THE INTERNATIONAL ENERGY AGENCY TECHNOLOGY COLLABORATION PROGRAMME ON HYDROPOWER

IEA Hydropower

MAINTENANCE WORKS AND DECISION-MAKING FOR HYDRO FACILITIES

Appendix 2: Good Practice Portfolio – Other Countries

October 2021

IEA Hydro Annex XV

Contents

P/S: Power Station
GS: Generating Station

1. Introduction

This book is a portfolio of good practice in oversea countries (except 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.

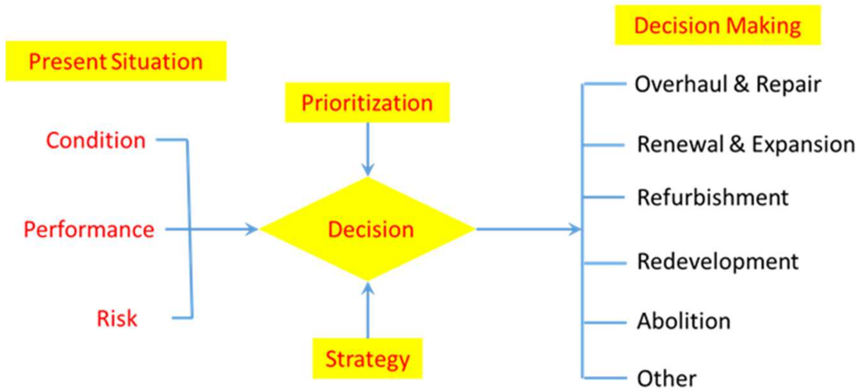

Fig. 4.2.2-1: Image of Decision Making Process

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, 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)
- Time of decision-making
- Target structure(s) (choices from Table 2)
- Driver (choices from Table-3)
- Phenomena caused by driver
- Type of Risk Management (choices from Table 4.1-2)
    - 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 is as shown in Fig. 2.

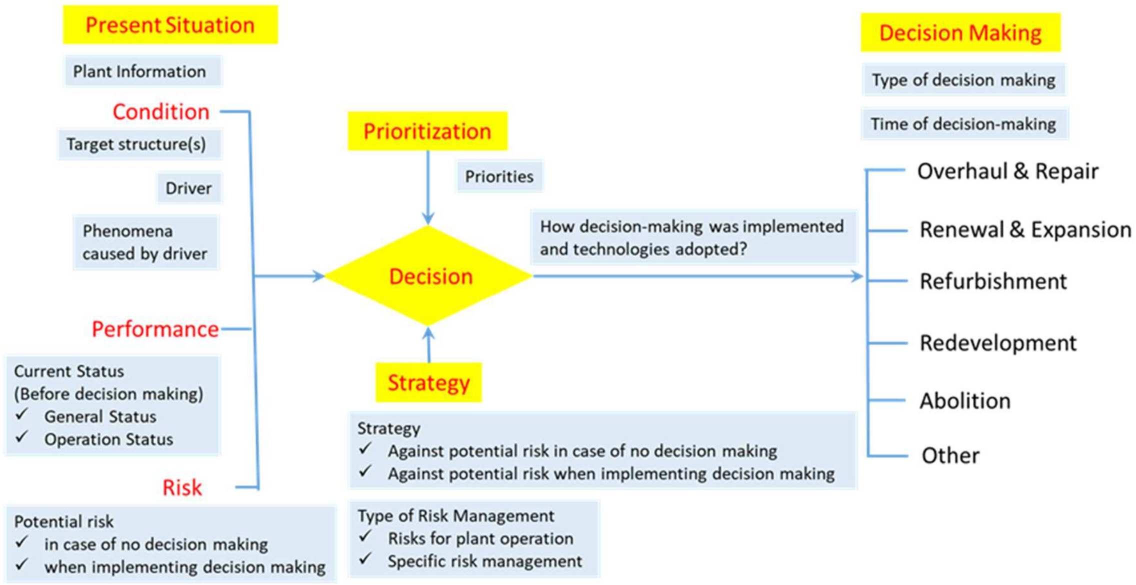

Fig. 2: Position of the table items in the process of Decision-Making

Table-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-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 -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 -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 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

4.

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

The decision-making process flowchart for aging of dams is shown in Fig. 3.1-1.

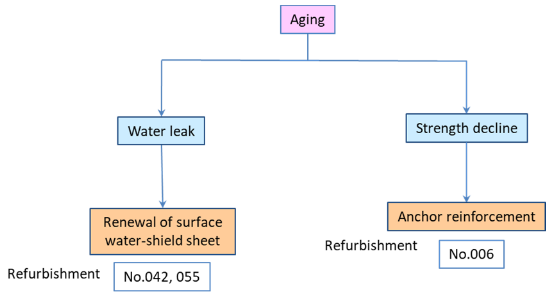

Fig. 3.1-1: Decision-Making Process Flowchart for Aging

(2) Poor Maintenance

The decision-making process flowchart for poor maintenance of dams is shown in Fig. 3.1-2.

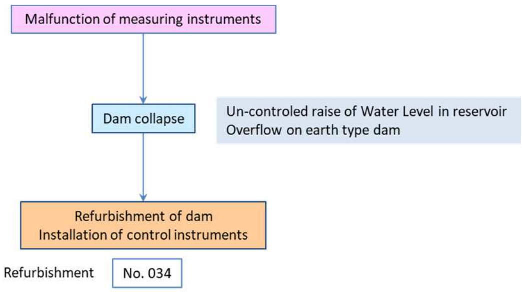

Fig. 3.1-2: Decision-Making Process Flowchart for Poor Maintenance

(3) External factors

The decision-making process flowchart for external factors regarding dams is shown in Fig. 3.1-3.

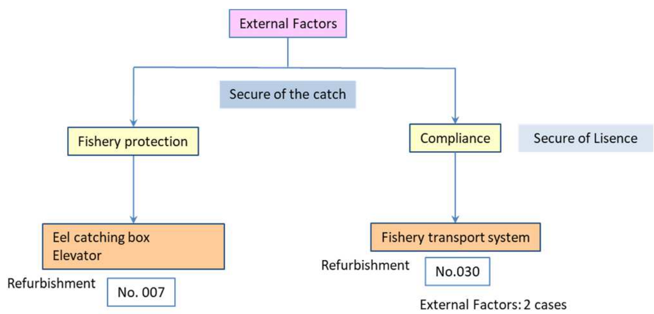

Fig. 3.1-3: Decision-Making Process Flowchart for External factors

3.2 Spillway

(1) Disaster

The decision-making process flowchart for disaster at spillway is shown in Fig. 3.2-1.

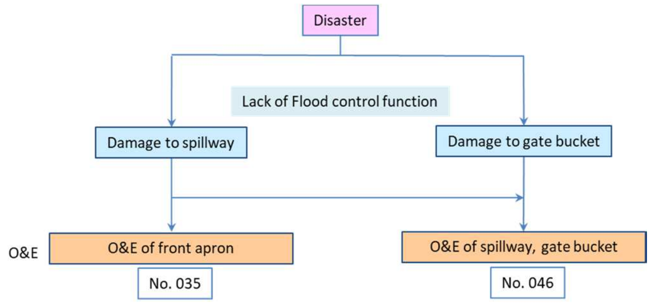

Fig. 3.2-1: Decision-Making Process Flowchart for Disaster

(2) External factors

The decision-making process flowchart for external factors regarding spillway is shown in Fig. 3.2-2.

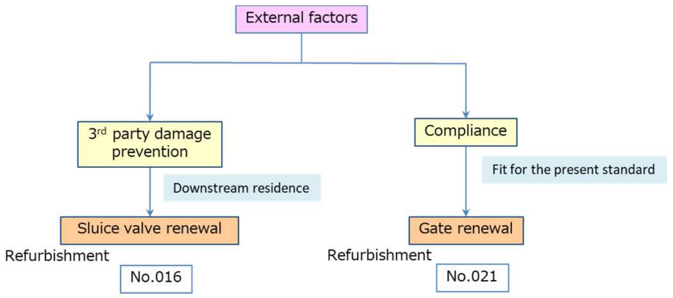

Fig. 3.2-2: Decision-Making Process Flowchart for External factors

3.3 Reservoir

(1) Aging

The decision-making process flowchart for aging of reservoirs is shown in Fig. 3.3-1.

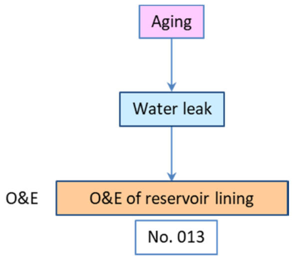

Fig. 3.3-1: Decision-Making Process Flowchart for Aging

(2) External factors

The decision-making process flowchart for aging of reservoirs is shown in Fig. 3.3-2.

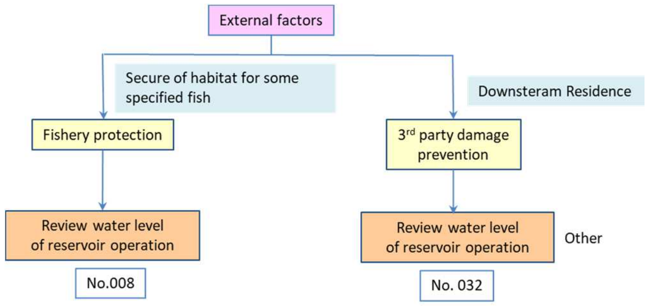

Fig. 3.3-2: Decision-Making Process Flowchart for External factors

3.4 Water Passage

(1) Aging

The decision-making process flowchart for aging of water passages is shown in Fig. 3.4-1.

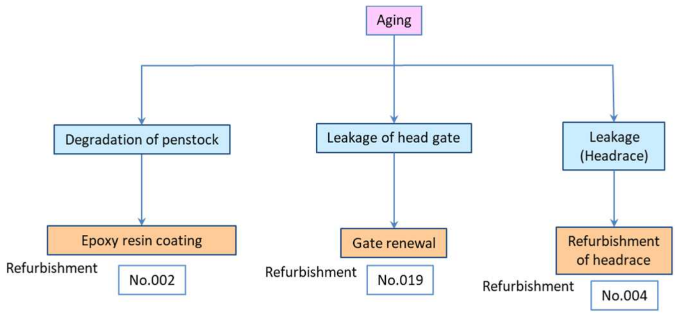

Fig. 3.4-1: Decision-Making Process Flowchart for Aging

(2) External factors

The decision-making process flowchart for external factors regarding water passages is shown in Fig. 3.4-2.

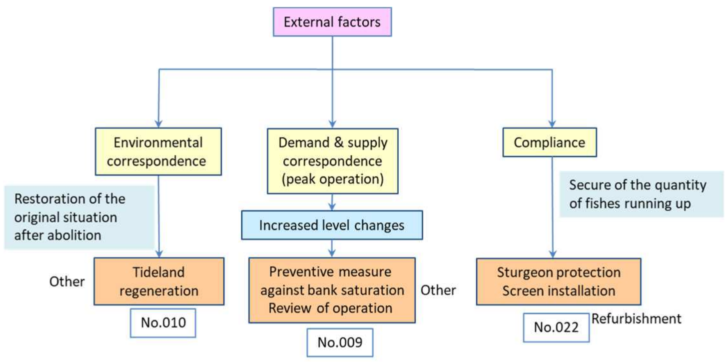

Fig. 3.4-2: Decision-Making Process Flowchart for External factors

3.5 Turbine Generator

(1) Aging

The decision-making process flowchart for aging of turbine generator is shown in Fig. 3.5-1.

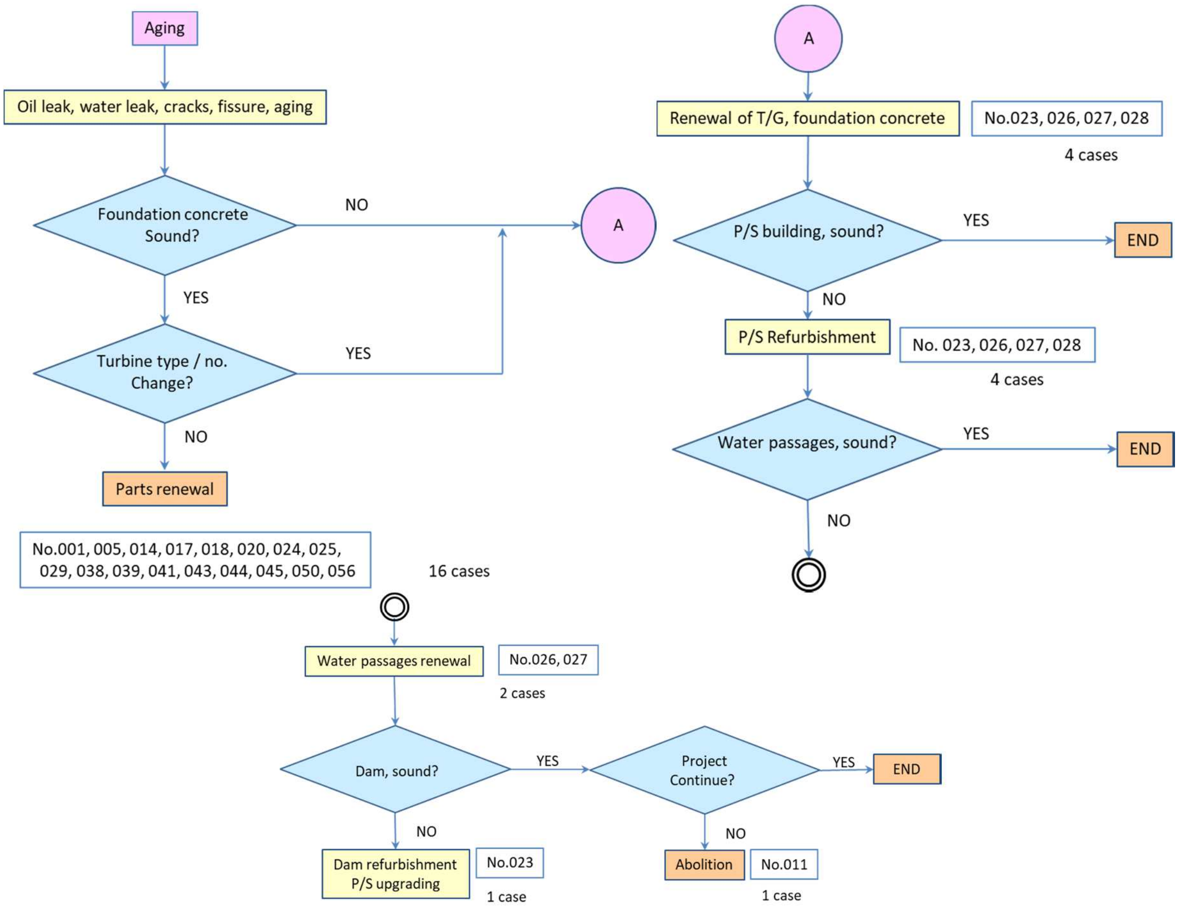

Fig. 3.5-1: Decision-Making Process Flowchart for Aging

(2) Poor Maintenance

The decision-making process flowchart for poor maintenance of turbine generator is shown in Fig. 3.5-2.

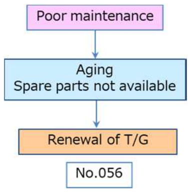

Fig. 3.5-2: Decision-Making Process Flowchart for Poor Maintenance

(3) External factors

The decision-making process flowchart for external factors regarding turbine generator is shown in Fig. 3.5-3.

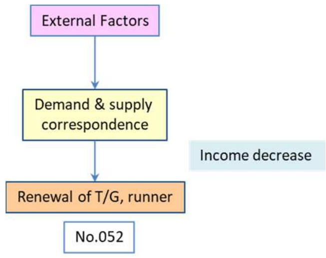

Fig. 3.5-3: Decision-Making Process Flowchart for External factors

(4) Asset Optimization & Review of Operation

The decision-making process flowchart for asset optimization & review of operation of turbine generator is shown in Fig. 3.5-4.

