the warranty period has expired, there is no support for failures or accidents, and there are many situations where performance deteriorates from an early stage. This is the key point where Japanese manufacturers add value to compete, and establishing a maintenance system, such as building a network of construction shops and agents that can carry out maintenance, is a key to their overseas strategy.

Collaboration with companies that have local operational know-how enables the advancement of equipment diagnosis technology such as preventive maintenance and predictive detection through the introduction of information and communication technology (ICT) and operational information data analysis technology. It is possible to reduce power generation costs by reducing maintenance costs and improving utilization rates. Create a new business model, such as building an after-sales service system that is linked to power plant operation management through advanced O&M.

4.2 Aiming for local expansion of Japanese manufacturers

Despite the recognition and understanding of the importance of high-quality hydroelectric power generation equipment for hydropower development in Indonesia, the reality is that initial costs must be emphasized in terms of recovering capital costs. It is necessary to create an environment that allows us to provide configurations, quality, and prices that meet the needs of users, and it is increasingly important to build a business model based on new ideas for maintaining high technological capabilities and cost competitiveness.

Japanese manufacturers tend to be reluctant to expand overseas due to the risks involved, and it is important to seek cost strategies with a long-term perspective in order to enhance their international competitiveness. For example, it is necessary to establish a joint venture with a company that can be a local partner in terms of manufacturing turbines, generators, and control equipment at overseas (mainly Asia) bases, while focusing on design and engineering in Japan. Collaboration with domestic and foreign companies and utilization of their overseas bases (networks) enables the reduction of initial costs by expanding the use of local products.

Moreover, when Japanese manufacturers (which are reluctant to accept orders overseas) enter the local market, consultant companies with the know-how to collaborate and support domestic and overseas companies with technological capabilities and price competitiveness play an important role. By collaborating with local consulting companies, we hope to create new projects, promote Japanese products, and inject technical resources into feasibility study (F/S) evaluations.

In order to promote the overseas expansion of Japanese manufacturers, it is necessary to overcome the cost hurdle and build an advanced risk communication system for risk reduction and risk transfer in overseas markets.

Chapter 5 Basics Design of the Infrastructure System

5.1 Overall plan for the power plant

Hydroelectric plants require a higher initial investment than other power sources with its civil engineering cost accounting for significant portion of the total cost; however, these plants can have a service life of over 100 years with proper maintenance. Moreover, mechanical equipment such as turbine and generators can also stay operational for a long period of time when these parts are repaired or replaced at appropriate intervals. Therefore, it is important to make an effort to perform preventive maintenance, such as by periodically executing equipment diagnostics and inspections on mechanical equipment, ascertaining any machinery defects or damage, and making repairs or renovations at appropriate intervals.

"Redevelopment" that changes structures of a power plant, such as the dam and waterway channels, requires construction equivalent to building a new facility, and river flow data using actual measurements is crucial for this process. Since the P company does not possess this data, the river discharge was estimated using a hydrologic analysis model. However, the correlation of the hydrologic analysis model and the flow measurement data could not be verified, there remains an accuracy problem. As a result, redevelopment is not being considered in this project. Changing the number of units has also been removed from the examination since doing so would be a large-scale civil engineering undertaking.

Furthermore, because various equipment diagnostic inspections such as nondestructive tests have not been performed on any of the three power plants under the scope, the scope and contents of the renovations are examined in the context of two patterns, partial replacement and full replacement, based on locally performed inspection results that took into account the degree of aging and degradation.

In the examination, renovation proposals are considered based on the following viewpoints that will allow stable operation for at least the next 20 to 30 years.

- Improvement in plant safety and reliability
- Extension of the usage limitations of equipment and performance restoration
- Lowering of maintenance costs
- Improvement in power output, efficiency, maximum power output, and generated power

5.1.1. Organizing the rehabilitation method

- Partial repair: Repairing the erosion of runners, etc. to maintain performance (overhauling).
  - ・ Turbines, etc.: Cavitation repair (welding) of runners
  - ・ Generators: Inspection and cleaning the inside generators
- Partial replacement: Similar to replacing the runners and stator coils, parts showing clear degradation will be replaced, improving performance (efficiency, etc.) to near initial performance levels
  - ・ Turbines, etc.: Replacement of runners, and replacement of sheet liner, and cover liner (fixed parts)
  - ・ Generators: Replacement of generator stator coils and cores
- Full Replacement: Full replacement of generator equipment large-scale modification construction for replacing the main equipment including buried equipment
  - ・ Full replacement of turbines and generators (scrap and build)
- Redevelopment: Changing the structures of the power plant, such as the dam and water channels which is construction is equivalent to building a new facility.
  - ・ Construction that changes structures of the power plant, such as dams and waterway channels
  - ・ This construction would be equivalent to building a new facility, and river flow data using actual river flow data would be crucial.

5.1.2. New technology of turbine equipment

(1) High-performance design technology for runners

It is essential to optimize the overall design of the turbines by improving the performance of the runners to increase the generated power. Replacing mainly the runners and guide vanes moves the highest efficiency point of the turbines, which makes it possible to improve the partial load efficiency and to increase the power output for the highest discharge point.

The structure of Francis turbine runners is not different from that of the existing runners. However, while the design of the existing runners focuses on the efficiency of the maximum power output point, in the newly designed runners, the flow within the runners is optimized for all operating areas, which optimizes turbine efficiency at all points. Efficiency of the turbines and the design of a runner shape that improves the operating traits seen for partial loads can be optimized by using a 3D flow analysis of Computational Fluid Dynamics (CFD), which makes it possible to improve efficiency by 1 to 3% compared to current runner design. The following figure shows an example of the efficiency characteristics of the existing runners and the newly designed runners.

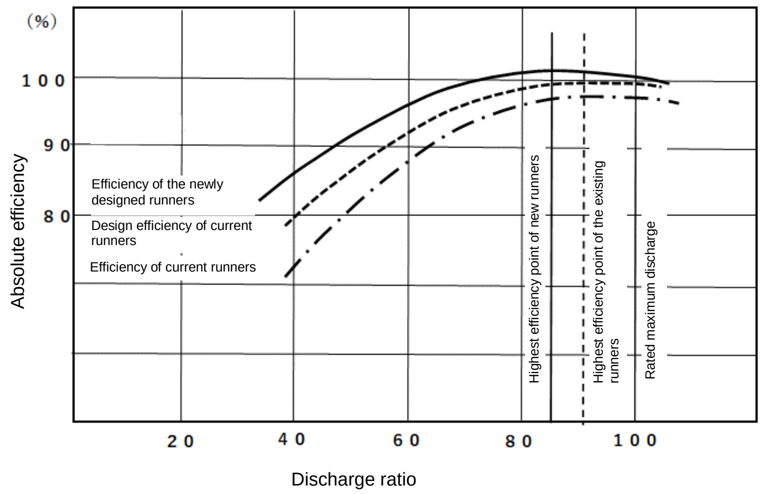


Fig. 5-1 Efficiency of the newly designed runners compared to the existing runners

The optimal design technology of turbines as a whole has already been established. In Japan, a runner design that focuses on stable operation in partial loads for low discharge areas is becoming the benchmark standard. The reason for this is that the design is effective at generating power from low-load to medium-load hydropower seen over the full year during which there is a significant change in discharge. Furthermore, the runner high-performance technology can be adapted not just for new turbines, but also for replacement runners installed in the existing turbines.

a. Application for the “A” Power Plant

When updated in 1995, the efficiency of the turbines installed at the “A” Power Plant improved from 83.1% to 90%, and the plant is therefore regarded as having a modern design. The 90% efficiency of the turbines is close to the limit of the Francis turbine’s low specific speed.

Although the highest efficiency yielded by applying CFD to the new design is small, the effect on efficiency improvement for the total flow area and especially on the partial load side is substantial. However, given the fact that there are no turbine efficiency curves for the full flow range and that no actual field efficiency measurements have been taken, the efficiency values derived in 1990s are not deemed to be very reliable.

b. Application for “B”-“C” Power Plant

For “B”-“C” power plants, the turbine efficiency according to their designs is not known, and therefore it is difficult to make any comparisons. However, given that their designs are from 1920s, the efficiency yielded from adopting modern designs would be substantial.

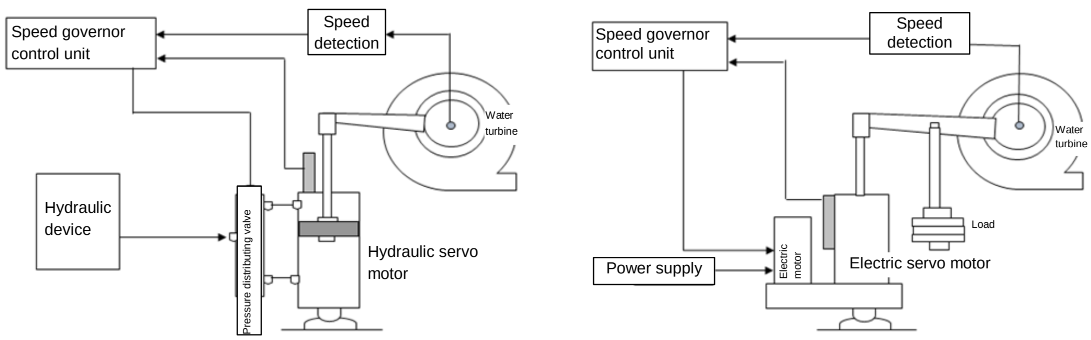
(2) Streamlining the turbine equipment

The streamlining of turbine equipment can be achieved by simplifying its structure and shape. We are striving for improvement in economic efficiency by simplifying and condensing the design such as adopting speed rings from which the inflow pocket curve is removed, and a thick plate integrated top cover to a cross-section casing equipped with a cast-iron turbine casing divided into eight sections with standard elbow welding shapes. Moreover, the turbine and generator will be packaged together, and the base will be shared to shorten the installation work.

(3) Streamlining the turbine installation equipment

Streamlining of the turbine equipment will involve implementing technologies that are motorized, lubricant-free, water-free, and maintenance-free. There is no performance record for such implementation in Indonesia; however, we are striving to adopt maintenance-free technologies such as motorized guide vanes and inlet valves as well as waterless, self-cooling bearings, etc. that will allow repair intervals to be extended.

However, because a crucial part of adopting these technologies will involve a transfer of technology, it will be necessary to examine certain details, such as considering the factors related to the demand and the feasibility of implementing these technologies, including finding a support partner company. As examples, the following Fig. 5-2 shows two configurations of drive motors for guide vanes, one that uses a hydraulic servo motor and one that uses an electric servo motor.



Hydraulic servo motor Electric servo motor

Source: "Hydro Turbine", published by the Turbomachinery Society of Japan

Fig. 5-2 System configuration of hydraulic servo motor and electric servo motor

(4) New technology for power generation equipment

Generators are generally produced on a high-variety, low-volume basis, and therefore the configuration of generators varies depending on the scale of the rated capacity, high/low rotation speed, and the type of turbine, which is the driving mechanism. However, for small capacity equipment, even though there is demand for standardization in planning and design, the percentage of the cost of generators in the construction of a power plant is small. Therefore, there is a strong tendency to focus on feature design that is optimized for a particular power plant.

Based on these circumstances, improving the insulation class of generators is an important element, and to downsize and lighten the equipment, it is essential to upgrade the insulation technology such as by adopting F-type insulation.

Generally speaking, salient-pole type synchronous, 3-phase generators are adopted in hydroelectric power generation, adopts by considering the power distribution system stability. On the other hand, recently in Indonesia, many cylindrical-type synchronous 3-phase generators have been adopted, but there have reportedly been no problems with power distribution systems. Compared to the salient-pole type synchronous, 3-phase generators, the cylindrical-type synchronous 3-phase generators are approximately 20 to 30% cheaper and therefore beneficial in terms of cost.

Moreover, adopting self-cooling bearings, which do not use coolant, will streamline maintenance equipment and lower maintenance costs.

(5) New technology for control and protective equipment

The control and protective equipment do not involve many elements that need to take into consideration the traits of a specific site or power generation output. Therefore, the equipment used is basically a combination of general-purpose parts that meet the required specifications. With the outstanding development of technologies for the general industrial field, there are now high-performance general-purpose parts, and adopting these makes it possible to cut costs. In particular, run-off-river power plants, which do not require any special specifications, use basic equipment for starting and stopping generators and standard protectors. Therefore, it is possible to apply a Programmable Logic Controllers (PLCs) for general industrial use and a general-purpose protector relays to them. The control equipment is upgraded to a system that uses the PLC and adopts Supervisory Control and Data Acquisition (SCADA) as its human-machine interface (HMI), which will make monitoring control highly reliable.

- A monitoring control system that integrates monitoring, control, and protection using PLC for general industrial use and a general-purpose protective relay
- Sequential control for starting and stopping of turbine generator
- Concentration of measurement and protective equipment
- Operation automation by water level adjustment operation

5.1.3. System configuration for hydropower equipment

Two examples of system configuration in hydraulic servos are shown below, the example shown in Fig. 5-3 uses a vertical bearing, and the example shown in Fig. 5-4 uses a horizontal bearing. Both represent system configuration examples of replacement equipment; the former Fig. 5-4 is from "A" Power Plant, and the latter is from "B"-"C" power plant.

