THE INTERNATIONAL ENERGY AGENCY TECHNOLOGY COLLABORATION PROGRAMME ON HYDROPOWER

IEA Hydropower

MAINTENANCE WORKS AND DECISION-MAKING FOR HYDRO FACILITIES

Appendix 1: Good Practice Portfolio - Japan

October 2021

IEA Hydro Annex XV

Contents

1. Introduction

This book is a portfolio of good practice in Japan collected for Annex XV.
Good practice collection was conducted using a survey questionnaire in connection with the investigation for asset management discussed in Chapter 3. In addition, we also found the possible cases for this Annex from the cases collected for Annex-XI which are closely related to the maintenance of hydropower plants and other cases featured in academic journals and conferences for hydropower engineering.
The basic concept for the model format is based on the process of decision making presented in the discussions with the participant states upon preparation of Statement of Objective for Annex-XV.

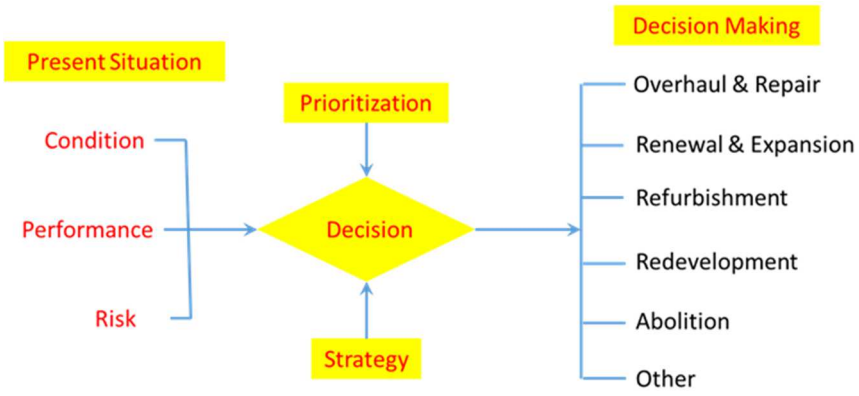

Fig. 1-1: Image of Decision Making Process

It is not appropriate to rigidly formulate the introductory descriptions of possible good practices as their features are diverse, but it is still desired from the standpoint of readers to unify the format to the extent possible for easily understanding those cases and comparing them with other cases.
For this reason, based on Fig. 1-1, we decided to unify the survey format as much as possible for collecting the information in a systematic and accurate manner as mentioned below:

- Plant Information (name, specifications, commissioning year and month, owner, and etc.)
- Type of decision making (choices from Table -1-1)
- Time of decision-making
- Target structure(s) (choices from Table-1- 2)
- Driver (choices from Table-1-3)
- Phenomena caused by driver
- Type of Risk Management (choices from Table-1-4)
  - Risks for plant operation
  - Specific risk management
- (1) Current Status (Before decision making)
  - 1) General Status
  - 2) Operation Status
  - 3) Risk
    - ✓ Potential risk in case of no decision making
    - ✓ Potential risk when implementing decision making
- (2) Priorities
- (3) Strategy
  - Against potential risk in case of no decision making
  - Against potential risk when implementing decision making
- (4) How decision-making was implemented and technologies adopted?
  - Reference documents / sources

Regarding to the relation between above items and Fig. 1-1 is as shown in Fig. 1-2.

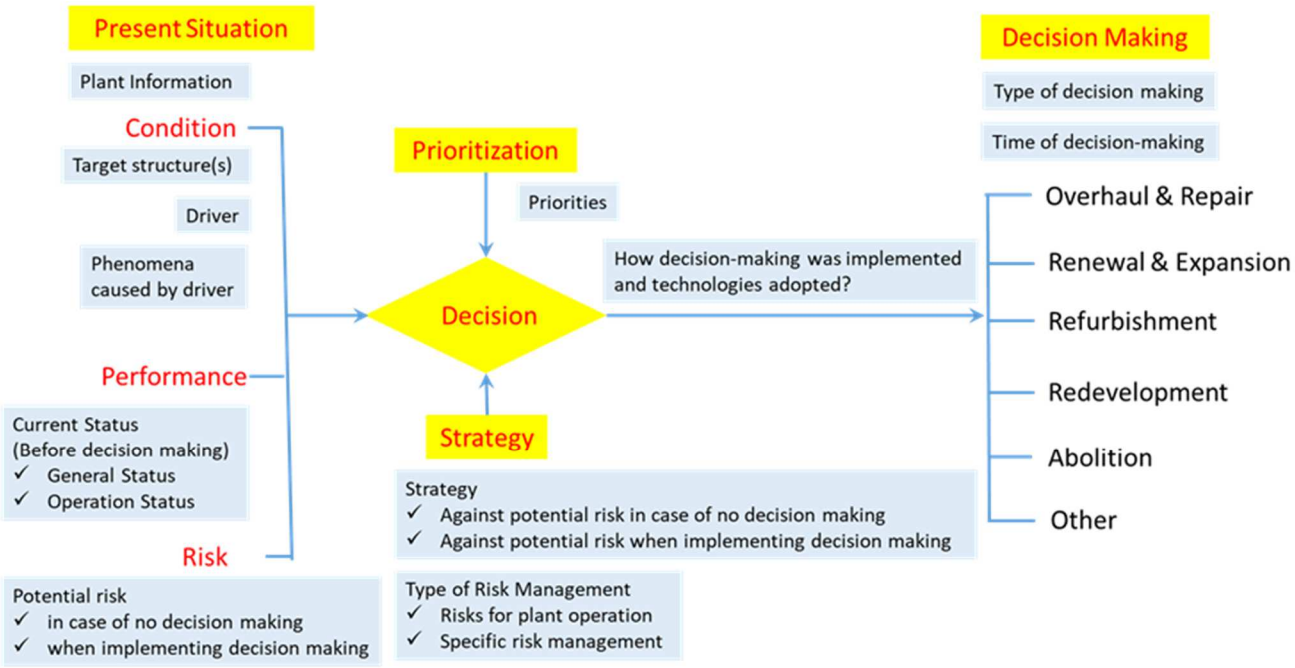

Fig. 1-2: Position of the table items in the process of Decision-Making

Table-1-1: Maintenance Works and Decision-Making for Hydro Facilities

Decision making matters	Descriptions
Overhaul & Repair (O&R)	Repair as an urgent measure of main plant structures / facilities or peripheral electric facilities
Renewal & Expansion (R&E)	Planned renewal and expansion of main plant structures / facilities or peripheral electric facilities (for power generation)
Refurbishment	Refurbishment required by surrounding social / natural environments of main plant structures / facilities or peripheral electric facilities (except for power generation)
Redevelopment	Development of plant with major construction work due to development of other projects or disasters
Abolition	Abolition of plant
Other	Change in operation / management methods, construction work of other than main plant structures / facilities or peripheral electric facilities

- Main plant structures: dam, intake, headrace, tank, penstock, powerhouse building, machine unit foundation, tailrace, outlet
- Main plant facilities: electric facilities (turbine, generation, etc.), mechanical facilities (indoor crane, gate, screen, piping, etc.)
- Peripheral facilities: facilities not directly related to power generation

Table-1-2: Target Structures of Decision Making

Names	Descriptions
Dam	Dam body. Includes weir
Spillway	Concrete structure including gate and other metal components
Reservoir	
Water Passage	Intake, headrace, tank, penstock, tailrance, spillway and their peripheral facilities
Powerhouse building	Structures above assembled units level in power plant
Turbine generator	Turbine generator and its peripheral equipment. Plant foundation concrete work is for renewal is included herein.
Peripheral electric facilities	Electric facilities other than turbine generator and its peripheral equipment
Other	Facilities other than the above

Table -1-3: Drivers for Decision Making

Drivers	Descriptions
Aging	Corresponds to what is being affected by aging of power generation facitlities
External factors	Corresondes to Public works, third party damage prevention, turbid water countermeasure, design standard changes, compliance
Asset optimization & review of operation	Corresponds to gateless modification of spillPassage, installation of dust remover in intake, Upgrading pump turbine generator in pumped storage plant from fixed to variable speed type, expansion of powerhouse building in connection with the foregoing, etc
Disaster	Corresponds to damage by earthquake or flood
Poor maintenance	Corresponds to insufficient maintenance, management

Table -1-4: Risk Management

Risk management	Descriptions
Avoidance	Not engaging in actions related to risks, or withdrawing from risky situations
Reduction	Reducing probability or impact scale of risks, or both of them
Transfer	Insurance policies, etc.
Tolerance	Positive tolerance (reserve funds, provision funds, savings, etc.), negative tolerance (not taking any measures upon recognition, disapproval, etc.)

2. How to use this portfolio

As noted, this appendix is a portfolio of case studies of powerplants in Japan which have demonstrated good practice in Maintenance Works and Decision-Making for Hydro Facilities.

The reader of this Appendix will seek examples of good practice that align with the challenges faced for their own hydro facilities. The process to identify such examples is as follows:

i. What is the structure where you find some phenomena which can invite some problem for sound operation of your plant?
ii. Find Decision-Making Process Flowchart group whose targeted structure corresponds to the structure you consider.
iii. Among the targeted structure group, consider the driver which cause the phenomena. You can access the chart you need by “Driver” group as shown in Table -3.
iv. Or check Box with Blue color among the targeted structure group, if you refer some phenomena you find.
v. Or check Box with Green color among the targeted structure group, if you refer some problem to be solved.
vi. When you find the Decision-Making Process Flowcharts you need, check the index number of good practice in the charts.
vii. Refer the number of portfolio in this book to get information. If you need more detailed information, refer “Reference documents / sources” shown in the table.

3. Decision-Making Process Flowchart

Legends of each figure is as follows;

- Box with Pink color: Driver of Decision-Making
- Box with Yellow color: Targeted Structure
- Box with Blue color: Phenomena regarded as “Problem” at the site
- Box with Green color: Problem to be solved
- Box with Orange color: Overview of Decision-Making
- Box with Blue outline with numbers: For “5.1”, index number in Appendix-1 is shown to identify Decision-Making Good Practice. And for “5.2”, index number in Appendix-2 is shown.

3.1 Dam

(1) Aging

Decisions made due to the aging of dam were refurbishment and overhaul & repair. The decision-making process flowchart of refurbishment is shown in Fig. 3.1-1.

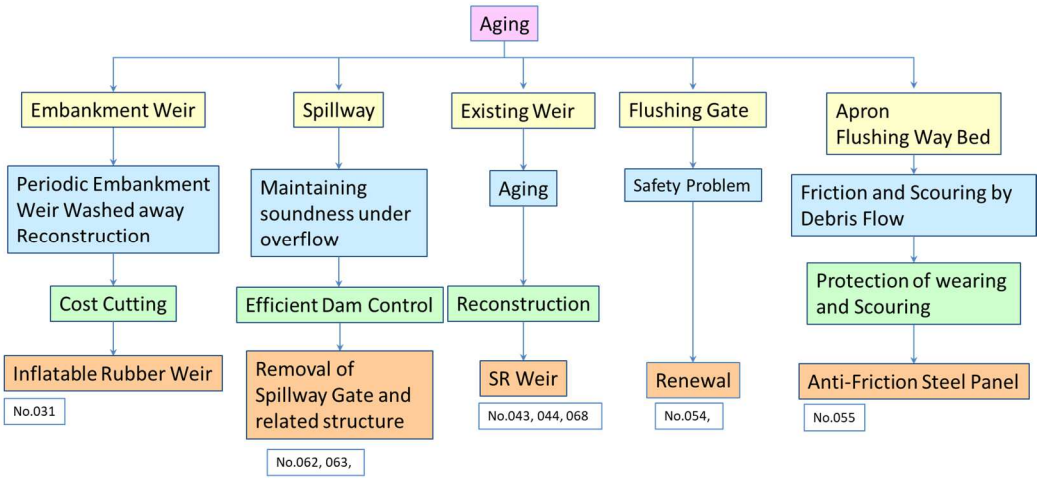

Fig. 3.1-1: Decision-Making Process Flowchart for “Refurbishment” for Aging of Dams

The decision-making process flowchart of overhaul & repair is shown in Fig. 3.1-2.

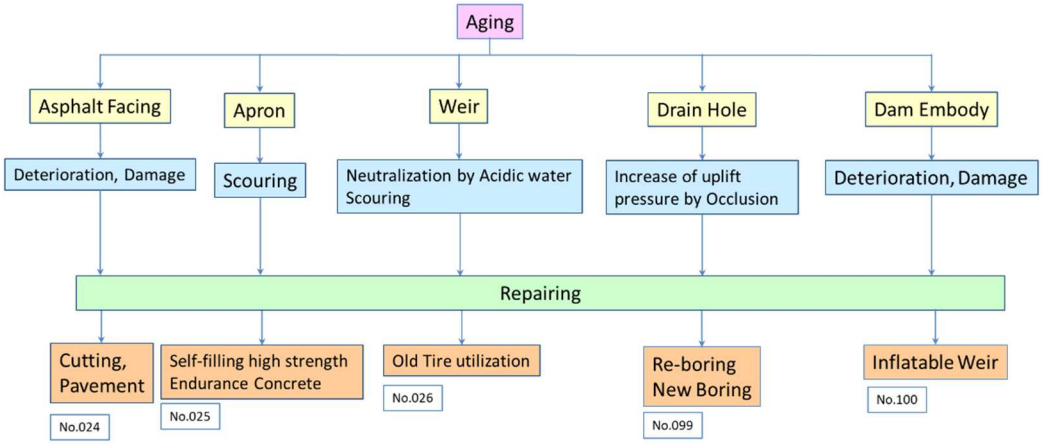

Fig. 3.1-2: Decision-Making Process Flowchart for “Overhaul & Repair” for Aging of Dams

(2) Disaster (Flood)

Decision made driven by disaster (flood) for dams was refurbishment only. The decision-making process flowchart for this case is shown in Fig. 3.1-3.

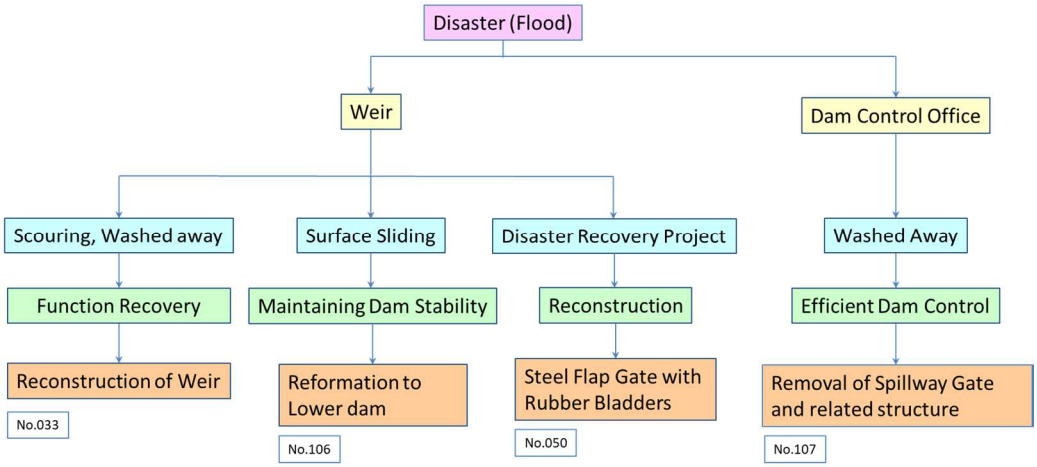

Fig. 3.1-3: Decision-Making Process Flowchart of "Refurbishment" for Aging of Dams

(3) Disaster (Earthquake)

Decisions made driven by disaster (earthquake) for dams were refurbishment and overhaul & repair. The decision-making process flowchart for these cases is shown Fig. 3.1-4.

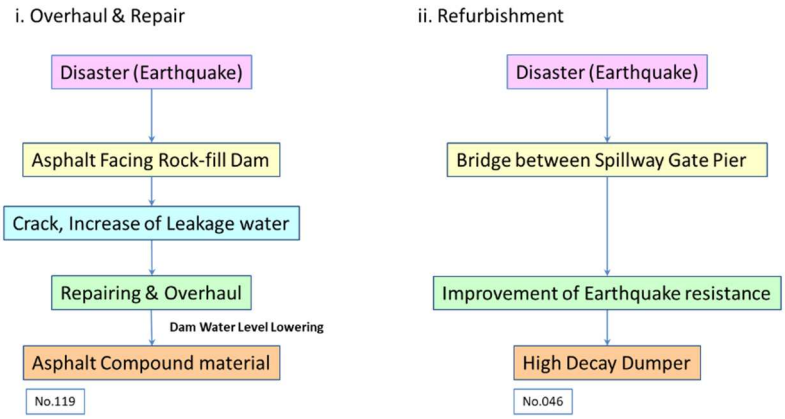

Fig. 3.1-4: Decision-Making Process Flowchart of "Overhaul & Repair" and "Refurbishment" of Dams

3.2 Spillway

(1) Aging

Decisions made driven by aging of spillway are refurbishment and overhaul & repair.
The decision-making process flowchart of refurbishment is shown in Figure 3.2-1.

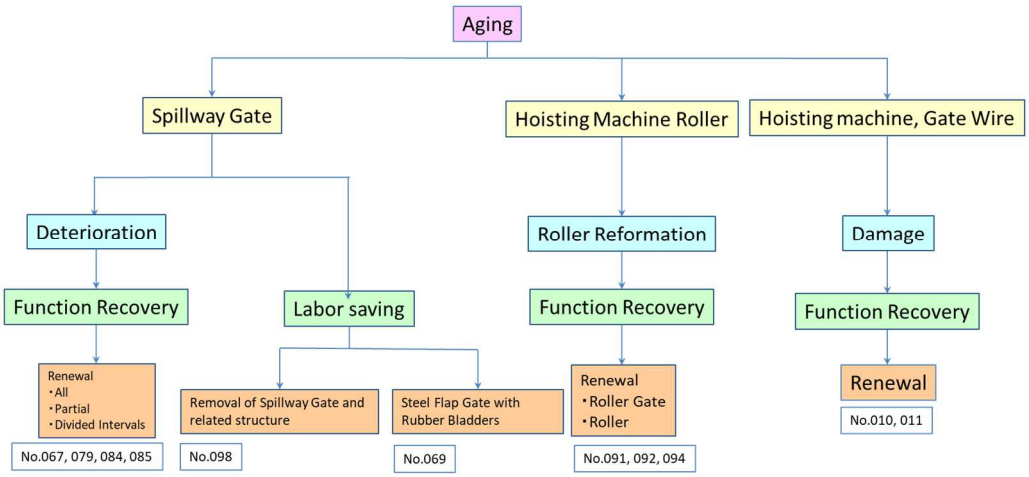

Fig. 3.2-1: Decision-Making Process Flowchart of "Refurbishment" for Aging of Spillways

The decision-making process flowchart of overhaul & repair is shown in Fig. 3.2-2.

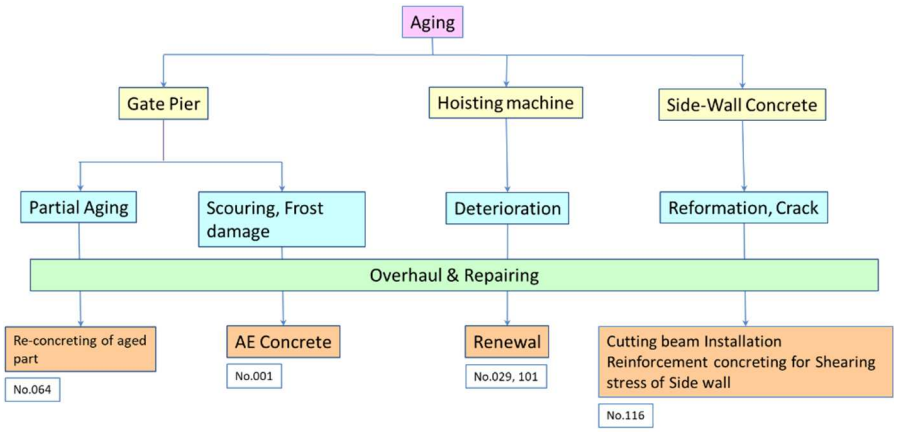

Fig. 3.2-2: Decision-Making Process Flowchart of "Overhaul & Repair" for Aging of Spillways

(2) Disaster

Decision made driven by disaster for spillways was refurbishment only, and the decision-making process flowchart for this case is shown in Fig. 3.2-3.

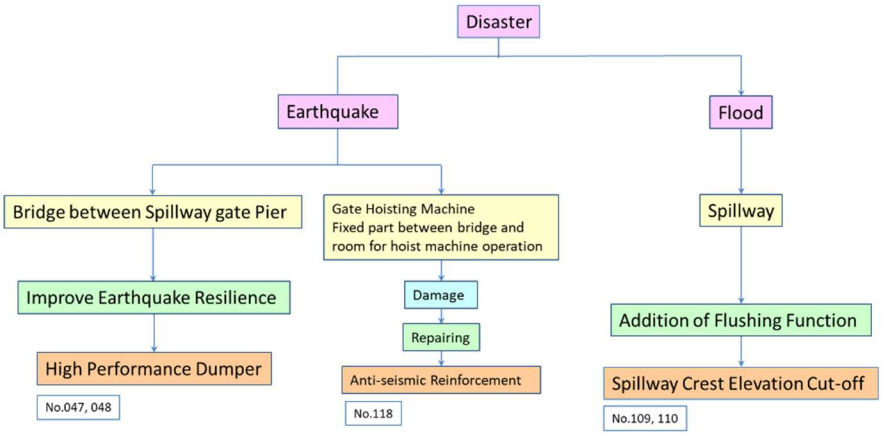

Fig. 3.2-3: Decision-Making Process Flowchart of "Refurbishment" Spillways against Disaster

(3) External factors

Decision made driven by external factors for spillway was refurbishment only, and the decision-making process flowchart for this case is shown in Fig. 3.2-4.

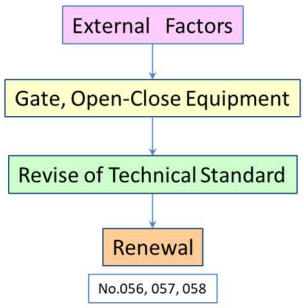

Fig. 3.2-4: Decision-Making Process Flowchart of "Refurbishment" of Spillways for External factors

(4) Asset Optimization & Review of Operation

Decision made driven by asset optimization & review of operation of spillway was refurbishment only, and the decision-making process flowchart for this case is shown in Fig. 3.2-5.

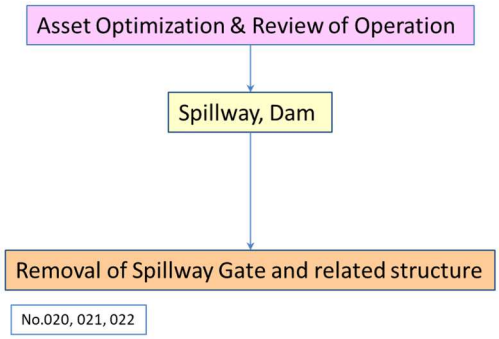

Fig. 3.2-5: Decision-Making Process Flowchart of “Refurbishment” of Spillways For Asset Optimization & Review of Operation

3.3 Reservoir

Decision made driven by external factors for reservoir was “refurbishment” only. The decision-making process flowchart for this case is shown in Fig. 5.1.3-1.

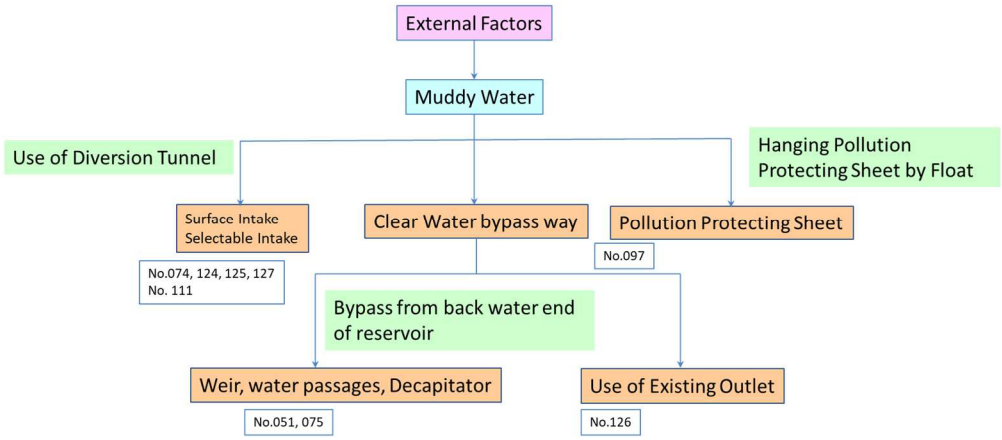

Fig. 3.3-1: Decision-Making Process Flowchart of “Refurbishment” of Reservoir for External factors

3.4 Water Passage

(1) Aging

Decisions made driven by aging of water passages were refurbishment and overhaul & repair.
The decision-making process flowchart of refurbishment is shown in Fig. 3.4-1.

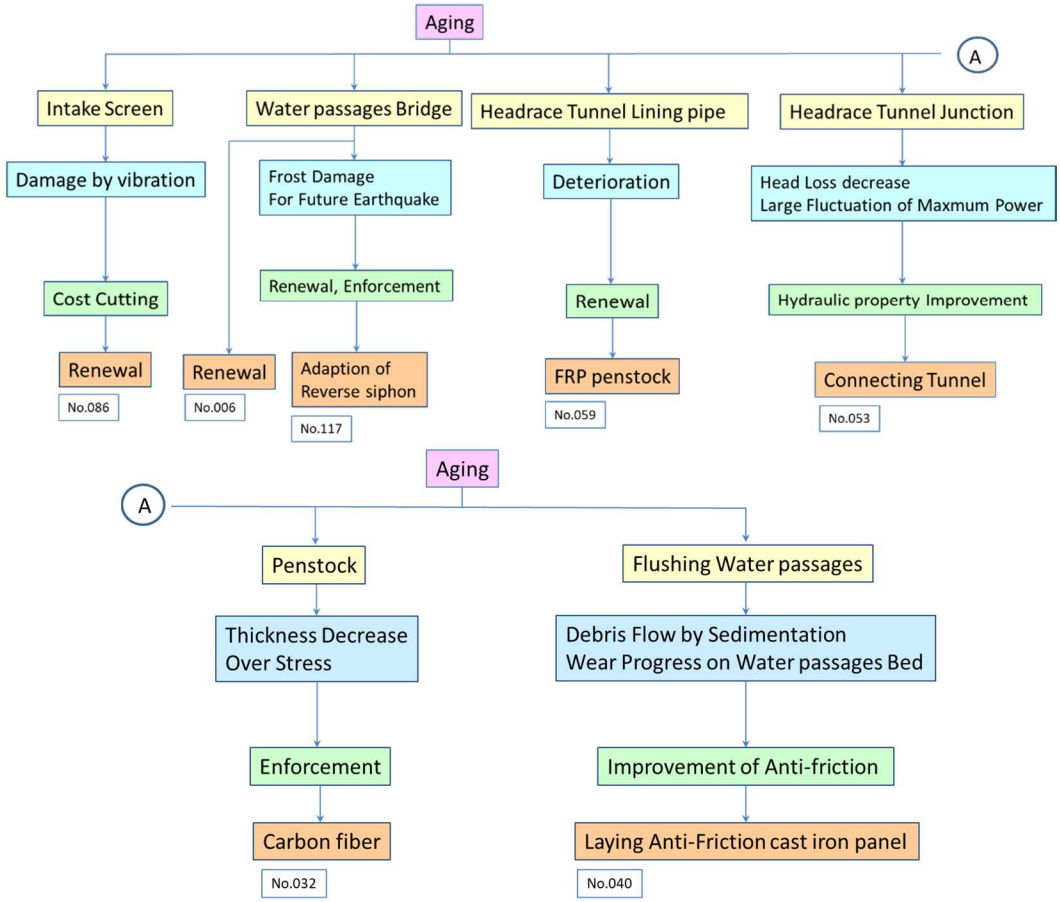

Fig. 3.4-1: Decision-Making Process Flowchart of "Refurbishment" for Aging of Water Passages

The decision-making process flowchart of overhaul & repair is shown in Fig. 3.4-2.

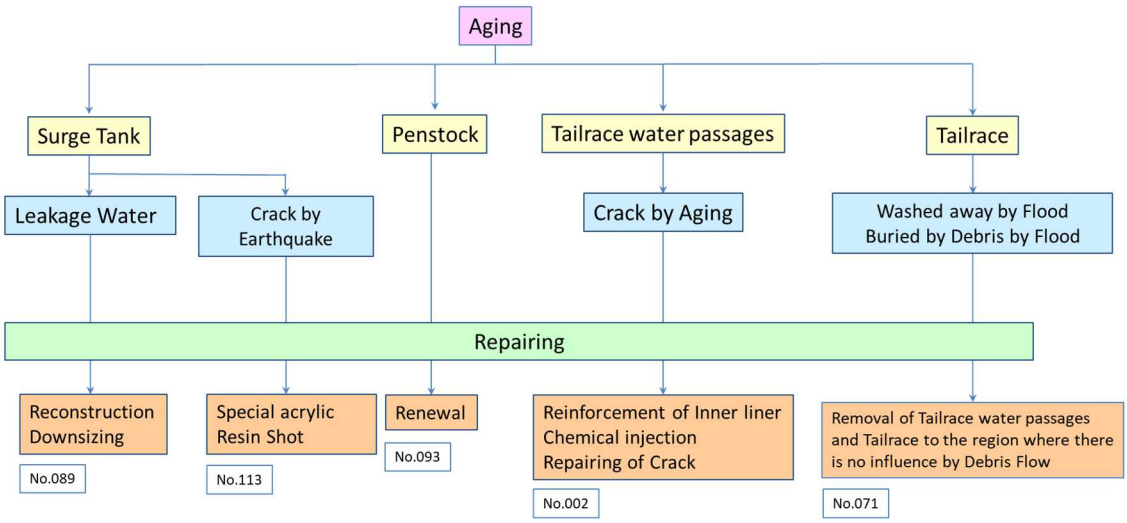

Fig. 3.4-2: Decision-Making Process Flowchart of "Overhaul & Repair" for Aging of Water Passages

(2) Disaster

Decisions made driven by disaster at water passages were refurbishment and overhaul & repair. The decision-making process flowchart of “refurbishment” is shown in Fig. 3.4-3.