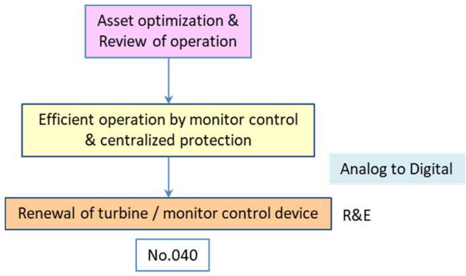

Fig. 3.5-4: Decision-Making Process Flowchart for Asset Optimization & Review of Operation

3.6 Peripheral Electric Facilities

(1) Aging

The decision-making process flowchart for aging of peripheral electric facilities is shown in Fig. 3.6-1.

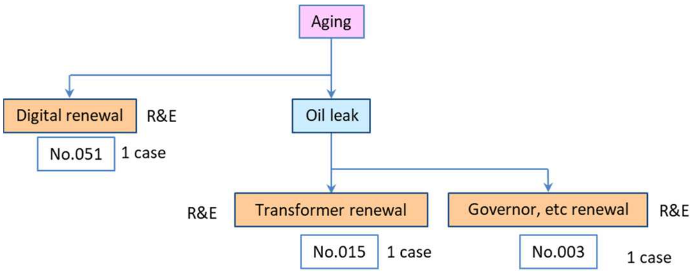

Fig. 3.6-1: Decision-Making Process Flowchart for Aging

(2) Asset Optimization & Review of Operation

The decision-making process flowchart for asset optimization & review of operation peripheral electric facilities is shown in Fig. 3.6-2.

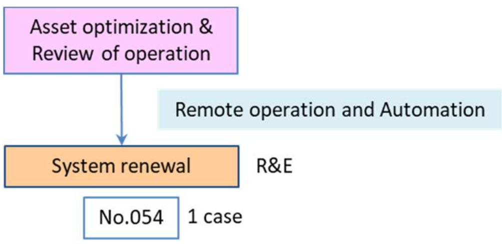

Fig. 3.6-2: Decision-Making Process Flowchart for Asset Optimization & Review of Operation

3.7 Water Passage + Turbine Generator

(1) Aging

The decision-making process flowchart for aging of water passage + turbine generator is shown in Fig. 3.7-1.

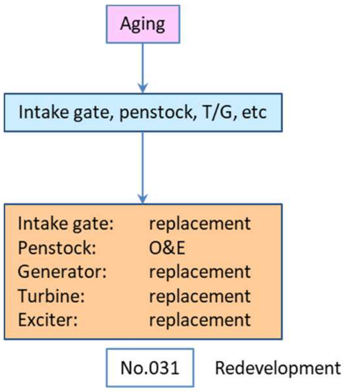

Fig. 3.7-1: Decision-Making Process Flowchart for Aging

3.8 Turbine Generator + Powerhouse Building

(1) Poor Maintenance

The decision-making process flowchart for poor maintenance of turbine generator + powerhouse building is shown in Fig. 3.8-1.

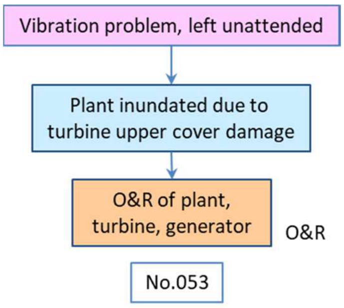

Fig. 3.8-1: Decision-Making Process Flowchart for Poor Maintenance

3.9 Water Passage + Turbine Generator + Powerhouse Building

(1) Disaster

The decision-making process flowchart for disaster at water passage + turbine generator + powerhouse building is shown in Fig. 3.9-1.

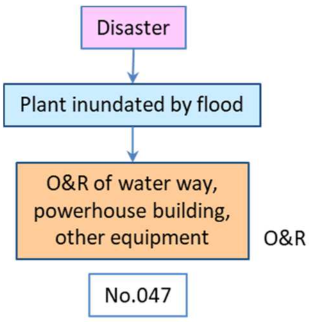

Fig. 3.9-1: Decision-Making Process Flowchart for Disaster

3.10 All Facilities

(1) Aging

The decision-making process flowchart for aging of all facilities is shown in Fig. 3.10-1.

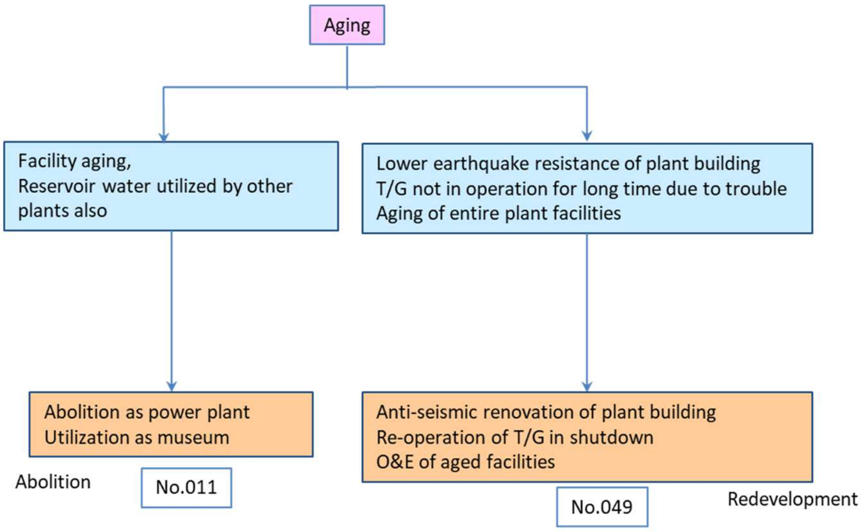

Fig. 3.10-1: Decision-Making Process Flowchart for Aging

(2) External factors

The decision-making process flowchart for external factors regarding all facilities is shown in Fig. 3.10-2.

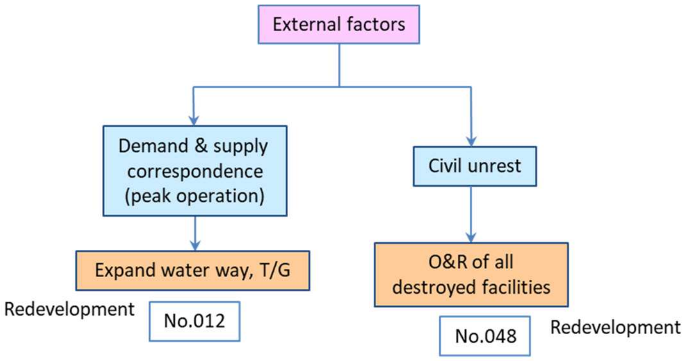

Fig. 3.10-2: Decision-Making Process Flowchart for External factors

3.11 Other

(1) External factors

The decision-making process flowchart for external factors regarding "other" is shown in Fig. 3.11-1.

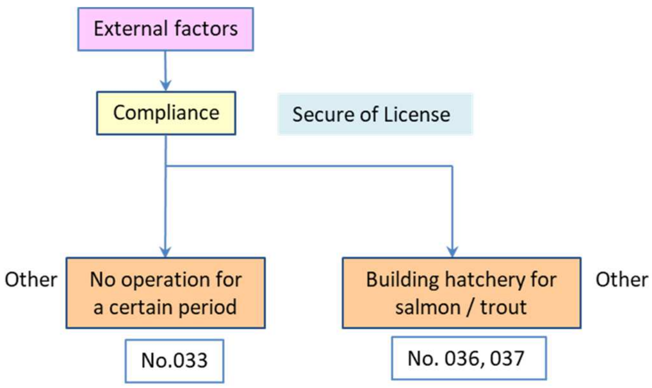

Fig. 3.11-1: Decision-Making Process Flowchart for External factors

4. Good Practice Portfolio

001 Poatina Modernization

Plant name		Poatina Power Plant	
Operation start		1965	**Work completion** 2010
Owner		Hydro Tasmania	
Country		Australia	
Max output	**kW**	360,000	**After work** (Not given)
Max generation discharge	**m³/s**	50.00	
Effective head	**M**	820.00	

Type of decision making	**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)		○					

Time of decision making	2006
Target structures	Turbine runner, bearing, inlet valve, governor, control / protective system
・Driver	Aging
・Phenomena (caused by Driver)	Generation discontinued, increased cost, declined safety of workers
Risk	Reduction
・Risks for plant operation	Reduction of profit, higher cost, impact on the environment
・Specific risk management	Renewal / refurbishment of electric facilities
(1) Current status (before decision making)	
1) General status	As the electric facilities were aging, the turbine runner and control system were refurbished and repair to restore their functions. The insufficient design and low-quality manufacture in the 1960's were problematic. From the turbine bearing, 20 to 30 liters of oil leaked to the tailbay each time the turbine is shut down. PLC-based electric governor and control system were over 40 years old without spare parts, so it was an unreliable, out-of-date system.
2) Operation status	Poatina Power Plant is the second largest plant of Hydro Tasmania with a large reservoir and making high profit by flexible operation.
3) Risks	**Potential risk in case of no decision making** Declined reliability, needs for inspection, cavitation generated in turbine runner Difficult maintenance of turbine bearing Oil leak from turbine bearing at load shutdown Rupture of penstock and inundation of plant due to non-operation of turbine inlet valve
	Potential risks when implementing decision-making items (Not specified)
(2) Priorities	Poatina Power Plant is positioned one of the 6 major hydropower of Hydro Tasmania as well as one of the 3 hydro plants having a great risk impact on the portfolio profit. Refurbishment is to be implemented from the standpoint of its strategic role.
(3) Strategy	**Against potential risk in case of no decision making** To refurbish the turbine runner and injector
	Against potential risks when implementing decision-making items (Not specified)

(4) How decision-making was implemented and technologies adopted	Strategic asset management was applied to the portfolio of Hydro Tasmania, and the amount of investment was decided. The project scope was determined in view of the asset status, required care of duty, and risk impact. The engineering decision for selecting the best business option was made by using the minimum lifecycle cost for 30 years or longer. For the net present price for 30 years, pivot pad design proved to be the choice of the highest cost effectiveness for the turbine bearing, and thus it was selected as the optimum option. 69 million AUD was invested for upgrading 3 units of T/G, 6 protective systems, inlet valve and risk management of main transformer oil leak . ・Upgrading efficiency of turbine runner and injector ・Durability of turbine runner, improving the injector reliability ・Extension of continuous operation duration of turbine runner ・Renewal of turbine shaft ・Improvement of inlet valve control / protection system ・Prevention of oil leak from turbine bearing ・Renewal of electric governor The main technological feature was the installation of safety device which prevents the fracture of the penstock and inundation of the power plant by penstock pulsation caused by the malfunctions of the turbine inlet vane.
Reference documents / sources IEA Hydro ANNEX 11 Renewal & Upgrading of Hydropower Plants Case Portfolio No.2 (detailed data) Au.01_ Poatina https://www.nef.or.jp/ieahydro/contents/pdf/4th_a11/au/01.pdf	

002 Not specified: Poatina P/S

Plant name	Poatina Power Plant						
Operation start	1965		**Work completion**	Unknown			
Owner	Hydro Tasmania						
Country	Australia						
Max output	**kW**	360	**After work**				
Max generation discharge	**m³/s**	55.00					
Effective head	**M**	820.00					
Type of decision making	**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)	○						
Time of decision making	Not specified						
Target structures	Penstock						
・Driver	Aging						
・Phenomena (caused by Driver)	Declined facility function, declined generation efficiency / operating rate						
Risk	Reduction						
・Risks for plant operation	Reduction of profit, increased cost, impact on the environment						
・Specific risk management	Repair of penstock						
1) General status	Aging was progressing after 45 years since commissioning.						
2) Operation status	(Not specified)						
3) Risks	**Potential risk in case of no decision making** Declined function and water leak from Penstock						
	Potential risks when implementing decision-making items ・Impact on the environment by wastes removed from the existing coating ・Work defects of coating implemented under cold weather ・Unsafe actions in the work done on scaffolding in steep locations						
(2) Priorities	To ensure the operation of one of th most important power plants in Tasamania						
(3) Strategy	**Against potential risk in case of no decision making** ・Removal of the existing coal tar enamel coating ・Re-coating of inner face of Penstock						
	Against potential risks when implementing decision-making items Not specified						
(4) How decision-making was implemented and technologies adopted	・Adoption of new type epoxy resin designed especially for the use in winter						

003 Tungatinah Modernization

Plant name		Tungatinah Power Plant					
Operation start		1955		**Work completion**	2013		
Owner		Hydro Tasmania					
Country		Australia					
Max output	**kW**	125,000		**After work**	140,000 Up rate (12%)		
Max generation discharge	**m³/s**	55.00					
Effective head	**M**	290.00					
Type of decision making		**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					

Time of decision making	2008
Target structures	Inlet valve, turbine, generator thrust bearing, turbine bearing, governor, protective system, excitation system
・Driver(s)	Aging
・Phenomena (caused by Driver)	Declined facility function, declined generation efficiency / operating rate, environmental degradation
Risk	Avoidance
・Risks for plant operation	Reduction of profit, increased cost, impact on the environment
・Specific risk management	Renewal / refurbishment of electric facilities
(1) Current status (before decision making)	
1) General status	For the aging of electric and other facilities, inlet vane, governor, etc. were renewed to increase the generated energy. Tungatinah Power Plant is located on River Nive upstream of River Derwent, designed with 5 Francis turbines. The degradation progressed year by year, and the generation output had gone down to the unacceptable level.
2) Operation status	Tungatinah Power Plant is ranked No.6 in the profit making portfolio of Hydro Tasmania.
3) Risks	**Potential risk in case of no decision making** Risks related to maintenance / cleaning, damage to penstock and casing, degradation of T/G including governor and control unit Incapable of responding as frequency control ancillary services Risks related to waterway oil contamination by oil leak from turbine bearing
	Potential risks when implementing decision-making items (Not specified)
(2) Priorities	The water river passing through Tungatinah Power Plant is utilized by 6 more power plants downstream, making this plant as a highly important point for water resource management of Hydro Tasmania, and thus refurbishment was carried out.
(3) Strategy	**Against potential risk in case of no decision making** 3 out of the 5 T/G units were renewed. Repair of hilltop valve, inlet valve, relief valve, introduction of new turbine operation system, old electro-mechanical governor changed to IC based speed type, existing self-excitation type replaced by static excitation system, change to new PLC-based protective control system, cleaning maintenance of rotor, replacement, cleaning maintenance of stator wedges
	Against potential risks when implementing decision-making items (Not specified)

(4) How decision-making was implemented and technologies adopted	Strategic asset management was employed to decide the timing of implementing the maintenance and upgrading. The project scope was determined in view of the asset status, required care of duty, and risk impact. The engineering decision for selecting the best business option was made by using the minimum lifecycle cost for 30 years or longer. 58 million AUD was invested for upgrading 3 out of the 5 T/G units between 2010 and 2013. The investment covered oil mist, occupational hygiene and safety, maintenance and cleaning, damage in the penstock and casing, aging of T/G including governor and control device, oil contamination in the waterway dur to leakage from turbine bearing and other risk management. The other 2 units may likely be given partial renewal.
Reference documents / sources IEA Hydro ANNEX 11 Renewal & Upgrading of Hydropower Plants Case Portfolio No.2 (detailed data) Au.02_ Tungatinah https://www.nef.or.jp/ieahydro/contents/pdf/4th_a11/nz/02.pdf	

004 Not specified: Upper P/S

Plant name	Upper Power Plant		
Operation start	1914	**Work completion**	Not specified
Owner	Hydro Tasmania		
Country	Australia		

Max output	**kW**	8,400	**After work**	(Not given)
Max generation discharge	**m³/s**	Not specified		
Effective head	**M**	Not specified		

Type of decision making	**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	Other
(○ where it applies)	○						