In Japan, adoption of the electric servo is expanding due to environmental concerns; however, in Indonesia there is no adoption track record for this type of equipment. Therefore, it is necessary to give consideration to such things as technology transfer and implementation needs in deciding whether or not adoption of the equipment is possible. For reference purposes, the following Fig. 5-5 shows a system configuration example of an electric servo for a horizontal bearing.

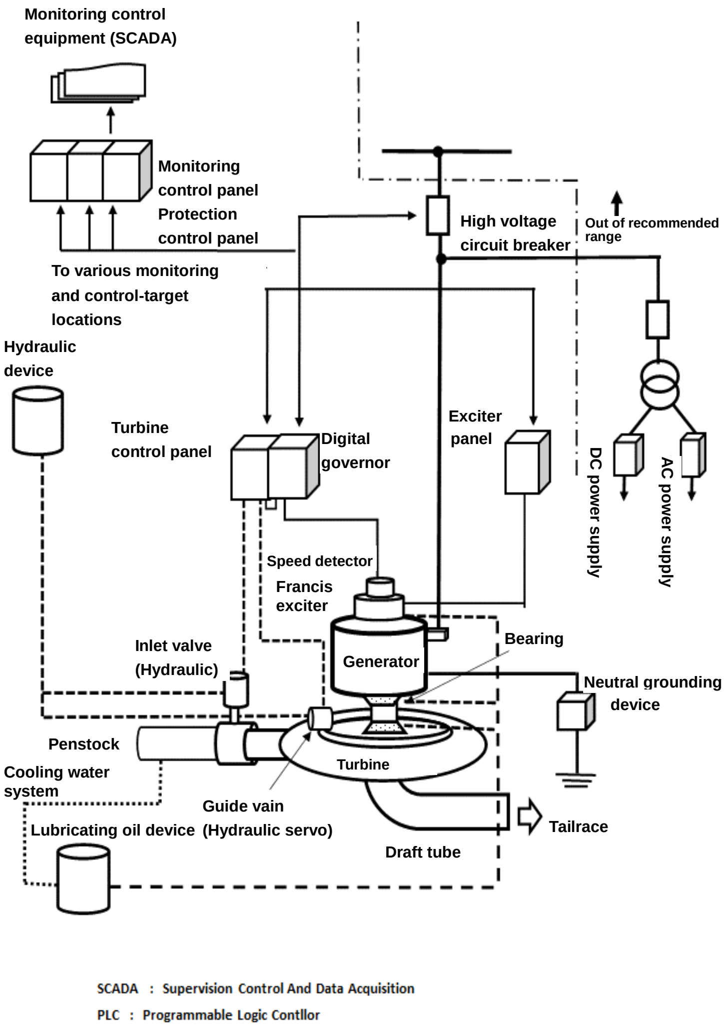


Fig. 5-3 System configuration example of a vertical bearing (hydraulic servo)
(System configuration example of replacement equipment for "A" Power Plant)

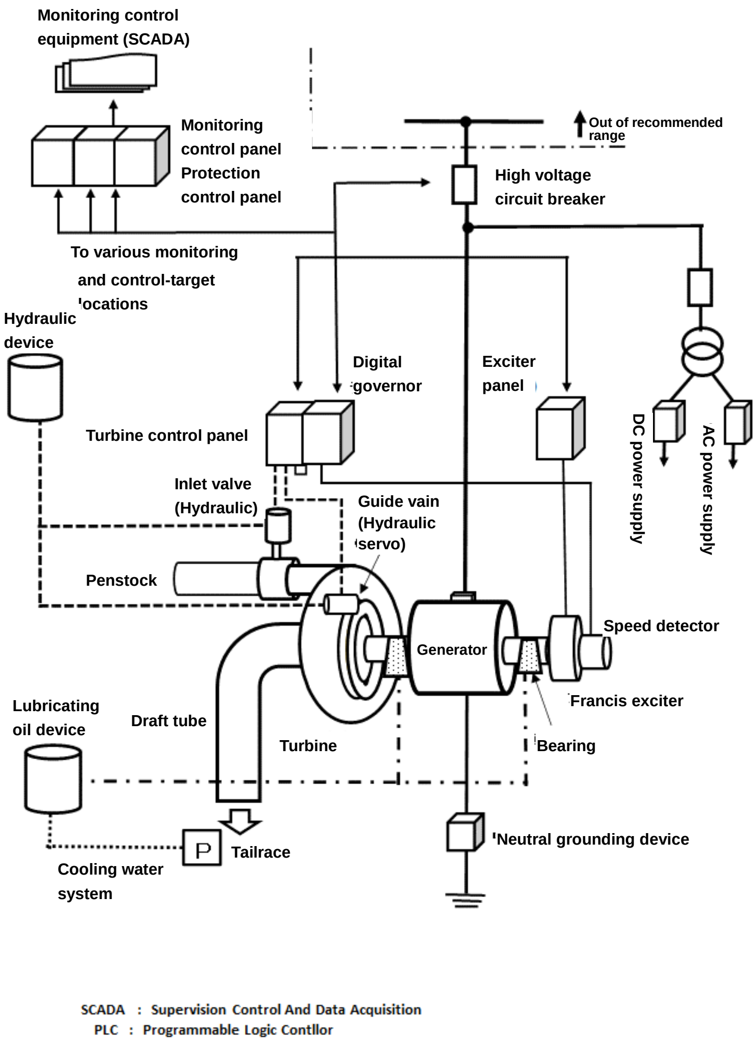
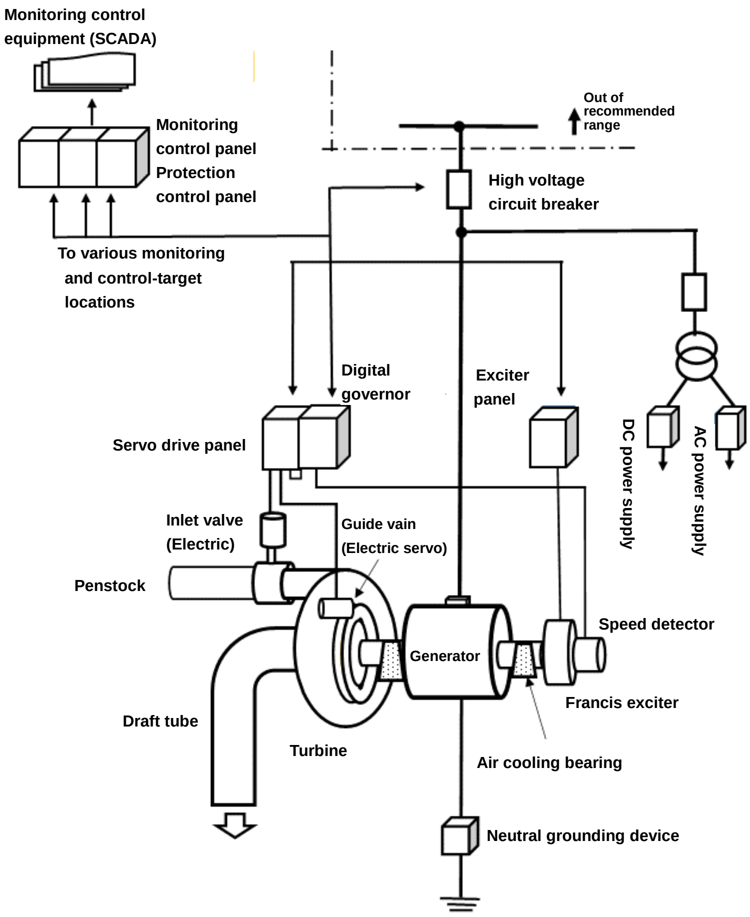


Fig. 5-4 System configuration example of a horizontal bearing (hydraulic servo adoption)
(System configuration example of replacement equipment at “B”-“C” Power Plant)



SCADA : Supervision Control And Data Acquisition
PLC : Programmable Logic Contllor

Fig. 5-5 System configuration example of a horizontal bearing

(Example using an electric servo motor)

5.2 System design

For each of the power plants that are being examined, a system design (rehabilitation plan) will be formulated to improve the efficiency of power generation equipment, reduce the burden on the environment, and reduce construction and operation maintenance costs.

5.2.1. Replacement plan for “A” Power Plant

After it was built in 1925, “A” Power Plant underwent large-scale renovations in 1995. There are renovation plates installed on the generators, which makes it possible to confirm that the main parts, such as the stator coil and the exciter were replaced.

There are no renovation nameplate on the turbines, and therefore the details of the equipment are unknown, but the turbine efficiency rates when the plant started operation (turbines No.1 and

No. 2: 83%, turbine No. 3: 89%) improved to 90% after replacement, and from this it can be extrapolated that parts affecting efficiency, such as the runners, guide vanes, etc., were replaced. However, a turbine efficiency of 90% seems too high for a low specific-speed turbine designed in the 1990s, and therefore the values are not deemed to be very reliable.

Since some of the stator coils and other equipment installed in the generators were partially replaced in 1995, we are considering two proposals: a "partial replacement proposal," in which the generator would be reused and equipment that contributes to the recovery of turbine efficiency, such as the turbine runners, would be replaced, and a "full replacement proposal", in which the turbines and generators would be replaced.

The conditions for examination are shown below.

- The maximum discharge is the same as that of the existing design.
  - Maximum water flow usage of power plant: 10.95 m³/s (maximum water usage flow per unit: 3.65 m³/s)
- For power plants that have a reservoir, when the ability to adjust power generation is employed, the effective head changes substantially, and so if a head other than the standard effective head is used, (power generation) efficiency falls. Therefore, it is important to examine the standard effective head. However, because the P company does not possess any information regarding head or efficiency, the standard effective head of 208 m shown in Table 2-1 is used. Moreover, the highest effective head was sought by calculating the waterway channel loss based on the penstock pipeline's vertical cross section illustration created for this project. The result of this calculation showed that the highest effective head was 212.85 m at maximum power output.
  - Standard effective head: 208 m
  - Highest effective head: 212.85 m
- According to the 1995 renovations, the turbine efficiency was 90%, but considering the design technology of the 1990s and the fact that the plant uses relatively low-speed turbines, under the technology that was

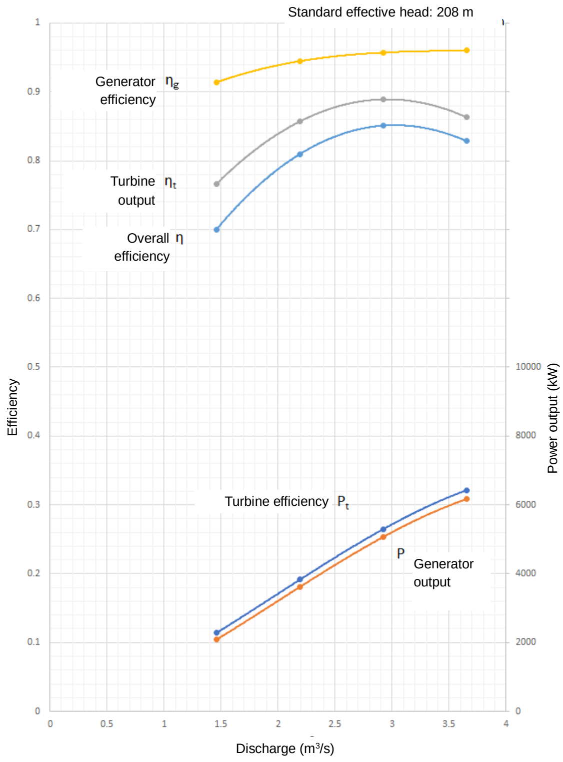


Fig. 5-6 Characteristic curve of the turbine used in the trial calculation

available at that time, a turbine efficiency of about 87 to 88% is more reasonable. Moreover, when the turbine efficiency is calculated from a turbine power output of 9,000 PK (6,600 kW), the result of 89% turbine efficiency (turbine power output/turbine power input) is obtained. Therefore, the original highest turbine efficiency for the existing design turbine is presumed to have been 89%.

- Original turbine highest efficiency: 89%

- The original efficiency (presumption) in the table is based on the turbine efficiency in the equipment outline, and was formulated for the study of this project while considering recent turbine performance improvement technologies. Reference was made to the "Guidebook for Small and Medium-sized Hydroelectric Power (Fifth Revised Edition)", "Hydro Valley Planning Guidebook", "Hydropower Development Guide Manual", etc. The turbine efficiency is calculated by estimating the highest efficiency from the specific speed of the turbine and multiplying that value by a relative factor to calculate the efficiency for each flow point. The Fig. 5-6 shows the characteristic curve of the turbine used in the trial calculations of the power output scale.

5.2.1.1. Partial replacement proposal for “A” Power Plant

The turbine equipment, including the foundation, will be reused, and a replacement plan that focuses on economic perspective will be considered.