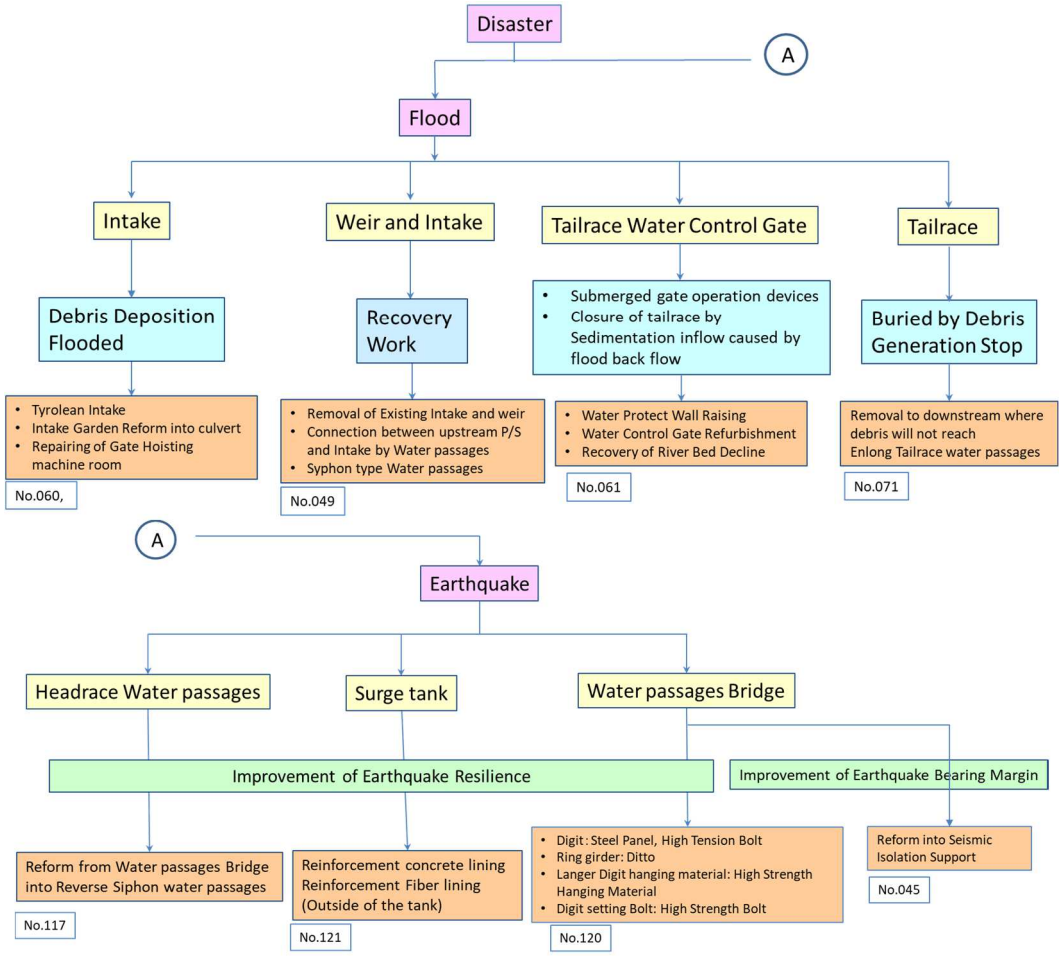

Fig. 3.4-3: Decision-Making Process Flowchart of “Refurbishment” for Disaster at Water Passages

The decision-making process flowchart of overhaul & repair is shown in Fig. 3.4-4.

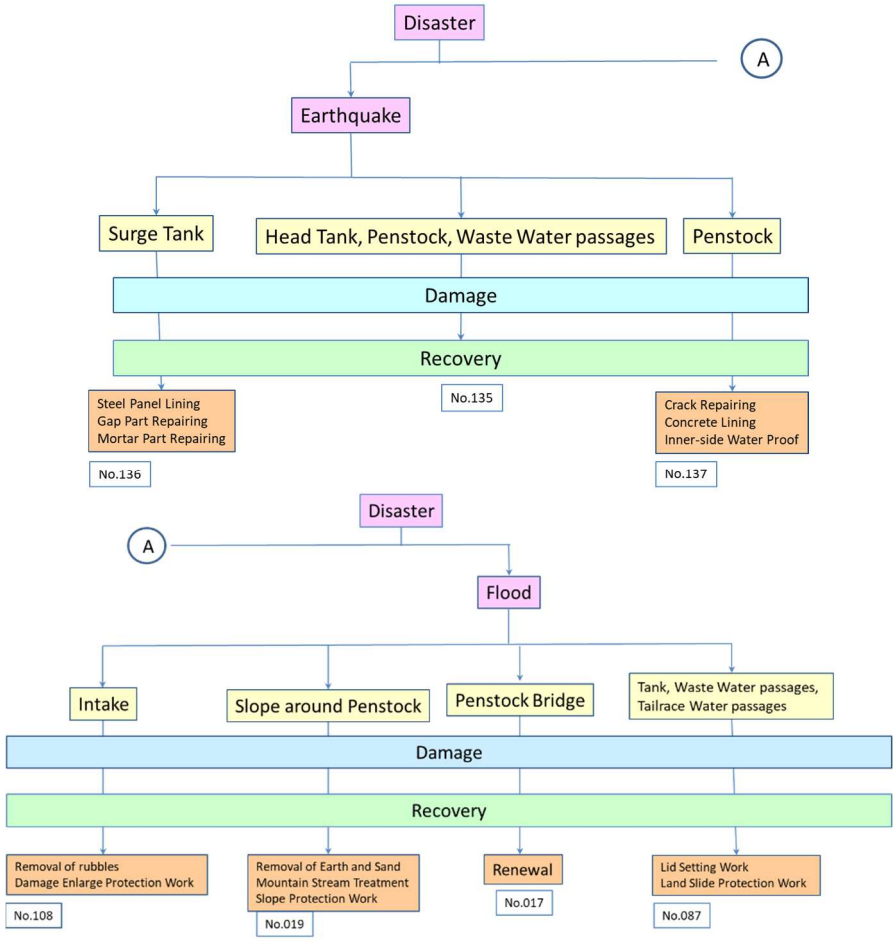

Fig. 3.4-4: Decision-Making Process Flowchart of "Overhaul & Repair" for Disaster at Water Passages

(3) External factors

Decision made driven by external factors for water passages was refurbishment only, and the decision-making process flowchart for this case is shown in Fig. 3.4-5.

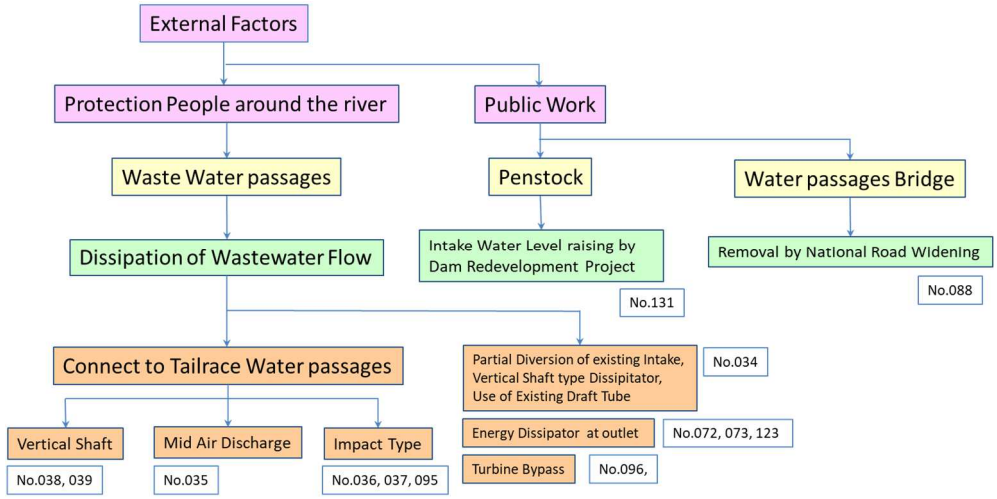

Fig. 3.4-5 Decision-Making Process Flowchart of "Refurbishment" of Water Passages for External factors

(4) Asset Optimization & Review of Operation

Decision made driven by asset optimization & review of operation of water passages was refurbishment only, and the decision-making process flowchart for this case is shown in Fig. 5.1.4-6.

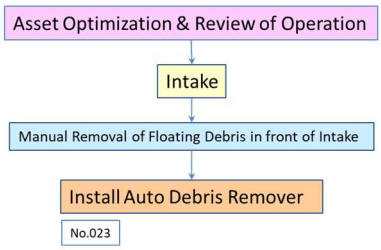

Fig. 3.4-6: Decision-Making Process Flowchart of "Refurbishment" of Water Passages for Asset Optimization & Review of Operation

3.5 Dam + Water Passage

Decision made for "dam + water passage" was driven only by disaster, and the decision was "overhaul & repair" only. The decision-making process flowchart for this case is shown in Fig. 3.5-1.

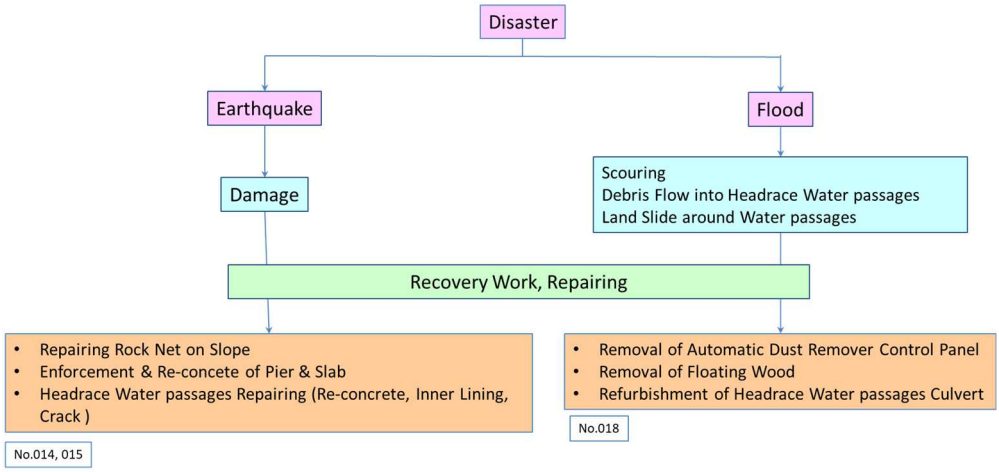

Fig. 3.5-1: Decision-Making Process Flowchart of "Overhaul & Repair" for Disaster at "Dam + Water Passage"

3.6 Power Plant

(1) Aging

The decision-making process flowchart for aging of power plant, etc. is shown in Fig. 3.6-1.

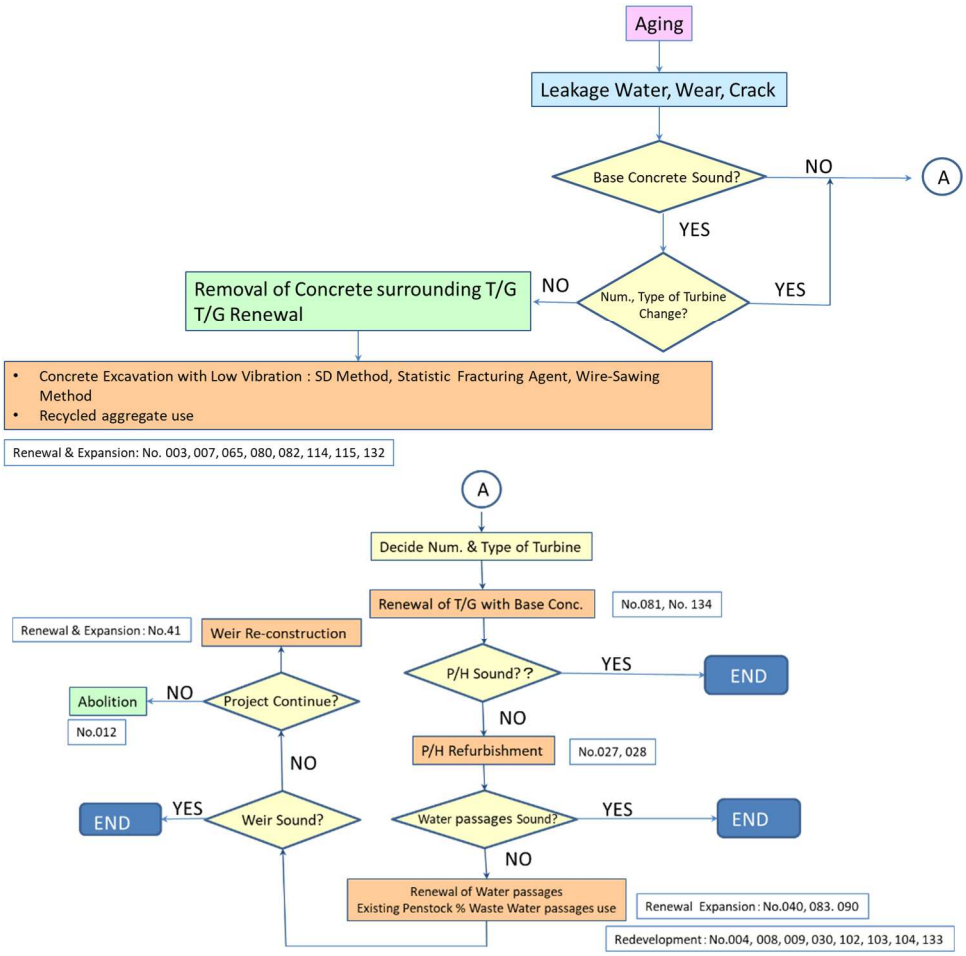

Fig. 3.6-1: Decision-Making Process Flowchart for Aging of Power Plant

(2) Disaster

Decision made driven by disaster at water passages was “overhaul & repair.” The decision-making process flowchart for overhaul & repair is shown in Fig. 3.6-2.

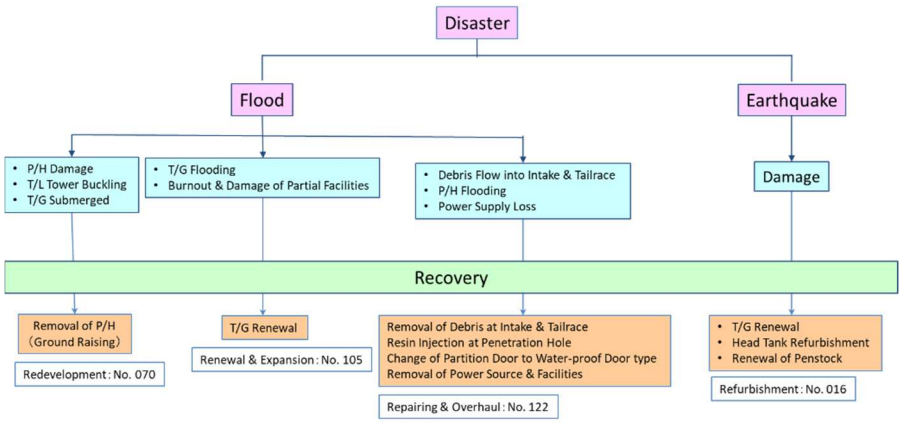

Fig. 3.6-2: Decision-Making Process Flowchart of “Overhaul & Repair” for Disaster at Power Plant

(3) External factors

The decision-making process flowchart for external factors regarding power plant, etc. is shown in Fig. 3.6-3.

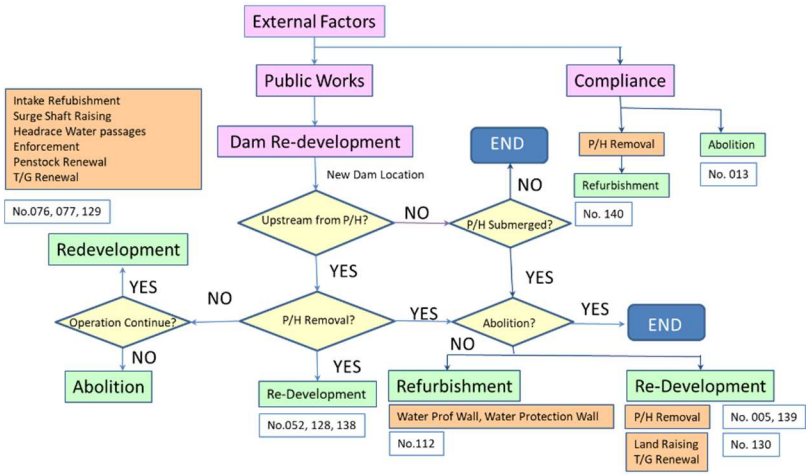

Fig. 3.6-3: Decision-Making Process Flowchart of External factors regarding Power Plant

(4) Asset Optimization & Review of Operation

Decision made driven by asset optimization & review of operation of water passages was renewal & expansion only, and the decision-making process flowchart for this case is shown in Fig. 3.6-4

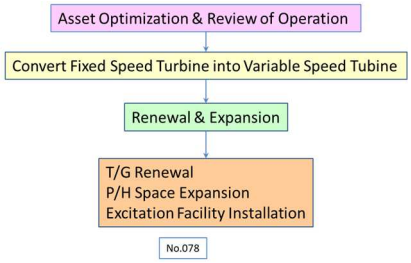

Fig. 3.6-4: Decision-Making Process Flowchart of Asset Optimization & Review of Operation for Power Plant

3.7 Peripheral electric facilities

(1) Aging

The decision-making process flowchart for aging of peripheral electric facilities is shown in Fig. 5.1.7-1.

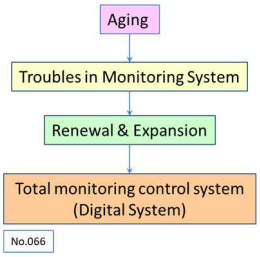

Fig. 3.7-1: Decision-Making Process Flowchart of Aging for Peripheral electric facilities

4. Good Practice Portfolio

001 Niikappu Dam Spillway Bed Refurbishment

Plant name	新冠 (Niikappu)						
Operation start	1974	**Completed**	2015	Age (41 years)			
Owner	Hokkaido EPCo						
Country	Japan						
Max output kW	200,000	**After work**	-	New / no change			
Max generation discharge m^3/s	234.00						
Effective head M	99.60						
Decision-making type (○ where it applies)	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
	○						
Time of decision making	2010						
Target structure(s)	Dam spillway						
・Driver	Aging						
・Phenomena (caused by Driver)	Aging / efficiency decline						
Risk	Reduction						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Dam reservoir repair						
(1) Current status	**(Before decision making)**						
1) General status	Aged about 40 years, scouring wear and frost damage in the spillway was progressing. AE concrete repair was performed to improve the resistance to frost damage, while movable / liftable scaffolding was temporarily used due to the site condition and work period restrictions.						
2) Operation status	Generation efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To use AE concrete to improve the resistance to freezing damage of the spillway bed after estimating that the main cause of aging is freezing / thawing effect near concrete casting edges						
(4) How decision-making was implemented and technologies adopted	The following issues and measures were considered / implemented: estimation of main causes of degradation (freezing-thawing effect around joints), limited work period (weather, power demand), adoption of AE concrete with high frost resistance, use of movable / liftable scaffolding						

Reference documents / sources Electric Power Civil Engineering (2016.11)

002 Tailrace Refurbishment: Hidaka P/S

Plant name	日高 (Hidaka)						
Operation start	1998	**Completed**	2017		Age (19 years)		
Owner	Hokkaido EPCo						
Country	Japan						
Max output kW	10,000	**After work**	-		New / no change		
Max generation discharge m^3/s	21.00						
Effective head M	56.60						
Decision-making type	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)	○						
Time of decision making	2014						
Target structure(s)	Tailrace						
・Driver	Aging						
・Phenomena (caused by Driver)	Aging / efficiency decline						
Risk	Reduction						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Water way, etc. repair						
(1) Current status	**(Before decision making)**						
1) General status	Aged about 20 years, the tailrace was repaired by internal coiling reinforcement (steel frames), chemical injection into gaps in the upper surface, and fixing cracks. The total length of repair section was 1,046 m.						
2) Operation status	Generation efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To conduct resistance check (numerical analysis) of the tailrace tunnel, to consider / select possible countermeasures against plastic pressure on the lining concrete and to perform repair						
(4) How decision-making was implemented and technologies adopted	The cause of deformation of lining concrete was considered, and the countermeasures were taken.						

Reference documents / sources Electric Power Civil Engineering (2015.9)

003 Turbine Units 1&2 Renewal (civil engineering): Hirafu P/S

Plant name		比羅夫 (Hirafu)						
Operation start		1940	**Completed**	2012		Age (72 years)		
Owner		Hokkaido EPCo						
Country		Japan						
Max output	kW	11,000	**After work**	-		New / no change		
Max generation discharge	m^3/s	37.10						
Effective head	m	37.30						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		2010						
Target structure(s)		T/G, etc						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		T/G renewal						
(1) Current status		**(Before decision making)**						
1) General status		Renewal of turbine generator in a 71-year-old power plant. The casing and foundation concrete were removed. Restructuring concrete was cast.						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To renew T/G to increase the output, to modify to oil-less unit, to reduce maintenance labor.To implement countermeasures against unloading the unit such as removed concrete and casing (by measuring the uplifting displacement with a communicating tube settlement gauge)						
(4) How decision-making was implemented and technologies adopted		Consideration was given to the remaining facilities when removing the plant foundation, and demolished concrete was recycled.						

Reference documents / sources Electric Power Civil Engineering (2012.7)

004 Shin-iwamatsu Power Plant New Construction

Plant name		新岩松 (Shiniwamatsu)						
Operation start		1942	**Completed**	2016		Age (74 years)		
Owner		Hokkaido EPCo						
Country		Japan						
Max output	kW	12,600	**After work**	16,000		Up rate↑ (27.0%)		
Max generation discharge	m^3/s	37.50						
Effective head	m	41.55						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		2013						
Target structure(s)		T/G, etc						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		T/G redevelopment						
(1) Current status		**(Before decision making)**						
1) General status		Aged about 60 years (commissioned in 1942), the existing facilities of aging Iwamatsu Power Plant would continue to be fully utilized while the maximum discharge was increased from 37.5 m3/s to 45.0 m3/s, and the maximum output from 12,600 kW to 16,000 kW from the standpoint of effective utilization of water resources.						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To perform the renewal of T/G (for increasing the max generation discharge and output) by conducting the work while the existing plant is operating, connecting the existing and new penstocks together, taking measures against freezing of the plant base soil retaining, as well as measures against the noise and vibration in consideration for birds, etc.						
(4) How decision-making was implemented and technologies adopted		The following issues and measures were considered / implemented: work undertaken while the existing plant is in operation, junction of roads and agricultural irrigation, connection of existing penstock and newly installed penstock, work undertaken in vicinity of existing substation and roads, measures against plant foundation earth retaining, measures against noise / vibration in consideration for birds inhabiting the area.						

Reference documents / sources Electric Power Civil Engineering (2015.5)

005 Eoroshi Power Plant Relocation

Plant name	江卸 (Eoroshi)						
Operation start	1945	**Completed**	2006	Age (61 years)			
Owner	Hokkaido EPCo						
Country	Japan						
Max output kW	18,600	**After work**	13,800	Down rate↓ (25.8%)			
Max generation discharge m^3/s	15.00						
Effective head m	150.70						
Decision-making type (○ where it applies)	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
					○		
Time of decision making	2002						
Target structure(s)	Headrace, penstock, T/G, etc						
・Driver	External factors						
・Phenomena (caused by Driver)	Flood safety improvement / local community cooperation						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Existing plant relocation						
(1) Current status	**(Before decision making)**						
1) General status	In response to Chubetsu Dam Construction Project immediately upstream of the outlet of Eoroshi Power Plant, the plant was relocated about 2.5 km upstream.						
2) Operation status	Generation shutdown / efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	Cooperative improvement in flood control safety						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To relocate the plant location (about 2.5 km upstream) in response to the construction of Chubetsu Dam upstream by selecting the waterway route, connecting with the existing headrace considering the geology, choosing the support for spillway energy dissipator. (The existing plant (powerhouse building, T/G, foundation) is to be removed while the waterway facility is partially recycled)						
(4) How decision-making was implemented and technologies adopted	The following issues and measures were considered / implemented: selection of water way route avoiding landslide-prone locations, connection with existing headrace in the softened geological condition through hydrothermal metamorphism, adoption of pile foundation for the support of spillway energy dissipator.						

Reference documents / sources Electric Power Civil Engineering (2003.5)

006 Uchinokura Waterway Bridge Replacement

Plant name	飯豊川第二 (Iidegawa No.2)						
Operation start	1921	**Completed**	2011		Age (90 years)		
Owner	Tohoku EPCo						
Country	Japan						
Max output kW	1,843	**After work**	-		New / no change		
Max generation discharge m^3/s	5.57						
Effective head m	43.80						
Decision-making type	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)	○						
Time of decision making	2008						
Target structure(s)	Waterway bridge						
・Driver	Aging						
・Phenomena (caused by Driver)	Aging / efficiency decline						
Risk	Reduction						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Water way, etc. repair						
(1) Current status	**(Before decision making)**						
1) General status	Rebuilding of water way bridge aged about 90 years (arch bridge of effective span L=39.76 m, for water duct of ϕ1.85m)						
2) Operation status	Generation efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To adopt the renewal of the entire waterway bridge as a permanent solution after considering LCC of the existing bridge. Warren truss design was chosen for the new bridge after structural examination						
(4) How decision-making was implemented and technologies adopted	New water way bridge type, shutdown period, heavy equipment operation restrictions were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2011.9)

007 T/G Renewal: Yabukami P/S

Plant name	薮神 (Yabukami)						
Operation start	1941	**Completed**	2006	Age (65 years)			
Owner	Tohoku EPCo						
Country	Japan						
Max output kW	8,500	**After work**	8,800	Up rate↑ (3.5%)			
Max generation discharge m^3/s	30.00						
Effective head m	35.00						
Decision-making type	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)		○					
Time of decision making	2003						
Target structure(s)	T/G, etc						
・Driver	Aging						
・Phenomena (caused by Driver)	Aging / efficiency decline						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	T/G renewal						
(1) Current status	**(Before decision making)**						
1) General status	Aged about 70 years, wear and cracks were found in various parts of turbine . For the renovation of aged facility, “SD method” was used for removing the turbine foundation. “Re-alkalization method” was employed against neutralization for the newly installed beams and pillars to support the generator.						
2) Operation status	Generation efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To conduct the renewal of turbine while considering the operation of adjacent turbines, control of vibration and dust, shortening the work period, neutralization of beams and pillars, environmental impact during the work and loss of power generation opportunities						
(4) How decision-making was implemented and technologies adopted	The following issues and measures were considered / implemented: work undertaken while the generator nearby is in operation, control of vibration and dust generation, work environment for onsite worker during the removal of the existing turbine, shortening work period, measures against the neutralization of beams and pillars, impact of work environment, reduction of loss of generation opportunities.						

Reference documents / sources Electric Power Civil Engineering (2005.5)

008 Toyomi Power Plant Refurbishment

Plant name	豊実 (Toyomi)						
Operation start	1929	**Completed**	2013	Age (84 years)			
Owner	Tohoku EPCo						
Country	Japan						
Max output kW	56,400	**After work**	61,800	Up rate↑ (9.6%)			
Max generation discharge m^3/s	270.00						
Effective head M	25.55						
Decision-making type (○ where it applies)	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
		○					
Time of decision making	2008						
Target structure(s)	Water tank, tailrace, T/G, etc						
・Driver	Aging						
・Phenomena (caused by Driver)	Aging / efficiency decline						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	T/G redevelopment						
(1) Current status **1) General status** **2) Operation status** **3) Risk**	**(Before decision making)** Large-scale renovation of a plant aged about 80 years. 6 units of existing turbine generators were consolidated into 2. Vertical valve turbine was adopted. Generation efficiency decline **Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To conduct large-scale refurbishment (consolidating 6 existing T/G units into 2) after considering hydrological phenomena by using vertical valve turbine, handling of the existing structures, recycling of removed concrete, etc.						
(4) How decision-making was implemented and technologies adopted	The following issues and measures were considered / implemented: undertaking renovation in limited area, measures against hydrological phenomena by adopting vertical valve turbines, leaving existing structures behind for later use, utilization of removed concrete.						

Reference documents / sources Electric Power Civil Engineering (2007.9/2009.1, 9/2010.5/2011.3, 11)

009 Kanose Power Plant Redevelopment

Plant name		鹿瀬 (Kanose)						
Operation start		1928	**Completed**	2017		Age (89 years)		
Owner		Tohoku EPCo						
Country		Japan						
Max output	kW	49,500	**After work**	54,200		Up rate↑ (9.5%)		
Max generation discharge	m^3/s	270.00						
Effective head	M	22.43						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		2012						
Target structure(s)		Water tank, tailrace, T/G, etc						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		T/G redevelopment						
(1) Current status		**(Before decision making)**						
1) General status		Large-scale renovation of a plant aged about 80 years. 6 units of existing turbine generators were consolidated into 2. Vertical valve turbine was adopted.						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To conduct large-scale refurbishment (consolidating 6 existing T/G units into 2) after considering hydrological phenomena by using vertical valve turbine, handling of the existing structures, recycling of removed concrete, etc.						
(4) How decision-making was implemented and technologies adopted		The following issues and measures were considered / implemented: undertaking renovation in limited area, measures against hydrological phenomena by adopting vertical valve turbines, leaving existing structures behind for later use, utilization of removed concrete.						

Reference documents / sources Electric Power Civil Engineering (2013.11)

010 Hourai Dam Spillway Gate / Winch Replacement

Plant name	蓬莱 (Hourai)						
Operation start	1938	**Completed**	2013		Age (75 years)		
Owner	Tohoku EPCo						
Country	Japan						
Max output kW	38,500	**After work**	-		New / no change		
Max generation discharge m^3/s	58.00						
Effective head m	77.60						
Decision-making type (○ where it applies)	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
		○					
Time of decision making	2005						
Target structure(s)	Spillway gate						
・Driver	Aging						
・Phenomena (caused by Driver)	Aging / efficiency decline						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Gate repair						
(1) Current status **1) General status**	**(Before decision making)** Replacement of roller type gate / wire-rope winch of spillway aged 67 years.						
2) Operation status	Generation efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To conduct replacement of the spillway roller type gate / wire rope winch units after considering reinforcement of the coffering gates, pre-use autonomous inspection, etc.						
(4) How decision-making was implemented and technologies adopted	Work period (non-flood season from November to March), reinforcement of cofferdam gate, and pre-operation autonomous inspection were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2006.7)

011 Miyashita Dam Gate / Winch Replacement

Plant name	宮下 (Miyashita)						
Operation start	1946	**Completed**	2015		Age (69 years)		
Owner	Tohoku EPCo						
Country	Japan						
Max output kW	94,000	**After work**	-		New / no change		
Max generation discharge m^3/s	320.00						
Effective head m	34.75						
Decision-making type (○ where it applies)	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
		○					
Time of decision making	2010						
Target structure(s)	Spillway gate						
・Driver	Aging						
・Phenomena (caused by Driver)	Aging / efficiency decline						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Gate repair						
(1) Current status **1) General status** **2) Operation status** **3) Risk**	**(Before decision making)** Replacement of radial type gate / wire-rope winch of spillway aged 63 years. Generation efficiency decline **Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To conduct replacement of the spillway radial type gate / wire rope winch units after considering main temporary facilities (delivery / installation), recycling of existing trunnion pins, pre-use autonomous inspection, etc.						
(4) How decision-making was implemented and technologies adopted	Main temporary facility (transport / installation) planning, work period (non-flood season from November to March), recycling of existing trunnion pins, and preoperation autonomous inspection were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2011.7)

012 Removal for Abolition of Numazawanuma Power Plant

Plant name	沼沢沼 (Numazawanuma)						
Operation start	1952	**Completed**	2004	Age (52 years)			
Owner	Tohoku EPCo						
Country	Japan						
Max output kW	43,700	**After work**	Abolition				
Max generation discharge m^3/s	24.20						
Effective head m	215.96						
Decision-making type	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)						○	
Time of decision making	2002						
Target structure(s)	All facilities						
・Driver	Aging						
・Phenomena (caused by Driver)	Aging / efficiency decline						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Abolition						
(1) Current status	**(Before decision making)**						
1) General status	Aged about 50 years, a power plant was abolished in September 2002 due to the declining availability and facility aging.						
2) Operation status	Generation efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** Repair, refurbish and continue operation **Against potential risk when implementing decision making** To conduct abolition (removal) of the plant due to the declining operation rate and facility aging while leaving the intake and headrace, removing / greening the penstock, removing / greening the powerhouse building, etc.						
(4) How decision-making was implemented and technologies adopted	Retaining from intake to headrace, removal / greening of penstock, and removal / greening of powerhouse building were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2005.3)

013 Removal for Abolition of Tsukinosawa Power Plant

Plant name	月の沢 (Tsukinosawa)						
Operation start	1953	**Completed**	2011	Age (58 years)			
Owner	Tohoku EPCo						
Country	Japan						
Max output kW	3,000	**After work**	Abolition				
Max generation discharge m^3/s	1.20						
Effective head m	297.27						
Decision-making type (○ where it applies)	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
						○	
Time of decision making	2008						
Target structure(s)	All facilities						
・Driver	Aging						
・Phenomena (caused by Driver)	Aging / efficiency decline						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Abolition						
(1) Current status	**(Before decision making)**						
1) General status	A 50-year-old power plant. Despite its high power-generation ratio against low discharge due to large effective head, the plant which played a major role in power supply was abolished due to the continuous deformation in the headrace caused by landslides, while it was deeded difficult to restrain and hold the landslides by renovative work.						
2) Operation status	Generation efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To conduct abolition (removal of exposed structures) due to repeated cases of displacement of the headrace (caused by landslide), as it was judged the landslides cannot be controlled by repair works based on the landslide displacement ranking and preventive work feasibility assessment (on continued operation of the plant) and the relevant legal procedure for the plant abolition						
(4) How decision-making was implemented and technologies adopted	Landslide displacement ranking and preventive work feasibility assessment were employed to judge if the plant could be used continuously, and the relevant legal procedure for the plant abolition was considered and handled.						