Time of decision making	(Not specified)
Target structures	Headrace
・Driver(s)	Aging
・Phenomena (caused by Driver)	Declined facility function, declined generation efficiency / operating rate
Risk	Avoidance
・Risks for plant operation	Reduction of profit
・Specific risk management	Renewal of existing headrace
(1) Current status (before decision making)	
1) General status	A 2.2-km long wooden headrace was renewed due to aging and severe water leakage.
2) Operation status	（Not specified）
3) Risks	**Potential risk in case of no decision making** ・Decline in generated energy due to water leak ・Landslide due to headrace water leak and third party damage arising from that
	Potential risks when implementing decision-making items Delayed work due to weather condition (rain, snow, etc) and labor disaster due to the environment (leeches, snakes, etc)
(2) Priorities	To ensure the safety of renewal work
(3) Strategy	**Against potential risk in case of no decision making** A 2.2-km long wooden headrace was renewed due to aging and severe water leakage.
	Against potential risks when implementing decision-making items The renewed headrace was made of wood similar to the existing one.
(4) How decision-making was implemented and technologies adopted	・Since the headrace was installed in a narrow, steep ridge in the mountains, we designed and manufactured a new, motor-driven transport vehicle to carry, store and install the new headrace parts to ensure work safety. ・The work was conducted against the severe natural conditions in Tasmania (rain, snow, leeches, snakes, etc).
Reference documents / sources The power of nature / Hydro Tasmania	

005 Not specified: Meadobank P/S, Paloona P/S, Cluny P/S, Repulse P/S

Plant name		Meadobank P/S,Paloona P/S,Cluny P/S,Repulse P/S							
Operation start		1967/1972/1968/1968		**Work completion**	2010				
Owner		Hydro Tasmania							
Country		Australia							
		Meadowb-an		Paloon-al		Cluny		Repulse	
Max output	**kW**	40,000		30,000		17,000		28,000	
Max generation discharge	**m³/s**	(Not given)		(Not given)		(Not given)		(Not given)	
Effective head	**M**	26.0		31.0		15.0		26.0	
After work	**kW**	(Not given)		(Not given)		(Not given)		(Not given)	
		Up rate (-%)		Up rate (-%)		Up rate (-%)		Up rate (-%)	
Type of decision making		**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**	
(○ where it applies)				○					
Time of decision making		(Not specified)							
Target structures		Hydraulic system of Kaplan turbine							
・Driver(s)		Aging (or improper facility specs)							
・Phenomena (caused by Driver)		Generation discontinued due to oil leak							
Risk		Avoidance							
・Risks for plant operation		Generation discontinued, impact on the environment							
・Specific risk management		Renewal of turbine hydraulic system, upgrading of oil leak prevention unit							
(1) Current status (before decision making)									
1) General status		Due to the oil leak from the aged hydraulic or improper use of oils, the function decline of the facility was of concern.							
2) Operation status		The total output of the Kaplan turbine plant as the target of renewal was 115,000 kW.							
3) Risks		**Potential risk in case of no decision making** ・Adverse impact on the environment due to discontinued generation							
		Potential risks when implementing decision-making items ・Oil leak due to improper work procedure							
(2) Priorities		Preventive maintenance against environmental damage due to oil leak from the plant							
(3) Strategy		**Against potential risk in case of no decision making** To avoid the risk, renewal of the hydraulic system and training for handling oil leak incidents would be implemented. ・Discontinuation of power generation and damage to the surrounding environment due to oil leak from the plant ・Expansion of the impact scope due to delayed response to oil leakage and untrained staff for handling oil collection							
		Against potential risks when implementing decision-making items ・Oil leak from the target facility							
(4) How decision-making was implemented and technologies adopted		・Renewal of turbine hydraulic system ・Installation of oil leak prevention barriers around the transformer oil tank ・Reinforcement of oil pipe racks, replacement of hydraulic system valves ・Renewal of the water / oil heat exchanger of transformer cooling unit ・Arrangement of oil leak correspondence organization							

006 Not specified: Catagunya P/S

Plant name		Catagunya Power Station						
Operation start		1962		**Work completion**		2010		
Owner		Hydro Tasmania						
Country		Australia						
Max output	**kW**	50,000		**After work**		50,000		
Max generation discharge	**m^3/s**	(Not specified)						
Effective head	**M**	(Not specified)						
Type of decision making		**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)		○						
Time of decision making		2004						
Target structures		Dam body						
・Driver(s)		Aging (corrosion of existing anchor cables)						
・Phenomena (caused by Driver)		Lack of stability of dam body						
Risk		Reduction						
・Risks for plant operation		Dam failure, generation discontinued, third party damage						
・Specific risk management		Connecting riverbed and dam with high-tension anchor cables						
(1) Current status (before decision making)								
1) General status		Catagunya Dam body and the riverbed were connected with high-tension anchor cables to ensure stability, and the inspection of the 50-year-old anchor cables since the construction revealed progressing corrosion and insufficent reliability, not meeting the international safety criteria.						
2) Operation status		-						
3) Risks		**Potential risk in case of no decision making** Possibility of abnormal water leak from the dam and in the worst case, the dam may fail, causing third party damage.						
		Potential risks when implementing decision-making items Weather condition, etc may increase the temporary facility construction cost and overall cost due to the extension of work period.						
(2) Priorities		(Not specified)						
(3) Strategy		**Against potential risk in case of no decision making** To ensure the dam stability, install Extensional high-tension anchor cables.						
		Against potential risks when implementing decision-making items (Not specified)						
(4) How decision-making was implemented and technologies adopted		The world's strongest high-tension, steel (carbon fiber) anchor cables (bearing capacity of 1,700t, ϕ350 mm), 92 of them, were put through the dam body of 75 m in height, and connected to the foundation rock ground.						

Reference documents / sources

The power of nature / Hydro Tasmania

007 Not specified: Trevallyn P/S

<table>
<tr><td colspan="2">Plant name</td><td colspan="7">Trevallyn Power Station</td></tr>
<tr><td colspan="2">Operation start</td><td colspan="2">1955</td><td colspan="2">Work completion</td><td colspan="3">2009</td></tr>
<tr><td colspan="2">Owner</td><td colspan="7">Hydro Tasmania</td></tr>
<tr><td colspan="2">Country</td><td colspan="7">Australia</td></tr>
<tr><td>Max output</td><td>kW</td><td colspan="2">95,800</td><td colspan="2" rowspan="3">After work</td><td colspan="3">95,800</td></tr>
<tr><td>Max generation discharge</td><td>m^3/s</td><td colspan="2">(Not specified)</td><td colspan="3"></td></tr>
<tr><td>Effective head</td><td>M</td><td colspan="2">(Not specified)</td><td colspan="3"></td></tr>
<tr><td colspan="2">Type of decision making</td><td>O&R</td><td>R&E</td><td>Refurbishment</td><td>Extension</td><td>Redevelopment</td><td>Abolition</td><td>Other</td></tr>
<tr><td colspan="2">(○ where it applies)</td><td></td><td></td><td>○</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Time of decision making</td><td colspan="7">(Not specified）</td></tr>
<tr><td colspan="2">Target structures</td><td colspan="7">Dam (new installation of fishway)</td></tr>
<tr><td colspan="2">・Driver(s)</td><td colspan="7">External factors (preventing young eels from swimming upstream)</td></tr>
<tr><td colspan="2">・Phenomena (caused by Driver)</td><td colspan="7">Impact on natural ecosystem</td></tr>
<tr><td colspan="2">Risk</td><td colspan="7">Avoidance</td></tr>
<tr><td colspan="2">・Risks for plant operation</td><td colspan="7">Request to stop power generation (remove the dam) from environmental organization, etc</td></tr>
<tr><td colspan="2">・Specific risk management</td><td colspan="7">Installation of a box for catching the young eels and a device which lifts up and down to and from the dam crown</td></tr>
<tr><td colspan="9">(1) Current status (before decision making)</td></tr>
<tr><td colspan="2">1) General status</td><td colspan="7">The young eels, an important species in the ecosystem of Tasmania were prevented from swimming upstream due to the dam.</td></tr>
<tr><td colspan="2">2) Operation status</td><td colspan="7">(Effect on power plant operation is not specified)</td></tr>
<tr><td colspan="2" rowspan="2">3) Risks</td><td colspan="7">Potential risk in case of no decision making
Rapid reduction of population of Tasmanian eels and possible extinction</td></tr>
<tr><td colspan="7">Potential risks when implementing decision-making items
Restoration of eels swimming upstream</td></tr>
<tr><td colspan="2">(2) Priorities</td><td colspan="7">Protection of social environment (natural ecosystem) surrounding the power business</td></tr>
<tr><td colspan="2" rowspan="2">(3) Strategy</td><td colspan="7">Against potential risk in case of no decision making
To install an assisting device which enables the eels to swim upstream</td></tr>
<tr><td colspan="7">Against potential risks when implementing decision-making items
The installed fish assisting unit may not function as intended as it does not suit the eels' behavior.</td></tr>
<tr><td colspan="2">(4) How decision-making was implemented and technologies adopted</td><td colspan="7">We installed a box for catching the young eels and a device which lifts up and down 30 m on the dam body slope in 2009. The height is the largest in the southern hemisphere.
We have observed this unit helps about 100,000 eels during the ascent season, and peak number of 5,000 a week.</td></tr>
<tr><td colspan="9">Reference documents / sources

The power of nature / Hydro Tasmania</td></tr>
</table>

008 Not specified: Poatina P/S

Plant name		Poatina Power Plant					
Operation start		1966, 1977		**Work completion**			
Owner		Hydro Tasmania					
Country		Australia					
Max output	**kW**	300,000		**After work**	(Not given)		
Max generation discharge	**m³/s**	50.00					
Effective head	**M**	820.00					
Type of decision making		**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)								○
Time of decision making		(Not specified)					
Target structures		Reservoir water level					
・Driver(s)		External factors (reservoir water management)					
・Phenomena (caused by Driver)		Depletion of habitat suitable for small fish rare species (Galaxiid)					
Risk		Avoidance					
・Risks for plant operation		Request to stop power generation from environmental organization, etc					
・Specific risk management		Review of reservoir water level management					
(1) Current status (before decision making)							
1) General status		Galaxiid, small fish, inhabiting the marshes, clear streams and lakes, are the species accounting for 64% of freshwater fish living in Tasmania, and thus important in many aspects of the ecosystem. 6 varieties of Galaxiid inhabit Lake Arthur and Lake Great, and 4 of them live only in certain water areas, and thus are viewed as rare species.					
2) Operation status		(Not specified)					
3) Risks		**Potential risk in case of no decision making** Decrease and extinction of rare species small fish (Galaxiid)					
		Potential risks when implementing decision-making items Reduction of power generation due to restricted water utilization					
(2) Priorities		Protection of social environment (natural ecosystem) surrounding the power business					
(3) Strategy		**Against potential risk in case of no decision making** To review the reservoir water level management to avoid the survival threats for the 4 small fish species and to secure their food and spawning grounds in Lake Arthur and Lake Great					
		Against potential risks when implementing decision-making items To find a suitable water area for the ecosystem of Galaxiid against the social environmental risks					
(4) How decision-making was implemented and technologies adopted		To manage reservoir water level management in the found water area to satisfy the following conditions ・To secure the habitat, spawning grounds, food and escape area for Galaxiid in Lake Arthur ・The low water level of Lake Great is to be controlled to be at a shoreline which ensures the condition suitable for the fish hatching ・The water level of Lake Arthur and Lake Great is to be kept so as to offer a favorable living condition for the fish					
Reference documents / sources The power of nature / Hydro Tasmania							

009 Not specified: Gordon P/S

Plant name	Gordon Power Station		
Operation start	1978, 1988 (Unit 3)	**Work completion**	
Owner	Hydro Tasmania		
Country	Australia		

Max output	**kW**	450,000	**After work**	(Not given)
Max generation discharge	**m³/s**	(Not specified)		
Effective head	**m**	(Not specified)		

Type of decision making	**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○				

Time of decision making	2006
Target structures	Reservoir (bank protection of downstream river)
・Driver(s)	External factors (sudden water level down in downstream river due to power generation)
・Phenomena (caused by Driver)	Collapse of riverbanks downstream due to seepage water
Risk	Avoidance
・Risks for plant operation	Reduction of profit,
・Specific risk management	Restrictions of power generation
(1) Current status (before decision making)	
1) General status	Experts pointed out the risk of erosion of the banks of Gordon River by the seepage water which takes place when Gordon Power Plant in full capacity operation rapidly reduces its output, and thus we reviewed the operation of the power plant.
2) Operation status	(Not specified)
3) Risks	**Potential risk in case of no decision making** When the river level drops rapidly, due to the high saturation in the riverbanks downstream the plant, the seepage water may cause the banks to collapse.
	Potential risks when implementing decision-making items Reduction of energy generation
(2) Priorities	Maintenance of the normal discharge capacity of the river downstream the plant
(3) Strategy	**Against potential risk in case of no decision making** To prevent erosion of the riverbanks downstream by reviewing the power generation operation
	Against potential risks when implementing decision-making items To minimize the reduction of energy generation according to the reviewed generation operation status
(4) How decision-making was implemented and technologies adopted	Hydro Tasmania developed power generation operation rules based on the seepage flowrate for the riverbanks. The rules allow for large operation margin when the bank saturation level is low, and the seepage flow is low but restrict the generation discharge only when the erosion risk by the seepage flow is high. These operation rules are applied to automatically only when applicable.
Reference documents / sources The power of nature / Hydro Tasmania	

010 Not specified: Ripple Canal

<table>
<tr><td colspan="2">Plant name</td><td colspan="7">—</td></tr>
<tr><td colspan="2">Operation start</td><td colspan="2">—</td><td colspan="2">Work completion</td><td colspan="3">2013</td></tr>
<tr><td colspan="2">Owner</td><td colspan="7">Hydro Tasmania</td></tr>
<tr><td colspan="2">Country</td><td colspan="7">Australia</td></tr>
<tr><td>Max output</td><td>kW</td><td colspan="2">—</td><td colspan="2" rowspan="3">After work</td><td colspan="3">(Not given)</td></tr>
<tr><td>Max generation discharge</td><td>m³/s</td><td colspan="2">—</td><td colspan="3"></td></tr>
<tr><td>Effective head</td><td>m</td><td colspan="2">—</td><td colspan="3"></td></tr>
<tr><td colspan="2">Type of decision making</td><td>O&R</td><td>R&E</td><td>Refurbishment</td><td>Extension</td><td>Redevelopment</td><td>Abolition</td><td>Other</td></tr>
<tr><td colspan="2">(○ where it applies)</td><td></td><td></td><td>○</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Time of decision making</td><td colspan="7">2013</td></tr>
<tr><td colspan="2">Target structures</td><td colspan="7">Marshland</td></tr>
<tr><td colspan="2">・Driver(s)</td><td colspan="7">External factors (supplying river water to a marshland to makie it a pond for irrigation)</td></tr>
<tr><td colspan="2">・Phenomena (caused by Driver)</td><td colspan="7">Water quality problem developed and ecosystem deteriorated</td></tr>
<tr><td colspan="2">Risk</td><td colspan="7">Avoidance</td></tr>
<tr><td colspan="2">・Risks for plant operation</td><td colspan="7">Natural environment disruption</td></tr>
<tr><td colspan="2">・Specific risk management</td><td colspan="7">Restoration of original natural environment, marshland</td></tr>
<tr><td colspan="9">(1) Current status (before decision making)</td></tr>
<tr><td colspan="2">1) General status</td><td colspan="7">An ecosystem had been developed in the tidal flatland of Lagoon of Islands, but it was inundated by floods, and then Ripple Canal was built to supply water there to be an irrigation source for the downstream area, and thus it ceased to be used for the original purpose. Therefore, Hydro Tasmania decided to cut off the connection with Ripple Canal and regenerate the area as a natural, healthy, sustainable marsh land as originally intended.</td></tr>
<tr><td colspan="2">2) Operation status</td><td colspan="7">—</td></tr>
<tr><td colspan="2" rowspan="2">3) Risks</td><td colspan="7">Potential risk in case of no decision making
Deterioration of water quality and depletion of ecosystem</td></tr>
<tr><td colspan="7">Potential risks when implementing decision-making items
Creation of natural environment with vegetation and animals not native to the original marshland</td></tr>
<tr><td colspan="2">(2) Priorities</td><td colspan="7">Restoration of natural environment</td></tr>
<tr><td colspan="2" rowspan="2"><u>(3) Strategy</u></td><td colspan="7">Against potential risk in case of no decision making
Restoration of water quality and ecosystem</td></tr>
<tr><td colspan="7">Against potential risks when implementing decision-making items
The follow-up investigation observed the water quality, vegetation, invertebrates, riverweeds, and algae.</td></tr>
<tr><td colspan="2">(4) How decision-making was implemented and technologies adopted</td><td colspan="7">After the water supply from Ripple Canal was discontinued, and in April 2013, a 6-m high earth dam of 320 m in crown length was built along with related facilities, the natural flora was regenerated in the tidal flatland. The follow-up investigation observed the improved water quality, vegetation, invertebrates, riverweeds, and algae.</td></tr>
<tr><td colspan="9">Reference documents / sources