(1) Summary of replacement proposal

- Reusing half-buried equipment casing and draft tube, and the runner, guide vane and liners which are worn parts due to contact with flowing water will be replaced. The new runners incorporate a new design that applies fluid analysis technology and in combination with guide vanes, improves turbine performance by optimizing the flow inside of turbines. Moreover, a new technology to simplify maintenance, such as non-lubricated guide vane operation mechanisms will be applied.

- Monitoring and control equipment will be reused.

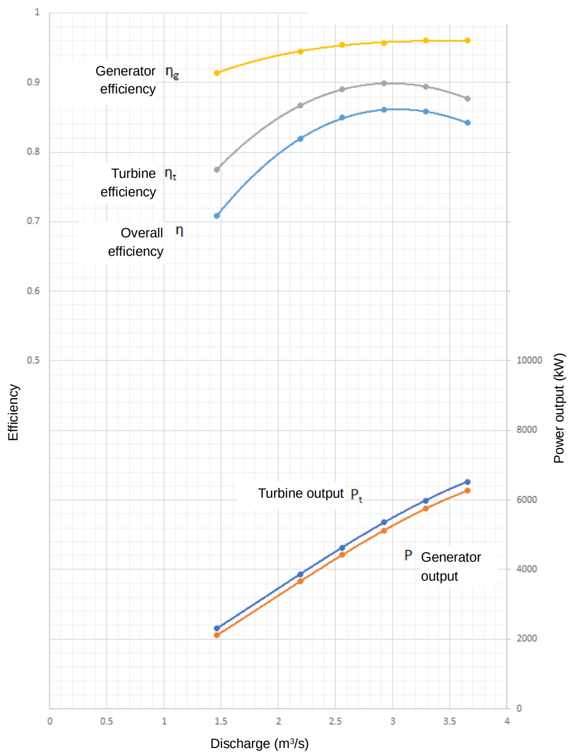


Fig. 5-7 Characteristic curve of the water turbine used in the trial calculation
(“A” Power Plant: After replacement)

(2) Trial calculation of turbine generator power output

The maximum power output of the turbine generator will be tentatively calculated based on prerequisite conditions used for examination purposes. The scope of power output of the turbine and generator is determined assuming that the maximum efficiency of the turbine improved to 90% with the new runner design. In the partial replacement proposal, the maximum output of the power plant can be increased by 200 kW compared to that of existing equipment (estimated).

Table 5-1 Maximum power output for highest effective head
("A" Power Plant - Partial replacement)

	Power output per device		Power plant's maximum power output (kW)
	Turbine power output (kW)	Generator power output (kW)	
Existing design (estimated)	6,600	6,300	19,000
Partial replacement proposal	6,700	6,400	19,200
Increased power output	100	100	200

(3) Elements of turbine generators

The following

Table 5-2 shows elements of the partial replacement proposal for the turbine generator.

Table 5-2 Elements of partial replacement proposal ("A" Power Plant)

Equipment	Specifications		
Turbine (A-1)	Vertical shaft Francis turbine		
	Maximum effective head	m	212.85
	Maximum discharge	m^3/s	3.65
	Turbine power output	kW	6,700
	Rotation speed	min-1	600
Generator (Existing equipment reused)	Synchronous, 3-phase, vertical shaft generator (thyristor exciter)		
	Rated capacity	kVA	7,250
	Power factor		0.9

(4) Replacement equipment

The following Table 5-3 shows a list of replacement equipment.

Table 5-3 Partial replacement equipment (“A” Power Plant)

	Equipment	Variety		Details
		New	Rep-aired	
A-1	Vertical shaft Francis turbine			
A-1-1	Casing		○	Inspection, nondestructive test, and repair paint
A-1-2	Draft tube		○	Inspect and repair paint
A-1-3	Runner	○		New design, SCS6 (13Cr-4Ni)
A-1-4	Upper cover, etc.	○		Upper cover, sheet liner, cover liner, etc.
A-1-5	Bottom ring related	○		Bottom ring, sheet liner, cover liner, etc.
A-1-6	Lower cover, etc.	○		
A-1-7	Main shaft water seal	○		Carbon backing
A-1-8	Turbine bearing	○		Self-contained lubrication, self-lubricating
A-1-9	Pressure regulation valve		○	Overhaul, nondestructive test, and cavitation repair
A-1-10	Main shaft		○	Main shaft sleeve replacement, runner key groove machining, and runout monitoring/measurement
A-1-11	Guide vane, etc.	○		SCS1, Guide ring, lever, ring, and non-lubricated bearing
A-1-12	Inlet valve	○		
A-2	Equipment accompanying turbine	○		Hydraulic equipment and water supply equipment
A-4	Control panel integrating control and protection features that uses PLC	○		Digital governor, automatic voltage adjuster, and generator protection
A-5	Shared control equipment using PLC	○		Auto-synchronizing equipment and generating line protection
A-6	Monitoring control equipment that uses SCADA	○		

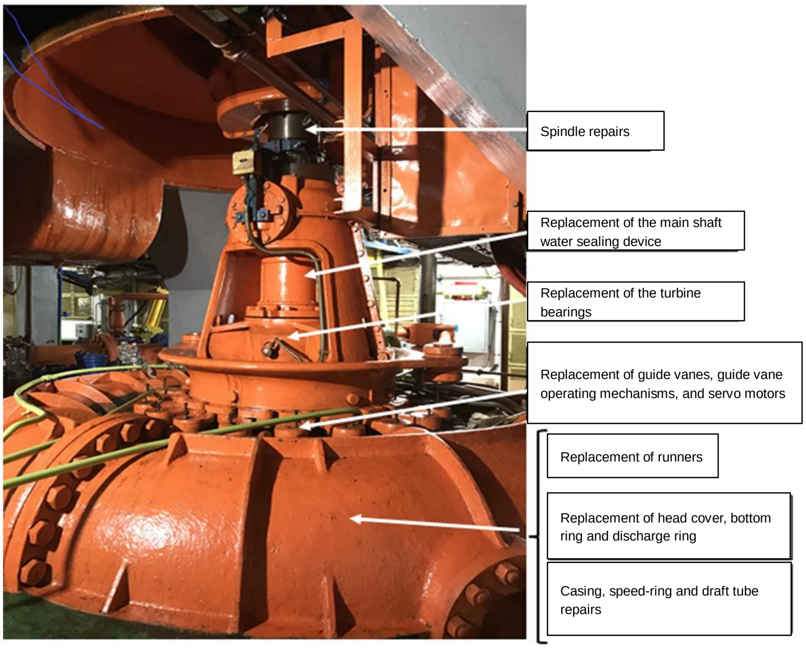


Fig. 5-8 Parts to be replaced and repaired in “A” Power Plant (partial replacement)

5.2.1.2. Proposal for full replacement of equipment at “A” Power Plant

This plan calls for the full replacement of three units. The plan focuses on a hydroelectric generator design that will have very little impact on the foundation of the turbine or the generator as well as the spillway structure.

(1) Summary of full replacement proposal

- Assuming the turbine uses a buried casing, the turbine generators and generators would all be fully replaced, including the casings and draft tubes.
- The rotation speed of the turbine would change from 600 min^{-1} to 750 min^{-1}, thereby improving turbine efficiency and reducing the overall size of the turbine generator by increasing the relative speed. As a result of these changes, we anticipate that the maximum output and annual amount of electricity generation will increase, and replacement costs will decrease. However, by adopting a high-turbine rotation speed, the turbine installation position will change, and the repair scope of the turbine foundation will be enlarged.
- The fluid analysis technology to the turbine will be applied to optimize the flow of the entire turbine from the stay vane of the casing to the draft tube and improving the efficiency of the entire turbine. This optimized innovation combines high-performance runners and new design guide vanes to yield a substantial benefit.
- The equipment will be replaced with devices that adopt new technologies to simplify

maintenance such as non-lubricated guide vane operation mechanisms and brushless exciters for generators.

- Monitoring and control equipment are replaced with a distributed control system that adopts PLC technology, enhancing monitor control and making protection highly reliable.
- In the full replacement proposal, the only transport route to the power plant is a winch, and its capacity and age could have a very significant impact on the equipment design and construction costs. Currently, the auxiliary runners are still not in use as they cannot be transported to the power plant using the winch. For this reason, this proposal is very limited by such things as the capacity of the winch and temporary equipment, and therefore when concrete plans are made, it will be necessary to consider this in more detail.

(2) Trial calculation of turbine generator power output

The maximum power output of the turbine generator will be tentatively calculated based on conditions used for examination purposes. In the full replacement proposal, the output power of the turbine and generator will be tentatively calculated, assuming that the maximum turbine efficiency could be improved to 90.3%. Moreover, in the full replacement proposal, the maximum output of the power plant can be increased by 500 kW, compared to that of the existing equipment (estimated).

Table 5-4 Maximum power output for maximum effective head

(“A” Power Plant: Full replacement)

	Power output per unit		Power plant’s maximum power output (kW)
	Turbine power output (kW)	Generator power output (kW)	
Existing design (estimated)	6,600	6,300	19,000
Full replacement proposal	6,700	6,500	19,500
Increased power output	100	200	500

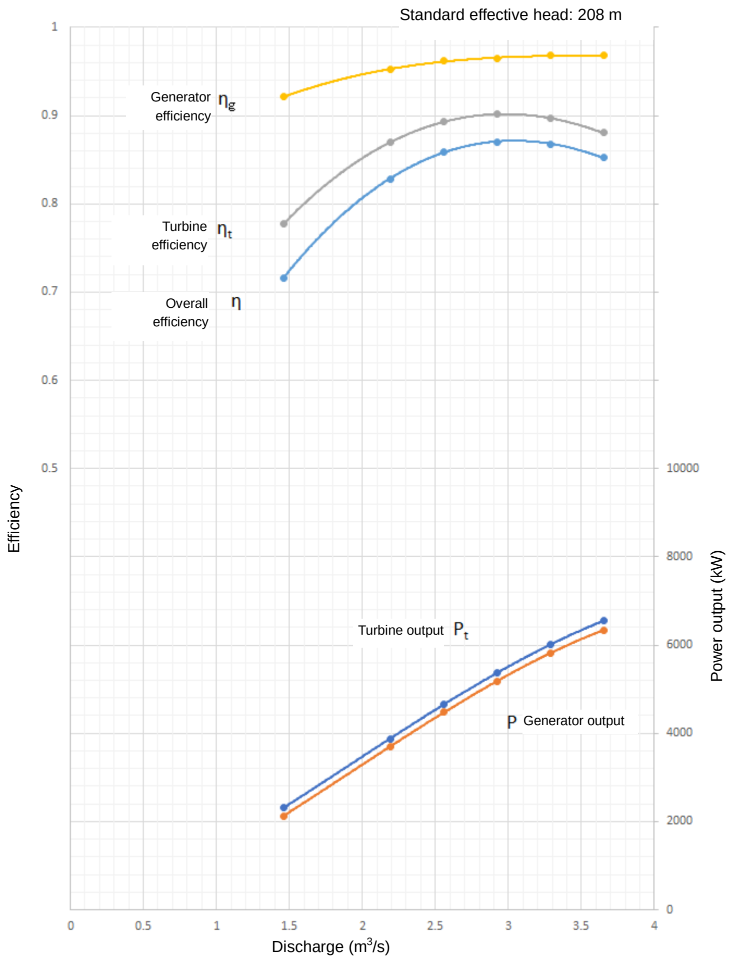


Fig. 5-9 Characteristic curve of the turbine used in trial calculations

("A" Power Plant: After full replacement)

(3) Elements of turbine generators

The following Table 5-5 shows various elements of the full replacement proposal of the turbine generator.

Table 5-5 Elements in the full replacement proposal for the turbine generator

("A" Power Plant)

Equipment	Specifications		
Turbine (A-1)	Vertical shaft Francis turbine		
	Maximum effective head	m	212.85
	Maximum discharge	m^3/s	3.65
	Turbine power output	kW	6,700
	Rotation speed	min^{-1}	750

Generator (A-3)	Synchronous, 3-phase, horizontal shaft generator (brushless exciter)		
	Rated capacity	kVA	7,250
	Power factor		0.9

(4) Replacement equipment

The following Table 5-6 shows a list of replacement equipment.

Table 5-6 Full replacement proposal for equipment ("A" Power Plant)

	Equipment	Details
A-1	Vertical shaft Francis turbine	
A-1-1	Casing	
A-1-2	Draft tube	
A-1-3	Runner	New design, SCS6 (13Cr-4Ni)
A-1-4	Upper cover	Sheet liner, cover liner, etc.
A-1-5	Bottom ring	Sheet liner, cover liner, etc.
A-1-6	Lower cover	Cover liner, etc.
A-1-7	Main shaft water seal	Carbon backing
A-1-8	Water turbine bearing	Self-contained lubrication, self-lubricating
A-1-9	Main shaft	
A-1-10	Guide vane, etc.	Guide ring, lever, ring, and non-lubricated bearing
A-1-11	Inlet valve	
A-2	Equipment accompanying turbine	Hydraulic equipment and water supply equipment
A-3	Synchronous, vertical shaft generators	
A-3-1	Synchronous generators	
A-3-2	Brushless exciter equipment	
A-3-3	Lubrication oil equipment	
A-4	Control panel integrating control and protection features that uses PLC	Digital governor, automatic voltage adjuster, and generator protection
A-5	Shared control equipment using PLC	Auto-synchronizing equipment and generating line protection
A-6	Monitoring control equipment that uses SCADA	

5.2.2. Replacement plan for “B” Power Plant

Regardless of the fact that nearly 90 years have passed since the “B” Power Plant became operational in 1923, the plant equipment has not been replaced, and the aging of the turbine generator equipment as a whole is becoming apparent as it becomes progressively obsolete. For example, based on the fact that the turbine governors are mechanical and that starting the power generation equipment is a completely manual process, there is an urgent need to modernize and automate the power generation equipment. Therefore, this plan will be considered as a full replacement project.