Reference documents / sources Electric Power Civil Engineering (2009.5)

014 Disaster Restoration for Iwate / Miyagi Inland Earthquake

Plant name	花山 (Hanayama)							
Operation start	1948		**Completed**	2009		Age (61 years)		
Owner	Tohoku EPCo							
Country	Japan							
Max output kW	1,100		**After work**	-		New / no change		
Max generation discharge m^3/s	4.36							
Effective head m	31.60							
Decision-making type (○ where it applies)	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**	
	○							
Time of decision making	2008							
Target structure(s)	Dam, intake, headrace, tailrace							
・Driver	Disaster							
・Phenomena (caused by Driver)	Generation shutdown / efficiency decline							
Risk	Reduction							
・Risks for plant operation	Cost increase / profit reduction							
・Specific risk management	Disaster (earthquake) restoration							
(1) Current status	**(Before decision making)**							
1) General status	In a disaster restoration work in the wake of Iwate / Miyagi Inland Earthquake in June 2008, dam slope rock nets were installed, dam flushing gate pier slabs were reinforced, and headrace was repaired (re-sealing, coiling, crack repair).							
2) Operation status	Generation shutdown / efficiency decline							
3) Risk	**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction							
(2) Priorities	RE utilization / securing profit							
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To conduct reinforcement of weir slope rock nets and flushing gate pier slabs, as well as refurbishment of the headrace, etc. as a disaster restoration work after considering the danger of secondary disaster by aftershocks, quality assurance and workability, evacuation standard for work inside tunnels, liaison with prefectural and other related bureaus, etc.							
(4) How decision-making was implemented and technologies adopted	Danger of secondary disaster by aftershocks, quality assurance and workability, evacuation standard for work inside tunnels, liaison with prefectural and other related bureaus were considered and the measures were implemented.							

Reference documents / sources Electric Power Civil Engineering (2010.3)

015 Disaster Restoration for Iwate / Miyagi Inland Earthquake

Plant name	山内 (Yamanouchi)						
Operation start	1941	**Completed**	2009		Age (68 years)		
Owner	Tohoku EPCo						
Country	Japan						
Max output kW	2,000	**After work**	-		New / no change		
Max generation discharge m^3/s	2.78						
Effective head m	98.20						
Decision-making type (○ where it applies)	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
	○						
Time of decision making	2008						
Target structure(s)	Dam, headrace, penstock						
・Driver	Disaster						
・Phenomena (caused by Driver)	Generation shutdown / efficiency decline						
Risk	Reduction						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Disaster (earthquake) restoration						
(1) Current status	**(Before decision making)**						
1) General status	In a disaster restoration work in the wake of Iwate / Miyagi Inland Earthquake in June 2008, dam slope rock nets were installed, dam flushing gate pier slabs were reinforced, and headrace was repaired (re-sealing, coiling, crack repair).						
2) Operation status	Generation shutdown / efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To conduct recasting of intake weir flushing gate pier and refurbishment of the headrace, etc. as a disaster restoration work after considering the danger of secondary disaster by aftershocks, quality assurance and workability, evacuation standard for work inside tunnels, liaison with prefectural and other related bureaus, etc.						
(4) How decision-making was implemented and technologies adopted	Danger of secondary disaster by aftershocks, quality assurance and workability, evacuation standard for work inside tunnels, liaison with prefectural and other related bureaus were considered and the measures were implemented.						

Reference documents / sources Electric Power Civil Engineering (2010.3)

016 Takino Power Plant Repair

Plant name	滝野 (Takino)						
Operation start	1910	**Completed**	2015		Age (105 years)		
Owner	Tohoku EPCo						
Country	Japan						
Max output kW	900	**After work**	-		New / no change		
Max generation discharge m^3/s	3.76						
Effective head m	28.18						
Decision-making type (○ **where it applies**)	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
		○					
Time of decision making	2012						
Target structure(s)	Water tank, water way						
・Driver	Disaster						
・Phenomena (caused by Driver)	Generation shutdown / efficiency decline						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Disaster (earthquake) restoration						
(1) Current status	**(Before decision making)**						
1) General status	In a disaster restoration work in the wake of the Great East Japan Earthquake in March 2011, the turbine generator units were renewed, water tank was modified, and penstock was replaced.						
2) Operation status	Generation shutdown / efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To renew T/G (from 2 units to 1), renew the tank, replace the penstock, electrify the control units, and omit the hydraulic units as part of the damage restoration for Great East Japan Earthquake after considering the river flow status changes with an upstream dam (increase in high-output operation time and annual generated energy) reduction of number of T/G units, environmental conservation, simplification of maintenance works, etc.						
(4) How decision-making was implemented and technologies adopted	The following issues and measures were considered / implemented: increase in high-output operation time and annual generated energy due to the river flow status changes caused by Surikami Dam of the Ministry of Land, Infrastructure, Transport and Tourism constructed upstream of the intake dam, reduction of number of turbine generator units, environmental conservation, simplification of maintenance works.						

Reference documents / sources Electric Power Civil Engineering (2015.7)

017 Penstock Management Bridge Restoration: Nagamatsu P/S

Plant name	永松 (Nagamatsu)						
Operation start	1946	**Completed**	2014		Age (68 years)		
Owner	Tohoku EPCo						
Country	Japan						
Max output kW	3,300	**After work**	-		New / no change		
Max generation discharge m^3/s	1.20						
Effective head m	349.05						
Decision-making type (○ where it applies)	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
			○				
Time of decision making	2011						
Target structure(s)	Penstock management bridge						
・Driver	Disaster						
・Phenomena (caused by Driver)	Generation shutdown / efficiency decline						
Risk	Reduction						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Disaster (flood / heavy rain) restoration						
(1) Current status	**(Before decision making)**						
1) General status	Restoration of the penstock management bridge damaged in Niigata / Fukushima Heavy Storm in July 2011.						
2) Operation status	Generation shutdown / efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To replace the penstock bridge damaged by Niigata / Fukushima Heavy Storm in 2011 after reviewing the design flood discharge and considering the penstock bridge structural type, etc.						
(4) How decision-making was implemented and technologies adopted	Design flood discharge was reviewed, and the structural type of penstock management bridge was considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2013.5)

018 Heavy Rain Disaster Restoration: Shimodai P/S

Plant name	下台 (Shimodai)						
Operation start	1922	**Completed**	2016		Age (94 years)		
Owner	Tohoku EPCo						
Country	Japan						
Max output kW	340	**After work**	-		New / no change		
Max generation discharge m^3/s	2.09						
Effective head m	26.97						
Decision-making type (○ where it applies)	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
			○				
Time of decision making	2013						
Target structure(s)	Intake dam, headrace, waterway bridge						
・Driver	Disaster						
・Phenomena (caused by Driver)	Generation shutdown / efficiency decline						
Risk	Reduction						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Disaster (flood / heavy rain) restoration						
(1) Current status	**(Before decision making)**						
1) General status	The intake dame was scoured, mud flowed into the headrace and the ground around the headrace collapsed and other damage to the facilities occurred due to local down pours on August 9, 2013. Thus the debris remover control panel was relocated, mud and trees were removed, and the headrace culvert was modified.						
2) Operation status	Generation shutdown / efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To relocate the debris remover control panel, remove the dirt and trees and to refurbish the headrace tunnel as the restoration for the facility damage caused by local downpours on August 9, 2013 after considering the damage to the penstock slope and headrace tunnel.						
(4) How decision-making was implemented and technologies adopted	Renovation of penstock slopes and modification of headrace culvert were considered and handled.						

Reference documents / sources Electric Power Civil Engineering (2017.11)

019 Heavy Rain Disaster Restoration: Sendatsu P/S

Plant name	先達 (Sendatsu)						
Operation start	1948	**Completed**	2014		Age (66 years)		
Owner	Tohoku EPCo						
Country	Japan						
Max output kW	5,300	**After work**	-		New / no change		
Max generation discharge m^3/s	4.20						
Effective head m	150.00						
Decision-making type	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○				
Time of decision making	2013						
Target structure(s)	Penstock slope, spillway channel						
・Driver	Disaster						
・Phenomena (caused by Driver)	Generation shutdown / efficiency decline						
Risk	Reduction						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Disaster (flood / heavy rain) restoration						
(1) Current status	**(Before decision making)**						
1) General status	After the serious damage by the “large-scale mud flow disaster” caused by the local downpours on August 9, 2013, the penstock slope surfaces were restored, and streaming water was handled.						
2) Operation status	Generation shutdown / efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To restore the penstock slope faces and handle the river streams as the restoration for the facility damage caused by local downpours on August 9, 2013 after considering the damage and refurbishment of detour water channel of river						
(4) How decision-making was implemented and technologies adopted	The damage to the penstock slope faces was restored and the diversion channel of stream water was repaired as its capacity was exceeded.						

Reference documents / sources Electric Power Civil Engineering (2017.11)

020 Kajigawa Dam Refurbishment (gateless modification)

Plant name	加治川 (Kajigawa)						
Operation start	1962	**Completed**	1995		Age (33 years)		
Owner	Tohoku EPCo						
Country	Japan						
Max output kW	17,000	**After work**	-		New / no change		
Max generation discharge m^3/s	10.00						
Effective head m	199.77						
Decision-making type	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○				
Time of decision making	1993						
Target structure(s)	Spillway (gateless modification)						
・Driver	Asset optimization & Review of operation						
・Phenomena (caused by Driver)	Generation efficiency improvement / higher management efficiency						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Management labor saving						
(1) Current status	**(Before decision making)**						
1) General status	Refurbishment of the dam for which adjustment operation needs were lessened in order to improve dam operation duties (gateless modification: dam height of 45 m). Dam refurbishment, installation of intake flushing channel, etc.						
2) Operation status	Generation efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To modify the dam to gateless type and install an intake flushing channel for improving the dam operating duties after considering the design flood discharge, dam stability calculation, building material transportation equipment, etc.						
(4) How decision-making was implemented and technologies adopted	Review of design flood discharge, dam stability calculation, building material transportation equipment, etc were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (1996.9)

021 Iidegawa No.1 Dam Refurbishment (gateless modification)

Plant name	飯豊川第一 (Iidegawa No.1)						
Operation start	1953	**Completed**	2001		Age (48 years)		
Owner	Tohoku EPCo						
Country	Japan						
Max output kW	5,600	**After work**	-		New / no change		
Max generation discharge m^3/s	10.00						
Effective head m	69.60						
Decision-making type	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○				
Time of decision making	1999						
Target structure(s)	Spillway (gateless modification)						
・Driver	Asset optimization & Review of operation						
・Phenomena (caused by Driver)	Generation efficiency improvement / higher management efficiency						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Management labor saving						
(1) Current status	**(Before decision making)**						
1) General status	Refurbishment of the dam to improve dam operation duties (gateless modification: dam height of 34.848 m). Dam refurbishment (widening concrete), river water diversion, etc.						
2) Operation status	Generation efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To modify the dam to gateless type to thicken the dam body and install diversion unit for improving the dam operating duties after considering the design flood discharge, dam stability calculation, building material transportation equipment,						
(4) How decision-making was implemented and technologies adopted	Review of design flood discharge, dam stability calculation, building material transportation equipment, etc were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2000.9)

022 Yunotani Dam Refurbishment (gateless modification)

Plant name	湯之谷 (Yunotani)						
Operation start	1924	**Completed**	2019		Age (95 years)		
Owner	Tohoku EPCo						
Country	Japan						
Max output kW	720	**After work**	-		New / no change		
Max generation discharge m^3/s	3.34						
Effective head m	26.59						
Decision-making type	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○				
Time of decision making	2016						
Target structure(s)	Spillway (gateless modification)						
・Driver	Asset optimization & Review of operation						
・Phenomena (caused by Driver)	Generation efficiency improvement / higher management efficiency						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Management labor saving						
(1) Current status	**(Before decision making)**						
1) General status	In consideration for reliability improvement, efficiency and safety assurance of the manually handled spillway gate operation (using electric hoist for wooden flashboard 13-gate unit), along with restoration of dam body damaged by floods in 2011, gateless modification was conducted instead of restoring the original design.						
2) Operation status	Generation efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To modify the dam to gateless type along with the dam body restoration (damaged in the flood of 2011) for improving the dam operation reliability after considering the design flood discharge, penstock bridge structural type, efficiency, safety						
(4) How decision-making was implemented and technologies adopted	The design flood discharge was reviewed, and the structural type of penstock management bridge was considered and implemented						

Reference documents / sources Electric Power Civil Engineering (2013.5)

023 Intake Debris Remover Installation

Plant name	実川 (Sanegawa)						
Operation start	1993	**Completed**	2004		Age (11 years)		
Owner	Tohoku EPCo						
Country	Japan						
Max output kW	8,200	**After work**	-		New / no change		
Max generation discharge m^3/s	6.00						
Effective head m	165.90						
Decision-making type	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○				
Time of decision making	2004						
Target structure(s)	Debris remover						
・Driver	Asset optimization & Review of operation						
・Phenomena (caused by Driver)	Generation efficiency improvement / higher management efficiency						
Risk	Reduction						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Management labor saving						
(1) Current status **1) General status** **2) Operation status** **3) Risk**	**(Before decision making)** While the debris removal work of intake screen handled manually was interrupted during winter for ensuring workers' safety, large amounts debris in the snowmelted water caused a large generation loss, not being able to take in the water from the intake, and thus a new debris remover was installed at the intake. Generation efficiency decline **Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To install a new debris remover in the intake for securing safety of the debris removal and avoiding the incapacitated intake during winters (loss of generation opportunities) after considering the interruptions of patrol due to snowfalls in winter, reduction of troubles such as overload, remote control and structures / materials durable for continuous operation, etc.						
(4) How decision-making was implemented and technologies adopted	The following issues and measures were considered / implemented: interruptions of patrol due to snowfalls in winter, reduction of troubles such as overload, structure, material durable for continuous operation, etc.						

Reference documents / sources Electric Power Civil Engineering (2006.1)

024 Konoyama Dam Impermeable Wall Renewal

Plant name	中津川第一 (Nakatsugawa No.1)						
Operation start	1924	**Completed**	2004		Age (80 years)		
Owner	Tokyo EPCo						
Country	Japan						
Max output kW	126,000	**After work**	-		New / no change		
Max generation discharge m^3/s	36.44						
Effective head m	414.88						
Decision-making type (○ where it applies)	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
	○						
Time of decision making	2001						
Target structure(s)	Dam						
・Driver	Aging						
・Phenomena (caused by Driver)	Aging / efficiency decline						
Risk	Reduction						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Dam reservoir repair						
(1) Current status	**(Before decision making)**						
1) General status	Aged about 30 years, the asphalt impermeable wall in the rock-fill dam was being degraded and damaged. The conventional road pavement method was fundamentally reviewed for the refurbishment of the impermeable wall, and thus a new method of combining cutting and pavement was devised and implemented.						
2) Operation status	Generation efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To consider and implement the soundness diagnosis method for asphalt impermeable wall, designing of asphalt mixture repair, refurbishment control and maintenance management methods.						
(4) How decision-making was implemented and technologies adopted	The following issues and measures were considered / implemented: soundness diagnosis method for asphalt impermeable wall using electromagnetic waves, designing of asphalt mixture able to follow up the integration and deformation behaviour of repair materials and existing materials, refurbishment control and maintenance management methods using laser survey techniques, etc.						

Reference documents / sources Electric Power Civil Engineering (2002.11/2006.3)

025 Odagiri Dam Apron Refurbishment

Plant name		小田切 (Odagiri)						
Operation start		1954	**Completed**	2006		Age (52 years)		
Owner		Tokyo EPCo						
Country		Japan						
Max output	kW	16,900	**After work**	-		New / no change		
Max generation discharge	m^3/s	140.00						
Effective head	m	14.44						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)		○						
Time of decision making		2006						
Target structure(s)		Dam						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Reduction						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Dam reservoir repair						
(1) Current status		**(Before decision making)**						
1) General status		The refurbishment of scouring at the apron of 50-year-old Odagiri Dam had been repeated. The conventional concrete repair method was reviewed, and an initiative was taken to use self-filling, high-strength, -durability concrete mixed with polypropylene fibers.						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To repair the scouring at the apron using self-filling, high-strength, durable concrete mixed with polypropylene fiber. To consider the quality control method for this new material.						
(4) How decision-making was implemented and technologies adopted		Quality control method for new material (fiber-mixed self-filling concrete) was considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2008.11)

026 Agatsuma River Intake Dam Flushing Channel Renewal

Plant name		箱島 (Hakojima)						
Operation start		1951	**Completed**	2003		Age (52 years)		
Owner		Tokyo EPCo						
Country		Japan						
Max output	kW	24,000	**After work**	-		New / no change		
Max generation discharge	m^3/s	34.00						
Effective head	m	81.60						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)		○						
Time of decision making		2002						
Target structure(s)		Dam (flushing channel)						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Reduction						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Dam reservoir repair						
(1) Current status		**(Before decision making)**						
1) General status		Aged about 50 years, the intake dam was suffering wear / scouring and degradation by neutralization caused by acid water. The conventional concrete repair method was reviewed, and old tires were used as a countermeasure against the wear and scouring by mud and stones flowing down during floods.						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To consider and implement a countermeasure against the wear and scouring of the intake dam using old tires (on how to install them effectively)						
(4) How decision-making was implemented and technologies adopted		Effective installation method was considered and implanted, which realized cost reduction by about 30%.						

Reference documents / sources Electric Power Civil Engineering (2005.1)

027 Nishikinugawa Power Plant Renewal

Plant name		西鬼怒川 (Nishikinugawa)						
Operation start		1928	**Completed**	1999		Age (71 years)		
Owner		Tokyo EPCo						
Country		Japan						
Max output	kW	1,000	**After work**	1,200		Up rate↑ (20.0%)		
Max generation discharge	m^3/s	12.22						
Effective head	m	11.21						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		1997						
Target structure(s)		T/G, etc						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		T/G renewal						
(1) Current status		**(Before decision making)**						
1) General status		Aged about 70 years, all facilities were aging and deteriorating. The turbine generator was reviewed, and anti-seismic design was implemented in the powerhouse building.						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To renew the T/G and conduct anti-seismic modification of the powerhouse building as a measure against the aging and degradation after considering the shape of water tank vertical shaft, turbine water control method, recycling of debris remover and other existing facilities, minimization of river modification scope, minimization of plant foundation excavation scope, etc.						
(4) How decision-making was implemented and technologies adopted		The following issues and measures were considered / implemented for optimization and cost reduction: shape of water tank vertical shaft (prevention of efficiency decline and cavitation), turbine water control method, recycling of debris remover and other existing facilities, minimization of river modification scope, minimization of plant foundation excavation scope, etc.						

Reference documents / sources Electric Power Civil Engineering (1999.5)

028 Kumagawa No.1 Power Plant Renewal

Plant name	熊川第一 (Kumagawa No.1)						
Operation start	1922	**Completed**	2015	Age (93 years)			
Owner	Tokyo EPCo						
Country	Japan						
Max output kW	2,400	**After work**	2,600	Up rate↑ (8.3%)			
Max generation discharge m^3/s	2.23						
Effective head m	140.33						
Decision-making type (○ **where it applies**)	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
		○					
Time of decision making	2014						
Target structure(s)	T/G, etc						
・Driver	Aging						
・Phenomena (caused by Driver)	Aging / efficiency decline						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	T/G renewal						
(1) Current status **1) General status** **2) Operation status** **3) Risk**	**(Before decision making)** Aged about 90 years, the main facilities were aging. The turbine generator was reviewed, and anti-seismic design was implemented in the powerhouse building. Generation efficiency decline **Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To renew T/G and conduct anti-seismic modification of the powerhouse building as a measure against the aging of main facilities after considering the omission of auxiliary equipment, shorter work period / longer cycles of turbine refurbishment, introduction of ICT-applied facility status monitoring system, adoption of integrated distribution panel, refurbishment focused on lifecycle cost, etc.						
(4) How decision-making was implemented and technologies adopted	The following issues and measures were considered / implemented: omission of auxiliary equipment, shorter work period / longer cycles of turbine refurbishment, introduction of ICT-applied facility status monitoring system, adoption of integrated distribution panel, refurbishment focused on lifecycle cost, etc.						

Reference documents / sources IEA Annex-11 Jp.05

029 Minochi Dam Spillway Gate Replacement

Plant name		水内 (Minochi)						
Operation start		1943	**Completed**	2003		Age (60 years)		
Owner		Tokyo EPCo						
Country		Japan						
Max output	kW	31,000	**After work**	-		New / no change		
Max generation discharge	m^3/s	138.00						
Effective head	m	27.00						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		1994						
Target structure(s)		Spillway gate						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Gate repair						
(1) Current status		**(Before decision making)**						
1) General status		Aging of corrosion and wear was progressing in the gate doors and winches aged about 50 years. All 14 gate doors were renewed in a 10-year plan starting in 1993 during the non-flood seasons due to the dam operation requirements.						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To conduct refurbishment of 14 radial type gates against the corrosion and wear in the gate doors and winches after considering the reduction of the number of existing gate doors by half and changing to roller type for the simplification of operation and maintenance, economic assessment, soundness of existing pier concrete, etc.						
(4) How decision-making was implemented and technologies adopted		The following issues and measures were considered / implemented: reduction of the number of existing gate doors (14) by half and changing to roller type for the simplification of operation and maintenance, economic assessment for temporary coffering and pier modification cost, soundness of existing pier concrete, etc. Refurbishment was carried out keeping the existing design of 14, radial type gates.						

Reference documents / sources Electric Power Civil Engineering (1997.1)

030 T/G Replacement and Penstock Partial Replacement

Plant name		駒橋 (Komahashi)						
Operation start		1907	**Completed**	2010		Age (103 years)		
Owner		Tokyo EPCo						
Country		Japan						
Max output	kW	21,200	**After work**	22,200		Up rate↑ (4.7%)		
Max generation discharge	m^3/s	25.04						
Effective head	m	103.05						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		2010						
Target structure(s)		Penstock, T/G, etc						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Water way, etc. repair						
(1) Current status		**(Before decision making)**						
1) General status		Due to severe aging for about 100 years, turbine generator units 1 and 2 were integrated, the foundation was refurbished, and penstock was replaced.						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To integrate T/G Units 1 and 2 (including the refurbishment of the foundation and replacement of steel pipes) for reducing the maintenance cost after considering the work while the nearby Unit 3 continued operating.						
(4) How decision-making was implemented and technologies adopted		The work was done while the nearby Unit 3 continued operating (while the vibration was monitored, and static crushing agent was used).						

Reference documents / sources Electric Power Civil Engineering (2011.9)

031 Taishoike Intake Weir Refurbishment

Plant name	霞沢 (Kasumizawa)						
Operation start	1928	**Completed**	2003		Age (75 years)		
Owner	Tokyo EPCo						
Country	Japan						
Max output kW	39,000	**After work**	-		New / no change		
Max generation discharge m^3/s	10.57						
Effective head m	453.65						
Decision-making type (○ **where it applies**)	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
			○				
Time of decision making	2002						
Target structure(s)	Dam						
・Driver	Aging						
・Phenomena (caused by Driver)	Aging / efficiency decline						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Dam reservoir repair						
(1) Current status	**(Before decision making)**						
1) General status	Aged about 50 years, the intake weir was within the special protection area of a national park and had been repeatedly maintained against the mud flow by volcanic eruptions of Mt. Yakedake, and a new refurbishment was carried out in connection with the renewal of water right. The existing bank weir which collapsed twice/year due to floods was renewed with rubber-coated cloth inflatable weir. A maintenance discharge facility (fish channel) was newly installed. The maintenance cost was reduced by about 10 million JPY annually.						
2) Operation status	Generation efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To refurbish the weir (from existing bank weir to rubber-coated cloth inflatable weir) and to install a maintenance discharge facility (fishway) for reducing the maintenance cost after considering the appearances in harmony with the landscape as a tourist destination and prevention of freezing in access tunnel for work during winter.						
(4) How decision-making was implemented and technologies adopted	Refurbishment in consideration for the tourist destination, designing appearances in harmony with the landscape and prevention of freezing in access tunnel for work during winter were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2004.5)

032 Penstock Reinforcement: Saiko P/S

Plant name		西湖 (Saiko)						
Operation start		1919	**Completed**	2007		Age (88 years)		
Owner		Tokyo EPCo						
Country		Japan						
Max output	kW	2,000	**After work**	-		New / no change		
Max generation discharge	m^3/s	4.32						
Effective head	m	63.64						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)				○				
Time of decision making		2007						
Target structure(s)		Penstock						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Reduction						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Water way, etc. repair						
(1) Current status		**(Before decision making)**						
1) General status		About 80-year-old penstock needed to be reinforced for the strain excess against the pipe thinning, and thus carbon fiber was used instead of conventional steel pipe replacement or steel ring reinforcement. The cost was reduced by 35% compared to steel ring reinforcement.						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To conduct reinforcement with carbon fiber as a countermeasure against excessive stress causing thinning of the penstock pipes after considering a new material (carbon fiber), establishment of refurbishment method, temperature changes, measures against electric corrosion, etc.						
(4) How decision-making was implemented and technologies adopted		Design of new material (carbon fiber), establishment of refurbishment method, temperature changes, measures against electric corrosion were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2010.1)

033

033 Uenogawa Intake Weir Restoration

Plant name	須川 (Sukawa)						
Operation start	1912	**Completed**	2013		Age (101 years)		
Owner	Tokyo EPCo						
Country	Japan						
Max output kW	6,000	**After work**	-		New / no change		
Max generation discharge m^3/s	7.79						
Effective head m	92.60						
Decision-making type	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○				
Time of decision making	2010						
Target structure(s)	Dam						
・Driver	Disaster						
・Phenomena (caused by Driver)	Generation shutdown / efficiency decline						
Risk	Reduction						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Disaster (flood / heavy rain) restoration						
(1) Current status	**(Before decision making)**						
1) General status	The protection bed downstream the intake weir was washed away, and intake weir foundation and left bank were scoured by disaster from Typhoon No.9 in 2010, so a new intake weir was installed downstream the existing intake weir.						
2) Operation status	Generation shutdown / efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To install a new intake weir downstream the existing one as a restoration measure against the disaster from Typhoon No.9 in 2010 after considering the repeatedly occurring floods and work interruptions by snowfalls.						
(4) How decision-making was implemented and technologies adopted	Repeatedly occurring floods and work interruptions by snowfalls were considered and handled.						