The power of nature / Hydro Tasmania</td></tr>
</table>

011 Not specified: Waddamana A P/S

Plant name		Waddamana A P/S						
Operation start		1916			**Work completion**	1965 (abolished)		
Owner		Hydoro Tasmania						
Country		Australia						
Max output	**kW**	49,000			**After work**	(Not given)		
Max generation discharge	**m^3/s**	(Not specified)						
Effective head	**M**	(Not specified)						
Type of decision making		**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)							○	
Time of decision making		1964						
Target structures		Power plant						
・Driver(s)		Aging (inefficient power generation facilicties)						
・Phenomena (caused by Driver)		Occurrences of troubles, insufficient power supply capability						
Risk		Avoidance						
・Risks for plant operation		Increased facility maintenance cost						
・Specific risk management		Power supply by more efficient plant (Poatina P/S)						
(1) Current status (before decision making)								
1) General status		Waddamana A P/S was commissioned in 1916, and Waddamana B P/S was built between 1939 and 1949 in response to the demand increase in Tasmania. Waddamana A P/S and Shannon P/S operated until 1964, and Waddamana B P/S until 1994. Waddamana A P/S was abolished and renovated as a museum.						
2) Operation status		(Not specified)						
3) Risks		**Potential risk in case of no decision making** Increased maintenance cost due to inefficient facilities, or blackout due to plant shutdown						
		Potential risks when implementing decision-making items Cost for abolishing the existing plant facilities, or accidents during the abolition work (man-made disaster, environmental impact)						
(2) Priorities		Stable supply of reasonably-priced electricity						
(3) Strategy		**Against potential risk in case of no decision making** Continued power supply by more efficient plant (Poatina P/S)						
		Against potential risks when implementing decision-making items Reduction of abolition cost by converting the existing facilities into a museum						
(4) How decision-making was implemented and technologies adopted		The water of Lake Great is currently utilized at Poatina P/S. Thanks to the abundant rainfalls in Great Western Tiers, this power plant operates more efficiently than Waddamana A P/S or Shannon P/S. The power plant was renovated as a museum visited by many people today.						

Reference documents / sources
The power of nature / Hydro Tasmania

012 Ranney Falls GS G3 Project: Ranney Falls GS

<table>
<tr><td colspan="2">Plant name</td><td colspan="7">Ranney Falls GS</td></tr>
<tr><td colspan="2">Operation start</td><td colspan="2">2015</td><td colspan="2">Work completion</td><td colspan="3">(Not given)</td></tr>
<tr><td colspan="2">Owner</td><td colspan="7">Ontario Power Generation</td></tr>
<tr><td colspan="2">Country</td><td colspan="7">Canada</td></tr>
<tr><td>Max output</td><td>kW</td><td colspan="2">10,000</td><td colspan="2" rowspan="3">After work</td><td colspan="3">20,000</td></tr>
<tr><td>Max generation discharge</td><td>m³/s</td><td colspan="2">167.00</td><td colspan="3"></td></tr>
<tr><td>Effective head</td><td>m</td><td colspan="2">14.40</td><td colspan="3"></td></tr>
<tr><td colspan="2">Type of decision making</td><td>O&R</td><td>R&E</td><td>Refurbishment</td><td>Extension</td><td>Redevelopment</td><td>Abolition</td><td>Other</td></tr>
<tr><td colspan="2">(○ where it applies)</td><td></td><td></td><td>○</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Time of decision making</td><td colspan="7">2011</td></tr>
<tr><td colspan="2">Target structures</td><td colspan="7">Spillway, penstock, plant (T/G), transmission facilities</td></tr>
<tr><td colspan="2">・Driver(s)</td><td colspan="7">External factors</td></tr>
<tr><td colspan="2">・Phenomena (caused by Driver)</td><td colspan="7">Restricted operation of existing Ranney GS (insufficient max generation discharge)</td></tr>
<tr><td colspan="2">Risk</td><td colspan="7">Reduction</td></tr>
<tr><td colspan="2">・Risks for plant operation</td><td colspan="7">Correspondence to abnormal floods</td></tr>
<tr><td colspan="2">・Specific risk management</td><td colspan="7">Refurbishment of spillway and installation of penstock, T/G</td></tr>
<tr><td colspan="9">(1) Current status (before decision making)</td></tr>
<tr><td colspan="2">1) General status</td><td colspan="7">The existing Ranney Falls G3 consists of two power plants, with max output of 5 MW each. These plants were upgrade in 2005 and 2007 from 4 MW. The second plant also has a unit of 0.8 MW which exceeded the design life and thus abolished.
These plants share the intake facility from Trent Canal, and the penstock branched from the intake channel supplies water to the third plant. The average total head is about 14.4 m. The average effective intake quantity is 167 m3/s, but the maximum discharge of the existing plants is about 100 m3/s. The spillway capacity of an existing regulating dam upstream is insufficient.</td></tr>
<tr><td colspan="2">2) Operation status</td><td colspan="7">The average effective intake quantity is 167 m3/s, but the maximum discharge of the existing plants is about 100 m3/s. The plant output is 10 MW, and the average annual energy generation is 50 to 80 GWh.</td></tr>
<tr><td colspan="2" rowspan="2">3) Risks</td><td colspan="7">Potential risk in case of no decision making
Submersion of communities along the intake like in flood cases (submersion risk of communities along the intake like of existing Ranney GS)</td></tr>
<tr><td colspan="7">Potential risks when implementing decision-making items
(Not specified)</td></tr>
<tr><td colspan="2">(2) Priorities</td><td colspan="7">To assure OPG the public safety and to create a favorable, cooperative relationship with local communities. The design flood inflow of TSW regulating dam is 1,110 m3/s while the design flood capacity is only 776m3/s. The project expands the spillway capacity by 170 m3/s to upgrade it to 946 m3/s.</td></tr>
<tr><td colspan="2" rowspan="2">(3) Strategy</td><td colspan="7">Against potential risk in case of no decision making
To correspond to a worsening relationship with local communities caused by not handling the submersion risk</td></tr>
<tr><td colspan="7">Against potential risks when implementing decision-making items
To strengthen the relationship between OPG and TSW by reducing the necessity of daily operation of TSW regulating dam in cases of generator shutdown</td></tr>
</table>

(4) How decision-making was implemented and technologies adopted	To safety separate the 0.87-MW unit in the Ranney Falls GS which has finished its service life and newly construct an 8- to 10-MW unit. *Currently and after the project completion, TSW engages in power plant water management and takes the responsibility for the operation of the water regulating structure (Dam #10). As the intake quantity is upgraded by the project, TSW has to carry out water regulation only for 2 months annually, and this means they can assign their onsite staff to engage in duties other than the operation of Dam #10. This also enables to reduce the cost between OPG-CHPG.
Reference documents / sources Ranney Falls G3 Project - Business Case	

013 Reservoir Lining Repair: Sur Adam Beck Pump GS

Plant name		Sur Adam Beck Pump GS						
Operation start		1957		**Work completion**		1957		
Owner		Ontario Power Generation						
Country		Canada						
Max output	**kW**	174,000		**After work**		(Not given)		
Max generation discharge	**m^3/s**	(Not specified)						
Effective head	**M**	(Not specified)						
Type of decision making		**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)		○						
Time of decision making		2011						
Target structures		Reservoir						
・Driver(s)		Aging						
・Phenomena (caused by Driver)		Water leak occuring far away from reservoir. The foundation and dam can be easily affected by the cavein hole.						
Risk		Reduction						
・Risks for plant operation		Closure of plant facilities						
・Specific risk management		To shield the foundation with liner						
(1) Current status (before decision making)								
1) General status		SAB PGS supports the peak operation of SAB. This indicates to store water during off-peak hours and generate the power with this water during the higher-price peak times. The base design of a reservoir is characterised by open, interconnected, vertical and horizontal joints. Measures need to be taken against the water leakage at locations far from the reservoir by using the soil with favorable particle size for the openings. Due to the base characteristics, the foundation and dam are easily affected by the formation of cave-in holes.						
2) Operation status		SAB PGS operation is integrated between SAB1 and SAB2 Plants, while the water stored in the reservoir generates peak-time power at all 3 plants. As a result, SAB PGS operation brings remarkable summer peak value to the power system in Ontario. SAB PGS improves the entire power management of SAB which can be used for supporting AGC (Automated Generation Control) service and ORS (Operation Reserve Service) service for the power system in Ontario.。						
3) Risks		**Potential risk in case of no decision making** Destruction of dam, closure of plant						
		Potential risks when implementing decision-making items 1) Technical risk: plan delay or design change by unexpected discoveries in the geological investigationto be conducted 2) Regulatory risk: unexpected delay or more cost by problems related to relevant regulations 3) Economic risk: design change requiring increased cost by unexpected discoveries made during thedecision-making processes						
(2) Priorities		To begin the geological investigation of the site and consider optimal reservoir lining method						
(3) Strategy		**Against potential risk in case of no decision making** Closure of plant Considerable cost is required to close PGS and restore safe site status. Preliminary estimation is 50 million USD.						
		Against potential risks when implementing decision-making items Detailed investigation is necessary to check the behavior and decide potential measures to ensure the current plant operation.						

(4) How decision-making was implemented and technologies adopted	The preliminary examination was completed, and the following two options were presented for refurbishment. 1) To shield the reservoir base with a liner 2) To install concrete underground walls for most of the reservoir circumference which go through thesurface ground reaching the base rock ground. The liner shielding of the base was chosen as a favorable option due to its cost effectiveness and lower risk. This option would be improved in the final stage by choosing optimal width and shoulder of the liner.
Sources indicating the overview of decision-making project, etc. DEFINITION PHASE BUSINESS CASE SUMM SAB PGS RESERVOIR REFURBISHMENT https://www.oeb.ca/documents/cases/EB-2006-0064/oebconsultation_regulatedhydroelectric_mmazza_190506.pdf	

014 G3 Renewal (New Runner and Generator Rewinding): SIR ADAM BECK 1 GS

Plant name		SIR ADAM BECK 1 GS						
Operation start		2013		**Work completion**	2013			
Owner		Ontario Power Generation						
Country		Canada						
Max output	**kW**	45,000		**After work**	54,000			
Max generation discharge	**m³/s**	(Not given)						
Effective head	**M**	(Not given)						
Type of decision making		**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		2009						
Target structures		T/G						
・Driver(s)		Aging						
・Phenomena (caused by Driver)		Discontinuation of power generation						
Risk		Avoidance						
・Risks for plant operation		Reduction of energy generation						
・Specific risk management		Risk reduction by renewal						
(1) Current status (before decision making)								
1) General status		SAB1 G3 began commercial operation in 1922, and there has been no major refurbishment since 1985. In August 2010, Hydro Engineering Division (HED) completed the status assessment of G3. The assessment report states the following facilities have reached their service life expiration: *Surface of air cooler, *Bearing cooler, *Stator winding, *Excitation system, *15-kV bus and indicators, *main output transformer, *Switch, *Protection and control system						
2) Operation status		The existing excitation system does not meet the current criteria of IESO such as reactive power capacity, response time and celling level. Many components including exciter, switch, and bus work which have completed their service life are antique products from the 1920's.						
3) Risks		**Potential risk in case of no decision making** Failure of T/G						
		Potential risks when implementing decision-making items Reduced profit due to discontinued power generation						
(2) Priorities		To ensure the continuous, reliable operation of G3						
(3) Strategy		**Against potential risk in case of no decision making** Discontinuation of power generation						
		Against potential risks when implementing decision-making items G3 runner is suitable for service life extension according to the engineering condition assessment, but the replacement of G3 is also valid since the expected efficiency and capacity are at a quite high level. The design of G3 runner is the same as that of G7 and G9. The new runner will increase the facility MCR by 9MW, contributing to the increase of 8 GWh of the total of 13 GWh realized by the renewal of G3.						
(4) How decision-making was implemented and technologies adopted		Major refurbishment of turbine and related facilities, major refurbishment of generator including stator rewinding, replacement of many parts of main transmission system, renewal of exciter system, replacement of main transformer, modernization of equipment protection and control system.						
Reference documents / sources **NIAGARAOPERATION** https://www.oeb.ca/documents/cases/EB-2006-0064/oebconsultation_regulatedhydroelectric_mmazza_190506.pdf								

015 Renewal of Main Transformer: Des Joachims GS

Plant name		Des Joachims GS						
Operation start		2013		**Work completion**	2013			
Owner		Ontario Power Generation						
Country		Canada						
Max output	**kW**	428,800		**After work**	(Not given)			
Max generation discharge	**m³/s**	(Not given)						
Effective head	**M**	(Not given)						
Type of decision making		**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		2006						
Target structures		Main transformer						
・Driver(s)		Aging						
・Phenomena (caused by Driver)		Discontinuation of power generation						
Risk		Avoidance						
・Risks for plant operation		Discontinuation of power generation						
・Specific risk management		Risk avoidance by renewal						
(1) Current status (before decision making)								
1) General status		The transformer is of water-cooled type (manufactured back in the 1950's) and experienced fracture damage in 1981. T2 Blue Phase transformer ruptured, and the oil flowed out to around the outlet. It was operated 10% above the rated capacity for about 20 years, and thereby the estimated life of the transformer has been reduced and close to the end of its service life. The oil test suggested the concentration of CO and high humidity. High level CO increased the thermal stress which degraded the transformer insulation system to a critical level. The humidity inside the transformer is a major factor which accelerates the degradation of insulation performance, particularly when, combined with the temperature rise during operation, the humidity level is close to ASTM which recommends humidity level for reliably safe operation. There are no methods to remove the humidity from deep inside the insulation system.						
2) Operation status		*Des Joachims GS consists of 4 transformer systems, each supplementing 2 generators. Each system has 3 single-phase transformers and one spare transformer in the plant (13 transformers in total). The rating plate of the transformer in operation indicates 33 MVA, but each system operates at 110 MVA or 10% over the rated capacity.						
3) Risks		**Potential risk in case of no decision making** *The oil test showed unacceptable oil humidity and gasification level, but the transformers are operated 10% over the capacity. These transformers are close to the end of their service life, with increased risks of destruction, jeopardizing the power generation operation. *The past transformer repair plans were not satisfactory, and it was said that their service life would not be extended by Extensional repairs. Protection of asset facilities and safety of operating staff in the event of transformer destruction.						
		Potential risks when implementing decision-making items Discontinuation of power generation						
(2) Priorities		This investment is intended to avoid double shutdown in connection with the turbine renewal project. The installation of transformers will be conducted during the operation shutdown planned for the turbine renewal and major refurbishment.						