The conditions for examination are shown below.

- The maximum discharge is the same as that of the existing design.
  - Maximum water volume usage: 4.08 m^3/s (maximum water usage per unit: 1.36 m^3/s)
- The maximum effective head is derived by calculating the water channel loss based on the penstock pipeline's vertical cross section illustration created for this project. (The standard effective head was treated as 104 meters in the power plant summary. However, because the P company did not keep detailed data regarding effective head, this value is derived based on the penstock pipeline's vertical cross section illustration created for this project.)
  - Maximum effective head: 100.45 m
- When the turbine efficiency is calculated from a turbine power output of 1,500 PK (1,100 kW), the turbine efficiency at the start of operation is estimated to be 79% (turbine power output/turbine power input [1,390 kW]). This is a reasonable turbine efficiency value for 1990s technology design, and is presumed to be the existing design turbine’s maximum turbine efficiency.
  - Original turbine maximum efficiency: 79%
- The original efficiency (presumption) in the table is based on the turbine efficiency in the equipment outline, and was formulated for the study of this project while considering recent turbine performance improvement technologies. Reference was made to the "Guidebook for Small and Medium-sized Hydroelectric Power (Fifth Revised Edition)", "Hydro Valley Planning Guidebook", "Hydropower Development Guide Manual", etc. The turbine efficiency is calculated by estimating the maximum efficiency from the specific speed of the turbine and multiplying that value by a relative factor to calculate the efficiency for each flow point.

5.2.2.1. Full replacement proposal for “B” Power Plant

Similar to “A” Power Plant, there are no drawings for the “B” Power Plant, and therefore the replacement plan to be considered will have little impact on the foundation of the turbine generators and the spillway structure, and the full replacement proposal will be considered for the existing three units with the same number of units.

(1) Summary of Replacement plans

- The turbine and the generator will be fully replaced, including the casing and the draft tubes. The rotation speed of the turbine would change from 750 min^{-1} to 1,000 min^{-1} and increases the relative speed, improving turbine efficiency and reducing the overall size of the turbine generator. As a result of these changes, the maximum output and annual amount of electricity generation will increase, and replacement costs can be decreased. However, when the turbine rotation speed increases, the turbine installation position will change, and the repair scope of the turbine foundation will be enlarged.

- The fluid analysis technology will be applied to the turbine to optimize the flow of the entire turbine from the stay vane of the casing to the draft tube. This combination of the high-performance runner and the new design guide vane improve the efficiency of the entire turbine. Moreover, a new technology to simplify maintenance, such as non-lubricated guide vane operation mechanisms will be applied.

- A brushless exciter will be adopted for the generator, which will simplify maintenance.

- Monitoring and control equipment are replaced with a distributed control system that adopts PLC technology, enhancing monitor control and making protection highly reliable.

(2) Trial calculation of power output scale of turbine generator

The power output of the turbine generator will be tentatively calculated based on prerequisite conditions used for examination purposes. The output scale of the turbine and generator will be derived, assuming that the maximum turbine efficiency could be improved to 89%. In the full replacement proposal, the maximum output of the power plant can be increased by 100 kW compared to that in the existing equipment.

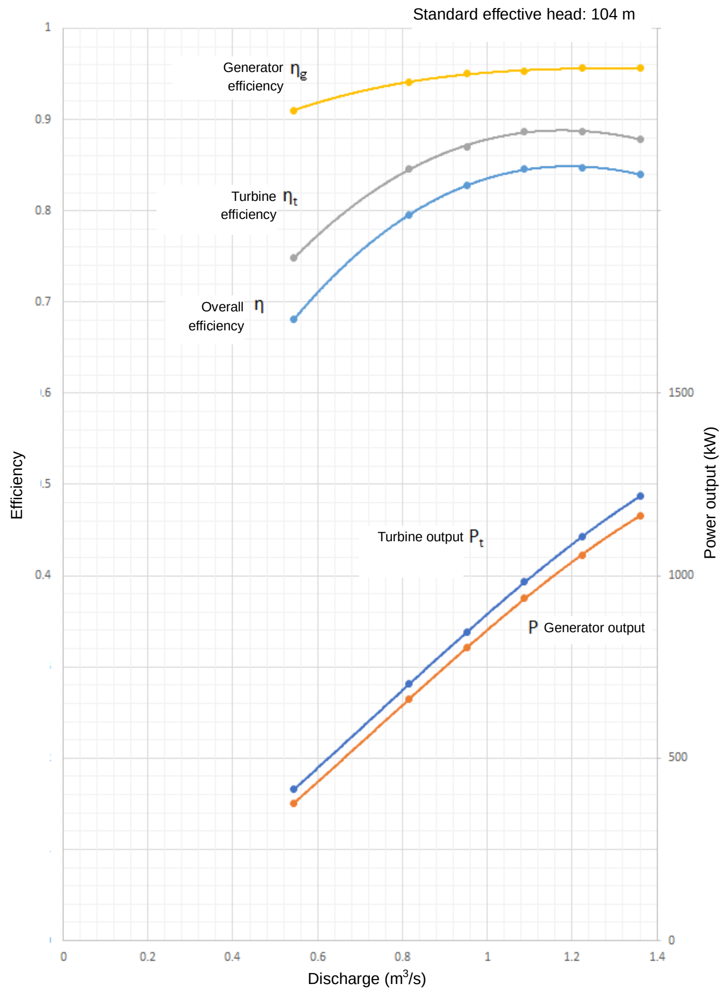


Fig. 5-10 Characteristic curve of the turbine used in trial calculations (“B” Power Plant: After full replacement)

Table 5-7 Maximum power generation for maximum effective head ("B" Power Plant: Full replacement)

	Maximum effective head 100.45 m		Power plant's maximum power output (kW)
	Turbine power output (kW)	Single-device maximum power output (kW)	
Existing design (estimated)	1,130	1,090	3,270
Full replacement proposal	1,180	1,120	3,360
Increased power output		30	100

(3) Elements of turbine generators

The following Table 5-8 shows various elements of the full replacement proposal of the turbine generator.

Table 5-8 Elements in the full replacement proposal of the turbine generator ("B" Power Plant)

Equipment name	Specifications		
Turbine (A-1)	Horizontal shaft Francis turbine		
	Maximum effective head	m	100.45
	Maximum discharge	m^3/s	1.36
	Turbine power output	kW	1,180
	Rotation speed	min^{-1}	1,000
Generator (A-3)	Synchronous, 3-phase, horizontal shaft generator (brushless exciter)		
	Rated capacity	kVA	1,200
	Rated voltage	kV	6.3
	Power factor		0.9

(4) Replacement equipment

The following Table 5-9 shows a list of replacement equipment.

Table 5-9 Full replacement equipment ("B" Power Plant)

	Equipment	Details
A-1	Horizontal shaft Francis turbine	
A-1-1	Casing	
A-1-2	Draft tube	
A-1-3	Runner	New design, SCS6 (13Cr-4Ni)
A-1-4	Upper cover	Sheet liner, cover liner, etc.
A-1-5	Bottom ring	Sheet liner, cover liner, etc.
A-1-6	Lower cover	Cover liner, etc.
A-1-7	Main shaft water seal	Carbon backing
A-1-8	Water turbine bearing	Self-contained lubrication, self-lubricating
A-1-9	Main shaft	
A1-10	Guide vane, etc.	Guide ring, lever, ring, and non-lubricated bearing
A-11	Inlet valve	
A-2	Equipment accompanying turbine	Hydraulic equipment and water supply equipment
A-3	Synchronous, horizontal shaft generators	
A-3-1	Synchronous generators	
A-3-2	Brushless exciter equipment	
A-3-3	Lubrication oil equipment	
A-4	Control equipment	
A-4-1	Control panel integrating control and protection features that uses PLC	Digital governor, automatic voltage adjuster, and generator protection
A-4-2	Shared control panel that uses PLC	Auto-synchronizing equipment and generating line protection
A-4-3	Monitoring control equipment that uses SCADA	
A-4-4	DC power source equipment	
B-1	Enclosed switchboard	6.3 kV generator cub and generator neutral point grounding cub
		6.3 kV Feeder Cub
B-2	Transformer	On-premise transformer
B-3	Emergency generator	

5.2.3. Replacement plan for “C” Power Plant

Nearly 90 years have passed since the “C” Power Plant became operational in 1923; however, the plant equipment has not been replaced, and the aging and obsolescence of the turbine power generation equipment as a whole is becoming apparent. For example, the turbine governors are mechanical, and the power generation equipment must be started manually, which attest to the urgent need to automate and modernize the turbine generator equipment. Therefore, this development will be considered as a full replacement project.

The conditions for examination are shown below.

- Based on the flow duration curve, the maximum discharge is the same as that in the existing design.
  - Maximum discharge: 2.25 m^3/s
- The maximum effective head is derived by calculating the water channel loss based on the penstock pipeline's vertical cross section illustration created for this project. (The standard effective head was treated as 44 meters in the power plant summary. As the P company did not keep detailed data regarding effective head, this value is derived based on the penstock pipeline's vertical cross section illustration created for this project.)
  - Maximum effective head: 42.76 m
- In the equipment overview, the turbine power output is stated as 750 PK (552 kW), but looking at this from the power generation track record, this was likely mistaken with 750 kW. At the start of operations, the turbine efficiency can be estimated to have been approximately 76% (turbine output/turbine output [970 kW]). This value is a reasonable turbine efficiency for 1990s design technology. Installing new design runners and modernizing the entire design will improve this.
  - Original turbine maximum efficiency: 76%
- The original efficiency (presumption) in the table is based on the turbine efficiency in the equipment outline, and was formulated for the study of this project while considering recent turbine performance improvement technologies. Reference was made to the "Guidebook for Small and Medium-sized Hydroelectric Power (Fifth Revised Edition)", "Hydro Valley Planning Guidebook", "Hydropower Development Guide Manual", etc. The turbine efficiency is calculated by estimating the maximum efficiency from the specific speed of the turbine and multiplying that value by a relative factor to calculate the efficiency for each flow point.

5.2.3.1. Full replacement proposal for “C” Power Plant

(1) Summary of Replacement plans

There are also no drawings for the “C” Power Plant structures, and therefore the replacement plan to be considered will have little impact on the foundation of the turbine generators and the spillway structure.

- The turbine generator has two rotation speeds to select: 750 min^{-1} (relative speed: 192) and 1,000 min^{-1} (relative speed: 257). When 1,000 min^{-1} is applied, size reduction becomes possible, but together with the degrading of the turbine efficiency, the repair scope of the turbine foundation becomes substantial, and therefore the same rotation speed as the existing design of 750 min^{-1} is adopted.

(2) Trial calculation of power output scale of turbine generator

The output scale of the turbine and generator will be derived, assuming that the maximum turbine efficiency could be improved to 89%. The output of the power plant can be increased by 90 kW compared to the existing equipment. Fig. 5-11 shows the characteristic curve of the turbine used in trial calculations.

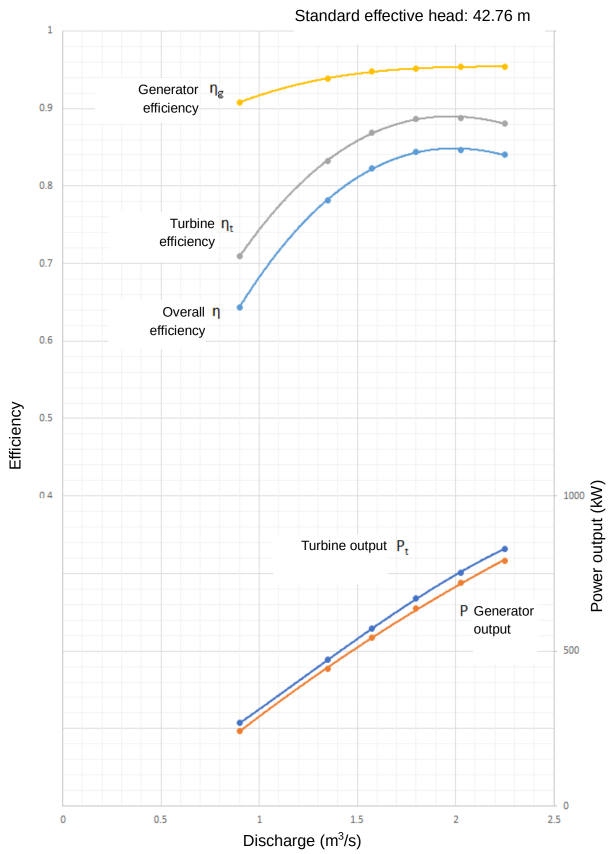


Fig. 5-11 Characteristic curve of the turbine used in trial calculations (“C” Power Plant: After full replacement)

Table 5-10 Maximum power generation for highest effective head ("C" Power Plant: Full replacement)

	Highest effective head 42.76 m		Power plant's maximum power output (kW)
	Turbine power output (kW)	Single-device maximum power output (kW)	
Existing design (estimated)	-	700	700
Full replacement proposal	830	790	790
Increased power output		90	90

(3) Elements of turbine generators

The following Table 5-11 shows elements of the full replacement of the turbine generator.