Reference documents / sources Electric Power Civil Engineering (2014.3)

034 New Spillway Channel Installation: Taira P/S

Plant name		〒 (Taira)						
Operation start		1957	**Completed**	2003		Age (46 years)		
Owner		Tokyo EPCo						
Country		Japan						
Max output	kW	15,600	**After work**	-		New / no change		
Max generation discharge	m^3/s	130.00						
Effective head	m	14.14						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)				○				
Time of decision making		2002						
Target structure(s)		Spillway channel						
・Driver		Disaster						
・Phenomena (caused by Driver)		Generation shutdown / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Public disaster risk reduction						
(1) Current status		**(Before decision making)**						
1) General status		Without spillway discharge facility, the spillage in cases of emergency plant shutdown used to be discharged directly from the spillway to the river, but a new spillway channel was installed by diverting part of the existing intake and utilizing a new energy dissipating mechanism through combination of vertical energy dissipator and an upper space of the existing draft, for ensuring safety of the increasing number of people visiting the river in recent years.						
2) Operation status		Generation shutdown / efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To newly install a spillway channel by diverting part of the existing intake and utilizing a new energy dissipating mechanism through combination of vertical energy dissipator and an upper space of the existing draft, for ensuring safety of the increasing number of people visiting the river in recent years after considering a method of dissipating the water energy in a limited space.						
(4) How decision-making was implemented and technologies adopted		A method for dissipating the water energy of high flowrate (104 m3/s) in narrow spaces was considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2004.5)

035 New Spillway Channel Installation: Inawashiro No.3 P/S

Plant name		猪苗代第三 (Inawashiro No.3)						
Operation start		1926	**Completed**	2005		Age (79 years)		
Owner		Tokyo EPCo						
Country		Japan						
Max output	kW	23,200	**After work**	-		New / no change		
Max generation discharge	m^3/s	65.69						
Effective head	m	40.62						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)				○				
Time of decision making		2005						
Target structure(s)		Spillway channel						
・Driver		Disaster						
・Phenomena (caused by Driver)		Generation shutdown / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Public disaster risk reduction						
(1) Current status		**(Before decision making)**						
1) General status		Spillage in cases of emergency plant shutdown used to be discharged directly from the spillway outlet to the river, but it was refurbished with an energy dissipation method of connecting the spillway channel directly to the tailrace and discharging water mid-air into the tailbay due to the possible damage to third parties.						
2) Operation status		Generation shutdown / efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To refurbish the spillway channel (by connecting it directly to the tailrace and discharging water mid-air into the tailbay) due to the possible damage to third parties after considering the direction change of high-speed flowing water (90°) and design of optimal shape of water discharge section for energy dissipation.						
(4) How decision-making was implemented and technologies adopted		Direction change of high-speed flowing water (90°) and design of optimal shape of water discharge section for energy dissipation were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2006.5)

036 Water Tank Spillway Channel Refurbishment: Yamakita P/S

Plant name		山北 (Yamakita)						
Operation start		1914	**Completed**	2009		Age (95 years)		
Owner		Tokyo EPCo						
Country		Japan						
Max output	kW	7,000	**After work**	-		New / no change		
Max generation discharge	m^3/s	20.90						
Effective head	m	39.87						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)				○				
Time of decision making		2008						
Target structure(s)		Spillway channel						
・Driver		Disaster						
・Phenomena (caused by Driver)		Generation shutdown / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Public disaster risk reduction						
(1) Current status		**(Before decision making)**						
1) General status		Spillage in cases of emergency plant shutdown used to be discharged directly from the spillway outlet to the river, but it was refurbished with an energy dissipation method of connecting the spillway channel directly to the tailrace and dissipating energy by 2-step impacting type mechanism, to avoid damaging people visiting the river.						
2) Operation status		Generation shutdown / efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To refurbish the spillway channel (by connecting it directly to the tailrace and dissipating energy by 2-step impacting type mechanism) in order to avoid damaging people visiting the river, after ensuring the overflow part extension in steep, narrow locations.						
(4) How decision-making was implemented and technologies adopted		Design of structure which ensures the overflow part extension in steep, narrow locations was considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2010.9)

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037 Water Tank Spillway Channel Refurbishment: Ikido P/S

Plant name		生土 (Ikido)						
Operation start		1930	**Completed**	2011		Age (81 years)		
Owner		Tokyo EPCo						
Country		Japan						
Max output	kW	6,200	**After work**	-		New / no change		
Max generation discharge	m^3/s	20.04						
Effective head	m	36.70						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)				○				
Time of decision making		2010						
Target structure(s)		Spillway channel						
・Driver		Disaster						
・Phenomena (caused by Driver)		Generation shutdown / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Public disaster risk reduction						
(1) Current status		**(Before decision making)**						
1) General status		Spillage in cases of emergency plant shutdown used to be discharged directly from the spillway outlet to the river, but it was refurbished with an energy dissipation method of connecting the spillway channel directly to the tailrace and impact type energy dissipator with discharge outlet due to the possible damage to the large number of river visitors.						
2) Operation status		Generation shutdown / efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To refurbish the spillway channel (by connecting it directly to the tailrace and dissipating energy and using impact type energy dissipator along with the discharge outlet) in order to avoid damaging people visiting the river, after considering the work in narrow spaces, impact on the existing facilities, securement of spaces necessary for maintenance, shorter operation shutdown period, etc.						
(4) How decision-making was implemented and technologies adopted		Work in narrow spaces was considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2012.1)

038 Spillway Channel Refurbishment: Kaise P/S

Plant name	海瀬 (Kaise)						
Operation start	1925	**Completed**	2013	Age (88 years)			
Owner	Tokyo EPCo						
Country	Japan						
Max output kW	4,400	**After work**	-	New / no change			
Max generation discharge m^3/s	13.91						
Effective head m	37.54						
Decision-making type (○ **where it applies**)	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
			○				
Time of decision making	2012						
Target structure(s)	Spillway channel						
・Driver	Disaster						
・Phenomena (caused by Driver)	Generation shutdown / efficiency decline						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Public disaster risk reduction						
(1) Current status **1) General status**	**(Before decision making)** Spillage in cases of emergency plant shutdown used to be discharged directly from the spillway outlet to the river, but it was modified into vertical type spillway channel directly connected to the tailrace which does not discharge directly to the river due to the possible damage to the large number of river visitors.						
2) Operation status	Generation shutdown / efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To refurbish the spillway channel (modified into vertical type spillway channel directly connected to the tailrace which does not discharge directly to the river) in order to avoid damaging people visiting the river, after considering the impact on						
(4) How decision-making was implemented and technologies adopted	the tailrace channel and vertical excavation in narrow spaces. Impact on tailrace channel (internal pressure, scouring) and vertical excavation in narrow spaces were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2013.9)

039 New Spillway Channel Installation: Sasadaira

Plant name		笹平 (Sasadaira)						
Operation start		1954	**Completed**	2012		Age (58 years)		
Owner		Tokyo EPCo						
Country		Japan						
Max output	kW	14,700	**After work**	-		New / no change		
Max generation discharge	m^3/s	140.00						
Effective head	m	12.38						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)				○				
Time of decision making		2009						
Target structure(s)		Spillway channel						
・Driver		Disaster						
・Phenomena (caused by Driver)		Generation shutdown / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Public disaster risk reduction						
(1) Current status		**(Before decision making)**						
1) General status		Spillage in cases of emergency plant shutdown used to be discharged directly from the spillway outlet to the river, but it was modified into vertical type spillway channel directly connected to the tailrace which does not discharge directly to the river due to the possible damage to the large number of river visitors.						
2) Operation status		Generation shutdown / efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To newly install a spillway channel directly connected to the tailrace (a vertical type which does not discharge directly to the river) in order to avoid damaging people visiting the river, after considering the suppression of vortexes caused by the air coming in the vertical shaft, vertical excavation in narrow spaces, work in the vicinity of residential buildings, workability, cost reduction, shorter work period etc.						
(4) How decision-making was implemented and technologies adopted		Suppression of vortexes caused the air coming in the vertical shaft, vertical excavation in narrow spaces, work in the vicinity of residential buildings, etc. were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2012.11)

040 Senzu Dam Flushing Channel Refurbishment

Plant name	湯山 (Yuyama)						
Operation start	1935	**Completed**	2016		Age (81 years)		
Owner	Chubu EPCo						
Country	Japan						
Max output kW	22,200	**After work**	-		New / no change		
Max generation discharge m^3/s	18.92						
Effective head m	143.60						
Decision-making type	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)	○						
Time of decision making	2014						
Target structure(s)	Dam (flushing channel)						
・Driver	Aging						
・Phenomena (caused by Driver)	Aging / efficiency decline						
Risk	Reduction						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Dam reservoir repair						
(1) Current status	**(Before decision making)**						
1) General status	An intake dam aged about 70 years. Sedimentation progressed due to large sad and mud carried from upstream the dam. The anti-wear performance of the flushing channel bed was improved by using anti-wear case steel plant against the flowing sand during dam discharges.						
2) Operation status	Generation efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To consider and implement a method of combined use of anti-wear cast steel plate and normal steel plate in view of total LCC.						
(4) How decision-making was implemented and technologies adopted	A method of combined use of anti-wear cast steel plate and normal steel plate was considered in view of total economic efficiency with reduced number of repair works and implemented accordingly.						

Reference documents / sources Electric Power Civil Engineering (2016.7)

041 Neo Power Plant Renewal: Neo

Plant name		根尾 (Neo)						
Operation start		1923	**Completed**	2017		Age (94 years)		
Owner		Chubu EPCo						
Country		Japan						
Max output	kW	4,700	**After work**	5,100		Up rate↑ (8.5%)		
Max generation discharge	m^3/s	7.12						
Effective head	m	81.56						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		2016						
Target structure(s)		T/G, etc						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		T/G renewal						
(1) Current status		**(Before decision making)**						
1) General status		Aged about 90 years, the turbine generator aging was progressing. The turbine generator was renewed, 2 units were integrated into one, and related civil engineering work was conducted.						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To renew T/G (integrating 2 units into 1) after considering facility optimization design, measures against noise and vibration during the work, impact on the river, excavation slope curing, etc.						
(4) How decision-making was implemented and technologies adopted		The following issues and measures were considered / implemented: facility simplification by optimized design (modification to single turbine unit), measures against noise and vibration during the work, impact on the river, excavation slope curing for work on steep slope prone to ground collapse, etc.						

Reference documents / sources Electric Power Civil Engineering (2018.3)

042 Minakata Power Plant Facilities Renewal

Plant name	南向 (Minakata)						
Operation start	1929	**Completed**	2000	Age (71 years)			
Owner	Chubu EPCo						
Country	Japan						
Max output kW	24,100	**After work**	26,000	Up rate↑ (7.9%)			
Max generation discharge m^3/s	37.70						
Effective head m	79.35						
Decision-making type	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)		○					
Time of decision making	1998						
Target structure(s)	All facilities						
・Driver	Aging						
・Phenomena (caused by Driver)	Aging / efficiency decline						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	T/G renewal						
(1) Current status **1) General status** **2) Operation status** **3) Risk**	**(Before decision making)** Aged about 70 years, the overall facility was aging and deteriorating. In connection with the replacement of the turbine generator, dam body, water ways and plant building were refurbished. Generation efficiency decline **Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To replace T/G and refurbish the dam body, water ways and plant building against the overall facility aging and deterioration, in order to improve the service life, safety, reliability and maintainability while considering the surrounding environment (low-frequency vibration).						
(4) How decision-making was implemented and technologies adopted	Life extension measures were taken by metal spraying (for durability) and plastic spraying (for wear resistance) onto the rolling gate in the dam construction. Channel Invert Chopping (CIC) robot method was used for the headrace repair.						

Reference documents / sources Electric Power Civil Engineering (200.7)

043 Saigawa Weir Refurbishment

Plant name	犀川 (Saigawa)						
Operation start	1923	**Completed**	2003		Age (80 years)		
Owner	Chubu EPCo						
Country	Japan						
Max output kW	1,700	**After work**	-		New / no change		
Max generation discharge m^3/s	10.71						
Effective head m	19.06						
Decision-making type	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○				
Time of decision making	2002						
Target structure(s)	Dam (SR weir modification)						
・Driver	Aging						
・Phenomena (caused by Driver)	Aging / efficiency decline						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Dam reservoir repair						
(1) Current status **1) General status** **2) Operation status** **3) Risk**	**(Before decision making)** Aged about 80 years, against the degradation of the intake weir, a new, large weir (SR weir) was introduced. The fixing rubber section was improved to be introduced in this domestic project. Generation efficiency decline **Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To conduct large-scale refurbishment of a new weir (SR weir) against the against the degradation of the flushing gate and shortage in discharge capacity, after considering the type comparison (rubber or SR weir), improvement of weir gradient in totally deflated state (for preventing sedimentation downstream and facilitating flushing performance) prevention of foreign objects from being caught						
(4) How decision-making was implemented and technologies adopted	The following issues and measures were considered / implemented: adoption of SR weir in comparison to rubber weir, improvement of weir gradient for preventing sedimentation in weir downstream and facilitating flushing performance when totally deflated state, clamp shape improvement and installation of fixing rubber cover for preventing from the fixing rubber section, key part for fixing the doors, from catching foreign objects, etc.						

Reference documents / sources IEA Annex-11 Jp.29

044 Nnishido Weir Refurbishment (SR weir)

Plant name	西渡 (Nishido)						
Operation start	1927	**Completed**	2009	Age (82 years)			
Owner	Chubu EPCo						
Country	Japan						
Max output kW	4,600	**After work**	2,300	Down rate↓ (50.0%)			
Max generation discharge m^3/s	6.51						
Effective head m	89.30						
Decision-making type	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○				
Time of decision making	2007						
Target structure(s)	Dam (SR weir modification)						
・Driver	Aging						
・Phenomena (caused by Driver)	Aging / efficiency decline						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Dam reservoir repair						
(1) Current status	**(Before decision making)**						
1) General status	An aged facility of about 80 years was refurbished against the aging, river flow status change caused by a hydropower plant developed upstream and the renewal of water right. SR synthetic inflatable weir (36.4 m in length, 2.7 m in height) was introduced.						
2) Operation status	Generation efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To conduct refurbishment (SR synthetic inflatable weir) in connection with the water right renewal after considering the power generation scale in response to the change in river flow status, adoption of SR inflatable weir in connection with planned flowrate and aging, etc.						
(4) How decision-making was implemented and technologies adopted	Review of power generation scale in response to the change in river flow status and adoption of SR inflatable weir in connection with planned flowrate and aging degradation were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2007.11)

045 Sekinosawa Waterway Bridge Base Isolation Bearing Modification

Plant name	奥泉 (Okuizumi)						
Operation start	1956	**Completed**	2008		Age (52 years)		
Owner	Chubu EPCo						
Country	Japan						
Max output kW	92,000	**After work**	-		New / no change		
Max generation discharge m^3/s	60.00						
Effective head m	168.70						
Decision-making type (○ where it applies)	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
			○				
Time of decision making	2007						
Target structure(s)	Water pipe bridge						
・Driver	Disaster						
・Phenomena (caused by Driver)	Generation shutdown / efficiency decline						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Earthquake disaster risk reduction						
(1) Current status	**(Before decision making)**						
1) General status	For a water pipe bridge (Lohse type for water pipe of 4.4 m in diameter and 60 m in length), its safety against large-scale earthquakes was brought into question, and thus 3-D dynamic analysis was performed. From the standpoint of seismic safety margin, steel locker bearing was replaced by anti-seismic rubber bearing at 26 locations.						
2) Operation status	Generation shutdown / efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To replace the 26 bearings of the water pipe bridge in order to reduce earthquake disaster risks after considering 3-D dynamic analysis and adoption of LRB (Lead Rubber Bearing in laminated layers with lead plugs), etc.						
(4) How decision-making was implemented and technologies adopted	The following issues and measures were considered / implemented: 3-D dynamic analysis using seismic waveforms publicized by Central Disaster Management Council of Cabinet Office, adoption of LRB (Lead Rubber Bearing in laminated layers with lead plugs) as base isolation bearing having high vibration attenuation effect and recovery function, etc.						

Reference documents / sources Electric Power Civil Engineering (2008.11)

046 asamagawa Dam Anti-Seismic Upgrading

Plant name		JII口 (Kawaguchi)					
Operation start		1958	**Completed**	2010		Age (52 years)	
Owner		Chubu EPCo					
Country		Japan					
Max output	kW	58,000	**After work**	-		New / no change	
Max generation discharge	m^3/s	90.00					
Effective head	m	75.30					
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)				○				
Time of decision making		2010						
Target structure(s)		Dam						
・Driver		Disaster						
・Phenomena (caused by Driver)		Generation shutdown / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Earthquake disaster risk reduction						
(1) Current status		**(Before decision making)**						
1) General status		High performance damper unit was installed in the existing gate operation bridge installed between gate piers for improving seismic safety margin against largescale earthquakes.						
2) Operation status		Generation shutdown / efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To install high-performance dampers in the existing gate operation bridge between the gate piers for improving the seismic safety margin while utilizing the existing management bridge.						
(4) How decision-making was implemented and technologies adopted		Development of method for improving seismic safety margin of dam piers of existing operation bridge (wherein high-performance damper used in this method is capable of reducing the vibration of water gate pillars within the region of high primary rigidity during earthquakes and absorbing temperature-induced extraction / contraction of Extensional steel girders with low resistance in normal times) was considered and implemented.						

Reference documents / sources IEA Annex-11 Jp.18

047 Dam Gate Pier Seismic Safety Margin Upgrading: Ikawa P/S

Plant name		井川 (Ikawa)						
Operation start		1952	**Completed**	2010		Age (58 years)		
Owner		Chubu EPCo						
Country		Japan						
Max output	kW	62,000	**After work**	-		New / no change		
Max generation discharge	m^3/s	80.00						
Effective head	m	92.70						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)				○				
Time of decision making		2009						
Target structure(s)		Spillway						
・Driver		Disaster						
・Phenomena (caused by Driver)		Generation shutdown / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Earthquake disaster risk reduction						
(1) Current status		**(Before decision making)**						
1) General status		High performance damper unit was installed in the existing gate operation bridge installed between gate piers for improving seismic safety margin against largescale earthquakes.						
2) Operation status		Generation shutdown / efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To install high-performance dampers in the existing gate operation bridge between the gate piers for improving the seismic safety margin while utilizing the existing management bridge.						
(4) How decision-making was implemented and technologies adopted		Development of method for improving seismic safety margin of dam piers of existing operation bridge (wherein high-performance damper used in this method is capable of reducing the vibration of water gate pillars within the region of high primary rigidity during earthquakes and absorbing temperature-induced extraction / contraction of Extensional steel girders with low resistance in normal times) was considered and implemented.						

Reference documents / sources Electric Power Civil Engineering （2011.3/2011.9)

048 Dam Gate Pier Seismic Safety Margin Upgrading: Ooigawa P/S

Plant name		大井川 (Ooigawa)						
Operation start		1936	**Completed**	2011		Age (75 years)		
Owner		Chubu EPCo						
Country		Japan						
Max output	kW	68,200	**After work**	-		New / no change		
Max generation discharge	m^3/s	72.35						
Effective head	m	112.70						
Decision-making type (○ where it applies)		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
				○				
Time of decision making		2010						
Target structure(s)		Spillway						
・Driver		Disaster						
・Phenomena (caused by Driver)		Generation shutdown / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Earthquake disaster risk reduction						
(1) Current status		**(Before decision making)**						
1) General status		High performance damper unit was installed in the existing gate operation bridge installed between gate piers for improving seismic safety margin against largescale earthquakes.						
2) Operation status		Generation shutdown / efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To install high-performance dampers in the existing gate operation bridge between the gate piers for improving the seismic safety margin while utilizing the existing management bridge.						
(4) How decision-making was implemented and technologies adopted		Development of method for improving seismic safety margin of dam piers of existing operation bridge (wherein high-performance damper used in this method is capable of reducing the vibration of water gate pillars within the region of high primary rigidity during earthquakes and absorbing temperature-induced extraction / contraction of Extensional steel girders with low resistance in normal times) was considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2011.3/2011.9)

049 Water Way Refurbishment: Shima P/S

Plant name		島 (Shima)						
Operation start		1927	**Completed**	2002		Age (75 years)		
Owner		Chubu EPCo						
Country		Japan						
Max output	kW	1,600	**After work**	-		New / no change		
Max generation discharge	m^3/s	4.17						
Effective head	m	49.17						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)				○				
Time of decision making		2001						
Target structure(s)		Intake, headrace						
・Driver		Disaster						
・Phenomena (caused by Driver)		Generation shutdown / efficiency decline						
Risk		Reduction						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Disaster (flood / heavy rain) restoration						

(1) Current status	**(Before decision making)**
1) General status	In a disaster restoration project for Tokai Heavy Rain Disaster in September 2000, the existing intake weir was removed, and an outlet of the upstream power plant was connected to the intake of Shima Power Plant with a connecting channel across the river. An intake and channel (siphon section: 64 m, culvert: 206 m, convergence tank) were installed and the existing weir was removed.
2) Operation status	Generation shutdown / efficiency decline
3) Risk	**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction
(2) Priorities	RE utilization / securing profit
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To remove the existing intake, connect an outlet of the upstream power plant with the intake of Shima Power Plant with a connecting channel (intake, siphon section, culvert, convergence tank) and to remove the existing Shima Dam in a disaster restoration project for Tokai Heavy Rain Disaster in September 2000, after considering the fluid analysis of siphon water channels.
(4) How decision-making was implemented and technologies adopted	Flow analysis of siphon water way was carried out for implementation.

Reference documents / sources Electric Power Civil Engineering (2002.9)

050 Tenjin Weir Refurbishment (SR weir)

Plant name		天神 (Tenjin)						
Operation start		1924	**Completed**	2008		Age (84 years)		
Owner		Chubu EPCo						
Country		Japan						
Max output	kW	600	**After work**	-		New / no change		
Max generation discharge	m^3/s	8.35						
Effective head	m	9.09						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)				○				
Time of decision making		2006						
Target structure(s)		Dam (fishway)						
・Driver		Disaster						
・Phenomena (caused by Driver)		Generation shutdown / efficiency decline						
Risk		Reduction						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Disaster (flood / heavy rain) restoration						

(1) Current status

(Before decision making)

1) General status

Typhoon No.23 in October 2004 caused inundation damage in the basin Miyagawa River. Gifu Prefecture offered “Subsidy for Flood Disaster Restoration in Miyagawa River System,” which was utilized to modify Tenjin Dam into movable weir capable of handling the river level rise in floods. SR synthetic inflatable weir (crest length: 52 m (26 m × 2 spans), height: 2.45 m) was newly installed and the existing weir was removed.

2) Operation status

Generation shutdown / efficiency decline

3) Risk

Potential risk in case of no decision making

Generation shutdown / efficiency decline

Potential risk when implementing decision making

Cost increase / profit reduction

(2) Priorities

RE utilization / securing profit

(3) Strategy

Against potential risk in case of no decision making

(None)

Against potential risk when implementing decision making

To renew the weir to be movable (removing the existing weir and installing SR synthetic inflatable weir as a measure against higher water levels in flood cases) considering the hydrological analysis, as a restoration project for the inundation damage by Typhoon No.23 in October 2004 along with “Subsidy for Flood Disaster Restoration in Miyagawa River System” by Gifu Prefecture.

(4) How decision-making was implemented and technologies adopted

Hydrologic analysis was performed to check the possible drift current caused by a central pillar to be installed in the middle of weir which may span over 50 m.

Reference documents / sources Electric Power Civil Engineering (2007.9)

051 Ooigawa Dam Clear Water Bypass Installation

Plant name	大井川 (Ooigawa)						
Operation start	1936	**Completed**	2013		Age (77 years)		
Owner	Chubu EPCo						
Country	Japan						
Max output kW	68,200	**After work**	-		New / no change		
Max generation discharge m^3/s	72.35						
Effective head m	112.70						
Decision-making type (○ where it applies)	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
			○				
Time of decision making	2011						
Target structure(s)	Reservoir						
・Driver	External factors						
・Phenomena (caused by Driver)	Environmental improvement / local community cooperation						
Risk	Reduction						
・Risks for plant operation	Environmental degradation / discord with local community						
・Specific risk management	Clear water bypass / sand bypass						
(1) Current status	**(Before decision making)**						
1) General status	In response to requests from local communities to improve the river environment, a water purification bypass facility was installed as a measure against turbid water. Intake weir (56 m in crest length, 4.76 m in height), inlet (4.5 m in width, 3.1 m in height), bypass water channel (634.540 m in total length of which tunnel of 614.740 m, open channel of 13.300 m and energy dissipator of 6.500 m) and other structures were built.						
2) Operation status	Environmental degradation						
3) Risk	**Potential risk in case of no decision making** Environmental degradation / discord with local community / opposition to power generation **Potential risk when implementing decision making** No effect, cost increase / profit reduction						
(2) Priorities	Environmental improvement						
(3) Strategy	**Against potential risk in case of no decision making** (Continued coordination with local communities on long-term turbid water) **Against potential risk when implementing decision making** To install a water purification bypass facility (intake weir, intake, bypass water channel) upon requests from local communities to improve the river environment, after considering the work to be conducted in close proximity to existing tunnel.						
(4) How decision-making was implemented and technologies adopted	Consideration was given to work to be conducted in close proximity to existing tunnel (minimum separation of 4.7 m in the category of “scope requiring countermeasures” which is the closes proximity level according to Japan’s Railway Technical Research Institute), and the work was carried out accordingly.						

Reference documents / sources Electric Power Civil Engineering (2013.7)

052 Redevelopment for Origawa Dam Construction

Plant name		小里川 (Origawa)						
Operation start		1926	**Completed**	2003		Age (77 years)		
Owner		Chubu EPCo						
Country		Japan						
Max output	kW	1,800	**After work**	-		New / no change		
Max generation discharge	m^3/s	3.00						
Effective head	m	73.90						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)						○		
Time of decision making		2000						
Target structure(s)		Penstock, T/G, etc						
・Driver		External factors						
・Phenomena (caused by Driver)		Flood safety improvement / local community cooperation						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Existing plant relocation						

(1) Current status **(Before decision making)**

1) General status

In conjunction with the construction of Origawa Dam by the Ministry of Land, Infrastructure, Transport and Tourism, three power plants including Origawa No.3 were abolished, and two of them were demolished. As an alternative facility Origawa Power Plant (output of 1,800 kW) was constructed immediately downstream from Origawa Dam.

2) Operation status

Generation shutdown / efficiency decline

3) Risk

Potential risk in case of no decision making

Generation shutdown / efficiency decline

Potential risk when implementing decision making

Cost increase / profit reduction

(2) Priorities

Cooperative improvement in flood control safety

(3) Strategy

Against potential risk in case of no decision making

(None)

Against potential risk when implementing decision making

To abolish 3 plants (2 to be removed) and newly construct a dam plant (immediately below Origawa Dam) in conjunction with the construction of Origawa Dam by the Ministry of Land, Infrastructure, Transport and Tourism, after considering the plant operation within the dam discharge, plant layout and handling of the abolished plants.

(4) How decision-making was implemented and technologies adopted

The following issues and measures were considered / implemented: continued power generation within the range of discharge from a dam not having capacity dedicated to power generation in the reservoir, power plant layout (whereby lower discharge pipe is branched to be connected to the turbine via 65-m long stainless steel pipe), disposable of the abolished power plants (in connection with new Origami Dam, that is, 3 plants built around 1910 whose civil engineering facilities were built almost entirely with local granite stacked up with traditional masonry skills. The bridge for passage to Plant 3 was 3-arch structure of stacked stones, which was relocated to Yamaoka Town to be saved as historical building), etc.

Reference documents / sources Electric Power Civil Engineering (2003.5)

053 Headrace Confluence Section Refurbishment: Ooigawa P/S

Plant name		大井川 (Ooigawa)						
Operation start		1936	**Completed**	2013		Age (77 years)		
Owner		Chubu EPCo						
Country		Japan						
Max output	kW	68,200	**After work**	-		New / no change		
Max generation discharge	m^3/s	72.35						
Effective head	m	112.70						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)				○				
Time of decision making		2012						
Target structure(s)		Headrace						
・Driver		Asset optimization & Review of operation						
・Phenomena (caused by Driver)		Generation efficiency improvement / higher management efficiency						
Risk		Reduction						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Raising profit						
(1) Current status		**(Before decision making)**						
1) General status		The confluence section of the headrace was improved in order to reduce the head loss of Ooigawa Power Plant and thus to obtain maximum output stably. A connecting tunnel (53.618m in length, 3.636 -5.182 m in diameter) was built.						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To construct a connecting tunnel and refurbish the confluence section of the headrace was in order to reduce the head loss of Ooigawa Power Plant and thus to obtain maximum output stably, after considering low blast vibration excavation method, etc.						
(4) How decision-making was implemented and technologies adopted		Low blast vibration excavation (New Rock Cracker) method and multi-stage and non-explosive rock blast system were considered as existing building proximity work method and implemented.						

Reference documents / sources Electric Power Civil Engineering (2013.9)

054 Flushing Gate Replacement: Jinzugawa No.1

Plant name		神通川第一 (Jinzugawa No.1)						
Operation start		1954	**Completed**	2012		Age (58 years)		
Owner		Hokuriku EPCo						
Country		Japan						
Max output	kW	82,000	**After work**	-		New / no change		
Max generation discharge	m^3/s	150.00						
Effective head	m	62.50						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		2010						
Target structure(s)		Flushing gate						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Gate repair						
(1) Current status		**(Before decision making)**						
1) General status		Based on safety assessment results for dam gates aged about 50 years, two flushing date of the dam were replaced.						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To replace two flushing gates based on the dam gate safety assessment results (seismic response analysis / stress check), while considering work period restrictions (non-flood period) and verification by stress measurement after gate replacement.						
(4) How decision-making was implemented and technologies adopted		Correspondence to large-scale earthquakes (seismic response analysis / stress check), work period restrictions (non-flood period from November to February), and verification by stress measurement after gate replacement were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering 2013.11

055 Zakurodani Intake Dam Apron Refurbishment

Plant name		称名川第二 (Shomyogawa No.2)						
Operation start		1960	**Completed**	2011		Age (51 years)		
Owner		Hokuriku EPCo						
Country		Japan						
Max output	kW	8,100	**After work**	-		New / no change		
Max generation discharge	m^3/s	4.35						
Effective head	m	227.50						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)				○				
Time of decision making		2011						
Target structure(s)		Dam						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Reduction						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Dam reservoir repair						

(1) Current status	**(Before decision making)**
1) General status	Intake facility aged about 50 years located in a fast-flowing river of average stream bed gradient of 5. In order to prevent wear and scour by flowing mud including boulders in floods, anti-wear cast steel plates (72 m2)were installed in the apron.
2) Operation status	Generation efficiency decline
3) Risk	**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction
(2) Priorities	RE utilization / securing profit
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To install anti-wear cast steel plates as a preventive measure against the wear and scouring of the apron, after comparing the refurbishment options (workability and economy) and restrictions of work period.
(4) How decision-making was implemented and technologies adopted	The following issues and measures were considered and implemented: comparison of possible refurbishment ideas considering workability and economy (① high-strength concrete, ② iron plates installation, ③ rail embedment, ④ special cast steel plates) and restrictions of work period (deep snow area exceeding elevation of 1000 m, only helicopter transport)

Reference documents / sources Electric Power Civil Engineering 2012.3

056 Jinzugawa No.1 Dam Radial Gate Renewal

Plant name		神通川第一 (Jinzugawa No.1)						
Operation start		1954	**Completed**	2012		Age (58 years)		
Owner		Hokuriku EPCo						
Country		Japan						
Max output	kW	82,000	**After work**	-		New / no change		
Max generation discharge	m^3/s	150.00						
Effective head	m	62.50						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)				○				
Time of decision making		2009						
Target structure(s)		Spillway gate						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Gate repair						
(1) Current status		**(Before decision making)**						
1) General status		Renewal of gate doors and open / close unit aged about 50 years, built before the stipulation for strength calculation regulations for dam gate, radial gate, trunnion bearing (1973).						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To renew the radial gate doors and open / close unit due to their aging after considering seismic response analysis, stress check, gate installation / delivery method, work period restrictions and verification by stress measurement after gate replacement.						
(4) How decision-making was implemented and technologies adopted		The following issues and measures were considered and implemented: correspondence to large-scale earthquakes (seismic response analysis / stress check), gate installation and delivery method (using cable crane method), work period restrictions (non-flood period of 8 months × 3 years) and verification by stress measurement after gate replacement.						

Reference documents / sources Electric Power Civil Engineering 2010.9

057 Jinzugawa No.2 Dam Radial Gate Renewal

Plant name	神通川第二 (Jinzugawa No.2)						
Operation start	1954	**Completed**	2012	Age (58 years)			
Owner	Hokuriku EPCo						
Country	Japan						
Max output kW	41,000	**After work**	44,000	Up rate↑ (7.3%)			
Max generation discharge m^3/s	160.00						
Effective head m	29.80						
Decision-making type	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○				
Time of decision making	2009						
Target structure(s)	Spillway gate						
・Driver	Aging						
・Phenomena (caused by Driver)	Aging / efficiency decline						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Gate repair						
(1) Current status	**(Before decision making)**						
1) General status	Renewal of gate doors and open / close unit aged about 50 years, built before the stipulation for strength calculation regulations for dam gate, radial gate, trunnion bearing (1973).						
2) Operation status	Generation efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To renew the radial gate doors and open / close unit due to their aging after considering seismic response analysis, stress check, gate installation / delivery method, work period restrictions and verification by stress measurement after gate replacement.						
(4) How decision-making was implemented and technologies adopted	The following issues and measures were considered and implemented: correspondence to large-scale earthquakes (seismic response analysis / stress check), gate installation and delivery method (using cable crane method), work period restrictions (non-flood period of 8 months × 3 years) and verification by stress measurement after gate replacement.						

Reference documents / sources Electric Power Civil Engineering 2010.9

058 Hotokebara Dam Radial Gate Renewal

Plant name	西勝原第三 (Nishikadohara No.3)						
Operation start	1968	**Completed**	2012		Age (44 years)		
Owner	Hokuriku EPCo						
Country	Japan						
Max output kW	220	**After work**	-		New / no change		
Max generation discharge m^3/s	1.27						
Effective head m	24.63						
Decision-making type (○ **where it applies)**	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
			○				
Time of decision making	2009						
Target structure(s)	Spillway gate						
・Driver	Aging						
・Phenomena (caused by Driver)	Aging / efficiency decline						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Gate repair						
(1) Current status	**(Before decision making)**						
1) General status	Renewal of gate doors and open / close unit aged about 50 years, built before the stipulation for strength calculation regulations for dam gate, radial gate, trunnion bearing (1973).						
2) Operation status	Generation efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To renew the radial gate doors and open / close unit due to their aging after considering seismic response analysis, stress check, gate installation / delivery method, work period restrictions and verification by stress measurement after gate replacement.						
(4) How decision-making was implemented and technologies adopted	The following issues and measures were considered and implemented: correspondence to large-scale earthquakes (seismic response analysis / stress check), gate installation and delivery method (vehicle delivery), work period restrictions (non-flood period of 8 months × 3 years) and verification by stress measurement after gate replacement.						

Reference documents / sources Electric Power Civil Engineering 2010.9

059 Headrace Refurbishment: Koguchigawa No.3 P/S

Plant name		小口川第三 (Koguchigawa No.3)						
Operation start		1931	**Completed**	2014		Age (83 years)		
Owner		Hokuriku EPCo						
Country		Japan						
Max output	kW	14,500	**After work**	-		New / no change		
Max generation discharge	m^3/s	2.78						
Effective head	m	621.20						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)				○				
Time of decision making		2012						
Target structure(s)		Headrace						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Reduction						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Water way, etc. repair						
(1) Current status		**(Before decision making)**						
1) General status		Pressure headrace aged about 80 years, made of concrete in a horseshoe-shape design. The channel collapsed shortly after commissioning due to water leakage and inner steel pipes were installed. Maintenance had been given, but aging progressed, and therefore they were replaced by Fiberglass Reinforced Plastic Mortar (FRPM) pipes.						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To renew with fiberglass reinforced plastic mortar (FRPM) pipes against the aged internal pipe in the penstock after considering the leakage assessment, comparison of methods (materials), filling materials on the back, etc.						
(4) How decision-making was implemented and technologies adopted		The following issues and measures were considered and implemented: headrace water leakage assessment based on surge tank level lowering speed when water intake is shut down in the headrace, trend in head loss increase due to aging progress in reference to roughness coefficient of headrace, comparison of steel and FRPM pipes to adopt FRPM, use of FA (fly ash) mortar as filling material on the back of FRPM pipes along with plastic mortar as a countermeasure against large quantities of spring water.						