(3) Strategy	**Against potential risk in case of no decision making** *The oil test showed unacceptable oil humidity and gasification level, but the transformers are operated 10% over the capacity. These transformers are close to the end of their service life, with increased risks of destruction, jeopardizing the power generation operation. *The past transformer repair plans were not satisfactory, and it was said that their service life would not be extended by Extensional repairs. Such measures are not acceptable in view of the protection of asset facilities and safety of operating staff in the event of transformer destruction.
	Against potential risks when implementing decision-making items To list up the duties to be performed during the plant shutdown and carry them out without fail
(4) How decision-making was implemented and technologies adopted	Replacement with single-phase transformer of air-cooled type: ・An air-cooled single-phase transformer is the same size as the existing transformer, and thus the civil engineering work can be minimized, ・Output upgrade by transformer is sufficient for the seasonal turbine upgrading program and allows the output increase by 10% in connection with the generator renewal, ・Large oil tank or refurbishment of structures are not necessary, ・The cost for replacement transformer is 1/13 of the total coast and 1/5 of the 3-phase transformer, ・Refurbishment of LV cables is not necessary as there will be no major Extensional refurbishment
Reference documents / sources https://mapio.net/pic/p-44764531/	

016 Renewal and Rehabilitation of Sluice Gates: Otto Holden P/S

Plant name		Otto Holden Power Plant						
Operation start		2015		**Work completion**	2015			
Owner		Ontario Power Generation						
Country		Canada						
Max output	**kW**	243,000		**After work**	(Not given)			
Max generation discharge	**m³/s**	(Not given)						
Effective head	**M**	(Not given)						
Type of decision making		**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)				○				
Time of decision making		2010						
Target structures		Sluice gates, gate winches, gate roller paths, concrete around gain						
・Driver(s)		Aging						
・Phenomena (caused by Driver)		・ Incapacitated flowrate control and subsequent inundation due to date malfunctions						
Risk		Avoidance						
・Risks for plant operation		Safety assurance for dam downstream communities						
・Specific risk management		Risk avoidance by gate renewal						
(1) Current status (before decision making)								
1) General status		・50 years after the commissioning, the gate had severely degraded, and water was leaking from the seals. ・ The damaged sluice gate in operation allowed overflow at the gate which poses risks endangering the safety of workers, public and secure dam operation.						
2) Operation status		Incapacitated flowrate control and subsequent inundation due to date malfunctions						
3) Risks		**Potential risk in case of no decision making** ・Not implementing this project will impose non-compliance risks OPG dam stability. Timely, highly reliable flowrate control by these sluice gates is necessary for handling regular discharge requests, unexpected plant shutdown, or dam failure. 。 ・If OGP does not implement this project, the cost invested already would not be recovered.						
		Potential risks when implementing decision-making items ・ Public safety risk in cases of uncontrollable discharge during the gate removal work ・ Environmental risk by the sluice gate repair work near the water surface for installation of new gates						
(2) Priorities		Dam stability, safety assurance for downstream communities						
(3) Strategy		**Against potential risk in case of no decision making** ・ The new gates can be in service for 50 years based on the current standard thanks to the technological advancements made in the past 50 years						
		Against potential risks when implementing decision-making items ・ To ensure dam safety, private and public sectors need to be involved in the matters responsible for dam instability. ・ To adopt gates which do not need anti-rust treatment, assembly and coating onsite on the water						

(4) How decision-making was implemented and technologies adopted	・ Replacement of 6 sluice gates in the following processes: [2009] ・ To remove the existing distribution system, dispose of properly and install a heater. To upgrade to a new extended power system. ・ To integrate the gate operation and telemetry into the Plant RTU. ・ To sandblast and coat the members on the surface of gate guide ・ To remove the monorail hoist, beams and crane and dispose of properly ・ To design, build and install a staircase tower with grating steps and bar-type grate on the ground on the Ontario side of the sluice structure. ・ To install lighting and kickboards where needed and installable, and repair / upgrade the grating on the bridge deck. [from 2010 to 2015] ・ To remove the existing sluice gate, dispose of properly, install a new gate, refurbish the hoist drive, repair the concrete on downstream of the gain, and perform this at the pace of one gate a year following the schedule below to complete the planned replacement. 2010 #1, 2011 #6, 2012 #5, 2013 #2, 2014 #4, 2015 #3
Reference documents / sources BUSINESS CASE SUMMARY Replace Sluicegates & Rehabilitate Sluicegates System https://commons.wikimedia.org/wiki/File:Otto_Holden_GS.JPG	

017 G5 Major Repair and Renewal: SIR ADAM BECK 1 GS

Plant name		SIR ADAM BECK 1 GS						
Operation start		2016		**Work completion**	2013			
Owner		Ontario Power Generation						
Country		Canada						
Max output	**kW**	45,000		**After work**	54,000			
Max generation discharge	**m³/s**	(Not given)						
Effective head	**M**	(Not given)						
Type of decision making		**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		2014						
Target structures		T/G						
・Driver(s)		Aging						
・Phenomena (caused by Driver)		Discontinuation of power generation						
Risk		Avoidance						
・Risks for plant operation		Reduction of energy generation						
・Specific risk management		Risk reduction by renewal						
(1) Current status (before decision making)								
1) General status		G5 was converted to 60Hz operation in 1985.						
2) Operation status		(Not given)						
3) Risks		**Potential risk in case of no decision making** Damage to T/G						
		Potential risks when implementing decision-making items Reduced profit due to discontinuation of power generation						
(2) Priorities		To ensure the continuous, reliable operation of G3						
(3) Strategy		**Against potential risk in case of no decision making** Risk reduction by repairs and parts renewal						
		Against potential risks when implementing decision-making items By carrying out this large-scale overhaul of the units and upgrading of components, reliable operation can be expected for 25 to 30 years when the next major overhaul may be necessary.						
(4) How decision-making was implemented and technologies adopted		New protector and control system, overhaul of generator, new excitation system, new switchgear, including turbine runner with higher efficiency.						
Reference documents / sources NIAGARA OPERATION https://en.wikipedia.org/wiki/Sir_Adam_Beck_Hydroelectric_Generating_Stations								

018 G4 Major Repair and Renewal: SIR ADAM BECK 1 GS

Plant name		SIR ADAM BECK 1 GS						
Operation start		2017		**Work completion**		2017		
Owner		Ontario Power Generation						
Country		Canada						
Max output	**kW**	45,000		**After work**		54,000		
Max generation discharge	**m³/s**	(Not given)						
Effective head	**M**	(Not given)						
Type of decision making		**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		2016						
Target structures		T/G						
・Driver(s)		Aging						
・Phenomena (caused by Driver)		Discontinuation of power generation						
Risk		Avoidance						
・Risks for plant operation		Reduction of energy generation						
・Specific risk management		Risk reduction by repairs and renewal						
(1) Current status (before decision making)								
1) General status		The project cost was decided based on the results of a unit diagnosis conducted in 2015.						
2) Operation status		(Not given)						
3) Risks		**Potential risk in case of no decision making** Damage to T/G						
		Potential risks when implementing decision-making items Reduced profit due to discontinuation of power generation						
(2) Priorities		To ensure the continuous, reliable operation of G3						
(3) Strategy		**Against potential risk in case of no decision making** Risk reduction by repairs and parts renewal						
		Against potential risks when implementing decision-making items By carrying out this large-scale overhaul of the units and upgrading of components, reliable operation can be expected for 25 to 30 years when the next major overhaul may be necessary.						
(4) How decision-making was implemented and technologies adopted		New protector and control system, overhaul of generator, new excitation system, new switchgear, including turbine runner with higher efficiency.						
Reference documents / sources								
NIAGARA OPERATION https://en.wikipedia.org/wiki/Sir_Adam_Beck_Hydroelectric_Generating_Stations								

019 Renewal of Head Gates and Repair of Gains: Otto Holden P/S

Plant name		Otto Holden Power Plant						
Operation start		2021		**Work completion**		2021		
Owner		Ontario Power Generation						
Country		Canada						
Max output	**kW**	243,000		**After work**		(Not given)		
Max generation discharge	**m^3/s**	(Not given)						
Effective head	**M**	(Not given)						
Type of decision making		**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)				○				
Time of decision making		2012						
Target structures		Head gates, gains (that is, slots guiding head gates)						
・Driver(s)		Aging						
・Phenomena (caused by Driver)		Discontinuation of power generation						
Risk		Avoidance						
・Risks for plant operation		Reduction of energy generation						
・Specific risk management		Risk avoidance by repai and renewal						
(1) Current status (before decision making)								
1) General status		The head gate, its related parts and hoist were installed in the 1950's and had been used since the commissioning. The head gate operating for all 8 units was refurbished only once in the 1990's. It is now in the final stage of its service life. There is a lot of water leaking from the seals and sills of the head gate and the hoist unit has some maintenance issues. The investigation was conducted in 2011, which checked the status of the head gate and its embedded parts. The future project plan was drawn.。						
2) Operation status		Otto Holden P/S, located on Ottawa River 9 km north of Mattawa, consists of 8 units of generator, and began its operation in 1952 at 243 MW and average annual generated energy of 990 GWh.						
3) Risks		**Potential risk in case of no decision making** Discontinuation of power generation						
		Potential risks when implementing decision-making items Loss of asset protection and workers safety assurance						
(2) Priorities		Asset protection and workers safety assurance						
(3) Strategy		**Against potential risk in case of no decision making** (Not given)						
		Against potential risks when implementing decision-making items ・To be implemented during the overhaul of T/G planned to start in 2015 ・The new gates can be in service for 50 years based on the current standard thanks to the technological advancements made in the past 50 years						
(4) How decision-making was implemented and technologies adopted		Renewal of head gate and repair of embedded parts and hoist The head gate is a safety facility used for shutting the water supply to turbines in cases of emergency and the final facility that can be used for stopping the generators. It is also used during the turbine generator repairs and inspections and when separating the T/G units. It is important to keep the head gate and gain including the matching of their seals and seal passes in a favorable condition for asset protection and ensuring the safety of maintenance staff.						
Reference documents / sources https://commons.wikimedia.org/wiki/File:Otto_Holden_GS.JPG								

020 Upper Bonnington Old Units Refurbishment: Upper Bonnington P/S

Plant name		Upper Bonnington Hydro Power Plant						
Operation start		1907-1940		**Work completion**		2021		
Owner		FORTIS BC inc.						
Country		Canada						
Max output	**kW**	18,400		**After work**				
Max generation discharge	**m³/s**	(Not specified)				Not changed		
Effective head	**M**	(Not specified)				Not changed		
Type of decision making		**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		2016						
Target structures		T/G						
・Driver(s)		Aging						
・Phenomena (caused by Driver)		Frequent malfunctions and troubles, releases of contaminated substances to the enrvironment						
Risk		Avoidance						
・Risks for plant operation		Decline in stable supply, decline in operation safety, increase in environmental impact						
・Specific risk management		Risk avoidance by renewal of facilities						
(1) Current status (before decision making)								
1) General status		About 100 years had passed since the commissioning of Upper Bonnington Hydropower Plant, and thus the aging (corrosion, rusting and wear) of the 4 T/G units and lack of spare parts for the old types of machinery were outstanding. Some parts of Unit 3 were broken recently, and they were replaced. Therefore, it was already difficult to continue highly safe and reliable operation in an environmentally responsible manner. The T/G units had reached their service life.						
2) Operation status		Despite the problems due to aging, operation is barely continued.						
3) Risks		**Potential risk in case of no decision making** Discontinuation of power generation due to the machinery damage						
		Potential risks when implementing decision-making items Increase in repair cost						
(2) Priorities		Not specified						
(3) Strategy		**Against potential risk in case of no decision making** Selection of appropriate renewal methods and timing						
		Against potential risks when implementing decision-making items Comparison and assessment of risks and cost for various options						
(4) How decision-making was implemented and technologies adopted		Three options (abolition, life extension, renewal) were compared and assessed from the standpoint of economy (initial cost / 50 years present value), safety, reliability and environmental impact, and the option for renewal was selected. For the selected renewal plant, more examination was given to the initial investment. The machine renewal was planned to be implemented in order starting from Unit 3, Unit 3, Unit 2, and Unit 1 from 2017 to 2021. There are no special technologies to be notated.						
Reference documents / sources								
FORTIS BC "Appendix D: Upper Bonnington Old Units Refurbishment Project -Business Case-"								

021 Corra Linn Dam Spillway Gates Renewal: Corra Linn P/S

Plant name		Corra Linn Power Plant						
Operation start		1932		**Work completion**	2021 (plan)			
Owner		FORTIS BC inc.						
Country		Canada						
Max output	**kW**	48,000		**After work**				
Max generation discharge	**m³/s**	(Not specified)			Not changed			
Effective head	**M**	16.00			Not changed			
Type of decision making		**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		N/A (plan)						
Target structures		Dam spillway gates						
・Driver(s)		External factors (revision of design standard / regulations, aging of facilities)						
・Phenomena (caused by Driver)		Operation suspended due to new standard to be met and malfunctions in gate operation						
Risk		Avoidance						
・Risks for plant operation		Dam instability and damage to spillway gates by large floods or earthquakes						
・Specific risk management		Renewal and expansion of spillway gates by applying the new standard						
(1) Current status (before decision making)								
1) General status		Corra Linn Dam in operation for 84 years after commissioning has 14 spillway gates(B = H = 10 m). The dam called Kootenay Lake Reservoir is used also by another power plant, and these spillway gates are the only discharge facility, playing a quite important role in the reservoir management. The investigation of gates and other facilities conducted in 2016 assessed them between “sound and unsound,” whereby FORTIS BC realized the gates are close to the end of life, requiring fundamental refurbishment. At the same time, the design standard and regulations have been revised recently, and the gates and the related facilities designed according to the old standard are now not meeting the criteria.						
2) Operation status		No specific descriptions about the status of current gate operation						
3) Risks		**Potential risk in case of no decision making** Obstacles to reservoir operation due to the aging of the gate facilities Damage to the facilities by large floods and earthquakes						
		Potential risks when implementing decision-making items Increased repair cost due to the new standard						
(2) Priorities		Not specified						
(3) Strategy		**Against potential risk in case of no decision making** Selection of appropriate renewal methods and timing						
		Against potential risks when implementing decision-making items Consideration on measures to reduce the project cost						
(4) How decision-making was implemented and technologies adopted		2 points were considered for the introduction of new spillway gates: 1. By using low friction bearings, the existing hoists can be used continuously. 2. Gates are transported by section for higher work efficiency, and they are fixed and welded on the site.As a caution for the refurbishment, the necessity of repairing the concrete under the tower base plates was not checked in the investigation, which should be assessed during the repair work.						
Reference documents / sources FORTIS BC "CORRA LINN DAM Spillway Gate Replacement CPCN Application ; 3. PROJECT JUSTIFICATION"								

022 Installation of Sturgeon Screens: Waneta P/S

Plant name	Waneta Generating Station		
Operation start	1954	**Work completion**	2015
Owner	Colombia Power Corporation and Colombia Basin Trust		
Country	Canada		

Max output	**kW**	335,000	**After work**	Not changed
Max generation discharge	**m³/s**	312.60		Not changed
Effective head	**M**	61.32		Not changed

Type of decision making	**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○				

Time of decision making	Unknown
Target structures	Tailbay
・Driver(s)	-
・Phenomena (caused by Driver)	External factors (compliance)
Risk	Avoidance
・Risks for plant operation	Discontinuation of power generation due to the license cancellation by the Federal Energy Regulatory Commission
・Specific risk management	Installation of sturgeon exclusion screen
(1) Current status (before decision making)	
1) General status	At Waneta Power Plant, during the long-term T/G shutdown, white sturgeon, an endangered species, have entered the section between the tailbay and draft tube / turbine. Columbia River Water System spreads both the United States and Canada, and the refurbishment was required to meet the environmental standards of both counties.
2) Operation status	In Waneta Power Plant, sturgeon have entered into the draft and turbine.
3) Risks	**Potential risk in case of no decision making** License cancellation by the Federal Energy Regulatory Commission
	Potential risks when implementing decision-making items It was the first, unprecedented attempt to install such a screen for preventing the entry of sturgeon.
(2) Priorities	Not specified particularly
(3) Strategy	**Against potential risk in case of no decision making** To avoid license cancellation and discharge the social responsibility implementing the preventive measure against white sturgeon
	Against potential risks when implementing decision-making items No descriptions
(4) How decision-making was implemented and technologies adopted	・Adoption of sturgeon exclusion screens at installed units Special screens (sturgeon exclusion screens) were installed at the outlet to prevent the fish entry. This screen goes down when the plant output reaches the lowest level to prevent the sturgeon to come into the draft and runner when the power generation is shut down. It was the first attempt to installed such a screen in North America. ・The operation requires to check if sturgeon is inside the draft tube, to conduct water extraction from the draft tube gradually, to slow down the start-up of each unit, to monitor the outlet during the unit start-up, record the signs of sturgeon being there, and to review the period of repair maintenance to shut down the units during the season wherein sturgeon are active.
Reference documents / sources	

https://www.ceaa-acee.gc.ca/FABAB7E3-docs/report_e.pdf
http://columbiapower.org/about/environmental-stewardship/waneta-expansion-project/

023 Upgrading and Re-development of Embretsfoss Hydropower Plant Facilities

Plant name	Embretsfoss IV (redevelopment of Embretsfoss II)		
Operation start	1916	**Work completion**	2013
Owner	EB Kraftproduksjon AS		
Country	Norway		

Max output	**kW**	9,000	**After work**	52,500 Up rate (583%)
Max generation discharge	**m³/s**	75.00		
Effective head	**M**	16.30		

Type of decision making	**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)		○					

Time of decision making	2009
Target structures	Dam, whole plant
・Driver(s)	Aging
・Phenomena (caused by Driver)	Decline in plant functions
Risk	Avoidance
・Risks for plant operation	increased cost, Reduction of profit
・Specific risk management	Restoration / renewal of plant functions, recovery / restoration of strength / safety
(1) Current status (before decision making)	
1) General status	For the aging of electric facilities, T/G, etc. were renewed to ensure profitability. Embretsfoss II was a quite old hydropower plant of run-of-river type without a reservoir capacity. The utilization efficiency of river water was low, and more maintenance was required because of that. Also, the impact on the ecosystem environment had to be minimized. Since 1921, some issues regarding the civil engineering facilities had been pointed out. The machines and electric facilities were low efficiency and prone to heat generation.
2) Operation status	Embretsfoss II and Embretsfoss III with the effective head of 16.3 m utilizes 225 m3/s and generates 215 GWh annually.
3) Risks	**Potential risk in case of no decision making** The dam is a small intake pond without reservoir capacity, and thus does not meet the design standard for both flood response and strength. The plant's E&M facilities have aged, making the operation dangerous. The facility maintenance cost is increasing.
	Potential risks when implementing decision-making items Investigation was conducted as part of the long-term strategy to develop the EB hydro portfolio within the profit limits. The consideration was given to the expected energy generation, cost estimates, facilities' technical service life, failure risks, electricity prices estimated for the future. The results confirmed the profit cannot be expected for the final few years.
(2) Priorities	To secure profits
(3) Strategy	**Against potential risk in case of no decision making** In order to meet the safety standard, a new dam is to be constructed along with a new power plant in a project.
	Against potential risks when implementing decision-making items To implement the option with the highest net present value (NPV). To increase the generation discharge and reduce the water loss for increasing the total energy generation by renewing the generation facilities. To take into consideration the power trade at the Norwegian-Swedish Electricity Certificate Market (incentive for developing new renewable energy projects).