Table 5-11 Elements in the full replacement of the turbine generator proposal ("C" Power Plant)

Equipment name	Specifications		
Turbine (A-1)	Horizontal shaft Francis turbine		
	Effective head	m	42.76
	Maximum discharge	m^3/s	2.25
	Turbine power output	kW	830
	Rotation speed	min^{-1}	750
Generator (A-3)	Synchronous, 3-phase, horizontal shaft generator (brushless exciter)		
	Rated capacity	kVA	880
	Rated voltage	kV	6.3
	Power factor		0.9

(4) Replacement equipment

The contents of the replacement equipment information are the same as that for "B" Power Plant.

Chapter 6 Project scale

6.1 Calculation of estimated project cost

The project cost for the proposed rehabilitation plan has been estimated in Chapter 5 based on the "Guidance" (March 2013) and based on the manufacturer's reference quotation.

6.1.1. "A" Power Plant rehabilitation cost

(1) Project cost based on "Guidance"

Rehabilitation cost will be about JPY 441 million for partial replacement and JPY 1,658 million for the full replacement plan. Moreover, the unit construction cost per kW is JPY 22 thousand for partial replacement and approximately JPY 74 to 80 thousand for the full replacement, and the unit construction cost per kWh is JPY 5.8 for partial replacement and approximately JPY 18.7 to 21.3 for the full replacement.

Unlike new construction or redevelopment, the unit construction cost is insignificant because only machinery and equipment are being replaced. Both proposed replacement plans will provide a good return on investment. Furthermore, there will be more room for cost reductions if low and high voltage enclosed switchboards along with other replacement equipment can be procured from within Indonesia.

Table 6-1 "A" Power Plant Rehabilitation Cost and Unit Construction Cost

Item	Unit	Partial replacement	Full replacement
Turbine type		Vertical shaft Francis turbine	Vertical shaft Francis turbine
Maximum effective head	m	212.85	
Maximum discharge	m^3/s	10.95 (3.65×3)	
Maximum output	kW	19,200 (6,410×3)	19,500 (6,490×3)
Turbine power output	kW	6,680×3	6,700×3
Amount of power generation	MWh	76,714	77,715
Construction cost	JPY 1 million	441	1,658
Unit construction cost per kW	Thousand JPY/kW	22	85
Unit construction cost per kWh	JPY/kWh	5.75	21.3

Table 6-2 Unit construction cost of “A” Power Plant for increased output and power (for reference)

Item	Unit	Partial replacement	Full replacement
Increased output	kW	200	500
Increased amount of power	kWh	6,223	7,224
Construction cost	JPY 1 million	441	1,658
Unit construction cost per increased kW	Thousand JPY/kW	2,205	3,316
Unit construction cost per increased kWh	JPY/kWh	70.9	229.5

(2) Project cost based on manufacturer’s reference quotation

Table 6-3 “A” Power Plant Rehabilitation Cost and Unit Construction Cost

Item	Unit	Partial replacement
Turbine type		Vertical shaft Francis turbine
Maximum effective head	M	212.85
Maximum discharge	m^3/s	10.95 (3.65×3)
Maximum output	kW	19,200 (6,410×3)
Turbine power output	kW	6,680×3
Amount of power generation	MWh	76,714
Construction cost	JPY 1 million	426
Unit construction cost per kW	Thousand JPY/kW	22
Unit construction cost per kWh	JPY/kWh	5.55

Table 6-4 Unit construction cost of “A” Power Plant for increased output and power (for reference)

Item	Unit	Partial replacement
Increased output	kW	200
Increased amount of power	kWh	6,223
Construction cost	JPY 1 million	426
Unit construction cost per increased kW	Thousand JPY/kW	2,130
Unit construction cost per increased kWh	JPY/kWh	68.5

6.1.2. “B” Power Plant rehabilitation cost

(1) Project cost based on "Guidance"

The rehabilitation cost of the “B” Power Plant is JPY 704 million, with a unit construction cost of JPY 209 thousand per kW and JPY 53 per kWh. Unlike new construction or redevelopment, the unit construction cost is small and the return on investment is high because only machinery and equipment are being replaced. Moreover, there will be more room for cost reductions if substation equipment, such as low and high voltage enclosed switchboards along with other rehabilitation equipment can be procured from within Indonesia.

Table 6-5 “B” Power Plant rehabilitation costs and unit construction cost

Item	Unit	Full replacement
Turbine type		Horizontal shaft Francis turbine
Maximum effective head	m	100.45
Discharge	m^3/s	4.08 (1.36×3)
Maximum output	kW	3,360 (1,120×3)
Turbine power output	kW	1,180×3
Amount of power generation	MWh	13,256
Construction cost	JPY 1 million	704
Unit construction cost per kW	Thousand JPY/kW	209
Unit construction cost per kWh	JPY/kWh	53

(2) Project cost based on manufacturer’s reference quotation

Table 6-6 “B” Power Plant rehabilitation cost and unit construction cost

Item	Unit	Full replacement
Turbine type		Horizontal shaft Francis turbine
Maximum effective head	M	100.45
Discharge	m^3/s	4.08 (1.36×3)
Maximum output	kW	3,360 (1,120×3)
Turbine power output	kW	1,180×3
Amount of power generation	MWh	13,256
Construction cost	JPY 1 million	422
Unit construction cost per kW	Thousand JPY/kW	126
Unit construction cost per kWh	JPY/kWh	32

6.1.3. “C” Power Plant rehabilitation plan

(1) Project cost based on "Guidance"

The rehabilitation cost of the “C” Power Plant is JPY 255 million, with a unit construction cost of JPY 322 thousand per kW and JPY 64 per kWh. Unlike new construction or redevelopment, the unit construction cost is small and the return on investment is high because only machinery and equipment are being renewed. Moreover, there will be more room for cost reductions if substation equipment, such as low and high voltage enclosed switchboards along with other renewal equipment can be procured from within Indonesia.

Table 6-7 Unit construction cost of “C” Power Plant

Item	Unit	Full replacement
Turbine type		Horizontal shaft Francis turbine
Maximum effective head	m	42.76
Discharge	m^3/s	2.25
Maximum output	kW	790
Turbine power output	kW	830
Amount of power generation	MWh	3,963
Construction cost	JPY 1 million	255
Unit construction cost per kW	Thousand JPY/kW	322
Unit construction cost per kWh	JPY/kWh	64

(2) Project cost based on manufacturer’s reference quotation

Table 6-8 Unit construction cost of “C” Power Plant

Item	Unit	Full replacement
Turbine type		Horizontal shaft Francis turbine
Maximum effective head	m	42.76
Discharge	m^3/s	2.25
Maximum output	kW	790
Turbine power output	kW	830
Amount of power generation	MWh	3,963
Construction cost	JPY 1 million	192
Unit construction cost per kW	Thousand JPY/kW	243
Unit construction cost per kWh	JPY/kWh	48.5

6.2 Calculation of power generation cost

The annual cost is the annual cost of operating a hydroelectric plant and is the basis for estimating service life levelized power generation cost. The annual cost calculation parameters in "Hydro Valley Planning Guidebook" are used to calculate the annual cost. Because the construction cost is only for the machinery and equipment, the repayment period is 22 years, which is the service life of the machinery and equipment. The service life levelized power generation cost can be obtained by the following formula:

Service life levelized power generation cost (yen/kWh) = annual levelized cost (JPY)/annual power generation (kWh)
＝unit construction cost per kWh (JPY/kWh) × construction cost rate (0.07334)

Table 6-9 Service life levelized power generation cost for rehabilitation of three power plants

	"A" Power Plant		"B" Power Plant	"C" Power Plant
	Partial replacement	Full replacement	Full replacement	Full replacement
Power generation cost (JPY/kWh)	0.4	1.6	3.7	4.7

The calculation parameters used to estimate the service life levelized power generation cost are shown in Table 6-10.

Table 6-10 Annual cost calculation factors

Item		Terms and conditions and numerical values
Depreciation cost	Amortized cost method	Fixed rate method
	Residual rate	10%
	Service life	Equivalent to repayment period
Interest rate		2%
Fixed assets tax		Construction cost/first year book value × book value × 1.4%
Labor cost		Construction cost × 0.17%
Repair cost	Initial annual rate	Construction cost × 0.310%
	Annual growth rate	Construction cost × 0.019%
Other expenses		Construction cost × 0.31%
General management fee		(Fixed assets tax + labor costs + repair costs + other expenses) × 12%
Discount rate		2%

Source: "Hydro Valley Planning Guidebook (March 2005)," Agency for Natural Resources and Energy; Ministry of Economy, Trade and Industry

An example of cost estimation in foreign countries is provided by the International Energy Agency (IEA). According to this, the cost of power generation by a small-scale new hydroelectric plant (100 kW to 300 MW) is between JPY 4 and JPY 8.

Because the proposed project is limited to the renewal of machinery and equipment, there are few variable factors in the power generation cost, making it easy to forecast the profitability. However, because it may vary depending on the characteristics of the country or region and the configuration of the equipment, the information should be closely monitored and understood when commercializing a product.

6.3 Increased power generation after rehabilitation

Estimate the amount of power generation after renewal at each power plant under consideration.

6.3.1. Calculation method for power generation

(1) Annual possible power generation discharge

The annual possible discharge is determined based on flow curves sorted by eight-year average generation flow curve in descending order of magnitude. The flow curve is divided as shown in Fig. 6-1. The respective "discharge x number of days x 24 h" is obtained, and the sum up to get the annual possible generation discharge.

Annual possible power generation discharge = Σ {(Q1 x D1 x 24) + (Q2 x D2 x 24)…+ (Qn x Dn x 24)}

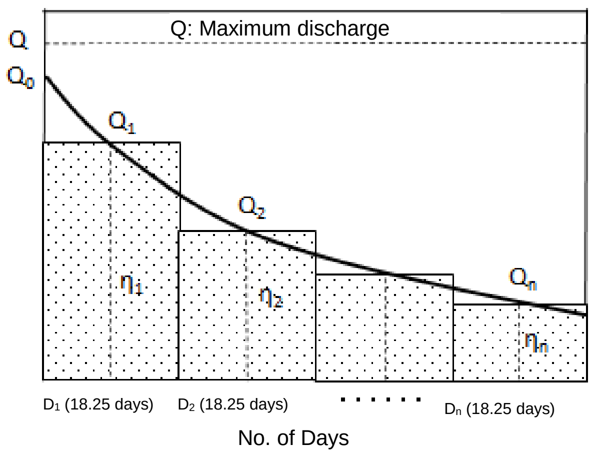


Fig. 6-1 Annual possible discharge for power generation

(2) Amount of power generation annually

For the possible discharge of the divided section, the annual possible power generation is determined from the overall efficiency at the standard head corresponding to the central discharge of the divided section.

Annual possible power generation = 9.8 x standard head x Σ {(Q1 x D1 x 24) x η1 +…+ (Qn x Dn x 24) x ηn}

(3) Discharge utilization factor

The discharge utilization factor is determined by the following formula.

Discharge utilization factor = Annual possible discharge / (maximum discharge x 365 x 24)

6.3.2. Annual possible discharge for power generation

Using the power generation flow curves in section 2.2, determine the annual possible discharge for power generation based on the formulas in the previous section.

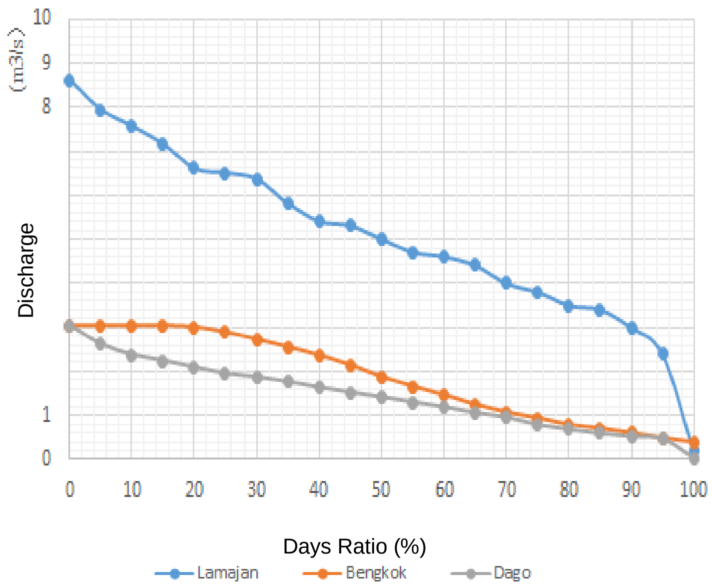


Fig. 6-2 Eight-year average power generation discharge for the three power plants

Table 6-11 Estimated results of annual possible discharge for power generation

	"A" Power Plant	"B" Power Plant	"C" Power Plant
Maximum discharge of the power plant (m^3/s)	10.95	4.08	2.25
Maximum average power generation discharge (m^3/s)	8.60	3.03	3.03
Annual possible power generation discharge (m^3/s-day)	44,584	16,316	12,111
Discharge utilization factor (%)	46	46	61

6.3.3. Calculation of the annual power generation

Compared to the average power generation over the past eight years, the rehabilitation plan is expected to significantly increase power generation by approximately 10% at "A" Power Plant, 65% at "B" Power Plant, and 26% at "C" Power Plant.