Reference documents / sources Electric Power Civil Engineering (2015.1)

060 Zakurodani Intake Facility Refurbishment

Plant name		称名川第二 (Shomyogawa No.2)						
Operation start		1960	**Completed**	2006		Age (46 years)		
Owner		Hokuriku EPCo						
Country		Japan						
Max output	kW	8,100	**After work**	-		New / no change		
Max generation discharge	m^3/s	4.35						
Effective head	m	227.50						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)				○				
Time of decision making		2006						
Target structure(s)		Intake						
・Driver		Disaster						
・Phenomena (caused by Driver)		Generation shutdown / efficiency decline						
Risk		Reduction						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Disaster (flood / heavy rain) restoration						

(1) Current status

(Before decision making)

1) General status

Heavy rain floods in 2004 and 2005 damaged the intake facility with sedimentation and inundation and rendered incapable of water intake. For ensuring stable intake, the intake facility was refurbished by installing Tyrolian type intake (L=12.5 m), modifying the forebay into tunnel (L=13.0 m) and renovating the gate / winch box (elevating by 4 m).

2) Operation status

Generation shutdown / efficiency decline

3) Risk

Potential risk in case of no decision making

Generation shutdown / efficiency decline

Potential risk when implementing decision making

Cost increase / profit reduction

(2) Priorities

RE utilization / securing profit

(3) Strategy

Against potential risk in case of no decision making

(None)

Against potential risk when implementing decision making

To refurbish the intake facility (by installing Tyrolian type intake, modifying the forebay into tunnel and renovating the gate / winch box) as a restoration project for the facility damage by the heavy rain floods in 2004 and 2005 while considering a stable intake method and cost reduction.

(4) How decision-making was implemented and technologies adopted

Stable intake method (altering from side intake to Tyrolian type) and cost reduction (altering structure of gate winch box, combined use of temporary facilities) were considered and implemented.

Reference documents / sources Electric Power Civil Engineering 2007.3

061 Tailrace Restoration: Shin-inotani P/S

Plant name	新猪谷 (Shininotani)						
Operation start	1964	**Completed**	2009	Age (45 years)			
Owner	Hokuriku EPCo						
Country	Japan						
Max output kW	33,500	**After work**	-	New / no change			
Max generation discharge m^3/s	45.00						
Effective head m	87.50						
Decision-making type	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○				
Time of decision making	2004						
Target structure(s)	Tailrace						
・Driver	Disaster						
・Phenomena (caused by Driver)	Generation shutdown / efficiency decline						
Risk	Reduction						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Disaster (flood / heavy rain) restoration						
(1) Current status	**(Before decision making)**						
1) General status	Unusual floods by Typhoon No. 23 on October 21, 2004 inundated the open / close unit and control panel of the outlet water control gate, while large quantities of mud and debris flowed into the tailrace from openings, making the water passage impossible. Restoration work was conducted to elevate the tailbay bulkheads, modify the outlet water control gate and lower the riverbed near the outlet.						
2) Operation status	Generation shutdown / efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To elevate the tailbay bulkheads, modify the outlet water control gate and lower the riverbed near the outlet in response to the facility damage by Typhoon No. 23 in 2004 while considering the recorded highest water level or flowrate with 100year return period, watertight modification of the outlet water control gate, elevation of open / close unit, tunnel modification of the outlet open section, and long-term work for sedimentation removal in the downstream regulating pond in connection with the riverbed lowering near the outlet.						
(4) How decision-making was implemented and technologies adopted	The following issues and measures were considered and implemented: structure resistant either to recorded highest water level or flowrate with 100-year return period, watertight modification of outlet water control gate, elevation of open / close unit, tunnel modification of open section of outlet, and long-term work for sedimentation removal in the downstream regulating pond in connection with the riverbed lowering near the outlet.						

Reference documents / sources Electric Power Civil Engineering (2010.3)

062 Obara Dam Refurbishment

Plant name	滝波川第一 (Takiminagawa No.1)						
Operation start	1965	**Completed**	2013		Age (48 years)		
Owner	Hokuriku EPCo						
Country	Japan						
Max output kW	12,500	**After work**	-		New / no change		
Max generation discharge m^3/s	5.00						
Effective head m	298.40						
Decision-making type (○ where it applies)	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
			○				
Time of decision making	2011						
Target structure(s)	Dam (gateless modification)						
・Driver	Asset optimization & Review of operation						
・Phenomena (caused by Driver)	Generation efficiency improvement / higher management efficiency						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Management labor saving						
(1) Current status **1) General status** **2) Operation status** **3) Risk**	**(Before decision making)** Gateless modification was carried out for optimizing dam management and as a countermeasure against the aged spillway gate. The spillway gate was removed, flushing gate was installed and passage bridge (about 44 m) was built. Generation efficiency decline **Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To implement gateless modification (by removing the spillway gate, installing a flushing gate and building a passage bridge) for efficient dam maintenance and the aged facilities while considering the difficulty in maintaining the dam and spillway gate, measures against scouring / erosion due to changed dam discharge method, installation of downstream revetment, and temporary discharge facility.						
(4) How decision-making was implemented and technologies adopted	The following issues and measures were considered and implemented: management method for dam and spillway gate (inaccessibility during winter, flood response risks, aging gate), gateless modification, installation of natural overflow spillway, measures against scouring / erosion due to changed dam discharge method (guide wall behind the dam), installation of downstream revetment, and temporary discharge facility (safe discharge by dam through-hole)						

Reference documents / sources Electric Power Civil Engineering (2013.11), NEF Practical Training (2016.2)

063 Oguchi No.1 Dam Refurbishment

Plant name	尾口 (Oguchi)						
Operation start	1938	**Completed**	2011		Age (73 years)		
Owner	Hokuriku EPCo						
Country	Japan						
Max output kW	17,200	**After work**	-		New / no change		
Max generation discharge m^3/s	11.52						
Effective head m	278.16						
Decision-making type (○ where it applies)	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
			○				
Time of decision making	2008						
Target structure(s)	Dam (gateless modification)						
・Driver	Asset optimization & Review of operation						
・Phenomena (caused by Driver)	Generation efficiency improvement / higher management efficiency						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Management labor saving						
(1) Current status	**(Before decision making)**						
1) General status	Gateless modification in view of cost effectiveness and discharge safety considering aging, heavy snowfalls, severe service condition (date discharge for 200 days annually). 4 spillway gates were removed, 1 flushing date was installed, dam height was elevated by 4.5 m, and a passage bridge of about 60 m was installed.						
2) Operation status	Generation efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To implement measures for reducing the environmental load by planning the work period with the golden eagles (nest building and chicks protection) and external expert instructions from in mind, considering the landscape on the concrete surface and recycling the removed concrete, etc.						
(4) How decision-making was implemented and technologies adopted	The following issues and measures were considered and implemented: adoption of gateless modification considering the cost benefits and discharge safety after comparison of various ideas (① gateless modification, ② replacement of spillway gate , ③ direct connection with upstream power plant), environmental considerations (work period planning in consideration of raptors), considerations for landscape (rock appearance imitation of concrete surfaces), effective utilization of waste concrete (used onsite after recycling as crushed stones).						

Reference documents / sources Electric Power Civil Engineering (2008.9), NEF Practical Training (2010.2)

064 Yomikaki Dam Pier, etc Repair

Plant name		読書 (Yomikaki)						
Operation start		1923	**Completed**	2013		Age (90 years)		
Owner		Kansai EPCo						
Country		Japan						
Max output	kW	117,100	**After work**	-		New / no change		
Max generation discharge	m^3/s	118.91						
Effective head	m	112.12						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)		○						
Time of decision making		2009						
Target structure(s)		Spillway						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Reduction						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Dam reservoir repair						
(1) Current status		**(Before decision making)**						
1) General status		Aged about 90 years, the reinforcement of gate pier conducted in 1983 and 1984 was deteriorating, and thus the degraded concrete of the dam piers (6 locations) was re-cast.						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To implement measures against the concrete degradation (re-casting the degraded sections) after the measurement of PC steel wire axial force, soundness assessment by concrete strength test, etc.						
(4) How decision-making was implemented and technologies adopted		The following issues and measures were considered and implemented: measurement of PC steel wire axial force, soundness assessment by concrete strength test, countermeasures against concrete aging, work planning in consideration of past flowrate data.						

Reference documents / sources Electric Power Civil Engineering (2011.7)

065 No.1 T/G Renewal: Toganoo

Plant name		栂ノ尾 (Toganoo)						
Operation start		1922	**Completed**	2017		Age (95 years)		
Owner		Kansai EPCo						
Country		Japan						
Max output	kW	750	**After work**	780		Up rate↑ (4.0%)		
Max generation discharge	m^3/s	1.67						
Effective head	m	57.70						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		2015						
Target structure(s)		T/G, draft, penstock						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		T/G renewal						
(1) Current status		**(Before decision making)**						
1) General status		Aged about 90 years, the aged facilities could not be maintained with partial repairs, and thus overall refurbishment was carried out including the turbine generator.						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To perform total refurbishment of T/G and other main facilities due to the aging and defects after considering the turbine selection, draft shape and penstock partial replacement while implementing the displacement management of the adjacent national route and earth retaining work.						
(4) How decision-making was implemented and technologies adopted		Displace observation and control were carried out for the public road and earth retaining work considering the national route road in the vicinity. Turbine selection, draft shape on the condition of continuous use of existing outlet, and penstock partial replacement were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2018.1)

066 Monitoring System Renewal: Ookawachi

Plant name		大河内 (Ookawachi)						
Operation start		1995	**Completed**	2015		Age (20 years)		
Owner		Kansai EPCo						
Country		Japan						
Max output	kW	1,280,000	**After work**	-		New / no change		
Max generation discharge	m^3/s	382.00						
Effective head	m	394.70						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		Not confirmed						
Target structure(s)		Protective / control system						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		T/G renewal						
(1) Current status		**(Before decision making)**						
1) General status		Aged about 10 years, troubles in the monitoring control system were manifested. The system was thus renewed by fully utilizing the advantages of total digital system, provided it does not adversely affect the plant's total system.						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To renew the monitor / control system which will not adversely affect the overall plant system due to the troubles in the monitoring control system being manifested for improving the system durability, safety and reliability and costreduction.						
(4) How decision-making was implemented and technologies adopted		Ring type network was introduced to enable high-speed cyclic communication of automatic control information in the multiple units in the plant system. Star type network was introduced for the switching system to avoid affecting other facilities even in cases of malfunctioning.						

Reference documents / sources NEF HP

067 Wachi Dam Spillway Gate Replacement

Plant name		和知 (Wachi)						
Operation start		1968	**Completed**	2017		Age (49 years)		
Owner		Kansai EPCo						
Country		Japan						
Max output	kW	5,700	**After work**	-		New / no change		
Max generation discharge	m^3/s	35.00						
Effective head	m	19.52						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		2012						
Target structure(s)		Spillway gate						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Gate repair						
(1) Current status		**(Before decision making)**						
1) General status		The aging of 40-year-old spillway gate and related units was progressing, and thus the 4 existing spillway gates (pure span of 9.0 m, door height of 12.7 m and rotational radius of 13 m) were replaced.						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To replace the 4 existing spillway gates against their aging and degradation of other facilities after considering their earthquake resistance, weigh increase control due to the use of high strength steel materials, setting a work period based on flowrate data, work method and procedure, etc.To change the speed reducer specs of the open / close unit for improving the machine efficiency and downsizing of the electric motor (to reduce the overall weight)						
(4) How decision-making was implemented and technologies adopted		The following issues and measures were considered and implemented: safety confirmation against large earthquakes, controlling the weigh increase due to use of high strength steel materials, setting work period based on flowrate data during gate replacement (the gat and adjacent gates could not be used for certain period), work method and procedure.						

Reference documents / sources Electric Power Civil Engineering (2014.11)

068 Omata Weir Refurbishment

Plant name		川原樋川 (Kawarabigawa)						
Operation start		1986	**Completed**	2010		Age (24 years)		
Owner		Kansai EPCo						
Country		Japan						
Max output	kW	11,400	**After work**	-		New / no change		
Max generation discharge	m^3/s	8.00						
Effective head	m	177.10						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)				○				
Time of decision making		2008						
Target structure(s)		Dam (SR weir modification)						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Dam reservoir repair						
(1) Current status		**(Before decision making)**						
1) General status		Due to the degradation of rubber weir aged about 30 years, it was replaced by hybrid inflatable weir (SR weir of pure span 26.0 m × weir height of 2.0 m).						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To renew the aged existing rubber weir with a hybrid inflatable weir (SR weir) after considering the comparative examination of gate types (in terms of water level control function, impact from flowing objects, impact on the environment, workability, and economy), flood response during the work, etc.						
(4) How decision-making was implemented and technologies adopted		① Rubber weir, ② hybrid inflatable weir, and ③ hydraulic steel inflatable gate were compared and assessed in terms of water level control function, impact from flowing objects, impact on the environment, workability, and economy. Flood response during the work (river coffering, installation of steel covers to prevent parts from being washed away) was considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2011.5)

069 Intake Dam Refurbishment: Iwanaka P/S

Plant name		岩中 (Iwanaka)						
Operation start		1957	**Completed**	2017		Age (60 years)		
Owner		Kansai EPCo						
Country		Japan						
Max output	kW	2,500	**After work**	-		New / no change		
Max generation discharge	m^3/s	8.00						
Effective head	m	38.39						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)				○				
Time of decision making		2016						
Target structure(s)		Spillway gate						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Dam reservoir repair						
(1) Current status		**(Before decision making)**						
1) General status		Aged 60-year-old spillway gate (steel shell rotor gate) was replaced by SR weir, capable of automatic discharge for optimized operation (labor saving), while multistep SR weir fishway was installed.						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To replace the existing spillway gate (steel shell rotor gate) with SR weir and install a multi-step SR weir fishway after considering the type options of movable weir (operation conditions, generation efficiency, construction cost, maintenance cost, waste discharge in floods), spillway gate automation, prevention of damage to the rubber bag fixing section by sand and mud, etc.						
(4) How decision-making was implemented and technologies adopted		Spillway gate automation for further optimization of dam operation and management. Use of steel clamps to prevent damage to the rubber bag fixing section by sand and mud and structure without spaces where sand and mud flow in were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2018.1)

070 Disaster Restoration: Nagatono P/S

Plant name		長殿 (Nagatono)						
Operation start		1937	**Completed**	2018		Age (81 years)		
Owner		Kansai EPCo						
Country		Japan						
Max output	kW	15,300	**After work**	16,200		Up rate↑ (5.9%)		
Max generation discharge	m^3/s	9.46						
Effective head	m	196.00						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)				○				
Time of decision making		2011						
Target structure(s)		Power Plant, T/G						
・Driver		Disaster						
・Phenomena (caused by Driver)		Generation shutdown / efficiency decline						
Risk		Reduction						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Disaster (flood / heavy rain) restoration						
(1) Current status		**(Before decision making)**						
1) General status		Typhoon No.12 in 2011 caused severe, catastrophic damage. The powerhouse building was completely destroyed, transmission steel towers buckled, and generator was inundated. The damage was so great because of mountain tsunami caused by large quantities of mud flowed into the river after the mountain slopes collapsed, in Extension to the floods from the record-breaking downpours.						
2) Operation status		Generation shutdown / efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To consider and implement the elevation of the water discharge level and plant site ground and modification to tailbay structure with retaining walls around the outlet for the catastrophic damage by Typhoon No.12 in 2011 based on the 50year riverbed change simulation and flood level of 100-year return period.						
(4) How decision-making was implemented and technologies adopted		Elevation of water discharge level and plant site ground based on 50-year riverbed change simulation and flood level of 100-year return period and modification to tailbay structure with retaining walls around the outlet were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2017.5)

071 Tailrace Tunnel Repair: Shin-Kurobe No.2 P/S

Plant name		新黒部川第二 (Shinkurobe No.2)						
Operation start		1966	**Completed**	2014		Age (48 years)		
Owner		Kansai EPCo						
Country		Japan						
Max output	kW	74,200	**After work**	-		New / no change		
Max generation discharge	m^3/s	46.00						
Effective head	m	189.80						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)				○				
Time of decision making		2009						
Target structure(s)		Tailrace						
・Driver		Disaster						
・Phenomena (caused by Driver)		Generation shutdown / efficiency decline						
Risk		Reduction						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Disaster (flood / heavy rain) restoration						
(1) Current status		**(Before decision making)**						
1) General status		Inundation and buried outlet in July 1995 resulted in plant operation shutdown and great loss of power generation opportunity, and thus the outlet was moved to the inside of dam pond not affected by floods or sand / mud, while the tailrace (about 1.4 km) was also refurbished.						
2) Operation status		Generation shutdown / efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** Sedimentation near outlet to be moved regularly to Daishidaira Dam downstream **Against potential risk when implementing decision making** To conduct replacement of the outlet and tailrace for the flood damage in July 1995 (resulted in plant operation shutdown and great loss of power generation opportunity) while considering the transport of construction equipment and materials, TSP (Tunnel Seismic Prediction) exploration and forward boring, and controlled blasts, etc.						
(4) How decision-making was implemented and technologies adopted		The following issues and measures were considered and implemented: installation of signal lights and signposts as the railways for transporting construction equipment and materials are connected or running alongside the commercial line of Kurobe Gorge Railway, education of train drivers, restrictions for disposal of excavated rocks as the work site is located inside a national park and conserved forests, TSP (Tunnel Seismic Prediction) exploration and forward boring for possibilities of large spring water and fracture zone in the shallow earth covering section right above the tunnel route, and controlled blasts to avid interruptions to the power plant facilities in operation.						

Reference documents / sources Electric Power Civil Engineering (2010.11/2014.3)

072 Spillway Channel Refurbishment: Ontake P/S

Plant name		御岳 (Ontake)						
Operation start		1945	**Completed**	2014		Age (69 years)		
Owner		Kansai EPCo						
Country		Japan						
Max output	kW	68,600	**After work**	-		New / no change		
Max generation discharge	m^3/s	34.40						
Effective head	m	229.00						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)				○				
Time of decision making		2013						
Target structure(s)		Spillway channel						
・Driver		Disaster						
・Phenomena (caused by Driver)		Generation shutdown / efficiency decline						
Risk		Reduction						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Public disaster risk reduction						
(1) Current status		**(Before decision making)**						
1) General status		Spillage in cases of emergency plant shutdown used to be discharge suddenly and in high-speed to the river which may cause damage to the river visitors, and thus an energy dissipator was structured in the utility-owned land adjacent to the existing spillway.						
2) Operation status		Generation shutdown / efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To install an energy dissipator unit in the utility-owned land adjacent to the existing spillway in order to prevent danger caused by the plant spillage after considering the hydrological model testing, modification of problematic sections, optimal shape to minimize the river discharge flowrate, refurbishment work while the plant continues its operation, etc.						
(4) How decision-making was implemented and technologies adopted		The following issues and measures were considered and implemented: verification of hydrological function of energy dissipator by model testing, modification of problematic sections, optimal shape to minimize the river discharge flowrate, refurbishment work while the plant continues its operation by extending the existing spillway channel with temporary pipe (moving the discharge outlet to downstream).						

Reference documents / sources Electric Power Civil Engineering (2014.3)

073 Spillway Refurbishment: Takigoshi P/S

Plant name		滝越 (Takigoshi)						
Operation start		1951	**Completed**	2017		Age (66 years)		
Owner		Kansai EPCo						
Country		Japan						
Max output	kW	28,900	**After work**	-		New / no change		
Max generation discharge	m^3/s	17.50						
Effective head	m	185.50						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)				○				
Time of decision making		2016						
Target structure(s)		Spillway channel						
・Driver		Disaster						
・Phenomena (caused by Driver)		Generation shutdown / efficiency decline						
Risk		Reduction						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Public disaster risk reduction						
(1) Current status		**(Before decision making)**						
1) General status		Spillage in cases of emergency plant shutdown used to be discharge suddenly and in high-speed to the river which may cause damage to the river visitors, and thus an energy dissipator was structured in the spillway outlet.						
2) Operation status		Generation shutdown / efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To install an energy dissipator unit in the existing spillway outlet in order to prevent danger caused by the plant spillage after considering the energy dissipating methods, comparison of energy dissipating unit types (flowrate and economy), hydrological model testing, shortening the plant shutdown period, consideration for workers in winter, etc.						
(4) How decision-making was implemented and technologies adopted		The following issues and measures were considered and implemented: comparison of possible designs of energy dissipator in terms of current flowrate and economy, hydrological model testing (to reproduce the current status and to check energy dissipating effect and flowrate of various proposals), final dissipation method (impact / standard type), temporary installations for shortening the plant shutdown period due to the work, and consideration for workers in winter at minus 20 degrees lowest.						

Reference documents / sources Electric Power Civil Engineering (2017.11)

074 Surface Intake Facility New Installtion: Shimokotori P/S

Plant name		下小鳥 (Shimokotori)						
Operation start		1973	**Completed**	2016		Age (43 years)		
Owner		Kansai EPCo						
Country		Japan						
Max output	kW	142,000	**After work**	-		New / no change		
Max generation discharge	m^3/s	65.00						
Effective head	m	251.10						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)				○				
Time of decision making		2012						
Target structure(s)		Reservoir						
・Driver		External factors						
・Phenomena (caused by Driver)		Environmental improvement / local community cooperation						
Risk		Reduction						
・Risks for plant operation		Environmental degradation / discord with local community						
・Specific risk management		Surface / selective intake facility						
(1) Current status		**(Before decision making)**						
1) General status		Extensional installation of surface water intake facility to take in the less turbid water as an initiative for long-term turbid water countermeasure.						
2) Operation status		Environmental degradation						
3) Risk		**Potential risk in case of no decision making** Environmental degradation / discord with local community / opposition to power generation **Potential risk when implementing decision making** No effect, cost increase / profit reduction						
(2) Priorities		Environmental improvement						
(3) Strategy		**Against potential risk in case of no decision making** (Continued coordination with local communities on long-term turbid water) **Against potential risk when implementing decision making** To add a surface intake facility against the long-term turbid water while considering the alleviation of dam level restrictions and informational improvement for large-scale excavation						
(4) How decision-making was implemented and technologies adopted		The following issues and measures were considered and implemented: installation of surface water intake facility to take in the less turbid water as an initiative for long-term turbid water countermeasure, intake facility optimal design by use of bell-mouth gate and straightening plate, alleviation of dam level restrictions by employing Caisson method for the lower section of intake facility, and informational improvement by installing various measuring instruments for large-scale excavation.						

Reference documents / sources Electric Power Civil Engineering (2013.3/2014.9/2017.1)

075 Tailrace Restoration: Okuyoshino P/S

Plant name		奥吉野 (Okuyoshino)						
Operation start		1978	**Completed**	1997		Age (19 years)		
Owner		Kansai EPCo						
Country		Japan						
Max output	kW	1,206,000	**After work**	-		New / no change		
Max generation discharge	m^3/s	280.00						
Effective head	m	505.00						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)				○				
Time of decision making		1994						
Target structure(s)		Reservoir						
・Driver		External factors						
・Phenomena (caused by Driver)		Environmental improvement / local community cooperation						
Risk		Reduction						
・Risks for plant operation		Environmental degradation / discord with local community						
・Specific risk management		Clear water bypass / sand bypass						
(1) Current status		**(Before decision making)**						
1) General status		The effect of deforestation conducted upstream was manifested despite the countermeasures being taken for the turbid water flowing into the reservoir during floods, such as operation of selective intake, installation of screening weir immediately below the dam, protective work for ground collapse around the reservoir. Extensionally, progress of sedimentation above the initial plan was expected. Therefore, a bypass flushing facility was build which discharges turbid water downstream Asahi Dam via a bypass tunnel of 2,350 m in length.						
2) Operation status		Environmental degradation						
3) Risk		**Potential risk in case of no decision making** Environmental degradation / discord with local community / opposition to power generation Potential risk when implementing decision making No effect, cost increase / profit reduction						
(2) Priorities		Environmental improvement						
(3) Strategy		**Against potential risk in case of no decision making** (Continued coordination with local communities on long-term turbid water) **Against potential risk when implementing decision making** To install a bypass flushing facility as a fundamental measure against the long-term turbid water issue after considering long-term turbidity, reducing sedimentation inside the reservoir, flushing effect of using a tunnel, economically optimal facility scale, hydrological calculations, simulations and hydrological experiments, operation methods, etc.						
(4) How decision-making was implemented and technologies adopted		The following issues and measures were considered and implemented: simulations and hydrological experiments for technical issues such as the actual effect on reduction of turbidity period and sedimentation, if large amounts of sand during floods can be flushed with a channel tunnel, the economically optimal size of facility, how to conduct hydrological calculations, etc. operation methods and effects (when operating the flushing bypass only for floods) for preventing long-term turbidity, reducing sedimentation inside the reservoir, river environment recovery by flushing sand downstream the dam, preventing eutrophication of reservoir during floods, etc.						

Reference documents / sources Electric Power Civil Engineering (1996.1)

076 Revelopment for Construction of Shinmaruyama Dam: Maruyama P/S

Plant name		丸山 (Maruyama)						
Operation start		1954		**Completed**	2029 (planned)	#VALUE!		
Owner		Kansai EPCo						
Country		Japan						
Max output	kW	138,000		**After work**	151,000	Up rate↑ (9.4%)		
Max generation discharge	m^3/s	192.90						
Effective head	m	Not confirmed						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)						○		
Time of decision making		2016						
Target structure(s)		Intake, water tank, T/G, etc						
・Driver		External factors						
・Phenomena (caused by Driver)		Flood safety improvement / local community cooperation						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Utilization of part of existing plant						
(1) Current status		**(Before decision making)**						
1) General status		In conjunction with the construction of Shinmaruyama Dam (elevation heightening redevelopment) by the Ministry of Land, Infrastructure, Transport and Tourism, the intake and regulation tank were elevated, headrace was reinforced, penstock was replaced, and turbine generator was renewed.						
2) Operation status		Generation shutdown / efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		Cooperative improvement in flood control safety						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To elevate the intake and regulation tank, reinforce the headrace, replace the penstock and renew the T/G in conjunction with the construction of ShinMaruyama Dam (elevation heightening redevelopment) by the Ministry of Land, Infrastructure, Transport and Tourism, for recovering the plant functions and improving the generation efficiency with new T/G units.						
(4) How decision-making was implemented and technologies adopted		Consideration was given whether to implement as the functional recovery of facilities other than the turbine generator or as focused on increasing the power generation efficiency by renewing the turbine generator.						
Reference documents / sources		NEF HP						

077 Revelopment for Construction of Shinmaruyama Dam: Shinmaruyama P/S

Plant name		新丸山 (Shinmaruyama)						
Operation start		1971		**Completed**	2029 (planned)	#VALUE!		
Owner		Kansai EPCo						
Country		Japan						
Max output	kW	63,000		**After work**	69,400	Up rate↑ (10.2%)		
Max generation discharge	m^3/s	93.00						
Effective head	m	78.10						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)						○		
Time of decision making		Unknown						
Target structure(s)		Intake, water tank, T/G, etc						
・Driver		External factors						
・Phenomena (caused by Driver)		Flood safety improvement / local community cooperation						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Utilization of part of existing plant						
(1) Current status		**(Before decision making)**						
1) General status		In conjunction with the construction of Shinmaruyama Dam (elevation heightening redevelopment) by the Ministry of Land, Infrastructure, Transport and Tourism, the intake and regulation tank were elevated, headrace was reinforced, penstock was replaced, and turbine generator was renewed.						
2) Operation status		Generation shutdown / efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		Cooperative improvement in flood control safety						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To elevate the intake and regulation tank, reinforce the headrace and penstock and renew the T/G in conjunction with the construction of Shin-Maruyama Dam (elevation heightening redevelopment)						
(4) How decision-making was implemented and technologies adopted		Consideration was given whether to implement as the functional recovery of facilities other than the turbine generator or as focused on increasing the power generation efficiency by renewing the turbine generator.						

Reference documents / sources NEF HP

078 Okutataragi Power Plant Variable Speed Modification

Plant name	奥多々良木 (Okutataragi)						
Operation start	1974	**Completed**	2011		Age (37 years)		
Owner	Kansai EPCo						
Country	Japan						
Max output kW	1,932,000	**After work**	-		New / no change		
Max generation discharge m^3/s	594.00						
Effective head m	387.50						
Decision-making type (○ where it applies)	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
		○					
Time of decision making	2010						
Target structure(s)	Generator motor, power plant, etc						
・Driver	Asset optimization & Review of operation						
・Phenomena (caused by Driver)	Generation efficiency improvement / higher management efficiency						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Operation changes						
(1) Current status	**(Before decision making)**						
1) General status	Widening excavation was performed for the existing adit (from about 5 m in width × 4 m in height (about 15 m^2) to about 14 m in width × about 12 m in height (about 147 m^2)) for securing the space for installing exciter, etc. necessary for variable speed operation.						
2) Operation status	Generation efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To introduce a variable speed pumped storage hydropower generation system by widening excavation for the existing adit and installing and other units while considering the vibration control and machine excavation for the operating plant facilities, setting of control level for preventing the vibration, various measurements, etc.						
(4) How decision-making was implemented and technologies adopted	The following issues and measures were considered and implemented: vibration control as the work location is in proximity to the operating plant facilities (while monitoring the vibration level at each blast), use of machine excavation in the vicinity of existing facilities, setting of control level for preventing the vibration exceeding the limit values, taking necessary measures in each stage, and measurement of various values (roof subsidence, inner space displacement, AE measuring, rock bolt axial force, etc).						

Reference documents / sources Electric Power Civil Engineering (2011.7)

079 Kutsugahara Dam Spillway Gate Refurbishment

Plant name		君田 (Kimita)						
Operation start		1941	**Completed**	2007		Age (66 years)		
Owner		Chugoku EPCo						
Country		Japan						
Max output	kW	9,620	**After work**	-		New / no change		
Max generation discharge	m^3/s	14.00						
Effective head	m	83.71						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)		○						
Time of decision making		2005						
Target structure(s)		Spillway gate						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Gate repair						
(1) Current status		**(Before decision making)**						
1) General status		Refurbishment of about 60-year-old spillway gates (all 4 stone gates of pure span of 8.7 m and door height of 3.2 m,). Replacement was minimized (recycling the existing door center section and replacing the door edge sections) by recycling the existing doors from the standpoint of function maintenance, reliability improvement and construction cost reduction.						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To conduct refurbishment after considering the work scope by recycling the existing doors from the standpoint of the function maintenance, reliability improvement and construction cost reduction.						
(4) How decision-making was implemented and technologies adopted		The scope of refurbishment in view of parts soundness was considered and implemented accordingly.						