(4) How decision-making was implemented and technologies adopted	A new dam was constructed instead of refurbishing the existing dam to meet the current design standard. The cost effectiveness was higher, and it made easier to operate the plant during the work on the existing Plants Ⅱ and Ⅲ. A new large-size Kaplan turbine (runner inlet diameter D2 = 6.7, rotational speed of 93.75 rpm and 16.3 m for 52.5 MW) was selected to add annual generated energy of about 120 GWh from a new renewable energy source. This more than doubled the output of the existing 2 plants. The renewal took into consideration the 50 years to come. Also, a new plant (IV) was constructed while continue the power generation by the existing Plants (Ⅱ and Ⅲ). In order to improve the project's value, the contaminated ground surface was removed to improve the landscape and preserve the living condition for fish. A spacious fishway was secured for the fishery (especially salmon and eels).

Reference documents / sources

IEA Hydro ANNEX 11 Renewal & Upgrading of Hydropower Plants Case Portfolio No.2 (detailed data) Nw.01_Embretsfoss #4
https://www.nef.or.jp/ieahydro/contents/pdf/4th_a11/nw/01.pdf

024 Hemsil II Hydro Power Plant Upgrading

<table>
<tr><td colspan="2">Plant name</td><td colspan="7">Hemsil Hydropower Plant II</td></tr>
<tr><td colspan="2">Operation start</td><td colspan="2">1960</td><td colspan="2">Work completion</td><td colspan="3">2006</td></tr>
<tr><td colspan="2">Owner</td><td colspan="7">E-CO Energi AS (publilc enterprise of Oslo City)</td></tr>
<tr><td colspan="2">Country</td><td colspan="7">Norway</td></tr>
<tr><td>Max output</td><td>kW</td><td colspan="2">82,000</td><td colspan="2" rowspan="3">After work</td><td colspan="3">98,000　Up rate (20%)</td></tr>
<tr><td>Max generation discharge</td><td>m³/s</td><td colspan="2">28.00</td><td colspan="3">31m3/s</td></tr>
<tr><td>Effective head</td><td>M</td><td colspan="2">370.00
(total head)</td><td colspan="3"></td></tr>
<tr><td colspan="2">Type of decision making</td><td>O&R</td><td>R&E</td><td>Refurbishment</td><td>Extension</td><td>Redevelopment</td><td>Abolition</td><td>Other</td></tr>
<tr><td colspan="2">(○ where it applies)</td><td></td><td>○</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Time of decision making</td><td colspan="7">2004</td></tr>
<tr><td colspan="2">Target structures</td><td colspan="7">Turbine runner, guide vane, tailrace, cooling ventilator</td></tr>
<tr><td colspan="2">・Driver(s)</td><td colspan="7">Aging</td></tr>
<tr><td colspan="2">・Phenomena (caused by Driver)</td><td colspan="7">Declined facility function, environmental degradation</td></tr>
<tr><td colspan="2">Risk</td><td colspan="7">Avoidance</td></tr>
<tr><td colspan="2">・Risks for plant operation</td><td colspan="7">Increased cost, Reduction of profit, impact on the environment, opposition from local communities and fishery cooperatives</td></tr>
<tr><td colspan="2">・Specific risk management</td><td colspan="7">Restoration / renewal of plant functions, recovery / restoration of strength / safety, renewal / refurbishment of electric facilities</td></tr>
<tr><td colspan="9">(1) Current status (before decision making)</td></tr>
<tr><td colspan="2">1) General status</td><td colspan="7">For the aging of electric facilities, turbine runner, etc. were renewed to increase the generated energy. After the start of operation, the control center was renewed and the generator stator was rewound (in 1990 and 1991), but no other major expansion has been implemented.
As the turbine continued to age, the generation efficiency declined by 1 to 1.5% compared to the time of commissioning, and the grease supplied to the guide vane leaked to the river downstream. The labyrinth seal rings were worn by the humus soil in the water, and the inlet valve control system needed to be refurbished.</td></tr>
<tr><td colspan="2">2) Operation status</td><td colspan="7">Intake from Eikredammen (dam lake) on Hemsil River. The average annual generation is 9.7 TWh for the total capacity of about 2,800 MW.</td></tr>
<tr><td colspan="2" rowspan="2">3) Risks</td><td colspan="7">Potential risk in case of no decision making
Declining efficiency due to facility aging.
Continuation of operation without renewal would lower the safety level, increase the maintenance cost with passage of time as well as the risks of destruction.
The guide vane lubricating oil may leak into the river, contaminating the environment.</td></tr>
<tr><td colspan="7">Potential risks when implementing decision-making items
To optimize the project (to determine the final scope)</td></tr>
<tr><td colspan="2">(2) Priorities</td><td colspan="7">To enhance the efficiency and increase the energy generation by renewing the facilities with declining efficiency due to their aging</td></tr>
<tr><td colspan="2" rowspan="2">(3) Strategy</td><td colspan="7">Against potential risk in case of no decision making
To renew T/G after making the comprehensive plan and giving economic and strategic considerations. To replace the aged electrical machines (E&M) to improve the efficiency and increase the power generation.</td></tr>
<tr><td colspan="7">Against potential risks when implementing decision-making items
To identify the maintenance work to be performed by shutting down the plant operation over a longer period of time than the annual regular inspection repairs, and to prevent unnecessary oil leakage and contamination of the river.</td></tr>
</table>

(4) How decision-making was implemented and technologies adopted	In order to examine the profitability of the project, the turbines and generators were renewed after comprehensive planning and economic, strategic deliberation including cost estimation, expected revenues, net present value (NPV) and other parameters. Lifecycle cost calculations (simulations) were conducted with malfunction probabilities. Based on these analyses, the project scope was decided. Moreover, the optimal equipment was selected in consideration of the models, manufacturers, cost, know-how developed so far, advice from experts, research and latest knowledge (most advanced technologies. The generator capacity was raised from 2×41 MW to 2×49 MW, and the average annual energy generation was upgraded from 503 GWh to 537 GWh (increase by about 6.8%). The generation discharge (design flowrate) was up by 3 m3/sec. When the operation of the upgraded machines began, the thermodynamic efficiency was measured, and it was slightly lower than the manufacturer guarantee. This was due to the larger turbulence inside the tailrace than the estimation, since the design of the turbine and tailrace was not optimized comprehensively. This situation was found by a detailed computer modelling conducted for identifying the cause of efficiency differential. No defects in the design and manufacture were found, but the said problem may have been found if the manufacturer had run an appropriate computer modelling in the process of selecting the runner. The maximum generator capacity was at the guaranteed level.
Reference documents / sources IEA Hydro ANNEX 11 Renewal & Upgrading of Hydropower Plants Case Portfolio No.2 (detailed data) Nw.02_Hemsil #2 https://www.nef.or.jp/ieahydro/contents/pdf/4th_a11/nw/02.pdf	

025 Hol 1 Hydro Power Plant Renewal and Upgrading

Plant name		Hol Hydropower Plant					
Operation start		1949		**Work completion**	2012		
Owner		E-CO Energi AS (publilc enterprise of Oslo City)					
Country		Norway					
Max output	**kW**	186,000		**After work**	220,000 Up rate (18%)		
Max generation discharge	**m³/s**	56.00			63.6 m3/s		
Effective head	**M**	385.00 (#1,2) 350.00 (#3,4)			395 m (#1,2) 355 m(#3,4)		

Type of decision making	**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)		○					

Time of decision making	2007
Target structures	E&M facilities (turbine, generator, inlet valve, governor, unit control system, HV conductor)
・Driver(s)	Aging
・Phenomena (caused by Driver)	Declined generation efficiency / operating rate, decline in plant functions
Risk	Avoidance
・Risks for plant operation	Reduction of profit, increased cost
・Specific risk management	Restoration / renewal of plant functions, renewal / refurbishment of electric facilities
(1) Current status (before decision making)	
1) General status	For the aging of electric facilities, T/G, etc. were renewed to secure the profitability. Hol Power Plant No.1 consists of 2 tributaries called Votna and Urunda, with 2 units for each tributary, the total of 4 turbine generators. The total head of Units 1 and 2 exceeds 400 m, which used to be the highest in the world for Francis turbine at the point of 1949. The output of these units is 44 MW, also the largest in the world. In the 1970's all generators were refurbished with new stator winding and static magnetization, while the turbines were upgraded with new labyrinth seals. The turbines were refurbished in the 1990's, but the runners remained the same as the time of commissioning until the extension project between 2009 and 2012. For the aging and degradation, E-CO Energi decided to carry out a comprehensive renewal of the power generation units.
2) Operation status	The energy generation before the upgrading was 754 GWh/year.
3) Risks	**Potential risk in case of no decision making** The risk analysis pointed out troubles in the turbine runner if the operation continued for a long time at over-speed. If not renewed, the maintenance and refurbishment cost would increase greatly within a few years.
	Potential risks when implementing decision-making items After refurbishment of Units 1 and 2, unexpected noise occurred. It was generated at the gap between the guide vane and turbine runner entrance, and then propagated to the headrace channel outdoors.
(2) Priorities	To make a renewal plan to improve the efficiency of aged main facilities and to increase the energy generation
(3) Strategy	**Against potential risk in case of no decision making** To renew E&M facilities (turbine, generator, inlet valve, governor, unit control system, HV conductor) To increase the energy generation as a by-product of technical modernization
	Against potential risks when implementing decision-making items

	To take the following measures for removing the noise issue: ・To provide support for the adjustment rings ・To provide new labyrinth rings underneath ・To cut away the runner blade entrance ・To replace with a new guide vane ・To provide a support to the undercover ・To isolate the headrace channel ・To contain the noise inside the plant building
I(4) How decision-making was implemented and technologies adopted	The decision was made to renew the turbines and generators were renewed after comprehensive planning and economic, strategic deliberation. The cost estimation, expected revenues, net present value (NPV) and other parameters were used. Lifecycle cost calculations were conducted with malfunction probabilities. The generators, turbines, inlet values, governors, unit control system and high-voltage conductors were renewed. In the planning stage, the energy generation was estimated to be 15 GWh/year from the 4 units, but the measurement after the project showed 20 GWh/year, proving to be 5 GWh/year higher than the original calculations.

Reference documents / sources

IEA Hydro ANNEX 11 Renewal & Upgrading of Hydropower Plants Case Portfolio No.2 (detailed data) Nw.04_Hol#1
https://www.nef.or.jp/ieahydro/contents/pdf/4th_a11/nw/04.pdf

026 Rånåsfoss Hydro Power Plant Upgrading

<table>
<tr><td colspan="2">Plant name</td><td colspan="7">Rånåsfoss Hydropower Plant I</td></tr>
<tr><td colspan="2">Operation start</td><td colspan="2">1922</td><td colspan="2">Work completion</td><td colspan="3">2016</td></tr>
<tr><td colspan="2">Owner</td><td colspan="7">Akershus Energi</td></tr>
<tr><td colspan="2">Country</td><td colspan="7">Norway</td></tr>
<tr><td>Max output</td><td>kW</td><td colspan="2">54,000</td><td colspan="2" rowspan="3">After work</td><td colspan="3">81,000 Up rate (50%)</td></tr>
<tr><td>Max generation discharge</td><td>m³/s</td><td colspan="2">540.00</td><td colspan="3">not specified</td></tr>
<tr><td>Effective head</td><td>M</td><td colspan="2">12.50</td><td colspan="3"></td></tr>
<tr><td colspan="2">Type of decision making</td><td>O&R</td><td>R&E</td><td>Refurbishment</td><td>Extension</td><td>Redevelopment</td><td>Abolition</td><td>Other</td></tr>
<tr><td colspan="2">(○ where it applies)</td><td></td><td>○</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Time of decision making</td><td colspan="7">2010</td></tr>
<tr><td colspan="2">Target structures</td><td colspan="7">T/G, powerhouse building</td></tr>
<tr><td colspan="2">・Driver(s)</td><td colspan="7">Aging</td></tr>
<tr><td colspan="2">・Phenomena (caused by Driver)</td><td colspan="7">Declined facility function, declined generation efficiency / operating rate</td></tr>
<tr><td colspan="2">Risk</td><td colspan="7">Avoidance</td></tr>
<tr><td colspan="2">・Risks for plant operation</td><td colspan="7">Reduction of profit, increased cost</td></tr>
<tr><td colspan="2">・Specific risk management</td><td colspan="7">Refurbishment, expansion, new installation of civil engineering facilities, renewal / refurbishment of electric facilities</td></tr>
<tr><td colspan="9">(1) Current status (before decision making)</td></tr>
<tr><td colspan="2">1) General status</td><td colspan="7">For the aging of electric facilities, T/G, etc. were renewed to increase the energy generation.
In the early stage after the commissioning, a runner trouble occurred in 3 units, and they were replaced immediately, and a reinforcing material was installed between the runner blades. The other 3 units are designed with long intervals in the main shaft bearing, and thus the shaft stress has caused runner cracking, which was repeatedly repaired by welding almost every year. Also, the main shaft of all units was replaced at least once.
The governors were changed from a mechanical to electrical hydraulic system by the end of the 1970’ s, and then digitalized in the 1990’s, but the T/G units remained as original, which required more and more frequent and wide-ranged repair works year by year.
In Extension to the increasing river flowrate in recent years, 3,500 to 7,500 people from Akershus County are visiting this power plant annually, so considerations are given to the preservation of the powerhouse building which is historically valuable.</td></tr>
<tr><td colspan="2">2) Operation status</td><td colspan="7">The average annual energy generation of Rånåsfoss I was 220 GWh.</td></tr>
<tr><td colspan="2" rowspan="2">3) Risks</td><td colspan="7">Potential risk in case of no decision making
The aged E&M facilities are deteriorating after the operation for over 40 years. Continuing the operation without renewal would further lower the safety level and increases the risks as more time passes (more maintenance cost and time, and risks of serious troubles).
Already time and resources have been spent for the maintenance of the existing plant, but more cost would be required in the future.
The ineffective discharge would increase against the recent river flowrate.</td></tr>
<tr><td colspan="7">Potential risks when implementing decision-making items
Option for controlling the river flow with coffering dam (covering the work area) is not realistic due to the cost and reduced power generation.
Decline in power generation due to the discontinuation of power generation.</td></tr>
<tr><td colspan="2">(2) Priorities</td><td colspan="7">To renew the aging facilities to improve the efficiency and to increase the energy generation</td></tr>
</table>