6.3.3.1. Annual power generation by "A" Power Plant

Table 6-12 shows the results of estimating the annual power generation by each rehabilitation plan based on the annual possible discharge in Table 6-11 and the overall efficiency curve in Fig.

5-7. Comparing the estimated results to the average amount of power generation over the past eight years (2014-21), the partial replacement and the full replacement plans would allow for a 9% and 10% increase in power generation, respectively. Moreover, the plant factor will improve to approximately 45% for each plan.

Table 6-12 Estimated power generation by “A” Power Plant

	Eight-year average	Partial replacement	Full replacement
Maximum power output (kW)	19,000	19,200	19,500
Amount of power generation (MWh)	70,491	76,714	77,715
Increased amount of power generation (MWh)	-	6,223	7,224
Increased rate	-	8.8	10.2
Plant factor (%)	42.4	45.4	45.5

6.3.3.2. Annual power generation by “B” Power Plant

Table 6-13 shows the results of estimating the annual power generation with full replacement plans based on the annual possible generation discharges listed in Table 6-11 and the overall efficiency curves in shown in Fig. 5-10. Comparing the estimated results to the average amount of power generation over the past eight years, the amount of power generation is expected to increase significantly by approximately 65%. Moreover, the plant factor will also improve to approximately 45%.

Table 6-13 Estimated power generation by “B” Power Plant

	Eight-year average	Full replacement
Maximum power output (kW)	3,270	3,360
Amount of power generation (MWh)	8,030	13,256
Increased amount of power generation (MWh)	-	5,226
Increased rate (%)	-	65
Plant factor (%)	28	45

6.3.3.3. Annual power generation by “C” Power Plant

Table 6-14 shows the results of estimating the annual power generation with full replacement based on the annual possible generation discharges listed in Table 6-11 and the overall efficiency curves shown in Fig. 5-11 Characteristic curve of the turbine used in trial calculations (“C” Power Plant: After full replacement). Comparing the estimated results to the average amount of power generation over the past eight years, the amount of power generation is expected to increase by approximately 26%. Moreover, the plant factor will improve to approximately 57%.

Table 6-14 Estimated power generation by the “C” Power Plant

	Eight-year average	Full replacement
Maximum power output (kW)	700	790
Amount of power generation (MWh)	3,156	3,963
Increased amount of power generation (MWh)	-	807
Increased rate (%)	-	26
Plant factor (%)	51.5	57.3

6.4 Cost of O&M phase

We will estimate the cost of inspections at each power plant under consideration.

6.4.1. Inspection cycle for hydroelectric plants

Maintenance of hydroelectric plants is performed through a combination of precision inspection by disassembling the turbines/generators (main machine); external and internal visual inspections without disassembly, external inspection to measure gaps and other dimensions, and intermediate precision inspection that includes internal inspection, turbine efficiency measurement test, and dimensional measurement of components.

External, internal, and intermediate precision inspections are conducted for confirmation of equipment abnormalities without disassembling the main unit, whereas the precision inspection disassembles of the main unit is conducted to inspect in detail the parts that cannot be seen in external and internal inspections. The main machine is a precision machine installed with an accuracy of a few hundredths of a millimeter, and even the slightest change in gap or wear can interfere with its operation. For this reason, the precision inspections are performed in detail on areas where wear or damage is expected, such as runners, bearings supporting rotating parts, guide vane shafts, sliding parts such as servo motors, and cooling water pipes that are prone to corrosion. Moreover, the casing and main shaft are subject to nondestructive testing to inspect for cracks, material defects, etc. Moreover, parts of runners, guide vanes, and various liners that are eroded, broken, or worn due to cavitation and sediment are repaired or replaced to restore functionality and performance (mainly to restore efficiency).

In accordance with IEC (JEC) regulations, turbine efficiency must be measured in absolute discharge on site. Also, the manufacturer's guaranteed efficiency and the decrease in efficiency over time must be checked and monitored on a regular basis. The most economical inspection cycle can be obtained by calculating the cost of loss due to reduced efficiency and the cost associated with replacement (levelized cost), and finding the number of years of use where the sum of the two is minimized.

A typical inspection cycle for a hydroelectric plant is shown in Table 6-15. It will be set according to the actual conditions at the power plant.

Table 6-15 Inspection cycle guideline

Initial inspection	After 1 year of operation
External inspection	Can be omitted, or once every 2 years
Internal inspection	Once every 2 to 4 years
Intermediate precision inspection	Intermediate precision inspection (tests and measurements such as turbine efficiency measurements)
Precision inspection	Once every 8 to 15 years (determined by economical repair cycle)

6.4.2. Inspection cycle and costs

The inspection cycles and costs for the three power plants under consideration are stated below.

Assuming a service life (under Japanese Tax Law) of 22 years, the total inspection cost required for the "A" Power Plant is JPY 336 million, or an average of about JPY 15 million per year. Similarly, the total inspection cost for "B" Power Plant and "C" Power Plant is JPY 132 million and JPY 44 million, respectively, with an average annual cost of approximately JPY 6 million and JPY 2 million, respectively. Moreover, Fig. 6-3 shows an example of the inspection cycle for the "A" Power Plant.

Table 6-16 "A" Power Plant inspection cost (in thousands (JPY))

Inspection items	Details	Cost	Frequency	Total amount
Internal/external inspection (Maintenance every 3 years)	Consumable replacement Test runs and adjustments	3,000	4	12,000
Intermediate precision inspection (Maintenance every 6 years)	Parts replacement Inspection and testing	10,000	2	20,000
Overhaul (Maintenance after 12 years)	Disassembly and parts replacement Test runs and adjustments	80,000	1	80,000
Inspection cost per unit (service life of 22 years)				112,000
Total 3 units				336,000
Average annual cost over service life				15,273

Table 6-17 “B” Power Plant inspection cost (in thousands (JPY))

Inspection items	Details	Cost	Frequency	Total amount
Internal/external inspection (Maintenance every 3 years)	Consumable replacement Test runs and adjustments	1,000	4	4,000
Intermediate precision inspection (Maintenance every 6 years)	Parts replacement Inspection and testing	5,000	2	10,000
Overhaul (Maintenance after 12 years)	Disassembly and parts replacement Test runs and adjustments	30,000	1	30,000
Inspection cost per unit (service life of 22 years)				44,000
Total 3 units				132,000
Average annual cost over service life				6,000

Table 6-18 “C” Power Plant inspection cost (in thousands (JPY))

Inspection items	Details	Cost	Frequency	Total amount
Internal/external inspection (Maintenance every 3 years)	Consumable replacement Test runs and adjustments	1,000	4	4,000
Intermediate precision inspection (Maintenance every 6 years)	Parts replacement Inspection and testing	5,000	2	10,000
Overhaul (Maintenance after 12 years)	Disassembly and parts replacement Test runs and adjustments	30,000	1	30,000
Inspection cost (service life of 22 years)				44,000
Average annual cost over service life				2,000

Inspection Type	Inspection Cycle Criteria	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
(a) Initial Inspection	After 1 year of operation	①	②	③																																					
(b) External Inspection	Can be omitted, or once every 2 years																																								
(c) Internal/External Inspection	Once every 2 to 4 years			①	②	③				①	②	③			①	②	③					①	②	③				①	②	③				①	②	③				①	②
(d) Intermediate Precision Inspection	During the precision inspection						①	②	③										①	②	③										①	②	③								
(e) Precision Inspection (OH)	Every 7 to 15 years												①	②	③										①	②	③										①	②	③		
Inspection Cost (in million yen)				1	1	1	5	5	5	1	1	1	80	80	80	1	1	1	5	5	5	1	1	1	80	80	80	1	1	1	5	5	5	1	1	1	80	80	80	1	1
Remarks		1. **Example of Inspection Cycle** External Inspection: Omitted Internal/External Inspection: Once 3 years Precision Inspection: Once 12 years 2. **Intermediate Precision Inspection (Tests and measurements such as turbine efficiency measurements)** Turbine efficiency measurement (Carry out acceptance test upon completion, and then carry out this measurement periodically) Carry out nondestructive tests during the precision inspection 3. **Days to stop operation** (a) 5 days (b) 1 day (c) 2 days (d) 3 days (e) 35 to 40 days 4. **Use the spare runners. After 12 years, replace them as needed, and update them after two repairs** (Note 1) ①: Unit 1 ②: Unit 2 ③: Unit 3 (Note 2) OH: Overhaul																																							

Fig. 6-3 Example of inspection cycle (for “A” Power Plant)

Chapter 7 Business schemes and related agreements

7.1 Business scheme for this project

In this project, an RO agreement will be concluded between the P company and SPC, in which Chodai, PT AMCO Hydro Indonesia (hereinafter, "AMCO") and other companies have stakes. SPC will perform facility upgrades and O&M at two existing hydroelectric plants owned by the P company, including replacement with highly efficient power generation turbines. The increase in power generation by the rehabilitation is as described in 6.3.3.

The P company will sell the entire amount of power generation to the PLN based on a power purchase agreement (PPA) and pay a portion of the income from these power sales to the SPC. Furthermore, the PPA will be revised based on the rehabilitation work at the power plant.

Moreover, the turbine will be procured from Japanese manufactures and other sources, and O&M will be performed by AMCO as subcontractor.

7.2 Major agreements related to the project

The details of the PPA between the P company and PLN will be sorted, and a term sheet for the RO agreement between the P company and SPC will be formulated based on the key terms of said PPA.

7.2.1. PPA

The P company sells all of its generated power to the PLN under the PPA.

7.2.1.1. Current business scheme

Under the current business scheme, for each power plant under consideration, the P company owns the power plant and land, including equipment and facilities, and the PLN owns the transmission facilities. Moreover, O&M is handled by the in-house department of the P company.

7.2.1.2. Status of PPA execution

The PPA has been signed between the P company and the PLN is mentioned in Table 7-1. The contents of "PPA 2018" and "PPA 2021" provided by the P company has been confirmed; though, the details of "PPA 2013" and "PPA 2015" could not be confirmed. However, "PPA 2013" and "PPA 2015" are cited in "PPA 2018" and both are considered valid. According to "PPA 2021," the “A” Power Plant, “B” Power Plant, and “C” Power Plant are both under one PPA.

So far, the duration of PPA has been 4 to 5 years. According to the provisional terms of the "PPA 2018," the terms of the PPA are preserved if the PPA is not renewed within the time limit.

Therefore, even in situations where the PPA has expired and not been revised, the PLN will continue purchasing power under the terms of the most recent PPA as long as the P company generates power.

Table 7-1 List of PPAs signed to date

Title	Date of signature	Effective period
Amendment and Restatement of PPA (“PPA 2013”)	12/4/2013	12/31/2017
Amendment and Restatement of PPA (“PPA 2015”)	6/12/2015	Not Clear
Amendment and Restatement of PPA (“PPA 2018”)	3/2/2018	1/1/2023
Amendment and Restatement of PPA (“PPA 2021”)	28/10/2021	1/1/2023

7.2.1.3. Key conditions of PPA

The minimum and maximum end-transmission outputs are stipulated in "PPA 2018". Under the take or pay clause, the PLN is obligated to purchase power from the P company as long as it is within the range of end-transmission output or net generation as determined by the PPA. If this is not possible due to negligence on the part of the PLN, the P company will be compensated.

The payment currency in the PPA is Indonesian Rupiah (IDR) and it should be noted the tariff shared by the P company is only for the capital cost recovery and O&M cost recovery (fixed and variable) components; the actual amount paid also includes other components such as unidentified water usage charges (variable) and adjustments due to foreign exchange gains/losses, etc. Tariffs are reviewed every six months. Moreover, if the P company and the PLN agree, there are no legal restrictions on adjusting (raising) tariffs in response to increased capacity due to rehabilitation work.

There are no legal restrictions on mortgaging of assets or transfer of rights, as long as both companies agree to do so. The same applies when the P company and/or the PLN assigns, transfers or sells its rights and obligations. In addition, it is assumed that restrictions will be added to the contract with the P company so that the assets will not be sold or transferred without the knowledge of the financing companies or SPC. Along with this, it will be necessary to revise the PPA concluded between P company and PLN. On the other hand, the PPA must be revised when replacing assets or making design changes that could affect the overall specifications.