Reference documents / sources Electric Power Civil Engineering (2006.3)

080 Turbine Generator Replacement: Uchinashi P/S

Plant name		打梨 (Uchinashi)						
Operation start		1939	**Completed**	2003		Age (64 years)		
Owner		Chugoku EPCo						
Country		Japan						
Max output	kW	21,770	**After work**	23,600		Up rate↑ (8.4%)		
Max generation discharge	m^3/s	24.00						
Effective head	m	115.24						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		1998						
Target structure(s)		T/G, etc						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		T/G renewal						
(1) Current status		**(Before decision making)**						
1) General status		About 60-year-old turbine generator was replaced. The generator foundation was changed from the existing double-floor type to barrel type for facility simplification and maintenance labor saving.						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To relace the T/G after deciding the work period and water shutdown period, plant foundation structure in view of economy and maintenance simplification (changing the T/G foundation from the existing double-floor type to barrel type) while ensuring the vibration management during the work						
(4) How decision-making was implemented and technologies adopted		The following issues and measures were considered and implemented: work period and water shutdown period, plant foundation structure in view of economy of replacement cost and maintenance simplification, and vibration management during the work (for preventing error operation of protective relays in the distribution panel room while demolishing the plant foundation)						

Reference documents / sources Electric Power Civil Engineering (2003.3)

081 Turbine Generator Replacement: Doi P/S

Plant name		土居 (Doi)						
Operation start		1938	**Completed**	2010		Age (72 years)		
Owner		Chugoku EPCo						
Country		Japan						
Max output	kW	8,000	**After work**	8,200		Up rate↑ (2.5%)		
Max generation discharge	m^3/s	7.60						
Effective head	m	129.60						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		2008						
Target structure(s)		T/G, etc						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		T/G renewal						
(1) Current status		**(Before decision making)**						
1) General status		About 70-year-old turbine generator was replaced. Two units were integrated into one (double turbine) from the standpoint of economy and simplified maintenance while utilizing the existing facilities to the extent possible. By improving the total machine efficiency, the generation output was raised by 200 kW (from 8,000 kW to 8,200 kW).						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To integrate two units of T/G into one (double turbine) from the standpoint of the work period and water shutdown period, plant foundation structure in view of economy and maintenance simplification, vibration management while demolishing the T/G foundation, investigation of possible impact of vibration on the existing penstock body, etc.						
(4) How decision-making was implemented and technologies adopted		The following issues and measures were considered and implemented: work period and water shutdown period, turbine type in view of economy of replacement cost and maintenance simplification, vibration management during the work for preventing error operation of protective relays in the distribution panel room while demolishing the plant foundation, and investigation of possible impact of vibration on the existing penstock body (for any adverse effect).						

Reference documents / sources Electric Power Civil Engineering (2010.11)

082 Turbine Generator Replacement: Katsuyama No.2 P/S (#3, #4)

Plant name		勝山第二(3・4 号機) (Katsuyama No.2)						
Operation start		1944	**Completed**	2017		Age (73 years)		
Owner		Chugoku EPCo						
Country		Japan						
Max output	kW	7,000	**After work**	7,600		Up rate↑ (8.6%)		
Max generation discharge	m^3/s	6.63						
Effective head	M	128.30						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		2015						
Target structure(s)		T/G, etc						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		T/G renewal						
(1) Current status		**(Before decision making)**						
1) General status		About 70-year-old turbine generator was replaced due to progressive aging. While the target turbine generator was being replace, other turbine generators continued operating.						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To renew the T/G for the aging degradation while considering the coordination of various activities, groove isolation by SD slot drilling, cutting of turbine casing using wire saw machine, etc. as the remaining T/G units continue operating during the work.						
(4) How decision-making was implemented and technologies adopted		Work in narrow spaces on the plant site, coordination of various activities, groove isolation by SD (slot drilling), cutting of turbine casing using wire saw machine, etc. were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2016.11)

083 Turbine Generator Replacement / Spillway Channel Safety Modification: Shimoyama P/S

Plant name		下山 (Shimoyama)						
Operation start		1934	**Completed**	2005		Age (71 years)		
Owner		Chugoku EPCo						
Country		Japan						
Max output	kW	10,000	**After work**	3,600		Down rate↓ (64.0%)		
Max generation discharge	m^3/s	14.32						
Effective head	M	85.50						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		2004						
Target structure(s)		T/G, spillway channel						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		T/G renewal						
(1) Current status		**(Before decision making)**						
1) General status		Replacement of about 70-year-old turbine generator. Since the commissioning as previously Takiyamagawa Power Plant (in 1959), the unit operated for low flowrate for its capacity at low utilization factor, and thus the machine was changed to the economically most optimal scale (maximum discharge: from 14.32 m3/s to 5.0 m3/s, and from 2 units to 1). Refurbishment for spillway channel was also performed to dissipate the spillage energy discharge when the generator is shut						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To renew the T/G and implement a safety measure (energy dissipation) of the spillage using the existing facility while considering the optimization of facility utilization factor (reduction of max generation discharge and integration of 2 T/G units into 1)						
(4) How decision-making was implemented and technologies adopted		Spillway structure utilizing the existing facilities and solution of multiple issues (aging, safety of spillway channel) were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2006.5)

084 Tateiwa Dam Spillway Gate Replacement

Plant name	打梨 (Uchinashi)						
Operation start	1939	**Completed**	2001		Age (62 years)		
Owner	Chugoku EPCo						
Country	Japan						
Max output kW	21,770	**After work**	-		New / no change		
Max generation discharge m^3/s	24.00						
Effective head m	115.24						
Decision-making type (○ where it applies)	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
		○					
Time of decision making	2000						
Target structure(s)	Spillway gate						
・Driver	Aging						
・Phenomena (caused by Driver)	Aging / efficiency decline						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Gate repair						
(1) Current status **1) General status** **2) Operation status** **3) Risk**	**(Before decision making)** Replacement of about 60-year-old spillway gate (all 6 steel radial gates of pure span of 5.8 m and door height of 4.8 m). Generation efficiency decline **Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To replace the spillway gates (all 6 in total) after considering the work period restricted by onsite conditions (to be undertaken in the river area).						
(4) How decision-making was implemented and technologies adopted	Work restricted by onsite conditions (to be undertaken in the river area) was considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2001.5)

085 Kobo Dam Spillway Gate Replacement

Plant name	神野瀬 (Kannose)						
Operation start	1945	**Completed**	2018		Age (73 years)		
Owner	Chugoku EPCo						
Country	Japan						
Max output kW	20,000	**After work**	-		New / no change		
Max generation discharge m^3/s	20.00						
Effective head m	121.08						
Decision-making type	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)		○					
Time of decision making	2013						
Target structure(s)	Spillway gate						
・Driver	Aging						
・Phenomena (caused by Driver)	Aging / efficiency decline						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Gate repair						
(1) Current status	**(Before decision making)**						
1) General status	Replacement of about 60-year-old spillway gate (all 5 steel radial gates of pure span of 8.0 m and door height of 5.5 m).						
2) Operation status	Generation efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To replace the spillway gates (all 5 in total) after considering the adequacy of hoisting heavy equipment, method of installing temporary structure, and work period restricted by onsite conditions (to be undertaken in the river area)						
(4) How decision-making was implemented and technologies adopted	Adequacy of hoisting heavy equipment suitable to the onsite conditions (movable crane was adopted), method of work with temporary structure (installed on the dam body), and work restrictions due to onsite conditions (to be undertaken in the river area) were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2013.11)

086 Intake Screen Replacement: Shin-Nariwagawa P/S

Plant name	新成羽川 (Shin-Nariwagawa)						
Operation start	1968	**Completed**	2011		Age (43 years)		
Owner	Chugoku EPCo						
Country	Japan						
Max output kW	303,000	**After work**	-		New / no change		
Max generation discharge m^3/s	424.00						
Effective head m	84.70						
Decision-making type (○ where it applies)	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
		○					
Time of decision making	2010						
Target structure(s)	Intake						
・Driver	Aging						
・Phenomena (caused by Driver)	Aging / efficiency decline						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Water way, etc. repair						
(1) Current status **1) General status** **2) Operation status** **3) Risk**	**(Before decision making)** Replacement of about 40-year-old intake screens (all 4 steel, cage-type fixed screens of 9.0 m in width, and 17.2 m (No.1) or 16.0 m (Nos.2-4) in vertical height). Generation efficiency decline **Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To replace the intake screens (all 4 in total) while considering the comparison of work methods, planning of coffering facilities, measures against vibration by Karman vortex around the intake screens, measures against corrosion by different metals in contact, coating specs (waterproofing and wear resistance), smoothing of part edges and welded sections (for longer anti-rust effect), etc.						
(4) How decision-making was implemented and technologies adopted	Clarification of trouble (fall, cracks, fracture) causes based on hydrological condition numerical analysis and screen vibration measurements (such as material fatigue due to Karman vortex) and parts specs (improved rigidity) were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2012.1)

087 Disaster Restoration: Ootagawa P/S

Plant name	太田川 (Ootagawa)						
Operation start	1961	**Completed**	2015		Age (54 years)		
Owner	Chugoku EPCo						
Country	Japan						
Max output kW	16,400	**After work**	-		New / no change		
Max generation discharge m^3/s	50.00						
Effective head m	39.12						
Decision-making type	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○				
Time of decision making	2014						
Target structure(s)	Water tank, spillway channel, trailrace						
・Driver	Disaster						
・Phenomena (caused by Driver)	Generation shutdown / efficiency decline						
Risk	Reduction						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Disaster (flood / heavy rain) restoration						
(1) Current status	**(Before decision making)**						
1) General status	The facilities were damaged by the local heavy rains and subsequent large-scale mud flow on August 19 and 20, 2014. Restorative and preventive work was undertaken to resume power generation such as restoration of the water tank, spillway channel, and tailrace, as well as clearing and preventing the clogging at the water tank and spillway channel (providing covers from the tank wall to 21 m downstream). Ground reinforcement (concrete retaining walls, slope frames and reinforcing bars) was given to the area around the tank for ensuring the safety						
2) Operation status	Generation shutdown / efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To perform the restorative and preventive work for the facility damage by the local heavy rains and subsequent large-scale mud flow in August 2014, including restoration of the water tank, spillway channel, and tailrace, clearing and preventing the clogging at the water tank and spillway channel, ground reinforcement around the tank for ensuring the safety after resuming the power generation, after considering the clogging preventive measures, temporary facility planning and secondary disaster prevention, etc.						
(4) How decision-making was implemented and technologies adopted	Measures against the clogging of water tank and spillway channel while realizing economic efficiency and shorter work period (cover installation was adopted), temporary facility planning for construction roads in view of workability and shorter work period (temporary piers were used) and secondary disaster preventive measures (alarm system and protective reinforcement) were considered and implemented accordingly.						

Reference documents / sources Electric Power Civil Engineering (2016.3)

088 Waterway Bridge Relocation: Toyokawa P/S

Plant name	豊川 (Toyokawa)						
Operation start	1928	**Completed**	2016		Age (88 years)		
Owner	Chugoku EPCo						
Country	Japan						
Max output kW	5,100	**After work**	-		New / no change		
Max generation discharge m^3/s	8.07						
Effective head m	77.47						
Decision-making type	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○				
Time of decision making	2013						
Target structure(s)	Waterway bridge						
・Driver	External factors						
・Phenomena (caused by Driver)	Flood safety improvement / local community cooperation						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Request from local community						
(1) Current status	**(Before decision making)**						
1) General status	A waterway bridge was relocated and replaced in conjunction with a national route widening project whereby some piers of the power generation waterway bridge needed to be removed, which was compensated by the road management bureau.						
2) Operation status	Generation shutdown / efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	Cooperation in refurbishing the national route						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To relocate (re-routing) the water pipe bridge with the compensation from the national route management bureau (in conjunction with a national route widening project whereby some piers of the power generation waterway bridge needed to be removed), while considering the basic policy, structural features, workability, river restrictions, economic comparison of various types, adoption of RFRPM pipe for future maintenance simplification, etc.						
(4) How decision-making was implemented and technologies adopted	Initially partial replacement was planned where the bridge piers interfered with the road construction, but the entire replacement was chosen as the new design did not meet the current river structure regulations of standard spans or blocking rate. The structural features, workability, river restrictions, economic comparison of various types, adoption of RFRPM pipe for future maintenance simplification, etc. were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2017.11)

089 Water Tank Refurbishment: Omogo No.1 P/S

Plant name		面河第一 (Omogo No.1)						
Operation start		1928	**Completed**	2006		Age (78 years)		
Owner		Shikoku EPCo						
Country		Japan						
Max output	kW	7,000	**After work**	-		New / no change		
Max generation discharge	m^3/s	9.79						
Effective head	m	91.19						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)		○						
Time of decision making		2005						
Target structure(s)		Water tank						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Water way, etc. repair						
(1) Current status		**(Before decision making)**						
1) General status		As the 90-year-old (commissioned in 1928) water tank continued to age and deteriorate, while water leakage increased due to Geiyo Earthquake in 2001, the water tank was refurbished. The required capacity was re-evaluated and the tank was downsized by 30% of the existing capacity.						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To refurbish the water tank in order to avoid leakage due to aging and earthquakes, after considering the re-evaluation of water tank capacity, maximum utilization of existing facilities, and control of water level changes and drift current due to tank downsizing						
(4) How decision-making was implemented and technologies adopted		Re-evaluation of water tank capacity necessary for the plant operation rules, maximum utilization of existing facilities, and control of water level changes and drift current due to tank downsizing were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering 2007.3

090 Yusuharagawa No.3 Power Plant Upgrading

Plant name		椿原川第三 (Yusuharagawa No.3)						
Operation start		1930	**Completed**	2008		Age (78 years)		
Owner		Shikoku EPCo						
Country		Japan						
Max output	kW	2,580	**After work**	-		New / no change		
Max generation discharge	m^3/s	7.79						
Effective head	m	41.80						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		2005						
Target structure(s)		T/G, penstock, headrace						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		T/G renewal						
(1) Current status		**(Before decision making)**						
1) General status		Aged 75 years, the aging deteriorations were manifest in various parts of the plant. The turbine generator was renewed, penstock / headrace tunnel reinforced, plant building elevated, and energy dissipating measures installed in the spillway channel.						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To renew the T/G, reinforce the penstock (with FRPM pipes for minimum maintenance) and headrace tunnel, elevate the plant site (in view of the inundation caused by the past typhoons) and in stall a spillage energy dissipator (as a safety measure for river visitors) against the manifested facility aging and degradation.						
(4) How decision-making was implemented and technologies adopted		Refurbishment was undertaken for the aging as a result of the remaining life diagnosis based on the penstock thickness investigation. FRPM pipes were selected for the penstock with minimum maintenance in mind, and spillway channel energy dissipator was installed utilizing the existing T/G chamber as a safety measure for river visitors. Also, in consideration for the past typhoon flooding data, the plant site was elevated.						

Reference documents / sources Electric Power Civil Engineering 2007.11

091 Tsuga Dam Gate Replacement

Plant name	津賀 (Tsuga)						
Operation start	1944	**Completed**	2009	Age (65 years)			
Owner	Shikoku EPCo						
Country	Japan						
Max output kW	18,650	**After work**	-	New / no change			
Max generation discharge m^3/s	23.91						
Effective head m	96.00						
Decision-making type	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)		○					
Time of decision making	2003						
Target structure(s)	Spillway gate						
・Driver	Aging						
・Phenomena (caused by Driver)	Aging / efficiency decline						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Gate repair						
(1) Current status	**(Before decision making)**						
1) General status	The spillway gate of a 70-year-old dam (completed in 1950) was aging. 10 spillway (steel radial) gates were replaced. The work was performed in dry season (from November to April) which was divided into 6 periods for work efficiency reasons.						
2) Operation status	Generation efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To replace the aged and degraded spillway gates (10 in total) in 6 divided work periods (from November to April) after considering the gate type, a change to highly reliable anchorage type, installation of temporary coffering and behaviour evaluation for installing pier concrete.						
(4) How decision-making was implemented and technologies adopted	The following issues and measures were considered and implemented: change to gate type for higher structural and maintainable specs (from gate type to π type), change to highly reliable anchorage type (from tension beam bearing plate to PC anchor intermediate bearing plate), installation of temporary coffering in front of gates to be replaced and adjacent gates (to prevent work interruptions due to flood and reduce the power generation loss during the work), and behaviour evaluation for installing pier concrete with uneven strength (wide-ranged distortion measurement using optical fiber sensor).						

Reference documents / sources Electric Power Civil Engineering 2005.3 Hydraulic Gate / Penstock N0.220

092 Kae Dam Gate Replacement

Plant name		加枝 (Kae)						
Operation start		1941	**Completed**	2005		Age (64 years)		
Owner		Shikoku EPCo						
Country		Japan						
Max output	kW	9,500	**After work**	-		New / no change		
Max generation discharge	m^3/s	29.00						
Effective head	m	39.50						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		2004						
Target structure(s)		Spillway gate						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Gate repair						

(1) Current status	**(Before decision making)**
1) General status	The spillway gate of a 80-year-old dam (completed in 1940) was aging. 4 spillway (steel roller) gates were replaced. The work was performed in one dry season (from November to April). Relatively new existing winches (open / close units) were utilized to minimize the replacement scale.
2) Operation status	Generation efficiency decline
3) Risk	**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction
(2) Priorities	RE utilization / securing profit
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To replace the aged and degraded spillway gates (4 in total) in the dry season (from November to April) after considering the minimization of replacement scale (by utilizing the existing open / close units, etc), temporary facilities in consideration for floods, work optimization, maintenance cost reduction after the refurbishment, etc.
(4) How decision-making was implemented and technologies adopted	The following issues and measures were considered and implemented: minimization of replacement scale by utilizing the existing open / close units, etc, use of assembled racks and transporting equipment in consideration for floods, work optimization by block division of gate doors, maintenance cost reduction by using stainless clad steel for skin plates, etc.

Reference documents / sources Electric Power Civil Engineering 2006.1 Hydraulic Gate / Penstock No

093 Penstock Replacement: Matsuogawa No.1 P/S

Plant name		松尾川第一 (Matsuogawa No.1)						
Operation start		1953	**Completed**	2005		Age (52 years)		
Owner		Shikoku EPCo						
Country		Japan						
Max output	kW	20,800	**After work**	-		New / no change		
Max generation discharge	m^3/s	6.30						
Effective head	m	382.40						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		2002						
Target structure(s)		Penstock						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Water way, etc. repair						
(1) Current status		**(Before decision making)**						
1) General status		About 70-year-old penstock (completed in 1953) was progressively aging. The replacement scale was the entire exposed section (1,080 m) of the total length of 1,097 m except the internal pipe section downstream the tank.						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To replace the entire exposed section (1,080 m) of the aged and degraded penstock of 1,097 m except the internal pipe section downstream the tank while considering the extremely severe work condition, efficient utilization of the existing structures, material / equipment transport, downsizing / elimination of assembly platforms, reduction of concrete work manhours by using double-pipe method, and adoption of internal reinforcing branching pipes.						
(4) How decision-making was implemented and technologies adopted		The following issues and measures were considered and implemented: extremely severe work condition in narrow, long steep slope with snowfalls in winter, efficient utilization of the existing structures (part of fixing racks), material / equipment transport with cable cranes (4 units, 6 lines) and inclines (2 units), downsizing / elimination of fixing racks with changed bearing method, reduction of concrete work manhours by using double-pipe method (patented No.4713898 as fixing method), and adoption of internal reinforcing branching pipes capable of loss reduction and external downsizing.						

Reference documents / sources Electric Power Civil Engineering 2005.3 Hydraulic Gate / Penstock N0.222

094 Omogo No.3 Dam Gate Roller Refurbishment

Plant name	面河第三 (Omogo No.3)						
Operation start	1984	**Completed**	2019		Age (35 years)		
Owner	Shikoku EPCo						
Country	Japan						
Max output kW	22,000	**After work**	-		New / no change		
Max generation discharge m^3/s	50.00						
Effective head m	52.00						
Decision-making type (○ where it applies)	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
			○				
Time of decision making	2019						
Target structure(s)	Spillway gate						
・Driver	Aging						
・Phenomena (caused by Driver)	Aging / efficiency decline						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Gate repair						
(1) Current status **1) General status** **2) Operation status** **3) Risk**	**(Before decision making)** Spillway gate aged about 30 years, which has performed a large number of discharges, about 20 times a year. Bending deformation was found on the key plate for fixing the lower-most roller axis of the steel roller gate which was supposed due to co-rotation of the roller and axis, and thus the roller part was replaced. Generation efficiency decline **Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To replace the defective roller part of the steel roller gates (for spillway) along with the changes in the roller shaft fixing type after considering the estimated causes, measures, etc.						
(4) How decision-making was implemented and technologies adopted	The following issues and measures were considered and implemented: estimation of causes based on the results of defect status observation and disassembly investigation of the roller part such as water or sand mixing with old grease, loss of part of bearing, deformation of key plate or bolts, and the countermeasures (such as changing the roller fixation method).						

Reference documents / sources No.354 Electric Power Civil Engineering 2011

095 Spillway Channel Refurbishment: Bunsui No.4 P/S

Plant name	分水第四 (Bunsuidaiyon)						
Operation start	1950	**Completed**	2005		Age (55 years)		
Owner	Shikoku EPCo						
Country	Japan						
Max output kW	8,100	**After work**	-		New / no change		
Max generation discharge m^3/s	16.00						
Effective head m	58.20						
Decision-making type	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○				
Time of decision making	2004						
Target structure(s)	Spillway channel						
・Driver	Disaster						
・Phenomena (caused by Driver)	Generation shutdown / efficiency decline						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Public disaster risk reduction						
(1) Current status	**(Before decision making)**						
1) General status	Spillage in cases of plant trip event was discharged from the siphon spillway to the stream near the water tank. Permanent safety improvement work was undertaken for a new spillway channel system using the existing siphon spillway connected with pipe on the downstream slope and part of the national route, leading to the discharge channel with an impact type energy dissipator.						
2) Operation status	Generation shutdown / efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To perform a safety improvement work of newly installing a new spillway channel system using the existing spillway connected with pipe on the downstream slope and part of the national route, leading to the existing discharge channel with an impact type energy dissipator while considering the verification of discharge capacity of existing spillway, optimal design of spillway channel (based on hydrological model experiments), onsite demonstration test after work completion, assurance of work safety by using high elevation slope excavator, etc.						
(4) How decision-making was implemented and technologies adopted	The following issues and measures were considered and implemented: verification of discharge capacity of existing siphon spillway (by plant emergency shutdown test during maximum capacity operation), optimal design of spillway channel (observation of water surface profile inside the spillway channel and review of basic design of impact energy dissipator by hydrological model experiments), onsite demonstration test after work completion, and assurance of work safety by using high elevation slope excavator for ground cutting of the spillway channel on steep slopes.						

Reference documents / sources Electric Power Civil Engineering 2006.7

096 Spillwater Discharge Facility Installation: Kirikoshi P/S

Plant name	切越 (Kirikoshi)						
Operation start	1931	**Completed**	2004		Age (73 years)		
Owner	Shikoku EPCo						
Country	Japan						
Max output kW	4,500	**After work**	-		New / no change		
Max generation discharge m^3/s	2.78						
Effective head m	185.15						
Decision-making type	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○				
Time of decision making	2003						
Target structure(s)	Spillway channel						
・Driver	Disaster						
・Phenomena (caused by Driver)	Generation shutdown / efficiency decline						
Risk	Reduction						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Public disaster risk reduction						
(1) Current status	**(Before decision making)**						
1) General status	New installation of spillage discharge facility (valve, spillway channel, energy dissipating tank) capable of discharging to the river bypassing the turbine in the same manner in generation mode even in cases of plant trip event, instead of the conventional discharging operation from the dam spillway. The unused penstock (cut off and blocked at the branching section) and tailrace (blocked with concrete, etc) after the past turbine generator refurbishment (reducing from 2 to 1 unit) were utilized, and the above facility was installed inside the existing powerhouse building.						
2) Operation status	Generation shutdown / efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To install a spillage discharge facility with a discharge valve and energy dissipating tank to prevent the danger for the river visitors while considering the recycling of the unused and tailrace after the past T/G refurbishment (reducing from 2 to 1 unit), energy dissipating effect by hydrological model experiments and downsizing the energy dissipating pond.						
(4) How decision-making was implemented and technologies adopted	The following issues and measures were considered and implemented: reduction of energy dissipating pond space by using fixed cone valve with energy dissipating box, utilization of the available spaces of the former turbine generator and tailrace, confirmation of optimal shapes and energy dissipating effect by hydrological model experiments, confirmation of energy dissipating effect, noise, vibration by onsite test after work completion.						

Reference documents / sources Electric Power Civil Engineering 2005.3

097 Nagasawa Reservoir Water Shielding Sheet Installation

Plant name	長沢 (Nagasawa)						
Operation start	1949	**Completed**	2005		Age (56 years)		
Owner	Shikoku EPCo						
Country	Japan						
Max output kW	5,200	**After work**	-		New / no change		
Max generation discharge m^3/s	9.50						
Effective head m	64.94						
Decision-making type (○ **where it applies)**	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
			○				
Time of decision making	2005						
Target structure(s)	Reservoir						
・Driver	External factors						
・Phenomena (caused by Driver)	Environmental improvement / local community cooperation						
Risk	Reduction						
・Risks for plant operation	Environmental degradation / discord with local community						
・Specific risk management	Turbid water prevention sheet						
(1) Current status	**(Before decision making)**						
1) General status	Impermeable water shielding sheets (fences) were installed by suspending them from the floats in the reservoir to reduce the prolonged water turbidity period in the dam reservoir (keeping clear water on the surface area downstream the fences and discharging the turbid water quickly in cases of flood)						
2) Operation status	Environmental degradation						
3) Risk	**Potential risk in case of no decision making** Environmental degradation / discord with local community / opposition to power generation **Potential risk when implementing decision making** No effect, cost increase / profit reduction						
(2) Priorities	Environmental improvement						
(3) Strategy	**Against potential risk in case of no decision making** (Continued coordination with local communities on long-term turbid water) **Against potential risk when implementing decision making** To install impermeable water shielding sheets (suspended fences) to reduce the prolonged water turbidity period in the dam reservoir, after considering the optimal fence specs and design methods by hydrological model experiments and numerical analyses, etc.						
(4) How decision-making was implemented and technologies adopted	The following issues and measures were considered and implemented: optimal fence specs and design methods by hydrological model experiments (assessment method of fence installation location against turbid water and installation method of anti-turbidity fences using the said assessment method, patented No. 48612-3).						

Reference documents / sources Electric Power Civil Engineering 2007.5Electricity Review2013.11

098 Myodani Dam Refurbishment

Plant name		切越 (Kirikoshi)						
Operation start		1931	**Completed**	2017		Age (86 years)		
Owner		Shikoku EPCo						
Country		Japan						
Max output	kW	4,500	**After work**	-		New / no change		
Max generation discharge	m^3/s	2.78						
Effective head	m	185.15						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)				○				
Time of decision making		2015						
Target structure(s)		Spillway gate						
・Driver		Asset optimization & Review of operation						
・Phenomena (caused by Driver)		Generation efficiency improvement / higher management efficiency						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Management labor saving						
(1) Current status		**(Before decision making)**						
1) General status		Excessive labor was necessary for dam management due to the small basin area, short time from rainfall to discharge, and frequent operation of the spillway gate. Thus refurbishment was undertaken for the spillway by changing it from the gate discharge to natural overflow (gateless) type when the major renewal project for main facilities was carried out.						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To perform dam gateless modification for solving the issue of dam maintenance (labor saving) after planning and designing the dam body and intake in full consideration of the safety upstream / downstream the dam, energy generation, sedimentation progress caused by mud inflow, facility damage, etc.						
(4) How decision-making was implemented and technologies adopted		The following issues and measures were considered and implemented: abolition of existing spillway gate and operation bridge, partial abolition of dam / pier concrete, elevation heightening of overflow section, new installation of intake auto debris remover and control bridge for maintenance labor saving, review of design flood discharge, confirmation of flood levels and overflow shape by hydrological model experiments and installation of diversion unit for safety in flood situations.						

Reference documents / sources Electric Power Civil Engineering (2018.3)

099 Morotsuka Dam Foundation Discharge Hole Improvement

Plant name		諸塚 (Morotsuka)						
Operation start		1961	**Completed**	2013		Age (52 years)		
Owner		Kyushu EPCo						
Country		Japan						
Max output	kW	50,000	**After work**	-		New / no change		
Max generation discharge	m^3/s	27.00						
Effective head	m	225.40						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)		○						
Time of decision making		2013						
Target structure(s)		Dam						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Reduction						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Dam reservoir repair						
(1) Current status		**(Before decision making)**						
1) General status		Re-boring and new boring (Extension of new discharge holes) were undertaken for the discharge holes of about 50-year-old dam in order to reduce the uplift pressure.						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To implement a measure to reduce the uplift pressure by re-boring and new boring of the existing discharge holes (Extension of new discharge holes after considering the optimal work methods inside the dam inspection gallery.						
(4) How decision-making was implemented and technologies		Work inside dam inspection gallery and selection of optimal measures were considered and implemented.						

Reference documents / sourcesadopted Electric Power Civil Engineering (2014.11)

100 Intake Weir Refurbishment for Progressive Sedimentation: Onagohata P/S

Plant name		女子畑 (Onagohata)						
Operation start		1926	**Completed**	2020		Age (94 years)		
Owner		Kyushu EPCo						
Country		Japan						
Max output	kW	29,500	**After work**	-		New / no change		
Max generation discharge	m^3/s	49.62						
Effective head	m	52.50						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)				○				
Time of decision making		2016						
Target structure(s)		Dam						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Dam reservoir repair						
(1) Current status		**(Before decision making)**						
1) General status		The existing intake weir aged about 90 years was demolished and a new movable weir was installed to improve the flood handling function.						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To demolish the aged and degraded existing intake weir and newly installed fixed weir + movable weir unit to improve the flood resistance function after comparative assessment of weir types (economy, operability, flowrate adjustment function, maintenance cost, etc), and conducting 2-dimensional unsteady flow analysis for the apron and bottom protection.						
(4) How decision-making was implemented and technologies adopted		Comparative assessment was conducted for ① fixed weir + movable weir, ② 3 roller gates, and ③ 2 steel inflatable gates, while 2-dimensional unsteady flow analysis was conducted for the apron and bottom protection.						

Reference documents / sources Electric Power Civil Engineering (2017.7)

101 Spillway Gate Replacement: Tsukabaru P/S

Plant name		塚原 (Tsukabaru)						
Operation start		1938	**Completed**	2008		Age (70 years)		
Owner		Kyushu EPCo						
Country		Japan						
Max output	kW	62,600	**After work**	-		New / no change		
Max generation discharge	m^3/s	73.80						
Effective head	m	100.08						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)				○				
Time of decision making		2004						
Target structure(s)		Spillway gate						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Gate repair						
(1) Current status		**(Before decision making)**						
1) General status		About 70-year-old (constructed in 1938) spillway gates (8 steel radial gate) were replaced for the concerns about the wear of trunnion pins and upgrading the discharge capacity.						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To renew the aged spillway gates after considering the gate facility renewal plan (adoption of structurally and dynamically simple panel designs, adoption of vertical assisting girder / horizontal main girder structure in consideration for the door shape and dimensions, enabling the plant operation even during the refurbishment, and the replacement with water stored in the dam reservoir)						
(4) How decision-making was implemented and technologies adopted		The following issues and measures were considered and implemented: gate facility renewal plan (gate arrangement and dimensions designed basically for the design flood discharge, as well as the recorded largest flowrate of 2,745 m3/s (by Typhoon No.19 in 1997) exceeding the design flood), adoption of structurally and dynamically simple panel designs, adoption of vertical assisting girder / horizontal main girder structure in consideration for the door shape and dimensions, enabling the plant operation even during the refurbishment (installing temporary coffering upstream of the gates to be replaced), and the replacement with water stored in the dam reservoir.						