(3) Strategy	**Against potential risk in case of no decision making** To replace the old Rånåsfoss Plant I with new Rånåsfoss III To remove the existing horizontal axis Francis turbine and to install exposed vertical propellor turbine To install the latest machines to simplify the maintenance work
	Against potential risks when implementing decision-making items To separate the civil engineering work area with the existing intake gate and discharge stop log in order to prevent the river water from flowing in To adopt exposed vertical propeller turbine to limit the scope of the civil engineering work to enable the facility renewal and expansion while operating the existing machines nearby.
(4) How decision-making was implemented and technologies adopted	In the FS investigation, it was recognized that the priority is to increase the generation discharge rather than the turbine efficiency to increase the power generation energy. The runner diameter was designed to be as large as possible within the restrictions of civil engineering structures, while the runner hub was to be as small as possible, and the spiral casing be replaced by the entrance cone. Considering the historical value of the building, the generator chamber was preserved together with the existing generator, while the draft tube and intake were renewed for improving the hydrological characteristics. The average annual generated energy of the refurbished Rånåsfoss Power Plant III is 280 GWh, up by 60 GWh. The estimated cost was 800 million Norwegian krone (or 100 to 105 million USD in the exchange rate of June 2015).
Reference documents / sources IEA Hydro ANNEX 11 Renewal & Upgrading of Hydropower Plants Case Portfolio No.2 (detailed data) Nw.07_Rånåsfoss #3 https://www.nef.or.jp/ieahydro/contents/pdf/4th_a11/nw/07.pdf	

027 Rendalen Hydro Power Plant Unit 2

<table>
<tr><td colspan="2">Plant name</td><td colspan="7">Rendalen Hydropower Plant</td></tr>
<tr><td colspan="2">Operation start</td><td colspan="2">1971</td><td colspan="2">Work completion</td><td colspan="3">2013</td></tr>
<tr><td colspan="2">Owner</td><td colspan="7">Opplandskraft DA (Power Production)</td></tr>
<tr><td colspan="2">Country</td><td colspan="7">Norway</td></tr>
<tr><td>Max output</td><td>kW</td><td colspan="2">92,000</td><td colspan="2" rowspan="3">After work</td><td colspan="3">94,000 Up rate (2%)</td></tr>
<tr><td>Max generation discharge</td><td>m^3/s</td><td colspan="2">55.00</td><td colspan="3"></td></tr>
<tr><td>Effective head</td><td>M</td><td colspan="2">210.00
(total head)</td><td colspan="3"></td></tr>
<tr><td colspan="2">Type of decision making</td><td>O&R</td><td>R&E</td><td>Refurbishment</td><td>Extension</td><td>Redevelopment</td><td>Abolition</td><td>Other</td></tr>
<tr><td colspan="2">(○ where it applies)</td><td></td><td>○</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Time of decision making</td><td colspan="7">2009</td></tr>
<tr><td colspan="2">Target structures</td><td colspan="7">Headrace tunnel, setting room, underground plant, T/G unit</td></tr>
<tr><td colspan="2">・Driver(s)</td><td colspan="7">Aging</td></tr>
<tr><td colspan="2">・Phenomena (caused by Driver)</td><td colspan="7">Generation discontinued, declined generation efficiency / operating rate</td></tr>
<tr><td colspan="2">Risk</td><td colspan="7">Avoidance</td></tr>
<tr><td colspan="2">・Risks for plant operation</td><td colspan="7">Reduction of profit</td></tr>
<tr><td colspan="2">・Specific risk management</td><td colspan="7">Refurbishment, expansion, new installation of civil engineering facilities, closure, relocation, new installation of plant building</td></tr>
<tr><td colspan="9">(1) Current status (before decision making)</td></tr>
<tr><td colspan="2">1) General status</td><td colspan="7">For the aging of electric facilities, T/ G, etc. were renewed to secure the profitability.
Facility inspection and maintenance have been performed since the commissioning, but the aging has progressed, and it is about the timing for replacement of the T/G. There has been one major shutdown due to the turbine trouble in its operational history.</td></tr>
<tr><td colspan="2">2) Operation status</td><td colspan="7">One unit of 92-MW Francis turbine generates energy of 675 GWh annually.</td></tr>
<tr><td colspan="2" rowspan="2">3) Risks</td><td colspan="7">Potential risk in case of no decision making
Machine maintenance requiring shutdown of T/G unit and inspection of headrace setting facility (operation shutdown for 2-3 weeks annually) causes economic loss due to reduced power generation. There are signs suggesting that, as aging progresses, more time may be necessary for appropriate maintenance and inspection.
In the future, a very long maintenance period will be necessary for ensuring profitably technical operation.</td></tr>
<tr><td colspan="7">Potential risks when implementing decision-making items
It was clarified the intake cannot be increased for power generation due to environmental reasons.
The ground rock quality was a serious concern throughout the project for building the headrace tunnel.</td></tr>
<tr><td colspan="2">(2) Priorities</td><td colspan="7">To improve the flexibility of maintenance work</td></tr>
<tr><td colspan="2" rowspan="2">(3) Strategy</td><td colspan="7">Against potential risk in case of no decision making
To improve the flexibility of maintenance work by alternately operating 2 T/G units To install the new unit about 200 m away from the existing unit</td></tr>
<tr><td colspan="7">Against potential risks when implementing decision-making items
Not to increase the total intake despite the upgrading due to the permitted intake of 55 m3/s for power generation.
Difficult excavation of pressure shaft of 4.5 m in diameter, 150 m in height. Raise boring shaft of 1.6 m in diameter was used as pilot boring to excavate from the top, and the precision of pilot boring for raise drilling was high despite the undesirable rock condition.</td></tr>
</table>

(4) How decision-making was implemented and technologies adopted	The current status was assessed, and it was concluded that new installation of a T/G unit about the same capacity as the existing unit is the most economical. The increase in the annual generated energy (average) was calculated to be 50 GWh. The civil engineering work and installation of a new unit (turbine generator) were completed while running the existing unit in full capacity. The total case was 356.5 million Norwegian krone (or about 60 million USD).

Reference documents / sources

IEA Hydro ANNEX 11 Renewal & Upgrading of Hydropower Plants Case Portfolio No.2 (detailed data) Nw.09_ Rendalen
https://www.nef.or.jp/ieahydro/contents/pdf/4th_a11/nw/09.pdf

028 Boulder Canyon Hydropower Plant Modernization

Plant name		Boulder Canyon Hydropower Plant						
Operation start		1910		**Work completion**		2012		
Owner		Boulder City, Colorado						
Country		USA						
Max output	**kW**	20,000		**After work**		10,000 Up rate (-50%)		
Max generation discharge	**m^3/s**	(Not specified)						
Effective head	**M**	(Not specified)						
Type of decision making		**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		2010						
Target structures		T/G, set of peripheral T/G equipment inclusing inlet valve, powerhouse building						
・Driver(s)		Aging						
・Phenomena (caused by Driver)		Generation discontinued, Declined facility function, declined generation efficiency / operating rate						
Risk		Avoidance						
・Risks for plant operation		Reduction of profit, declined safety of workers						
・Specific risk management		Renewal / refurbishment of electric facilities, refurbishment, expansion, new installation of civil engineering facilities						
(1) Current status (before decision making)								
1) General status		For the aging of its electric and other facilities, as well as the reduction in the generation discharge, T/G, etc. were renewed to increase the energy generation. The 2 units of turbine generator (10 MW each) were refurbished in the 1930's and 40's. The generator of one of them was not usable and repairable after 2000, and the other one was predicted to be nonfunctioning within 5 years. The unit in operation was an old system of one-nozzle Pelton turbine of max efficiency of 82%.The power plant waterflow condition changed largely from the initial situation, making it an excessive facility with low efficiency.						
2) Operation status		The Pelton T/G in operation is 1-nozzle, max efficiency of 82% and minimum discharge of 4 to 5cfs (0.11-0.14 m3/s)						
3) Risks		**Potential risk in case of no decision making** The installed capacity is excessive for the reduced generation discharge available, lowering the operation efficiency. As aging progresses with degraded conductors, asbestos, etc. the safety of plant operating staff is in danger.						
		Potential risks when implementing decision-making items The initiatives to be taken for environmental safety are to dispose of aged transformers, to install lightning protections, and to remove the old hydraulic tank.						
(2) Priorities		This modernization project which utilizes a grants-in-aid scheme under the Rehabilitation Act (American Recovery and Reinvestment Act) from the Wind / Hydro Program, Energy Efficiency / Renewable Energy Division of the United States Department of Energy.						
(3) Strategy		**Against potential risk in case of no decision making** The existing units (10 MW × 2) were replaced by high efficiency 5-MW Pelton turbine						
		Against potential risks when implementing decision-making items To install new conductors and remove asbestos in order to ensure the safety of operating staff and facilities To replace the 2 oil-cooling transformers (manufactured in the 1940'S) with a smaller transformer and renew the switching unit as an environmental conservation measure						

(4) How decision-making was implemented and technologies adopted	This project was granted a subsidy of 1,180,000 USD, or 20.1% of the project cost, as a grants-in-aid scheme under the Rehabilitation Act from the Wind / Hydro Program by the United States Department of Energy. The key decisions made during the project were to downsize the capacity of T/G from 6 MW to 5 MW and to replace Unit A instead of Unit B. The possibility of 6 MW was discussed, but it was clarified that the peak flowrate timing coincides with the water demand peak, in other words, the usable water discharge for power generation would not exceed 5 MW in that season. The replacement of Unit A instead of Unit B was advantageous in many ways, such as reduction of concrete removal volume, simplification of detour piping and distribution lines, shorter shutdown duration, and optimization of coordination and operation. The new, 5-MW T/G is much more compact than the former 10-MW unit, but the annual generated energy increased by 37% as it is operable according to the usable flowrate. The refurbishment was undertaken while preserving the historical hydropower generation facilities.

Reference documents / sources

IEA Hydro ANNEX 11 Renewal & Upgrading of Hydropower Plants Case Portfolio No.2 (detailed data) US.02_Boulder Canyon
https://www.nef.or.jp/ieahydro/contents/pdf/4th_a11/us/02.pdf

029 (TAPOCO Project) Cheoah Refurbishment: Cheoah P/S

Plant name		Cheoah Hydropower Plant					
Operation start		1919		**Work completion**	2012		
Owner		Alcoa Inc. (one of three major US aluminum chemical companies)					
Country		USA					
Max output	**kW**	144,700		**After work**	(Not given)		
Max generation discharge	**m³/s**	268.00					
Effective head	**M**	(Not specified)					

Type of decision making	**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)		○					

Time of decision making	2008
Target structures	T/G and peripheral equipment
・Driver(s)	Aging
・Phenomena (caused by Driver)	Generation discontinued, declined generation efficiency / operating rate、environmental degradation
Risk	Avoidance
・Risks for plant operation	Reduction of profit, impact on the environment
・Specific risk management	Renewal / refurbishment of electric facilities
(1) Current status (before decision making)	
1) General status	For the aging electric facilities, T/G, were renewed to increase the generated energy. Cheoah Power Plant before the expansion project was comprised by a dam and 5 Francis turbines. 4 of them have been in operation since the commissioning and the 5th unit was added in 1949. The authorized output was 144.7 MW in total, maximum discharge of 9,436 csf (about 268 m3/s). Unit 2 suffered malfunctions in 2007. The average age of the facilities in Cheoah Power Plant exceeded 90 years, and thus unexpected trouble risks (as manifested in Unit 2 in 2007) are increasing year after year for this typical aged plant.
2) Operation status	Cheoah Hydropower Plant (FERC No.2169) constructed in 1919 supplies the generated power to Alcoa Inc., the owner of the project. The plant is part of the TAPOCO Hydro Development Project, consisting of 4 hydropower plants of Santeetlah, Cheoah, Calderwood, and Chilhowee.
3) Risks	**Potential risk in case of no decision making** The malfunctions and troubles at Cheoah largely affect the upstream and downstream plant operations and greatly interfere with the power supply to the local communities. Environmental impact by lead painting, asbestos, insulation oils, grease.
	Potential risks when implementing decision-making items How to fulfill the current standard requirements
(2) Priorities	Tennessee Valley Authority (TVA) assessed the TAPOCO region and designated Cheoah Power Plant as the top priority of modernization planning.
(3) Strategy	**Against potential risk in case of no decision making** To renew T/G (machine efficiency up by about 40%) To install oil fences for the transformers, to remove the grease lubricated bearings of transformers, discharge water cooling system and turbine water contact surface (use of oils onsite down by 60%) To address the issue of lead painting and asbestos of 4 T/G units and to improve the noise level in the generator room
	Against potential risks when implementing decision-making items (Not specified)

(4) How decision-making was implemented and technologies adopted	This project was granted a subsidy of 12,174,956USD equivalent to 17.6% of the project cost, as a grants-in-aid scheme under the Rehabilitation Act from the Wind / Hydro Program by the United States Department of Energy. Units 1 and 2 were upgraded to output 50% more, from 22 MW to 33 MW, each.
Reference documents / sources IEA Hydro ANNEX 11 Renewal & Upgrading of Hydropower Plants Case Portfolio No.2 (detailed data) US.03_Cheoah https://www.nef.or.jp/ieahydro/contents/pdf/4th_a11/us/03.pdf	

030 Cushman No.2 Dam of North Fork Skokomish P/S

Plant name		North Fork Skokomish Power Plant					
Operation start		2013		**Work completion**	2013		
Owner		Tacoma City, Washington					
Country		USA					
Max output	**kW**	3,600		**After work**	3,600		
Max generation discharge	**m³/s**	(Not specified)					
Effective head	**M**	(Not specified)					
Type of decision making	**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)							○
Time of decision making	2009						
Target structures	Dam (fish guilding and catching system)						
・Driver(s)	External factors						
・Phenomena (caused by Driver)	Reduction of generation discharge (ineffective discharge), environmental degradation						
Risk	Reduction						
・Risks for plant operation	Impact on the environment, opposition from local communities and fishery cooperatives, reduction of profit						
・Specific risk management	Closure, relocation, new installation of plant building, environmental conservation measures						

(1) Current status (before decision making)	
1) General status	In connection with the license renewal of the power plant and requests for improving the environmental conservation, we installed a fish guiding and catching system, etc. Cushman Project No.2 (completed in 1926) expired its licences (for 50 years) in 1974, and for 24 years after that, a permit was issued every year through discussions with various stakeholders. When the dam operation license for Cushman No.2 Dam was issued in 1998, multiple groups filed an objection against that decision (for licensing) for different reasons. During the objection proceedings, a reassessment of the environmental impact was requested to the Federal District Court, and some fish species inhabiting the State of Washington were listed pursuant to the Endangered Species Act. An Extensional complaint was filed thereafter.
2) Operation status	(Not specified)
3) Risks	**Potential risk in case of no decision making** License invalidation for Cushman No.2 Project Reduction of profit due to ineffective discharge
	Potential risks when implementing decision-making items Insufficient grounding of transformer facilities (based on ground geological assessment)
(2) Priorities	After the renewed approval of the plant operation, lawsuits (multiple cases) were filed regarding the compensation from the project. As part of settlement agreement, the hydropower facilities will intensify their environmental conservation measures, and a new plant will be constructed to utilize the unused energy.
(3) Strategy	**Against potential risk in case of no decision making** New construction of a power plant having a fish guiding and catching system
	Against potential risks when implementing decision-making items To add grounding rods and to install special boundary grounding system

(4) How decision-making was implemented and technologies adopted	This project was granted a subsidy of 4,671,304 USD as a grants-in-aid scheme under the Rehabilitation Act from the Wind / Hydro Program by the United States Department of Energy. This amount accounted for 17.5% of the project cost, and the rest was funded by Tacoma City. The new plant has 2 units of Francis turbine generator of 1.8 MW. In the plant, an integrated control system is installed wherein all control units for turbine, generator, discharge valves, and fish transfer are integrated into one system. The innovative fish transfer system releases part of the discharge through the screen bed of a concrete fish trap while the fish is drawn into the trap through a groove-shaped fish entrance and lifted to the dam crown using a transport hopper / tram. The jib crane hoists the hopper from the tram and moves it to the receiving tank in the new fish transport system. The fish are sorted out, counted and marked (if necessary). And then, the fish are transported in the tank to two locations upstream of Cushman Dam or one of the two hatcheries.