Furthermore, at present, we do not envisage the use of loan in Japanese yen currency, but if we do proceed with loan in Japanese yen currency, it will be necessary to consider future policies accordingly.

7.2.2. RO agreement

While taking into account the contents of the aforementioned PPA, a term sheet for the RO agreement is created that will be signed between the company and the SPC. See Appendix 1 for the term sheet.

The RO contract fee is assumed to be "electricity sold to PLN (kWh) x profit shared with SPC (IDR/kWh)." See Chapter 9 for specific amounts and other information.

7.3 Risk analysis

The major risks associated with the project are shown in Table 7-2.

Table 7-2 Major risks

Risk	Details	Countermeasures
Legal	Risk of changes in permits (licenses) and laws and regulations	Regarding the RO business, 100% foreign capital is possible by obtaining a license for the electric power support service business. On the other hand, in order to obtain this license, it is necessary to meet the requirements such as registration as a qualified engineer and passing a practical test. Discuss with the local agent company that supports license acquisition and check the requirements in detail.
Engineering, procurement, and construction (EPC):	Risks regarding quality of construction, contracting, storage, and transportation associated with rehabilitation work	In the RO business, the selection of a manufacturer to deliver a complete set of turbine equipment is particularly important. In bidding, not only the technical performance but also the business scope is checked in detail to ensure that there are no omissions, thereby preventing unexpected additional costs. In addition, by checking the details of the series of schedules for design, manufacturing, transportation, and installation, the risks that may arise shall be identified in advance, be prepared to respond appropriately if they do occur.
Transmission lines	Demand risk, underdeveloped transmission lines, power outages, transmission losses	The project site is close to the power demand area and is planned to be linked with PLN's power transmission system that has already been developed. In the future, discuss with PLN and obtain approval for grid connection after a detailed grid study.
End-user	Risks associated with off-takers (PLN) and operators (the P company)	In the event that PLN and the PLN Group undergo restructuring for some reason in the future, discuss legal measures with a law firm in order to be able to execute security interests and protect claims based on the RO agreement.
Inevitable incidents force majeure	Natural disasters or government-induced force majeure	For items that can be covered by insurance, such as natural disasters, confirm the insurance details while considering the balance with insurance premiums. Further, confirm the details with IIGF and private insurance companies for risks caused by the government and consider them comprehensively.

Financial:	Foreign exchange losses, inflation	It is assumed that the income from this project will be denominated in the local currency, and the funding will also be procured in the same currency. On the other hand, project costs such as turbine facilities are assumed to be denominated in foreign currencies (US dollars and euros), and exchange risk will arise temporarily. However, in the long run, business operating expenses are in the same currency as income in the local currency, so risks in terms of business continuity are limited.
Social and environmental:	Adverse social and environmental impacts (community, water, air, soil, etc.)	This project will replace the existing equipment in the power plant, and the social and environmental impact will be very limited. On the other hand, management will be done in such a way that there will be less impact from construction work, etc. at the time of replacement.。
Pandemic	Impact on demand due to pandemics such as COVID-19	As this project is adjacent to a power demand area and has competitiveness as a power source (power generation cost and base load / peak load response), even in the event of a pandemic, it is expected that the power to PLN could be sold on a priority basis.
Country-related risk	Import restrictions, riots and mass demonstrations, war, vandalism, economic crisis, etc.	The use of insurance, etc. for country risks, while considering the balance with insurance costs will be examined.

Chapter 8 Finance scheme

8.1 Funding method

The possibility of investments by Japanese companies and financing by local financial institutions, etc., for the project, as well as the possibility of obtaining guarantees, are examined through interviews with relevant parties.

8.1.1. Equity (potential investment by Japanese companies)

As a potential investor, online discussion was held with the S company. Although the company expressed interest in the investment, they sought clarification regarding the specific project risks. In particular, because the PPA period is short as mentioned above, there is concerned about the possibility that the PLN will lower the tariff. The company is hoping to secure a 15% equity internal rate of return (EIRR) with a maximum 10-year participation as the minority investor. Discussions will be continued with the company.

8.1.2. Debt (possibility of financing by financial institutions, etc.)

As potential financial sources, online discussions have been held with the I company and the M company Discussions will be continued with both the companies.

According to the I company, a loan term of six to seven years is suitable. However, the nature of the project needs to be closely examined.

On the other hand, the M company is likely to understand the significance of this project in hydroelectric power generation in Indonesia and to positively consider funding. The bank commented that the loan term will be up to 10 years with a floating interest rate denominated in Indonesian rupiah. As a collateral, power plant assets and an account for transferring funds from the P company to the SPC will be required. On the other hand, there are concerns about the short duration of the PPA. The P company advised that payments to the SPC will be fixed and not tied to the amount of power generated or the price at which power is sold.

8.2 Security

Online discussions have been held with the Indonesia government guarantee agency regarding the possibility of providing a guarantee for payments from the PLN under the PPA. Indonesia government guarantee agency's guarantee covers government agencies or state-owned enterprises that are public contracting authorities; the project must be a public-private partnership (PPP) scheme in order to receive a guarantee. Discussions will be continued with the Indonesia government guarantee agency.

Chapter 9 Financial analysis

9.1 Expected returns from this project[17]

The expected returns at each of the power plants under consideration has been estimated using multiple scenarios. Discussions with the P company will continue, particularly with respect to profit sharing with the P company, agreement term, and review of tariffs between the P company and the PLN.

Table 9-1 Estimated returns under each scenario (in real price terms)

Power plant	Replacement Details	Tariff	Project cost basis	CapEx (Billion IDR)	PIRR	EIRR
“A”	Partial	Current	"Guidance"	56.3	10.40%	10.81%
	Partial	Current	Manufacturer's quotation	54.5	10.84%	11.43%
	Full	Current	"Guidance"	201.1	▲5.25%	▲7.93%
	Full	Adjusted	"Guidance"	207	13.81%	15.75%
“B”-”C”	Full	Current	"Guidance"	115.5	▲13.69%	▲17.08%
	Full	Current	Manufacturer's quotation	74.5	▲10.27%	▲13.38%
	Full	Adjusted	"Guidance"	119.6	13.37%	15.08%
	Full	Adjusted	Manufacturer's quotation	77	13.95%	15.93%

9.1.1. Returns from “A” Power Plant

All scenarios are based on the following common conditions.

- Installed capacity: 19.2 MW
- Plant factor: 46 (%)
- RO agreement term: 20 years

9.1.1.1. Returns on the partial replacement of “A” Power Plant

(1) For project cost based on the current tariff and "Guidance"

The partial replacement of the “A” Power Plant is expected to generate 76.71 GWh of power per year. Moreover, capital expenditures (CapEx) based on the "Guidance" will amount to IDR 56.29 billion. The comparison of the P company’s profit with and without rehabilitation is shown in Table 9-2. Under these conditions, the SPC's project internal rate of return (PIRR) and EIRR are expected to be 10.4% and 10.81%, respectively.

[17] Project costs are converted from Japanese yen to Indonesian rupiah.

Table 9-2 Annual Profit of the P company (Partial replacement at “A”: Current tariff and "Guidance")

	Without replacement	With replacement
1-10	IDR 1,776 million	IDR 1,910 million
11-20		IDR 2,064 million
Total for 20 years	IDR 35,513 million	IDR 39,738 million

(2) For project costs based on current tariff/manufacturer’s reference quotation

If the CapEx considered based on the manufacturer's reference quotation, the project cost is IDR 54.51 billion. The comparison of the P company's profit with and without replacement is shown in Table 9-5. Under these conditions, the SPC's project internal rate of return (PIRR) and EIRR are expected to be 10.84% and 11.43%, respectively.

Table 9-3 Annual Profit of the P company (Partial replacement at “A”: Current tariff and quotation)

	Without replacement	With replacement
1-10	IDR 1,776 million	IDR 1,910 million
11-20		IDR 2,064 million
Total for 20 years	IDR 35,513 million	IDR 39,738 million

(3) For adjusted tariffs

For the projects which business feasibility was confirmed even with the current tariff, no estimation is made with an adjusted tariff.

9.1.1.2. Returns on full replacement at “A” Power Plant

(1) For project costs based on the current tariff and "Guidance"

The full replacement of “A” Power Plant is expected to generate 77.72 GWh of power per year. The CapEx based on the "Guidance" is IDR 201.15 billion. The comparison of the P company’s profit with and without replacement is shown in Table 9-7. Under these conditions, SPC’s PIRR and EIRR are expected to be ▲7.93% and ▲5.25%, respectively, with no business feasibility.

Table 9-4 Annual Profit of the P company (Full replacement at “A” Power Plant: Current tariff and "Guidance")

	Without replacement	With replacement
1-10	IDR 1,776 million	IDR 1,935 million
11-20		IDR 2,091 million
Total for 20 years	IDR 35,513 million	IDR 40,256 million

(2) For project cost based on the adjusted tariff and "Guidance"

Because business feasibility cannot be expected with the current tariff, re-estimate is done by raising the tariff to IDR 750/kWh. In this case, annual power sales revenue is expected to be IDR 58.3 billion. The CapEx based on the "Guidance" is IDR 207 billion. The comparison of the P company's profit with and without rehabilitation is shown in Table 9-5. Under these conditions, the SPC's PIRR and EIRR are expected to be 13.81% and 15.75%, respectively.

Table 9-5 Annual Profit of the P company (Full replacement at “A” Power Plant: Adjusted tariff and "Guidance")

	Without replacement	With replacement
1-10	IDR 5,287 million	IDR 6,994 million
11-20		IDR 10,880 million
Total for 20 years	IDR 105,737 million	IDR 178,743 million

9.1.2. Returns from “B”-“C” Power Plant

All scenarios are based on the following common conditions.

- Installed capacity: 4.175 MW
- Plant factor: 47%
- RO agreement term: 20 years

9.1.2.1. Returns on full replacement at “B”-“C” Power Plant

(1) For project cost based on the current tariff and "Guidance"

The full replacement at “B”-“C” Power Plant is expected to generate 17.22 GWh of power per year. The CapEx based on the "Guidance" is IDR 115.55 billion. The comparison of the P company's profit with and without rehabilitation is shown in Table 9-6. Under these conditions, the SPC's PIRR and EIRR are expected to be ▲13.69% and ▲17.08%, respectively, with no business feasibility.

Table 9-6 Annual profit of the P company (Full replacement at “B”-“C” Power Plant: Current tariff and "Guidance")

	Without replacement	With replacement
1-10	IDR 282 million	IDR 429 million
11-20		IDR 463 million
Total for 20 years	IDR 5,636 million	IDR 8,919 million

(2) For project costs based on current tariff/manufacturer's reference quotation

The CapEx is based on the manufacturer's reference quotation is IDR 74.48 billion. In this case, the comparison of the P company's profit with and without rehabilitation is shown in Table 9-7. Even under these conditions, the SPC's PIRR and EIRR are expected to be ▲10.27% and ▲13.38%, respectively, with no business feasibility.

Table 9-7 Annual profit of the P company (Full replacement at “B”-”C” Power Plant: Current tariff and quotation)

	Without replacement	With replacement
1-10	IDR 282 million	IDR 429 million
11-20		IDR 463 million
Total for 20 years	IDR 5,636 million	IDR 8,919 million

(3) For project costs based on the adjusted tariff and "Guidance"

Because business feasibility cannot be expected with the current tariff, the re-estimate is done by raising the tariff to IDR 1700/kWh. In this case, annual power sales revenue is expected to be IDR 29.27 billion. Moreover, CapEx shall be IDR 119.59 billion based on the "Guidance." The comparison of the P company’s profit with and without rehabilitation is shown in Table 9-8. Under these conditions, the SPC's PIRR and EIRR are expected to be 13.37% and 15.08%, respectively.

Table 9-8 Annual profit of the P company (Full replacement at “B”-“C” Power Plant: Adjusted tariff and "Guidance")

	Without replacement	With replacement
1-10	IDR 1,902 million	IDR 3,272 million
11-20		IDR 4,994 million
Total for 20 years	IDR 38,032 million	IDR 82,651 million

(4) For project costs based on adjusted tariff/manufacturer’s reference quotation

Similarly, re-estimate is considered and CapEx as IDR 76.99 billion based on the manufacturer's reference quotation by raising the tariff to IDR 1,150/kWh. In this case, annual power sales revenue is expected to be IDR 19.8 billion. Moreover, the comparison of the P company’s profit with and without rehabilitation is shown in Table 9-17. Under these conditions, the SPC's PIRR and EIRR are expected to be 13.95% and 15.93%, respectively.

Table 9-9 Annual profit of the P company (Full replacement at “B”-“C” Power Plant: Adjusted tariff and quotation)

	Without replacement	With replacement
1-10	IDR 1,286 million	IDR 1,894 million
11-20		IDR 2,411 million
Total for 20 years	IDR 25,728 million	IDR 43,048 million

Chapter 10 Schedule for order receipt and project implementation

10.1 RO agreement with the P company

The overviewing the process for concluding an RO contract with the P company and the status of discussions with the P company will be described briefly here.