Reference documents / sources Electric Power Civil Engineering (2008.5)

102 Tsukabaru Power Plant General Renewal

Plant name	塚原 (Tsukabaru)						
Operation start	1938		**Completed**	2019		Age (81 years)	
Owner	Kyushu EPCo						
Country	Japan						
Max output kW	62,600		**After work**	66,600		Up rate↑ (6.4%)	
Max generation discharge m^3/s	73.80						
Effective head m	100.08						
Decision-making type	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)					○		
Time of decision making	2014						
Target structure(s)	Penstock, T/G, power plant, etc						
・Driver	Aging						
・Phenomena (caused by Driver)	Aging / efficiency decline						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	T/G redevelopment						
(1) Current status **1) General status** **2) Operation status** **3) Risk**	**(Before decision making)** Aged 76 years, the severely degraded turbine generator, building, etc were renewed. Also the plant was relocated to a nearby area due to the inundation damage caused by record-breaking rainfalls and floods in Typhoon No.14 in September 2005. Generation efficiency decline **Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To relocate the plant with aged T/G units and buildings which were damaged by the record-breaking rainfalls and floods in September 2005 while considering the backwater calculations, new outlet location, 3-D flow analysis in the water pipe, work in extremely narrow areas (adjacent to a number of residential houses and public roads), work while the existing plant continues to operate, construction of large cross-section tunnel under the national route (safety designing of timber patterns), tunnel construction with shallow earth covering going across under the tributary, etc.						
(4) How decision-making was implemented and technologies adopted	The following issues and measures were considered and implemented: work in extremely narrow areas adjacent to a number of residential houses and public roads, work while the existing plant continues to operate, construction of large cross-section tunnel under the national route, construction of a tunnel with shallow earth covering going across under the tributary, etc.						

Reference documents / sources Electric Power Civil Engineering (2014.7)

103 Shinkousa Power Plant New Construction

Plant name	新甲佐 (Shinkousa)						
Operation start	1951		**Completed**	2019		Age (68 years)	
Owner	Kyushu EPCo						
Country	Japan						
Max output kW	3,900		**After work**	7,200		Up rate↑ (84.6%)	
Max generation discharge m^3/s	19.30						
Effective head m	25.10						
Decision-making type (○ where it applies)	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
					○		
Time of decision making	2012						
Target structure(s)	Penstock, T/G, power plant, etc						
・Driver	Aging						
・Phenomena (caused by Driver)	Aging / efficiency decline						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	T/G redevelopment						
(1) Current status	**(Before decision making)**						
1) General status	Redevelopment of 61-year-old, deteriorating power plant while upgrading the maximum discharge (from 19.3 to 35.0 m3/s) and maximum output (from 3,900 to 7,200 kW).						
2) Operation status	Generation efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** To expand the width of existing headrace tunnel **Against potential risk when implementing decision making** To redevelop the aged and degraded power plant (by increasing the maximum generation discharge and output) after considering the work while the existing power plant keeps operating to the extent possible, work in proximity to the existing headrace, cost reduction, and solution of multiple issues (aging, safety spillway channel, measures against inundation of plant facilities), underwater level monitoring during the new headrace excavation against the depletion of spring water, landscape, conservation of animals and plants, maintenance of water cleanliness, etc.						
(4) How decision-making was implemented and technologies adopted	Work while the existing power plant keeps operating to the extent possible for securing supply capacity, work in proximity to the existing headrace, cost reduction, and solution of multiple issues (aging, safety spillway channel, measures against inundation of plant facilities) were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2014.7/2015.9)

104 Shinnaongawa Power Plant New Construction

Plant name		新名音川 (Shinnaongawa)						
Operation start		1956	**Completed**	2016		Age (60 years)		
Owner		Kyushu EPCo						
Country		Japan						
Max output	kW	7	**After work**	370		Up rate个 (5592.3%)		
Max generation discharge	m^3/s	0.14						
Effective head	m	77.77						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)						○		
Time of decision making		2014						
Target structure(s)		Headrace, penstock, T/G, etc						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		T/G redevelopment						
(1) Current status		**(Before decision making)**						
1) General status		Redevelopment of 58-year-old, deteriorating power plant while upgrading the maximum discharge (from 0.138 to 0.600 m3/s) and maximum output (from 65 to 370 kW).						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To redevelop the aged and degraded power plant (by increasing the maximum generation discharge and output) after considering the recycling use of existing intake facility, powerhouse building (partially expanded), conservation of rare species, measures against being bitten by snakes, and installation of access						
(4) How decision-making was implemented and technologies adopted		Conservation of rare animal and plant species, countermeasure against being bitten by animals including viper, securing access roads, etc were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2016.1)

105 Kamishiiba Power Plant Restoration

Plant name	上椎葉 (Kamishiiba)						
Operation start	1955	**Completed**	2010		Age (55 years)		
Owner	Kyushu EPCo						
Country	Japan						
Max output kW	93,200	**After work**	-		New / no change		
Max generation discharge m^3/s	73.00						
Effective head m	144.00						
Decision-making type	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)		○					
Time of decision making	2005						
Target structure(s)	Power plant, T/G						
・Driver	Disaster						
・Phenomena (caused by Driver)	Generation shutdown / efficiency decline						
Risk	Reduction						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Disaster (flood / heavy rain) restoration						
(1) Current status	**(Before decision making)**						
1) General status	Typhoon No.14 in September 2005 causes serious damage to the plant such as inundation of the turbine generator, burnout and destruction of other facilities. Relatively lightly damaged turbine generator of Unit No.2 was washed, dried and maintained to operate tentatively, while that of Unit No.1 was replaced. The tentatively restored No.2 was severely aged and degraded, and thus it was replaced after Unit No.1.						
2) Operation status	Generation shutdown / efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To renew the T/G, etc. seriously damaged by Typhoon No.14 in September 2005 while considering the effect of fires, impact on the river environment, simplified facility configuration, adoption of high-efficiency runners, increased output by improved generator efficiency, improved maintainability by using power-driven guide vane motor and inlet servo motor thus eliminating hydraulic units, etc.						
(4) How decision-making was implemented and technologies adopted	The power plant was important for demand-supply control and water system management, and thus long-term shutdown would restrict the water management of downstream plants and waste the power generation opportunity with dam discharge. Therefore urgent correspondence was necessary also for reducing the lost water resources. In such a situation, the following issues and measures were considered and implemented: effect of fires, impact on the river environment, simplified facility configuration, adoption of high-efficiency runners, increased output by improved generator efficiency (from 90,000 kW (45,000 kW × 2 units) to 93,200 kW (46,600 kW × 2 units)), and environmental load reduction and improved maintainability by using power-driven guide vane motor and inlet servo motor thus eliminating hydraulic units.						

Reference documents / sources Electric Power Civil Engineering (2010.9)

106 Yamashitaike Dam Restoration

Plant name	畑 (Hata)						
Operation start	1918	**Completed**	2007	Age (89 years)			
Owner	Kyushu EPCo						
Country	Japan						
Max output kW	950	**After work**	-	New / no change			
Max generation discharge m^3/s	1.39						
Effective head m	90.90						
Decision-making type	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○				
Time of decision making	2006						
Target structure(s)	Dam (low dam modification)						
・Driver	Disaster						
・Phenomena (caused by Driver)	Generation shutdown / efficiency decline						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Disaster (flood / heavy rain) restoration						
(1) Current status **1) General status** **2) Operation status** **3) Risk**	**(Before decision making)** Typhoon No.14 in September 2005 caused surface layer slippage in part of the dam body back side, which required refurbishment (low dam modification). Generation shutdown / efficiency decline **Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To refurbish the dam (lowering the height) as its surface layer slipped in part due to Typhoon No.14 in September 2005 after considering the prevention of the seepage line from seeping over to the downstream slope of the dam body due to						
(4) How decision-making was implemented and technologies adopted	Prevention of the seepage line from seeping over to the downstream slope of the dam body due to rainwater penetration and improved safety of downstream slopes were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2008.5)

107 Nishihata Dam Refurbishment

Plant name	新菅原 (Shinsugawara)						
Operation start	1958	**Completed**	2017		Age (59 years)		
Owner	Kyushu EPCo						
Country	Japan						
Max output kW	7,500	**After work**	-		New / no change		
Max generation discharge m^3/s	5.50						
Effective head m	164.10						
Decision-making type	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○				
Time of decision making	2012						
Target structure(s)	Dam (gateless modification)						
・Driver	Disaster						
・Phenomena (caused by Driver)	Generation shutdown / efficiency decline						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Disaster (flood / heavy rain) restoration						
(1) Current status	**(Before decision making)**						
1) General status	As the record-breaking heavy rains by Typhoon No.5 in August 2007 damaged the dam operation office building, etc, the existing spillway gate was removed, implementing gateless modification.						
2) Operation status	Generation shutdown / efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To remove the spillway gates (gateless modification) from the dam which was damaged by Typhoon No.5 in August 2007 after considering the securing of discharge capacity, ensuring of safety of impermeable walls, and improvement in damage control operation.						
(4) How decision-making was implemented and technologies adopted	Securing discharge capacity as the facility-related issue, ensuring safety of impermeable walls, and improvement in damage control operation such as gate discharge operability were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2013.5)

108 Intake Facility, etc Restoration: Kawabegawa No.1 P/S

Plant name	川辺川第一 (Kawabegawa No.1)						
Operation start	1937	**Completed**	2012		Age (75 years)		
Owner	Kyushu EPCo						
Country	Japan						
Max output kW	2,500	**After work**	-		New / no change		
Max generation discharge m^3/s	16.10						
Effective head m	19.60						
Decision-making type	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○				
Time of decision making	2008						
Target structure(s)	Intake weir, fishway, intake						
・Driver	Disaster						
・Phenomena (caused by Driver)	Generation shutdown / efficiency decline						
Risk	Reduction						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Disaster (flood / heavy rain) restoration						
(1) Current status **1) General status**	**(Before decision making)** New installation of spillage discharge facility (valve, spillway channel, energy dissipating tank) capable of discharging to the river bypassing the turbine in the same manner in generation mode even in cases of plant trip event, instead of the conventional discharging operation from the dam spillway. The unused penstock (cut off and blocked at the branching section) and tailrace (blocked with concrete, etc) after the past turbine generator refurbishment (reducing from 2 to 1 unit) were utilized, and the above facility was installed inside the existing powerhouse building.						
2) Operation status	Generation shutdown / efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To remove the broken facility debris from river, prevent the extended damage to the facilities and restore the entire plant due to the damage to the intake facility, etc by the seasonal rain front in June 2008, after considering the caused identified, prevention of damage extension, work period, safe and efficient work inside the river, etc.						
(4) How decision-making was implemented and technologies adopted	The following issues and measures were considered and implemented: reduction of energy dissipating pond space by using fixed cone valve with energy dissipating box, utilization of the available spaces of the former T/G and tailrace, confirmation of optimal shapes and energy dissipating effect by hydrological model experiments, confirmation of energy dissipating effect, noise, vibration by onsite test after work completion.						

Reference documents / sources Electric Power Civil Engineering (2010.3）、NEF Practical Training (2013.2)

109 Yamasubaru Dam Refurbishment

Plant name	山須原 (Yamasubaru)						
Operation start	1932	**Completed**	2022		Age (90 years)		
Owner	Kyushu EPCo						
Country	Japan						
Max output kW	40,700	**After work**	-		New / no change		
Max generation discharge m^3/s	120.00						
Effective head m	40.70						
Decision-making type (○ where it applies)	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
			○				
Time of decision making	2011						
Target structure(s)	Spillway gate						
・Driver	Disaster						
・Phenomena (caused by Driver)	Generation shutdown / efficiency decline						
Risk	Reduction						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Flood disaster risk reduction						
(1) Current status **1) General status** **2) Operation status** **3) Risk**	**(Before decision making)** For the purpose of adding a sand passage function to the existing spillway gate, the overflow crown of the dam was cut down, and modified to a large spillway. Generation shutdown / efficiency decline **Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** To thicken dam body and pier width to ensure dam stability **Against potential risk when implementing decision making** To refurbish the dam by cutting down the dam overflow crest and installing large spillway gates with a flushing function after considering the work while power generation and dam operation continue and the countermeasures against large volume of flowing tress in front of the dam.						
(4) How decision-making was implemented and technologies adopted	Work while power generation and dam operation were continued (river water detour, diverting unit for securing water permeability during flood discharges, installation / operation of coffering gate) and countermeasures against large volume of flowing tress in front of the dam were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2012.9)

110 Saigo Dam Refurbishment

Plant name		西郷 (Saigo)						
Operation start		1929	**Completed**	2018		Age (89 years)		
Owner		Kyushu EPCo						
Country		Japan						
Max output	kW	27,100	**After work**	-		New / no change		
Max generation discharge	m^3/s	120.00						
Effective head	m	27.27						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)				○				
Time of decision making		2011						
Target structure(s)		Spillway gate						
・Driver		Disaster						
・Phenomena (caused by Driver)		Generation shutdown / efficiency decline						
Risk		Reduction						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Flood disaster risk reduction						
(1) Current status		**(Before decision making)**						
1) General status		Excessive labor was necessary for dam management due to the small basin area, short time from rainfall to discharge, and frequent operation of the spillway gate. Thus refurbishment was undertaken for the spillway by changing it from the gate discharge to natural overflow (gateless) type when the major renewal project for main facilities was carried out.						
2) Operation status		Generation shutdown / efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To refurbish the dam by cutting down the dam overflow crest and installing large spillway gates with a flushing function after considering the work plan while power generation and dam operation continue.						
(4) How decision-making was implemented and technologies adopted		The following issues and measures were considered and implemented: abolition of existing spillway gate and operation bridge, partial abolition of dam / pier concrete, elevation heightening of overflow section, new installation of intake auto debris remover and control bridge for maintenance labor saving, review of design flood discharge, confirmation of flood levels and overflow shape by hydrological model experiments and installation of diversion unit for safety in flood situations.						

Reference documents / sources Electric Power Civil Engineering (2012.9/ 2013.7, 9

111 Selective Intake Facility Refurbishment: Hitotsuse P/S

Plant name		一ツ瀬 (Hitotsuse)						
Operation start		1963		**Completed**	2002		Age (39 years)	
Owner		Kyushu EPCo						
Country		Japan						
Max output	kW	180,000		**After work**	-		New / no change	
Max generation discharge	m^3/s	137.00						
Effective head	m	151.99						
Decision-making type (○ where it applies)		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
				○				
Time of decision making		1999						
Target structure(s)		Reservoir						
・Driver		External factors						
・Phenomena (caused by Driver)		Environmental improvement / local community cooperation						
Risk		Reduction						
・Risks for plant operation		Environmental degradation / discord with local community						
・Specific risk management		Surface / selective intake facility						
(1) Current status		**(Before decision making)**						
1) General status		Typhoon No.14 in September 2005 manifested the long-term turbidity issue. Further measures against turbid water were taken in response to the quantitative analysis results for the measures taken thus far.						
2) Operation status		Environmental degradation						
3) Risk		**Potential risk in case of no decision making** Environmental degradation / discord with local community / opposition to power generation Potential risk when implementing decision making No effect, cost increase / profit reduction						
(2) Priorities		Environmental improvement						
(3) Strategy		**Against potential risk in case of no decision making** (Continued coordination with local communities on long-term turbid water) **Against potential risk when implementing decision making** To implement refurbishment of the emergency discharge facility and countermeasures in the upstream area (tree-planting at collapsed mountain slopes) against the long-term turbid water, while considering the quantitative effect analysis of measures taken already, discussions held by the inhouse technical examination group with experts and a turbid water advisory committee consisting of Miyazaki Prefecture, local municipalities in the basin, and experts, simulative effect predictions, environmental assessment of the downstream area, etc.						

(4) How decision-making was implemented and technologies adopted	Inhouse technical examination group with experts and a turbid water advisory committee consisting of Miyazaki Prefecture, local municipalities in the basin, and experts discussed the following items on the agenda for long-term water turbidity: ① basic measure is to control the generating sources of turbid water and reduce the retention of turbid water, ② in the reservoir, the basic measures is to control long-term turbid water by selective intake and discharge, ③ winter current flow, however, is a dominant cause of long-term turbidity which mixes the surface clear wate with turbid water to make selective intake difficult, ④ and therefore, to implement water level lowering measures by using emergency discharge facility beyond the limit of power generation operation and mandatory discharge in case large quantity of turbid water flows in due to large floods. The above proposals, simulative effect prediction on the turbid water, environmental assessment of the downstream area, modification of emergency discharge facility, correspondence by the upstream measures, etc were considered and implemented.

Reference documents / sources Electric Power Civil Engineering (2008.9)

112 Civil Engineering Facilities Relocation for Kasegawa Dam Construction: Ayunose

Plant name		鮎の瀬 (Ayunose)						
Operation start		1958	**Completed**	2011		Age (53 years)		
Owner		Kyushu EPCo						
Country		Japan						
Max output	kW	17,600	**After work**	-		New / no change		
Max generation discharge	m^3/s	11.00						
Effective head	m	192.00						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)						○		
Time of decision making		2010						
Target structure(s)		Dam, settling basin						
・Driver		External factors						
・Phenomena (caused by Driver)		Flood safety improvement / local community cooperation						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Utilization of part of existing plant						

(1) Current status

(Before decision making)

1) General status

Countermeasures against inundation by impermeable walls and bulkheads in preparation for the water level rise caused by the construction of Kasegawa Dam (by Ministry of Land, Infrastructure, Transport and Tourism) downstream.

2) Operation status

Generation shutdown / efficiency decline

3) Risk

Potential risk in case of no decision making

Generation shutdown / efficiency decline

Potential risk when implementing decision making

Cost increase / profit reduction

(2) Priorities

Cooperative improvement in flood control safety

(3) Strategy

Against potential risk in case of no decision making

(None)

Against potential risk when implementing decision making

To implement the countermeasures against the possible inundation by installing impermeable walls and bulkheads in preparation for the water level rise caused by the construction of Kasegawa Dam (by Ministry of Land, Infrastructure, Transport and Tourism) after considering the comparison of utilization of the existing headrace facilities and new installation thereof, and further utilization of other existing facilities, etc.

(4) How decision-making was implemented and technologies adopted

Comparison of utilizing the existing facilities and installation of new headrace tunnel for the refurbishment of the headrace (from the first culvert to settling basin) and utilization of other existing facilities (conversion of the first culvert into open box culvert, settling basin, structuring of impermeable walls / bulkheads) were considered and implemented.

Reference documents / sources Electric Power Civil Engineering (2012.1)

113 Surge Tank Cracks Repair: Tedorigawa No.1 P/S

Plant name		手取川第一 (Tedorigawa No.1)						
Operation start		1979	**Completed**	2002		Age (23 years)		
Owner		J-Power						
Country		Japan						
Max output	kW	250,000	**After work**	-		New / no change		
Max generation discharge	m^3/s	180.00						
Effective head	m	162.40						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)		○						
Time of decision making		2002						
Target structure(s)		Surge tank						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Reduction						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Water way, etc. repair						

(1) Current status	**(Before decision making)**
1) General status	For the cracks generated in the concrete structures in the upper part of the surge tank aged about 20 years, the method of machine spraying special acrylic resin material was used to prevent the water permeation in the concrete surface and the extension of cracks.
2) Operation status	Generation efficiency decline
3) Risk	**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction
(2) Priorities	RE utilization / securing profit
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To implement the preventive measures against the crack extension in the concrete structures in the upper part of the surge tank by machine spraying special acrylic resin material, after considering the repair material characteristics, spraying work performance, shorter work period, cautions involved, etc.
(4) How decision-making was implemented and technologies adopted	Characteristics of filling material (① low viscosity allowing infiltration inside from the cracks, adhesion and filling the crevices, ② low elastic coefficient allowing follow-up on concrete expansion / contraction, ③ high adhesive strength making it hard to be peeled off against crack progression, ④ water-proof, impermeable, ⑤ effective in 1-2 hours not requiring curing time), improved workability and shorter work time due to spraying application, cautions (necessary to verify as a filling material through use results), etc were considered and implemented.

Reference documents / sources Electric Power Civil Engineering (2003.7)

114 Turbine Generator Renewal: Nukabira P/S

Plant name		糠平 (Nukabira)						
Operation start		1956	**Completed**	2009		Age (53 years)		
Owner		J-Power						
Country		Japan						
Max output	kW	42,000	**After work**	44,200		Up rate↑ (5.2%)		
Max generation discharge	m^3/s	45.00						
Effective head	m	110.39						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		2006						
Target structure(s)		T/G, etc						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		T/G renewal						
(1) Current status		**(Before decision making)**						
1) General status		Complete renewal of 50-year-old, degraded turbine generator. The generation efficiency to be improved by about 6% (from 42,000 kW to 44,200 kW). The concrete around the generator was destroyed.						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To complete renew the degraded turbine generator in order to improve the generation efficiency after considering the destruction / restoration methods in view of the reinforcement bars and buried items, control monitoring during the work, etc.						
(4) How decision-making was implemented and technologies adopted		Destruction / restoration in consideration for the pipes and buried items, design change after finding the diameter of reinforcing bars to be recycled in restoration of slab concrete was smaller than estimation, control monitoring during the work (measuring vibration, displacement of outer walls, penstock surface temperature), etc were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2007.11)

115 Turbine Generator Renewal: Tagokura P/S

Plant name		田子倉 (Tagokura)						
Operation start		1959	**Completed**	2002		Age (43 years)		
Owner		J-Power						
Country		Japan						
Max output	kW	380,000	**After work**	400,000		Up rate↑ (5.3%)		
Max generation discharge	m^3/s	420.00						
Effective head	m	105.00						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		2004						
Target structure(s)		T/G, etc						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		T/G renewal						
(1) Current status		**(Before decision making)**						
1) General status		Complete renewal of 50-year-old, degraded turbine generator. The generation efficiency to be improved by about 6% (from 380 kW to 400 kW). Renewal of all 4 units of turbine generator. Minimization of renewal scale by utilizing most of the existing casing, reduction of waste materials, shortening of work period and cost reduction were carried out.						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To complete renew the degraded turbine generator (to improve the generation efficiency) while recycling most of the existing casing (for minimization of renewal scale and reduction of waste materials, shortening of work period and cost reduction) after considering the work method in narrow spaces, shorter work period, reducing the waste materials, etc.						
(4) How decision-making was implemented and technologies adopted		Work method in narrow spaces, shorter work period, replacement of only the inside the casing for reducing the waste materials, etc. were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2005.9/2006.7/2008.7)

116 Spillway Retaining Walls Restoration: Yanase P/S

Plant name	魚梁瀬 (Yanase)						
Operation start	1965	**Completed**	2016		Age (51 years)		
Owner	J-Power						
Country	Japan						
Max output kW	36,000	**After work**	-		New / no change		
Max generation discharge m^3/s	50.00						
Effective head m	85.10						
Decision-making type	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○				
Time of decision making	2014						
Target structure(s)	Spillway						
・Driver	Aging						
・Phenomena (caused by Driver)	Aging / efficiency decline						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Dam reservoir repair						
(1) Current status	**(Before decision making)**						
1) General status	For the displacement of the flow channel side of the spillway side wall and partial flaking in the concrete near the bottom of the said side wall in a dam aged about 50 years, shear reinforcement and strut installation were performed for preventing the displacement progress.						
2) Operation status	Generation efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To perform a restoration project for the displacement of the flow channel side of the spillway side wall and partial flaking in the concrete near the bottom of the said side wall in a dam side wall by shear reinforcement, strut installation after considering the ensuring of the required shear strength, side wall displacement control, prevention of temperature-induced expansion and contraction of the short struts, etc.						
(4) How decision-making was implemented and technologies adopted	Adoption of ceramic cap bars (CCb) wherein ceramic caps are attached at the bar edges with epoxy resin for securing the shear strength to reinforce the side walls, adoption of cold-press formed angular tubes (BCP235) a short struts installed for preventing dislocation of the side walls, use of heat-shielding / heat-insulating paint (Cooltherm) as a middle coat for preventing temperature-induced expansion and contraction of the short struts, etc were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2016.9)

117 Headrace Refurbishment: Meto No.2 P/S

Plant name	芽登第二 (Metodaini)						
Operation start	1958		**Completed**	2021 (planned)			
Owner	J-Power						
Country	Japan						
Max output kW	28,100		**After work**	-	New / no change		
Max generation discharge m^3/s	33.00						
Effective head m	102.50						
Decision-making type (○ **where it applies)**	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
			○				
Time of decision making	2017						
Target structure(s)	Headrace						
・Driver	Aging						
・Phenomena (caused by Driver)	Aging / efficiency decline						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Water way, etc. repair						
(1) Current status **1) General status**	**(Before decision making)** Headrace refurbishment work for about 60-year-old, progressively degraded waterway bridge exposed to frost damage by replacing it with inverted siphon waterway, also as an anti-seismic measure against large earthquakes.						
2) Operation status	Generation efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To refurbish the headrace by replacement with inverted siphon type against the aging degradation (mainly frost damage) and large earthquakes, after considering other options, hydrological model experiments, prevention of air entrainment, overall refurbishment plan, etc.						
(4) How decision-making was implemented and technologies adopted	Refurbishment plan (modification to inverted siphon type instead of replacement for the waterway aged over 50 years, exposed to frost damage to the concrete at temperatures below minus 20 degrees in winter, while security reliability against large earthquakes is required), hydrological model experiments to confirm hydrological condition, verification of prevention of air entrainment, etc were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2018.5)

118 Kushiro Coast Earthquake Disater Restoration: Kumaushi P/S

Plant name	熊牛 (Kumaushi)						
Operation start	1987	**Completed**	1993		Age (6 years)		
Owner	J-Power						
Country	Japan						
Max output kW	15,400	**After work**	-		New / no change		
Max generation discharge m^3/s	41.00						
Effective head m	44.50						
Decision-making type	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)	○						
Time of decision making	1993						
Target structure(s)	Spillway gate						
・Driver	Disaster						
・Phenomena (caused by Driver)	Generation shutdown / efficiency decline						
Risk	Reduction						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Disaster (earthquake) restoration						
(1) Current status	**(Before decision making)**						
1) General status	Kushiro Coast Earthquake of Japanese seismic intensity 5 (in Obihiro area) which occurred on January 15, 1993 damaged the spillway gate winch and operation bridge fixing section. Repair work was undertaken to restore the spillway gate functions.						
2) Operation status	Generation shutdown / efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To restore the spillway gate functions against the damage to the gate winches and operation bridge fixing section by Kushiro Coast Earthquake for improving the earthquake resistance.						
(4) How decision-making was implemented and technologies adopted	Anti-seismic modification plan (wherein joints (gear coupling) designed with slide spec ± 75 mm were selected and installed for the permissible slide spec of ± 2.75 mm of the existing bearing joint) was considered and implemented.						

Reference documents / sources IEA Annex-11 Jp.37

119 Mumappara Dam Asphalt Surface Impermeable Wall Repair

Plant name	沼原 (Numappara)							
Operation start	1973	**Completed**	2011		Age (38 years)			
Owner	J-Power							
Country	Japan							
Max output kW	675,000	**After work**	-		New / no change			
Max generation discharge m^3/s	172.50							
Effective head m	478.00							
Decision-making type (○ where it applies)	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**	
	○							
Time of decision making	2011							
Target structure(s)	Dam							
・Driver	Disaster							
・Phenomena (caused by Driver)	Generation shutdown / efficiency decline							
Risk	Reduction							
・Risks for plant operation	Cost increase / profit reduction							
・Specific risk management	Disaster (earthquake) restoration							
(1) Current status	**(Before decision making)**							
1) General status	The Great East Japan Earthquake on March 11, 2011 generated cracks in the asphalt impermeable walls of the upper dam of the pumped storage power plant, and then its power generation was suspended (from March to July) due to the increased water leakage and lower water level. The cracks were repaired by overlaying an asphalt mixture material.							
2) Operation status	Generation shutdown / efficiency decline							
3) Risk	**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction							
(2) Priorities	RE utilization / securing profit							
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To repair the cracks in the asphalt impermeable walls (resulting in an increase in the water leak of the upper dam) due to the Great East Japan Earthquake with asphalt mixture overlay, after considering the repair methods and materials, impossibility of emergency investigation (due to snow and ice), and assessment of sections to be repaired by long-term monitoring and exposure samples, etc.							
(4) How decision-making was implemented and technologies adopted	Overlay repair with asphalt mixture material, impossibility of emergency investigation due to natural condition (snow and ice), and assessment of sections to be repaired by long-term monitoring and exposure samples (monitoring continued) were considered and implemented.							

Reference documents / sources Electric Power Civil Engineering (2012.11)

120 Nojiri Waterway Bridge Anti-Seismic Reinforcement: Totsugawa No.1 P/S

Plant name		十津川第一 (Totsugawa No.1)					
Operation start		1960	**Completed**	2010		Age (50 years)	
Owner		J-Power					
Country		Japan					
Max output	kW	75,000	**After work**	-		New / no change	
Max generation discharge	m^3/s	60.00					
Effective head	M	144.23					
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)				○				
Time of decision making		2009					
Target structure(s)		Waterway bridge					
・Driver		Disaster					
・Phenomena (caused by Driver)		Generation shutdown / efficiency decline					
Risk		Avoidance					
・Risks for plant operation		Cost increase / profit reduction					
・Specific risk management		Earthquake disaster risk reduction					
(1) Current status		**(Before decision making)**					
1) General status		Anti-seismic reinforcement of the water way (length of 217 m, steel pipe internal diameter of 4.2 m). Reinforcement was provided to the Langer girders (with steel plates and high strength bolts), ring girders (with stiffeners and steel plates), Langer girder members (replacement with higher strength suspension members) and bearing fixing bolts (replacement with higher strength bolts).					
2) Operation status		Generation shutdown / efficiency decline					
3) Risk		**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction					
(2) Priorities		RE utilization / securing profit					
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To replace the Langer girder members and bearing fixing bolts after checking the anti-seismic performance and considering the reinforcement methods of Langer girders and ring girders.					
(4) How decision-making was implemented and technologies adopted		Work during water pipe drained period (from November 2 to January 25 next year) and work with monitoring management for Langer girder members replacement (load on temporary suspension members and displacement of water pipe) were considered and implemented.					

Reference documents / sources Electric Power Civil Engineering 2011.01

121 Surge Tank Anti-Seismic Reinforcement: Owase No.1 P/S

Plant name	尾鷲第一 (Owase No.1)						
Operation start	1962		**Completed**	2011		Age (49 years)	
Owner	J-Power						
Country	Japan						
Max output kW	40,000		**After work**	-		New / no change	
Max generation discharge m^3/s	21.00						
Effective head m	225.00						
Decision-making type	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○				
Time of decision making	2011						
Target structure(s)	Surge tank						
・Driver	Disaster						
・Phenomena (caused by Driver)	Generation shutdown / efficiency decline						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Earthquake disaster risk reduction						
(1) Current status	**(Before decision making)**						
1) General status	Earthquake resistance reinforcement was undertaken for the surge tank against predicted Tokai / East Nankai Sea / Nankai Earthquake by providing reinforcing concrete and fiber lining to the tank external faces.						
2) Operation status	Generation shutdown / efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To provide reinforcing concrete and fiber lining to the surge tank external faces as an earthquake resistance reinforcement against predicted Tokai / East Nankai Sea / Nankai Earthquake, after considering how to transport materials and equipment (combined use of helicopter and monorail), concrete casting method (long-distance super high-pressure casting), etc.						
(4) How decision-making was implemented and technologies adopted	Transport of materials and equipment to the narrow and elevated work site, combined use of helicopter and monorail, and concrete casting (long-distance super high-pressure casting) were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2012.7)

122 Disaster Restoration: Taki P/S

Plant name	滝 (Taki)						
Operation start	1961	**Completed**	2014		Age (53 years)		
Owner	J-Power						
Country	Japan						
Max output kW	92,000	**After work**	-		New / no change		
Max generation discharge m^3/s	300.00						
Effective head m	35.82						
Decision-making type (○ where it applies)	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
			○				
Time of decision making	2011						
Target structure(s)	All facilities						
・Driver	Disaster						
・Phenomena (caused by Driver)	Generation shutdown / efficiency decline						
Risk	Reduction						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Disaster (flood / heavy rain) restoration						
(1) Current status	**(Before decision making)**						
1) General status	Disaster restoration for the damage (mud inflow into the intake inlet, generation capacity loss due to plant inundation, etc) caused by Niigata / Fukushima Heavy Storm in July 2011. The mud and sand were removed (from the intake, casing, draft and tailbay) and inundated plant was restored (by filling the cable dust holes with resin materials, water-proofing the partition doors, and relocating the power generating units, etc).						
2) Operation status	Generation shutdown / efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To remove the sand and mud and to take measures against the inundation of the plant facilities in the wake of the disaster caused by Niigata / Fukushima Heavy Storm while considering the work methods, restrictions imposed by the natural condition, etc.						
(4) How decision-making was implemented and technologies adopted	Work methods (removal of sedimented mud inside the draft, handling of obstacles) and restrictions by natural conditions (snow thawing, summer seasonal floods) were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2016.01)

123 Water Tank Spillway Channel Refurbishment: Meto No.2 P/S

Plant name	芽登第二 (Meto No.2)						
Operation start	1958	**Completed**	2002		Age (44 years)		
Owner	J-Power						
Country	Japan						
Max output kW	28,100	**After work**	-		New / no change		
Max generation discharge m^3/s	33.00						
Effective head m	102.50						
Decision-making type (○ where it applies)	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
			○				
Time of decision making	2002						
Target structure(s)	Spillway channel						
・Driver	Disaster						
・Phenomena (caused by Driver)	Generation shutdown / efficiency decline						
Risk	Reduction						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Public disaster risk reduction						
(1) Current status **1) General status**	**(Before decision making)** The water tank spillway channel was refurbished as the spillage discharged from there which had been performed at the start-up / shutdown of the generator and the generator trip which happens once a year on average may cause damage to the fishing people who constantly come close to the outlet of the tank spillway.						
2) Operation status	Generation shutdown / efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To refurbish the water tank spillway for preventing the public disaster for the river visitors, after considering the types of spillway energy dissipator, structural calculations, hydrological model experiments, etc.						
(4) How decision-making was implemented and technologies adopted	The following issues and measures were considered and implemented: type of spillway energy dissipation (hydraulic jump) in comparison of generation discharge, geography, economy, etc, decision of basic design with structural calculations, confirmation of dissipation effect by hydrological model experiments, and structural shape to realize the target discharge flowrate of 1 to 2 m/s which is the max walking speed in the river.						

Reference documents / sources Electric Power Civil Engineering (2003.7)

124 Sakamoto Intake Facility Refurbishment: Nishiyoshino No.1 P/S

Plant name		西吉野第一 (Nishiyoshino No.1)					
Operation start		1956	**Completed**	2011		Age (55 years)	
Owner		J-Power					
Country		Japan					
Max output	kW	33,000	**After work**	-		New / no change	
Max generation discharge	m^3/s	16.70					
Effective head	M	231.30					
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)				○				
Time of decision making		2008					
Target structure(s)		Reservoir					
・Driver		External factors					
・Phenomena (caused by Driver)		Environmental improvement / local community cooperation					
Risk		Reduction					
・Risks for plant operation		Environmental degradation / discord with local community					
・Specific risk management		Surface / selective intake facility					
(1) Current status		**(Before decision making)**					
1) General status		Measures for turbid water reduction were taken by removing the existing gate sheets and installing a new surface intake facility. Also, anti-seismic reinforcement was given to the intake (with strut, ground anchor, filling concrete and thickening concrete).					
2) Operation status		Environmental degradation					
3) Risk		**Potential risk in case of no decision making** Environmental degradation / discord with local community / opposition to power generation **Potential risk when implementing decision making** No effect, cost increase / profit reduction					
(2) Priorities		Environmental improvement					
(3) Strategy		**Against potential risk in case of no decision making** (Continued coordination with local communities on long-term turbid water) **Against potential risk when implementing decision making** To install a surface intake facility and reinforce the intake against earthquakes as a measure for alleviating the water turbidity, while considering the work conditions (narrow workspaces, restrictions of work period and reservoir water level), work methods, temporary facility planning, prolonged work period due to floods (typhoons), etc.					
(4) How decision-making was implemented and technologies adopted		Narrow workspaces inside and around the intake tower, restrictions of work period and reservoir water level, and extension of work period by one year due to typhoon-caused floods were considered and implemented.					

Reference documents / sources Electric Power Civil Engineering 2011.09

125 Surface Intake Facility Refurbishment: Totsugawa No.2 P/S

Plant name		十津川第一 (Totsugawa No.2)						
Operation start		1960	**Completed**	2018		Age (58 years)		
Owner		J-Power						
Country		Japan						
Max output	kW	75,000	**After work**	-		New / no change		
Max generation discharge	m^3/s	60.00						
Effective head	M	144.23						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)				○				
Time of decision making		2016						
Target structure(s)		Reservoir						
・Driver		External factors						
・Phenomena (caused by Driver)		Environmental improvement / local community cooperation						
Risk		Reduction						
・Risks for plant operation		Environmental degradation / discord with local community						
・Specific risk management		Surface / selective intake facility						

(1) Current status

(Before decision making)

1) General status

Persistence of turbid water was manifested soon after the commissioning in 1960 and reduction measures were taken with the surface intake facility, but the longterm turbidity became more serious due to multiple, large-scale mountain slope collapses in the dam basin caused by Typhoon No.12 in 2011. Against this situation, the surface intake facility was refurbished as a stronger preventive measure against the long-term turbid water issue.

2) Operation status

Environmental degradation

3) Risk

Potential risk in case of no decision making

Environmental degradation / discord with local community / opposition to power generation

Potential risk when implementing decision making

No effect, cost increase / profit reduction

(2) Priorities

Environmental improvement

(3) Strategy

Against potential risk in case of no decision making

(Continued coordination with local communities on long-term turbid water)

Against potential risk when implementing decision making

To consider and implement the utilization and operability improvement of the existing facilities, improvement in low-turbidity intake functions and facility reliability.

(4) How decision-making was implemented and technologies adopted

The following issues and measures were considered and implemented:
modification of intake facility using liner, multistage steel roller gate for improving the reliability, operability and capability of intaking low-turbidity water at shallower intake depth, replacing the existing rubber sheet rolling type, light-weight design for reducing the load on the existing structures, etc.

Reference documents / sources Electric Power Civil Engineering (2017.11)

126 Clear Water Bypass Installation: Nishiyoshino No.2 P/S

Plant name	西吉野第二 (Nishiyoshino No.2)						
Operation start	1955	**Completed**	2010	Age (55 years)			
Owner	J-Power						
Country	Japan						
Max output kW	13,100	**After work**	-	New / no change			
Max generation discharge m^3/s	20.00						
Effective head m	77.40						
Decision-making type	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○				
Time of decision making	2007						
Target structure(s)	Reservoir						
・Driver	External factors						
・Phenomena (caused by Driver)	Environmental improvement / local community cooperation						
Risk	Reduction						
・Risks for plant operation	Environmental degradation / discord with local community						
・Specific risk management	Clear water bypass / sand bypass						
(1) Current status	**(Before decision making)**						
1) General status	Persistence of turbid water in Sarutani Reservoir was manifested due to the recent large-scale floods. Particularly the floods of recurring typhoons in 2004 caused the turbid water to persist from June for about half year in Kinokawa River and tributary Nyugawa River. Some even insisted to stop the diversion from Sarutani Reservoir. Therefore, a clear water bypass was installed to intake water directly from Nyugawa River upstream (where Kurobuchi Reservoir discharges) of the outlet of Nishiyoshino No.1 Power Plant to which Sarutani Reservoir discharges and discharges immediately downstream Kurobuchi Dam, thereby replacing the existing river maintenance discharge facility.						
2) Operation status	Environmental degradation						
3) Risk	**Potential risk in case of no decision making** Environmental degradation / discord with local community / opposition to power generation Potential risk when implementing decision making No effect, cost increase / profit reduction						
(2) Priorities	Environmental improvement						
(3) Strategy	**Against potential risk in case of no decision making** (Continued coordination with local communities on long-term turbid water) **Against potential risk when implementing decision making** To install a clear water bypass replacing the existing river maintenance discharge facility as a countermeasure against the persistence of turbid water, after considering the verified effect of reducing the long-term water turbidity by the clear water bypass, methods of building the water way, pipe materials and installation methods, etc.						
(4) How decision-making was implemented and technologies adopted	The following issues and measures were considered and implemented: effect of clear water bypass on reduction of persisting turbid water (verified for 10 years from 1999 to 2008 and confirmed to reduce the period of turbidity over 15 ppm by 60% on annual average), water way construction method (earth shuttle method adopted as enabling shorter work period), specs of earth shuttle method (primary or pilot excavation with diameter of ϕ311 mm and ϕ251 mm from the intake to outlet, then secondary or widening excavation up to the final section of ϕ610 mm), pipe material and work method (high-density polyethylene pipe was adopted for its high tensile strength, flexibility, resistance to wear, corrosion and durability, while the gap between the installed pipe and ground was filled with mortar to avoid damage by ground collapse and to prevent the pipe vibration), etc.						

Reference documents / sources Electric Power Civil Engineering 2009.07

127 Sakamoto Dam Surface Intake / Turbid Water Fences

Plant name	尾鷲第一 (Owase No.1)						
Operation start	1962	**Completed**	2005		Age (43 years)		
Owner	J-Power						
Country	Japan						
Max output kW	40,000	**After work**	-		New / no change		
Max generation discharge m^3/s	21.00						
Effective head M	225.00						
Decision-making type (○ where it applies)	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
			○				
Time of decision making	2003						
Target structure(s)	Surface intake facility						
・Driver	External factors						
・Phenomena (caused by Driver)	Environmental improvement / local community cooperation						
Risk	Reduction						
・Risks for plant operation	Environmental degradation / discord with local community						
・Specific risk management	Surface / selective intake facility						
(1) Current status **1) General status**	**(Before decision making)** Recently, increased amounts of turbid water flowed into the dam due to land collapses upstream caused by large floods, which caused the persistence of turbid water and impact on the sea (Owase Bay) as the power generation discharges the turbid water downstream. To improve this situation, a surface intake facility was installed in the existing dam intake to reduce the long-term turbidity and impact on the downstream.						
2) Operation status	Environmental degradation						
3) Risk	**Potential risk in case of no decision making** Environmental degradation / discord with local community / opposition to power generation **Potential risk when implementing decision making** No effect, cost increase / profit reduction						
(2) Priorities	Environmental improvement						
(3) Strategy	**Against potential risk in case of no decision making** (Continued coordination with local communities on long-term turbid water) **Against potential risk when implementing decision making** To install a clear water bypass as a countermeasure against the persistence of turbid water, after considering the alternatives (turbidity prevention screens, linear multi-stable water-shielding panels, etc), basic planning (to install at the existing intake), removal of the existing screens, recycling the screen girders as anti-						
(4) How decision-making was implemented and technologies adopted	The following issues and measures were considered and implemented: current status of Sakamoto Dam Furukawa Intake (45-degree gradient reinforce concrete structure with 75-m long screen in front), basic concept of surface intake facility (tilted linear multi-stage (3) steel roller gate to be mounted on the Furukawa Intake structure), decisions for modification (existing screen would be removed, but the girders would be left as effective anti-seismic members), etc.						

Reference documents / sources Electric Power Civil Engineering (2004.11)

128 Isawa No.1 Power Plant New Construction in Conjunction with Construction of Isawa Dam

Plant name	胆沢第一 (Isawa No.1)						
Operation start	1954	**Completed**	2014		Age (60 years)		
Owner	J-Power						
Country	Japan						
Max output kW	14,200	**After work**	-		New / no change		
Max generation discharge m^3/s	16.00						
Effective head m	101.30						
Decision-making type (○ where it applies)	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
					○		
Time of decision making	2013						
Target structure(s)	Penstock, T/G, etc						
・Driver	External factors						
・Phenomena (caused by Driver)	Flood safety improvement / local community cooperation						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Existing plant relocation						
(1) Current status **1) General status** **2) Operation status** **3) Risk**	**(Before decision making)** A new power plant was built immediately downstream Tanzawa Dam which was to be constructed and thereby the existing dam, power plant and intake facility would be submerged and abolished. Generation shutdown / efficiency decline **Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	Cooperative improvement in flood control safety						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To abolish the existing power plant and build a new plant immediately downstream Tanzawa Dam which is to be newly built after considering the construction cost reduction by effective use of the temporary discharge tunnel, coordination with multiple parties about how to promote the work, etc.						
(4) How decision-making was implemented and technologies adopted	Reduction of construction cost by effective utilization of temporary discharge tunnel, coordination with multiple parties about the narrow, limited workspaces (national, prefectural governments, JP) were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2012.9/2014.7)

129 Refurbishment in Conjunction with Construction of New Katsurazawa Dam: Katsurazawa P/S

Plant name		桂沢 (Katsurazawa)						
Operation start		1957		**Completed**	2022 (planned)	#VALUE!		
Owner		J-Power						
Country		Japan						
Max output	kW	15,000		**After work**	16,800	Up rate↑ (12.0%)		
Max generation discharge	m^3/s	23.50						
Effective head	m	75.00						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)						○		
Time of decision making		2018						
Target structure(s)		Headrace, water tank, T/G, etc						
・Driver		External factors						
・Phenomena (caused by Driver)		Flood safety improvement / local community cooperation						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Existing plant relocation						
(1) Current status		**(Before decision making)**						
1) General status		The existing power plant was abolished, and a new plant was built since Katsurazawa Dam was elevated in the Ikushunbetsu River General Development Project by Hokkaido Regional Development Bureau, and thus the specs of the existing plant were not suitable for power generation.						
2) Operation status		Generation shutdown / efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		Cooperative improvement in flood control safety						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To abolish the existing power plant and build a new plant in conjunction with the elevation of Katsurazawa Dam (Ikushunbetsu River General Development Project) after considering the elevation of the surge tank, reinforcement of the headrace, renewal of the T/G, etc.						
(4) How decision-making was implemented and technologies adopted		Elevating of surge tank, reinforcement of headrace, renewal of turbine generator, etc were considered and implemented.						

Reference documents / sources

130 Refurbishment in Conjunction with Construction of New Katsurazawa Dam: Kumaoi P/S

Plant name	熊追 (Kumaoi)						
Operation start	1957		**Completed**	2022 (planned)	#VALUE!		
Owner	J-Power						
Country	Japan						
Max output kW	4,900		**After work**	5,100	Up rate↑ (4.1%)		
Max generation discharge m^3/s	4.00						
Effective head m	146.40						
Decision-making type (○ **where it applies**)	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
					○		
Time of decision making	2018						
Target structure(s)	Power plant, T/G, etc						
・Driver	External factors						
・Phenomena (caused by Driver)	Flood safety improvement / local community cooperation						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Utilization of part of existing plant						
(1) Current status **1) General status**	**(Before decision making)** The plant site was elevated, and the turbine generator was renewed in conjunction with the construction of Shinkatsurazawa Dam (elevation redevelopment) by the Ministry of Land, Infrastructure, Transport and Tourism.						
2) Operation status	Generation shutdown / efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	Cooperative improvement in flood control safety						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To elevate the plant site and renew the turbine generator in conjunction with the construction of Shinkatsurazawa Dam (elevation redevelopment) by the Ministry of Land, Infrastructure, Transport and Tourism after considering the comparison between elevation and relocation, power generation shutdown during the work, environmental impact of geographic changes, comparisons of project cost, land acquisition, etc.						
(4) How decision-making was implemented and technologies adopted	Comparison between elevation and relocation, power generation shutdown during the work, environmental impact of geographic changes, comparisons of project cost, land acquisition, etc. were considered and implemented.						

Reference documents / sources Electric Power Civil Engineering (2018.7)

131 Refurbishment in Conjunction with Redevelopment of Tsuruta Dam: Sendaigawa No.1 P/S

Plant name		川内川第一 (Sendaigawa No.1)						
Operation start		1965	**Completed**	2018		Age (53 years)		
Owner		J-Power						
Country		Japan						
Max output	kW	120,000	**After work**	-		New / no change		
Max generation discharge	m^3/s	150.00						
Effective head	m	93.10						
Decision-making type (○ where it applies)		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
						○		
Time of decision making		2007						
Target structure(s)		Penstock						
・Driver		External factors						
・Phenomena (caused by Driver)		Flood safety improvement / local community cooperation						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Utilization of part of existing plant						
(1) Current status		**(Before decision making)**						
1) General status		The penstock was relocated to be able to take in water from lower level in conjunction with Tsuruta Dam Redevelopment (water level changes due to dam operation changes) by the Ministry of Land, Infrastructure, Transport and Tourism.						
2) Operation status		Generation shutdown / efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		Cooperative improvement in flood control safety						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To relocate the penstock in conjunction with Tsuruta Dam Redevelopment by the Ministry of Land, Infrastructure, Transport and Tourism while considering the holemaking in the dam body, large depth coffering unit, underwater excavation / concrete casting for the foundation of coffering unit, alteration to floating type coffering unit, etc.						
(4) How decision-making was implemented and technologies adopted		Hole-making in the dam body, large depth coffering unit, underwater excavation / concrete casting for the foundation of coffering unit, change to floating type coffering unit, etc. were considered and implemented.						

Reference documents / sources Dam Technology (2015.1)

132 Shiroyama Power Plant Renewal

Plant name		城山 (Shiroyama)						
Operation start		1965	**Completed**	2010		Age (45 years)		
Owner		Public sector						
Country		Japan						
Max output	kW	250,000	**After work**	250,000				
Max generation discharge	m^3/s	192.00						
Effective head	m	123.90						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		1996						
Target structure(s)		T/G, protective / control system, etc						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		T/G redevelopment						
(1) Current status		**(Before decision making)**						
1) General status		Aged about 40 years, there were many cases of aging and malfunctioning. The turbine generator was renewed, and the protective / control system was upgraded for ensuring the safety operation of the pumped storage hydropower plant.						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To renew the T/G and improve the protective / control system to ensure stable plant operation while considering the difficulty in procuring maintenance supplies, refurbishment in view of shortage of manufacturer maintenance engineers due to						
(4) How decision-making was implemented and technologies adopted		Advancing facility aging, repeated malfunctions which might lead to lower efficiency or serious accidents, difficulty in procuring maintenance supplies, modification in view of shortage of manufacturer maintenance engineers due to their aging, etc. were considered and implemented.						

Reference documents / sources IEA Annex-11 Jp.14

133 Shin-Oonagara No.1 Power Plant Construction: Shinoonagatani No.1 P/S

Plant name		新大長谷第一 (Shinoonagatani No.1)						
Operation start		1955	**Completed**	2001		Age (46 years)		
Owner		Public sector						
Country		Japan						
Max output	kW	4,000	**After work**	7,500		Up rate↑ (87.5%)		
Max generation discharge	m^3/s	3.25						
Effective head	m	146.61						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		1997						
Target structure(s)		Headrace, penstock, T/G, etc						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		T/G redevelopment						
(1) Current status		**(Before decision making)**						
1) General status		Due to the degradation of about 40-year-old headrace tunnel, almost all facilities from intake, headrace to the powerhouse were newly installed. The existing penstock was recycled as a spillway pipe.						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To newly install almost all facilities from intake, headrace to the powerhouse due to the degradation of the headrace tunnel, after considering the adoption of integrated TBM method for headrace installation, recycling of the existing penstock as a spillway, and other new technologies and cost reduction means.						
(4) How decision-making was implemented and technologies adopted		Adoption of integrated TBM method (concrete sprayed immediately after excavation) for headrace installation, recycling of existing penstock as spillway, and other new technologies and cost reduction means were considered and implemented.						

Reference documents / sources IEA Annex-11 Jp.27

134 Kikuka Power Plant Construction (Redevelopment)

Plant name	菊鹿 (Kikuka)						
Operation start	1956	**Completed**	2004	Age (48 years)			
Owner	Public sector						
Country	Japan						
Max output kW	460	**After work**	560	Up rate↑ (21.7%)			
Max generation discharge m^3/s	1.10						
Effective head m	62.00						
Decision-making type	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)		○					
Time of decision making	1998						
Target structure(s)	T/G						
・Driver	Aging						
・Phenomena (caused by Driver)	Aging / efficiency decline						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	T/G redevelopment						
(1) Current status	**(Before decision making)**						
1) General status	Aged about 40 years, the turbine generator was renewed, the effective head was upgraded by changing the turbine generator installation position, while the existing waterway was used continuously.						
2) Operation status	Generation efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To increase the effective head by renewing the T/G and its installation position in this redevelopment project for the aged facilities by changing the business operator (from local co-op to prefectural bureau) for continued, effective utilization of the existing facilities and considering the adoption of latest turbine generator, etc.						
(4) How decision-making was implemented and technologies adopted	For the redevelopment driven by facility aging, the operator was changed (from local co-op to prefectural bureau) for the continuation of effective utilization of clean energy. Utilization of existing facilities, adoption of latest turbine generator, etc. were considered and implemented.						

Reference documents / sources IEA Annex-11 Jp.02

135 Earthquake Disaster Restoration: Ishioka No.1 P/S

Plant name	石岡第一 (Ishioka No.1)						
Operation start	1911	**Completed**	2011		Age (100 years)		
Owner	Public sector						
Country	Japan						
Max output kW	5,500	**After work**	-		New / no change		
Max generation discharge m^3/s	3.90						
Effective head m	161.10						
Decision-making type (○ where it applies)	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
	○						
Time of decision making	2011						
Target structure(s)	Water tank, penstock						
・Driver	Disaster						
・Phenomena (caused by Driver)	Generation shutdown / efficiency decline						
Risk	Reduction						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Disaster (earthquake) restoration						
(1) Current status	**(Before decision making)**						
1) General status	Early restoration for the facilities damaged by the Great East Japan Earthquake in March 2011 and East Shizuoka Earthquake in March 2011. The water tank, spillway channel and water channel (FRPM) were restored.						
2) Operation status	Generation shutdown / efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	RE utilization / securing profit						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To restore the water tank, spillway channel and water channel (FRPM) as an early recovery project for the facility damage caused by the large-scale earthquakes (the Great East Japan Earthquake and East Shizuoka Earthquake) while considering the demand peak in summer in the wake of earthquake disasters, adoption of weather-resistant FRPM pipe for the water channel, etc.						
(4) How decision-making was implemented and technologies adopted	Priority was given to the water tank restoration to be ready for the demand peak in summer in the wake of earthquake disasters (the land collapse below the tank was given temporary slope protection, and the tank was built in conventionally designed reinforced concrete structure resistant to earthquake of Level 1), and weather-resistant FRPM pipe (ϕ1.5 m, internal pressure type) was adopted for the water channel.						

Reference documents / sources IEA Annex-11 Jp.42

136 Civil Engineering Structures Restoration: Kariyado P/S

Plant name	狩宿 (Kariyado)							
Operation start	1919		**Completed**	2011		Age (92 years)		
Owner	Public sector							
Country	Japan							
Max output kW	1,700		**After work**	-		New / no change		
Max generation discharge m^3/s	4.16							
Effective head m	50.00							
Decision-making type	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**	
(○ where it applies)	○							
Time of decision making	2011							
Target structure(s)	Surge tank, penstock							
・Driver	Disaster							
・Phenomena (caused by Driver)	Generation shutdown / efficiency decline							
Risk	Reduction							
・Risks for plant operation	Cost increase / profit reduction							
・Specific risk management	Disaster (earthquake) restoration							
(1) Current status	**(Before decision making)**							
1) General status	Early restoration for the facilities damaged by the Great East Japan Earthquake in March 2011 and East Shizuoka Earthquake in March 2011. For the surge tank, steel plate lining, inner face misalignment repair, and mortar filling were performed.							
2) Operation status	Generation shutdown / efficiency decline							
3) Risk	**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction							
(2) Priorities	RE utilization / securing profit							
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To perform steel plate lining, misaligned inner faces repair and mortar filling of the surge tank after considering the possible repair measures as an early recovery project for the facility damage caused by the large-scale earthquakes (the Great East Japan Earthquake and East Shizuoka Earthquake)							
(4) How decision-making was implemented and technologies adopted	Restoration work methods (of joining the misaligned sections on the surge tank wall face with chemical anchor via channel steels, covering the joints cylindrically with steel plates, and filling with mortar) were considered and implemented.							

Reference documents / sources IEA Annex-11 Jp.42

137 Civil Engineering Structures Restoration: Hananukigawa No.2 P/S

Plant name		花貫川第二 (Hananukigawa No.2)						
Operation start		1920	**Completed**	2011		Age (91 years)		
Owner		Public sector						
Country		Japan						
Max output	kW	750	**After work**	-		New / no change		
Max generation discharge	m^3/s	0.83						
Effective head	m	112.60						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)		○						
Time of decision making		2011						
Target structure(s)		Surge tank, penstock						
・Driver		Disaster						
・Phenomena (caused by Driver)		Generation shutdown / efficiency decline						
Risk		Reduction						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		Disaster (earthquake) restoration						

(1) Current status

(Before decision making)

1) General status

Early restoration for the facilities damaged by the Great East Japan Earthquake in March 2011 and East Shizuoka Earthquake in March 2011. For the penstock, crack repair, concrete lining, and inner face waterproofing were performed.

2) Operation status

Generation shutdown / efficiency decline

3) Risk

Potential risk in case of no decision making

Generation shutdown / efficiency decline

Potential risk when implementing decision making

Cost increase / profit reduction

(2) Priorities

RE utilization / securing profit

(3) Strategy

Against potential risk in case of no decision making

(None)

Against potential risk when implementing decision making

To repair the cracks and provide concrete lining and inner face waterproofing in the penstock after considering the possible recovery / repair measures as an early recovery project for the facility damage caused by the large-scale earthquakes
(the Great East Japan Earthquake and East Shizuoka Earthquake)

(4) How decision-making was implemented and technologies adopted

The following issues and measures were considered and implemented for the restoration work: in the water channel, the fractured sections were lined with concrete, the cracks were filled with epoxy resin material and the leaking sections were coated with solvent-based primer and epoxy resin waterproofing agent, while for the surge tank, the cracks on the outside were filled with epoxy resin material and coated with siliceous waterproofing material, and on the inside, they were filled the same manner as the outside and epoxy resin waterproofing agent was coated as a lining.

Reference documents / sources IEA Annex-11 Jp.42

138 Nogawa No.2 Power Plant Redevelopment

Plant name	野川第二 (Nogawa No.2)						
Operation start	1961	**Completed**	2009	Age (48 years)			
Owner	Public sector						
Country	Japan						
Max output kW	11,000	**After work**	8,900	Down rate↓ (19.1%)			
Max generation discharge m^3/s	10.00						
Effective head m	136.90						
Decision-making type	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)					○		
Time of decision making	2005						
Target structure(s)	Penstock, T/G, powerhouse building, etc						
・Driver	External factors						
・Phenomena (caused by Driver)	Flood safety improvement / local community cooperation						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Existing plant relocation						
(1) Current status	**(Before decision making)**						
1) General status	Redevelopment of Nogawa No.2 Power Plant (commissioned in 1961) changing the output from 11,000 kW to 8,900 kW which was relocated to an upstream location in conjunction with the construction of Nagai Dam by the Ministry of Land, Infrastructure, Transport and Tourism.						
2) Operation status	Generation shutdown / efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	Cooperative improvement in flood control safety						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To relocate the power plant (to upstream) and redevelop it (to increase the output) in conjunction with the construction of Nagai Dam by the Ministry of Land, Infrastructure, Transport and Tourism while considering the adoption of NATN method for large dept vertical excavation, driving of rock bolts of 4 m in length, support of the upper structure with ground anchor, adoption of stainless steel for the penstock, etc.						
(4) How decision-making was implemented and technologies adopted	Adoption of NATN method for large dept vertical excavation (45 m in depth, 2 m in diameter), driving of rock bolts of 4 m in length, support of the upper structure with ground anchor (otherwise, steel timbering), adoption of stainless steel for the penstock were considered and implemented.						

Reference documents / sources IEA Annex-11 Jp.13

139 Shin-nogawa No.1 Power Plant Redevelopment

Plant name	新野川第一 (Shinnogawa No.1)						
Operation start	1954	**Completed**	2010	Age (56 years)			
Owner	Public sector						
Country	Japan						
Max output kW	6,100	**After work**	10,000	Up rate↑ (63.9%)			
Max generation discharge m^3/s	10.00						
Effective head m	73.29						
Decision-making type (○ where it applies)	**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
					○		
Time of decision making	2004						
Target structure(s)	penstock T/G, etc						
・Driver	External factors						
・Phenomena (caused by Driver)	Flood safety improvement / local community cooperation						
Risk	Avoidance						
・Risks for plant operation	Cost increase / profit reduction						
・Specific risk management	Utilization of part of existing plant						
(1) Current status	**(Before decision making)**						
1) General status	Redevelopment of Shin-Nogawa No.1 Power Plant (commissioned in 2010 at 10,000 kW) upon abolition of N Nogawa No.2 Power Plant (commissioned in 1954, at 6,100 kW) in conjunction with the construction of Nagai Dam by the Ministry of Land, Infrastructure, Transport and Tourism.						
2) Operation status	Generation shutdown / efficiency decline						
3) Risk	**Potential risk in case of no decision making** Generation shutdown / efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities	Cooperative improvement in flood control safety						
(3) Strategy	**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To abolish the existing power plant and construct a new plant (redevelopment) in conjunction with the construction of Nagai Dam by the Ministry of Land, Infrastructure, Transport and Tourism and the compensation for the plant abolition while considering the safety, workability, procedure, etc for the penstock slope tunnel adjacent to the dam.						
(4) How decision-making was implemented and technologies adopted	Raise boring in consideration or the safety and workability for the penstock inclined shaft in proximity to Nagai Dam by MLIT and the order of work processes (pilot boring, pilot expansion boring and reaming in order) were considered and implemented.						

Reference documents / sources IEA Annex-11 Jp.13

140 Hydropower Plant Facilities Refurbishment and Design Alteration for Compliance: Shiratagawa P/S

Plant name		白田川 (Shiratagawa)						
Operation start		1927		**Completed**	2015		Age (88 years)	
Owner		Public sector, etc						
Country		Japan						
Max output	kW	2,900		**After work**	3,100		Up rate↑ (6.9%)	
Max generation discharge	m^3/s	2.07						
Effective head	m	179.29						
Decision-making type		**O & R**	**R & E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)						○		
Time of decision making		2014						
Target structure(s)		T/G, powerhouse building						
・Driver		Aging						
・Phenomena (caused by Driver)		Aging / efficiency decline						
Risk		Avoidance						
・Risks for plant operation		Cost increase / profit reduction						
・Specific risk management		T/G redevelopment						
(1) Current status		**(Before decision making)**						
1) General status		Aged about 90 years, the turbine and other facilities needed fundamental refurbishment. The powerhouse building was rebuilt at a different location in compliance with the “Precipice Regulations”, but the facility configuration was the same as original (without changes in the building and layout inside the generator room).						
2) Operation status		Generation efficiency decline						
3) Risk		**Potential risk in case of no decision making** Generation efficiency decline **Potential risk when implementing decision making** Cost increase / profit reduction						
(2) Priorities		RE utilization / securing profit						
(3) Strategy		**Against potential risk in case of no decision making** (None) **Against potential risk when implementing decision making** To refurbish the penstock, T/G, and generating facilities (for increasing the output) without changing the building and generator room layout as a fundamental measure against the aging of the T/G and other facilities while considering the Shizuoka Prefecture Regulations (on precipices), plane shape of penstock, etc.						
(4) How decision-making was implemented and technologies adopted		Shizuoka Prefecture Regulations (on precipices) on the location of the new building (relocated from the original plant to the river side) and the plane shape of penstock (in gentle S-shape curve) were considered and implemented.						

Reference documents / sources NEF Practical Training (2015.2)