10.1.1. Process for signing RO agreement with the P company

Procurement of goods and services by state-owned enterprises and their subsidiaries and affiliated companies will be carried out through public tender/selection, limited tender/limited selection, or direct appointment in accordance with "Ministry of State-Owned Enterprises Regulation No. PER-08/MBU/12/2019 on General Guidelines on the Implementation by State Owned Enterprises of the Procurement of Goods and Services (MSOE Reg 8/2019)."

(1) Public tender/selection

When an SPC that does not belong to the P company group or a consortium with the P company group serves as the RO contractor, procurement is conducted via a public tender in which bidders are widely invited through mass media. This tender method is most likely to be used for this project as well.

(2) Limited tender/limited selection

If justified and approved by the PLN and the P company, procurement can also be conducted through a limited tender process in which only companies pre-selected by the P company will participate.

(3) Direct appointment

If the SPC is a group company of the P company, it may be possible to procure through direct appointment to award the contract to a specific company if certain conditions are satisfied. Not applicable to this project.

10.1.2. Discussion status with the P company regarding RO contract

We are continuing discussions with the P company about an RO contract. The major points of discussion are the merits and demerits of the P company's participation with capital in this project, and the increase in the tariff rate. In the future, we will obtain quotations from multiple turbine suppliers, and we will make concrete discussions based on more detailed project costs.

10.2 Regulations, licenses, etc. related to this project

There are no restrictions on foreign investment in RO projects. 100% ownership by foreign capital operators is possible. On the other hand, in Industry Category[18], to which this project applies, the investment amount is set at a minimum of IDR 20 billion, excluding the value of land and buildings, and the issued and paid-up capital is set at a minimum of IDR 10 billion.

To implement RO projects, following three licenses must be obtained:

- Electric power support services project (Izin Usaha Jasa Penyedia Tenaga Listrik)
- Project identification number (Nomor Induk Berusaha)
- Project entity certificate (Sertifikasi Badan Usaha)

10.3 List of relevant laws and regulations

Table 10-1 Investment related laws and regulations

Law no./Year	Title of laws and regulations	Summary of laws and regulations
Law No. 25 of 2007 (amended by Law No. 11 of 2020)	Investment (Law No. 25 of 2007) and Job Creation (Law No. 11 of 2020)	1. foreign investment in Indonesia shall be conducted in the form of Indonesian limited liability company ("PT") which shall be located in Republic of Indonesia territory 2. foreign investor (could be any foreign individual, foreign business entity, or foreign government) can conduct their investment in several means, namely by: ・ Establishing a new PT and taking ownership in shares at the time of establishment; ・ Participating their capital, together with any Indonesian partner in an existing PT or by establishing new joint venture company; or ・ Taking other means in accordance with the provisions set out under relevant laws and regulations. 3. Linked to Presidential Regulation No. 49/2021, the foreign investment in RO Project shall be conducted by injecting foreign capital to a local legal entity in Indonesia, whether it is a new established company or an existing company
Presidential Regulation No. 10 of 2021 as amended by Presidential Regulation No. 49 of 2021	Business Sector	1. Indicates the four business sectors that are open for foreign investment 2. Linked to Law No. 25 of 2007 (as amended by Law No. 11 of 2020), the foreign investment in RO Project shall be conducted by injecting foreign capital to a local legal entity in Indonesia, whether it is a new established company or an existing company

[18] Based on the Indonesian Standard Industrial Classification (KBLI) 2020, RO projects are classified into the following industries: KBLI 35121 (Installation and Operation of Power Supply), KBLI 43211 (Installation of Electrical Equipment Including Maintenance).

Table 10-2 Corporate laws and regulations

Law no./Year	Title of laws and regulations	Summary of laws and regulations
Law No. 40 of 2007 (amended by Law No. 11 of 2020)	Limited Liability Company or *Perseroan Terbatas* ("PT") (Law No. 40 of 2007) and Job Creation (Law No. 11 of 2020)	1. The company to perform RO Project should be established by at least 2 (two) persons. 2. Definition of "person" is an individual (could be Indonesian or foreign citizen) or a legal entity (could be Indonesian or foreign legal entity). 3. The company shall be registered to the Ministry of Law and Human Rights registry and obtain its legal status, along with all relevant certificate and/or business license. 4. Minimum foreign investment value per KBLI is IDR 10,000,000,000 (ten billion Rupiah), exclude of the land and building values owned by the foreign investor. Since the RO Project required two KBLIs, the minimum investment value will be IDR 20,000,000,000 (twenty billion Rupiah), exclude land and building value.
Law No. 7 of 2011	Currency	1. All transactions related to payments or settlement of any other obligations, and/or other financial transactions in the territory of Republic of Indonesia shall use Rupiah currency.
Government Regulation No. 62 of 2012 ("GR No. 62/2012").	Electric Power Support Services Business	1. To conduct RO Project, the company is required to obtain IUJPTL that shall be granted by the Minister of Energy and Mineral Resources when the majority of the company's shares are held by foreign investor.
Minister of Finance Regulation No. 196/PMK.03/2007 ("MOF Reg No. 196/2007"), lastly amended by Minister of Finance Regulation No. 123/PMK.03/2019.	Procedures of Bookkeeping Using Foreign Languages and Units of Currency Other Than Rupiah and the Obligation to Submit Annual Income Tax Notification Letter of the Corporate Taxpayer	1. In principle, company shall use Rupiah currency for its bookkeeping. 2. In the event the company wishes to use other currency than Rupiah for its bookkeeping, it shall obtain a written approval from the Minister of Finance of the Republic of Indonesia. 3. Other than Rupiah currency and Bahasa Indonesia, the company is only allowed to use US Dollar currency and English for its bookkeeping.
Minister of Energy and Mineral Resources Regulation No. 12 of 2021 ("MEMRR No. 12/2021").	Classification, Qualification, Accreditation, and Certification of Electric Power Support Service Business	1. Stipulates several conditions which shall be met by the company to obtain the SBU which needed as a proof of formal acknowledgment of the suitability of classification and qualifications on the ability of business actors in the business sector of electric power support services.

Table 10-3 O&M laws and regulations

Law no./Year	Title of laws and regulations	Summary of laws and regulations
Law No. 30 of 2009 (amended by Law No. 11 of 2020)	Electricity (Law No. 30 of 2009) and Job Creation (Law No. 11 of 2020)	1. Indicates that electricity business consists of: ・ electric power provision business, and ・ electric power support business. 2. Moreover, it indicates that electric power support business shall consist ・ electric power support services business, and ・ electric power support industry business. 3. Electric power support services business shall be conducted by state-owned enterprises, regional-owned enterprises, private enterprises, public service entities, and cooperatives that have certification, classification, and qualifications
Central Bureau of Statistics Regulation No. 2 of 2020 ("KBLI 2020")	Indonesia Business Field Standard Classification	1. The proper KBLI to perform RO Project are KBLI 35121 and KBLI 43211. 2. KBLI 35121 describes the industry classification for those operating businesses carried out by other parties for generating facilities that produce electrical energy, electric power transmission system facilities, and electricity distribution systems. 3. KBLI 43211 description includes activities for the construction, installation, maintenance, reconstruction of electrical installations at generators, transmissions, substations, distribution of electric power, power supply systems, and electrical installations for residential and non-residential buildings, such as the installation of low-voltage electricity networks. This also includes the installation and maintenance of electrical installations in civil buildings, such as roads, railways, and airfields.

Table 10-4 Laws and regulations related to RO agreements

Law no./Year	Title of laws and regulations
Law No. 25 of 2007 (amended by Law No. 11 of 2020)	Investment (Law No. 25 of 2007) and Job Creation (Law No. 11 of 2020)
Law No. 40 of 2007 (amended by Law No. 11 of 2020)	Limited Liability Company or Perseroan Terbatas ("PT") (Law No. 40 of 2007) and Job Creation (Law No. 11 of 2020)
Law No. 20 of 2008 (amended by Law No. 11 of 2020)	Small, Micro, and Medium Business (Law No. 20 of 2008) and Job Creation (Law No. 11 of 2020)
Law No. 30 of 2009 (amended by Law No. 11 of 2020)	Electricity (Law No. 30 of 2009) and Job Creation (Law No. 11 of 2020)
Law No. 7 of 2011	Currency
Government Regulation No. 5 of 2005	Establishment, Management, Supervision, and Dissolution of State-Owned Enterprise
Government Regulation No. 62 of 2012	Electric Power Support Services Business
Government Regulation No. 5 of 2021	Organization of Risk-Based Business Licensing
Government Regulation No. 25 of 2021	Implementation of the Energy and Mineral Resources Sector.
Presidential Regulation No. 35 of 2015	Cooperation between the Government and Business Entity in the Provision of Infrastructure
Presidential Regulation No. 63 of 2019	Use of Indonesian Language
Presidential Regulation No. 10 of 2020 (amended by Presidential Regulation No. 49 of 2021)	Investment Business Fields
Central Bureau of Statistics Regulation No. 2 of 2020	Indonesia Business Field Standard Classification (KBLI 2020)
Investment Coordinating Board Regulation No. 4 of 2021	Guidance and Procedures of Risk-based Business Licensing and Investment Facility
Minister of Finance Regulation No. 196/PMK.03/2007 (lastly amended by Minister of Finance Regulation No. 123/PMK.03/2019)	Procedures of Bookkeeping Using Foreign Languages and Units of Currency Other Than Rupiah and the Obligation to Submit Annual Income Tax Notification Letter of the Corporate Taxpayer
Minister of Energy and Mineral Resource Regulation No. 10 of 2017 (amended by Minister of Energy and Mineral Resource Regulation No. 10 of 2018	Principles within Power Purchase Agreement
Minister of Energy and Mineral Resource Regulation No. 50 of 2017 (lastly amended by Minister of Energy and Mineral Resources Regulation No. 4 of 2020)	Utilization of Renewable Energy for the Provision of Electricity Power
Minister of State-Owned Enterprises Regulation No. PER-08/MBU/12/2019 of 2019	General Guidance of Goods and Services Provision of State-Owned Enterprises
Minister of Energy and Mineral Resources Regulation No. 5 of 2021	Standard of Business Activity and Product on the Organization of Risk-based Business Licensing of Energy and Mineral Resources Sector
Minister of Energy and Mineral Resources Regulation No. 12 of 2021	Classification, Qualification, Accreditation, and Certification of Electric Power Support Service Business

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Chapter 11 CO_2 emission quantity control and environmental improvement effect

11.1 CO_2 emission reduction amount

Because all of the power plants under consideration are hydroelectric, CO_2 emissions are already under control at present. The project aims to increase power generation by enhancing output and improving operational efficiency for these power plants. Therefore, the CO_2 emission reduction amount added by the increase in power generation due to the project was calculated as the CO_2 emission reduction amount in the project.

Emission coefficients are based on the "Guidelines for Public Offering for the Subsidy of Carbon Dioxide Emission Control Projects (Bilateral Credit System Financial Assistance Project for Equipment) for FY 2022 to 2024" issued by the Global Environment Centre Foundation (April 6, 2022). For Java, it is as per the following.

[Case 1] Replacing grid power generation only: 0.613 tCO_2/MWh

[Case 2] Replacing both grid power and in-house power generation: 0.533 tCO_2/MWh

Since this is a rehabilitation and not a new construction, the increase in power generation was multiplied by the emission factor above. Since the increased portion is to be used to sell electricity, 0.613 of Case 1 was used.

The assumed CO_2 emission reductions (annual) are shown in Table 11-1.

Table 11-1 CO_2 emission reduction (annual)

Power plant	Power generation amount (MWh)		Emission coefficient (tCO_2/MWh)	CO_2 reduction (tCO_2)		CO_2 reduction effect (tCO_2) by the implementation of this project
	Present condition	After rehabilitation		Present condition	After rehabilitation	
“A”	70,491	76,714	0.613	43,211	47,026	3,815
“B”-”C”	11,186	17,219		6,857	10,555	3,698
Total CO_2 emission reductions due to the implementation of this project (tCO_2)						7,513

11.2 Environmental and social impact

This project is a rehabilitation of an existing aging hydroelectric plant. In principle, there will be no environmental and social impacts because the project will not make any land alterations. Note that an Environmental Management Program and Environmental Monitoring Program (UKL-UPL) is required for new power sources.

Reference Documents

New Energy Foundation: "Guidebook for Small and Medium-sized Hydroelectric Power (Fifth Revised Edition)" (May 2019)

Hydro Valley Plan Guidebook, Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry (March 2005)

New Energy and Industrial Technology Development Organization, "NEDO Renewable Energy Technology White Paper (Second Edition)" (February 2014): Chapter 8; Small and Medium-Sized Hydroelectric Power

Japan International Cooperation Agency, Electric Power Development Company, and Kaihatsu Sekkei Consultants, Inc.: "Hydroelectric Power Development Guide Manual" (March 2011)

Japan Turbomachinery Association: "Hydroelectric Turbine (First edition, First print)" (June 1991)

Japan Society Mechanical Engineers: "Mechanical Engineering Handbook, Applied Systems, γ2, Fluid Machinery" (August 2007)