Reference documents / sources

IEA Hydro ANNEX 11 Renewal & Upgrading of Hydropower Plants Case Portfolio No.2 (detailed data) US.04_North Fork Skokomish
https://www.nef.or.jp/ieahydro/contents/pdf/4th_a11/us/04.pdf

031 (US Rehabilitation Act) Fond du Lac P/S

<table>
<tr><td colspan="2">Plant name</td><td colspan="7">Fond du Lac Hydropower Plant</td></tr>
<tr><td colspan="2">Operation start</td><td colspan="2">1924</td><td colspan="2">Work completion</td><td colspan="3">2013</td></tr>
<tr><td colspan="2">Owner</td><td colspan="7">Minnesota Power</td></tr>
<tr><td colspan="2">Country</td><td colspan="7">USA</td></tr>
<tr><td>Max output</td><td>kW</td><td colspan="2">12,000</td><td colspan="2" rowspan="3">After work</td><td colspan="3">12,000</td></tr>
<tr><td>Max generation discharge</td><td>m³/s</td><td colspan="2">(Not specified)</td><td colspan="3"></td></tr>
<tr><td>Effective head</td><td>M</td><td colspan="2">(Not specified)</td><td colspan="3"></td></tr>
<tr><td colspan="2">Type of decision making</td><td>O&R</td><td>R&E</td><td>Refurbishment</td><td>Extension</td><td>Redevelopment</td><td>Abolition</td><td>Other</td></tr>
<tr><td colspan="2">(○ where it applies)</td><td></td><td>○</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Time of decision making</td><td colspan="7">(Not specified)</td></tr>
<tr><td colspan="2">Target structures</td><td colspan="7">T/G, turbine bearing cooling system, generator excitation system, intake gate, ceiling crane, penstock</td></tr>
<tr><td colspan="2">・Driver(s)</td><td colspan="7">Aging</td></tr>
<tr><td colspan="2">・Phenomena (caused by Driver)</td><td colspan="7">Generation discontinued, Declined facility function, declined generation efficiency / operating rate</td></tr>
<tr><td colspan="2">Risk</td><td colspan="7">Avoidance</td></tr>
<tr><td colspan="2">・Risks for plant operation</td><td colspan="7">Reduction of profit</td></tr>
<tr><td colspan="2">・Specific risk management</td><td colspan="7">Restoration / renewal of plant functions</td></tr>
<tr><td colspan="9">(1) Current status (before decision making)</td></tr>
<tr><td colspan="2">1) General status</td><td colspan="7">For the aging of plant facilities, the turbine generator and civil engineering facilities were renewed to increase the generation output.
Fond du Lac Hydropower Plant was operated with aged equipment and building materials, and thus the plant had to be refurbished and upgraded. The 12-MW turbine was deteriorating gradually, and the bushing, bearing and seals needed to be replaced. The existing generator stator and rotor had been in operation since 1924, almost reaching the end of service life. Extensionally, the excitation system, intake gate and runner also had to be changed.
The water way inspection in a shutdown condition revealed the degraded state of the penstock, needing major repairs as well.</td></tr>
<tr><td colspan="2">2) Operation status</td><td colspan="7">The gate opening was limited to 78% due to the cracks in the intake gate upper cover.</td></tr>
<tr><td colspan="2" rowspan="2">3) Risks</td><td colspan="7">Potential risk in case of no decision making
Generation discontinued, declined facility function, declined generation efficiency / operating rate</td></tr>
<tr><td colspan="7">Potential risks when implementing decision-making items
Flood of 500-year return period occurred before repairing the penstock, which caused the dam level to go up to upstream Thompson Power Plant and risks of further complicating the repair and reassembly processes</td></tr>
<tr><td colspan="2">(2) Priorities</td><td colspan="7">(Not specified)</td></tr>
<tr><td colspan="2" rowspan="2">(3) Strategy</td><td colspan="7">Against potential risk in case of no decision making
To replace with T/G with high efficiency latest stainless steel runner
To renew stator / rotor coils
To improve efficiency of turbine bearing cooling system and to prevent oil splashing
To upgrade generator excitation system to static excitation system
To replace intake gates and automate ceiling crane　To repair penstock</td></tr>
<tr><td colspan="7">Against potential risks when implementing decision-making items
(Not specified)</td></tr>
</table>

(4) How decision-making was implemented and technologies adopted	This project was granted a subsidy of 815,995 USD, or 14.7% of the project cost, as a grants-in-aid scheme under the Rehabilitation Act from the Wind / Hydro Program by the United States Department of Energy. During the project, unexpected defects were found in the penstock, and a flood of 500-year return period occurred, but the project continued despite such difficulties without time loss while the plant was in the operation continuously, and therefore the output was successfully upgraded.

Reference documents / sources

IEA Hydro ANNEX 11 Renewal & Upgrading of Hydropower Plants Case Portfolio No.2 (detailed data) US.05_Fond du Lac
https://www.nef.or.jp/ieahydro/contents/pdf/4th_a11/us/05.pdf

032 Alternation of Mossyrock Dam Operation

Plant name		Mossyrock Dam Power Plant							
Operation start		1968		**Work completion**		-			
Owner		Tacoma Power							
Country		The United States							
Max output	**kW**	382,000		**After work**		Not changed			
Max generation discharge	**m³/s**	(Not specified)				Not changed			
Effective head	**M**	(Not specified)				Not changed			
Type of decision making		**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**	
(○ where it applies)								○	
Time of decision making		2017							
Target structures		Dam							
・Driver(s)		External factors (third party damage prevention)							
・Phenomena (caused by Driver)		Damage / flood in earthquakes due to insufficient anti-seismic strength of dam							
Risk		Reduction							
・Risks for plant operation		Impossibility of plant operation due to opposition against dam operation \							
・Specific risk management		Lowering of operation water level							
(1) Current status (before decision making)									
1) General status		Mossyrock Dam is located at the highest elevation in the State of Washington. Constructed in 1968, the dam was supplying with the output of 382 MW. The earthquake assessment by the US Geological Survey pointed out a low likelihood of catastrophic earthquakes but the possibilities of the spillway pier bridges being destroyed by a large-scale earthquake, and thus advised the dam operation at low water levels.							
2) Operation status		Before earthquake prediction updates, the dam and plant were operated normally							
3) Risks		**Potential risk in case of no decision making** Damage to downstream area when earthquakes strike							
		Potential risks when implementing decision-making items Reduction of generated energy							
(2) Priorities		External factors to be given priority							
(3) Strategy		**Against potential risk in case of no decision making** Not specified							
		Against potential risks when implementing decision-making items To reinforce the dam as a measure to be taken in the future							
(4) How decision-making was implemented and technologies adopted		To keep the dam level between 778 ft and 749 ft during the summer (about 745 ft during the winter since before) The future plan is to implement anti-seismic reinforcement of the dam. Only the operation methods were changed without technological applications.							
Reference documents / sources https://tdn.com/news/local/riffe-lake-to-be-lower-as-hedge-against-earthquakes/article_30af2dcb-2303-55f6-b40a-7b292f9914b6.html									

033 Wynoochee river project

Plant name	Wynoochee river project		
Operation start	1993	**Work completion**	-
Owner	Tacoma Power		
Country	The United States		

			After work
Max output	**kW**	12,800	Not changed
Max generation discharge	**m³/s**	(Not specified)	Not changed
Effective head	**M**	(Not specified)	Not changed

Type of decision making	**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)							○

Time of decision making	2016
Target structures	Other
・Driver(s)	External factors (compliance)
・Phenomena (caused by Driver)	Protection of salmon, trout
Risk	Avoidance
・Risks for plant operation	Discontinuation of power generation due to license cancellation by FERC
・Specific risk management	Compliance for license
(1) Current status (before decision making)	
1) General status	In the Wynoochee River Project, the dam was constructed in 1972 for the flood control purpose, and the power plant was constructed in 1993 for power generation using a renewable energy source. The power plant operation license issued by FERC provided the following conditions regarding the fish conservation: ・To operate a fish collection facility 2 miles downstream the dam ・To keep several fish as parents and to transport the rest by tank lorry 5 miles upstream.
2) Operation status	The criteria for license are met and the operation is continued
3) Risks	**Potential risk in case of no decision making** Invalidation of license issued by FERC due to insufficient external factors **Potential risks when implementing decision-making items** Decline in energy generation, reduction of profit from electricity sales
(2) Priorities	To comply with the criteria in order to maintain the license issued by FERC
(3) Strategy	**Against potential risk in case of no decision making** In consideration for the fishery, the plant operation is shut down for 77 days during spring to allow salmon and trout to swim downstream in the river. 。 **Against potential risks when implementing decision-making items** No descriptions about the measures against the decline in energy generation
(4) How decision-making was implemented and technologies adopted	In consideration for the fishery, the plant operation is shut down for 77 days during spring to allow salmon and trout to swim downstream in the river. This way, the fish conservation is ensured while operating the hydropower plant continuously. This measure is taken by shutting down the operation, without technological applications.
Reference documents / sources	
https://www.mytpu.org/community-environment/fish-wildlife-environment/wynoochee-river-project/#:~:text=To%20protect%20the%20fishery%2C%20we,through%20outlets%20in%20the%20dam. https://www.mytpu.org/about-tpu/services/power/about-tacoma-power/dams-power-sources/wynoochee-river-project/#pattern_2	

034 Taum Sauk Pumped Storage Project

<table>
<tr><td colspan="2">Plant name</td><td colspan="7">Taum Sauk Pumped Storage Project</td></tr>
<tr><td colspan="2">Operation start</td><td colspan="2">1969</td><td colspan="2">Work completion</td><td colspan="3">2010 (resumed operation)</td></tr>
<tr><td colspan="2">Owner</td><td colspan="7">Ameren Missouri</td></tr>
<tr><td colspan="2">Country</td><td colspan="7">The United States</td></tr>
<tr><td>Max output</td><td>kW</td><td colspan="2">450,000</td><td colspan="2" rowspan="3">After work</td><td colspan="3">Not changed</td></tr>
<tr><td>Max generation discharge</td><td>m³/s</td><td colspan="2">(Not specified)</td><td colspan="3">Not changed</td></tr>
<tr><td>Effective head</td><td>M</td><td colspan="2">260.00</td><td colspan="3">Not changed</td></tr>
<tr><td colspan="2">Type of decision making</td><td>O&R</td><td>R&E</td><td>Refurbishment</td><td>Extension</td><td>Redevelopment</td><td>Abolition</td><td>Other</td></tr>
<tr><td colspan="2">(○ where it applies)</td><td>○</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Time of decision making</td><td colspan="7">2005</td></tr>
<tr><td colspan="2">Target structures</td><td colspan="7">Dam</td></tr>
<tr><td colspan="2">・Driver(s)</td><td colspan="7">Poor maintenance</td></tr>
<tr><td colspan="2">・Phenomena (caused by Driver)</td><td colspan="7">During pumping operation, overflow from the dam crown of the upper reservoir caused the dam to collapse and a flood downstream</td></tr>
<tr><td colspan="2">Risk</td><td colspan="7">Avoidance</td></tr>
<tr><td colspan="2">・Risks for plant operation</td><td colspan="7">Plant operation shutdown</td></tr>
<tr><td colspan="2">・Specific risk management</td><td colspan="7">Dam restoration, investigations, external factors</td></tr>
<tr><td colspan="9">(1) Current status (before decision making)</td></tr>
<tr><td colspan="2">1) General status</td><td colspan="7">This pumped storage hydropower plant had a rockfill weir for the upper reservoir and a concrete gravity dam for the lower reservoir. The water was pumped up and stored in the upper reservoir, but the pumped water exceeded the designated level. That was because of the malfunctioning transducer which indicated water levels lower than the real situation. As a result, the upper reservoir failed, and 3,800,000m3 of water flowed out.</td></tr>
<tr><td colspan="2">2) Operation status</td><td colspan="7">The plant operation was continued without troubles, but the upper reservoir was operated at higher water levels than the rules. After the accident, the operation was suspended due to the collapse of the upper reservoir.</td></tr>
<tr><td colspan="2" rowspan="2">3) Risks</td><td colspan="7">Potential risk in case of no decision making
Impossiblity to operate, loss of energy generation</td></tr>
<tr><td colspan="7">Potential risks when implementing decision-making items
Covering the constuction cost of restoration</td></tr>
<tr><td colspan="2">(2) Priorities</td><td colspan="7">Resumption of operation, external factors (compensations, et)</td></tr>
<tr><td colspan="2" rowspan="2">(3) Strategy</td><td colspan="7">Against potential risk in case of no decision making
Loss due to violation of electricity sales contract as the operation was impossible</td></tr>
<tr><td colspan="7">Against potential risks when implementing decision-making items
To aim at resuming the operation together with FERC and local municipalities while implementing external factors</td></tr>
<tr><td colspan="2">(4) How decision-making was implemented and technologies adopted</td><td colspan="7">The operation was resumed successfully by rebuilding the damaged dam while implanting the external factors to FERC and local municipalities after the large-scale disaster. The dam was rebuilt in roller compressed gravity concrete method instead of the original rockfill type. A spillway was newly installed which was not designed before the accident. Extensionally, a water level monitoring system was added to as a preventive measure.</td></tr>
<tr><td colspan="9">Reference documents / sources https://www.ferc.gov/industries-data/resources/project-directory/taum-sauk-pumped-storage-project https://damfailures.org/case-study/taum-sauk-dam-missouri-2005/</td></tr>
</table>

035 Oroville Dam spillway Repair Project

Plant name		Thermalto Pumping-Generating Plant						
Operation start		1961			**Work completion**	2018		
Owner		California Department of Water Resource						
Country		The United States						
Max output	**kW**	819,000			**After work**	Not changed		
Max generation discharge	**m³/s**	(Not specified)				Not changed		
Effective head	**M**	187.00				Not changed		
Type of decision making		**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)		○						
Time of decision making		2017						
Target structures		Dam						
・Driver(s)		Disaster						
・Phenomena (caused by Driver)		Damage to spillway, dam collapse						
Risk		Avoidance						
・Risks for plant operation		Plant shutdown due to the loss of dam functions						
・Specific risk management		Repair of spillway						

(1) Current status (before decision making)	
1) General status	The rainy season 2016- 2017 recorded the largest winter rainfalls in California. An unprecedented amount was water flowed in from the Feather River, which was discharged from the spillway. In February, the discharge reached 1400m3/s, at which point an abnormality was detected, and an over 12m deep caved hole was discovered at the concrete foundation. The rain, however, continued to fall, so the spillway had to be in operation continuously, while the damage extended. There was an emergency spillway facility, but the use of it could have impacted the transmission line, so it was avoided to the extent possible, which as another reason why the damage spillway continued to be used.
2) Operation status	There was an emergency spillway facility in Extension to the regular spillway, but the discharge from there could have caused the weakened dam to collapse, so the regular spillway continued to be used. Eventually, the emergency spillway discharged water, which prompted the downstream communities to evacuate.
3) Risks	**Potential risk in case of no decision making** Dam collapse due to the deteriorated dam functions
	Potential risks when implementing decision-making items Increase in the contruction cost
(2) Priorities	Not specified particularly
(3) Strategy	**Against potential risk in case of no decision making** This risk was not taken because dam collapse will cause damage to the downstream communities and the loss of power generation capability.
	Against potential risks when implementing decision-making items No descriptions
(4) How decision-making was implemented and technologies adopted	A quick decision making was done for the emergency. In the operation from 2017 to 2018 after the accident, the dam water level was kept low to reduce the possibility of having to use the spillway next winter. In the first year of repair project, temporary reinforcement was given, and from 2018, full reinforcement began, such as reinforced concrete was case upon roller compacted concrete.
Reference documents / sources https://en.wikipedia.org/wiki/Oroville_Dam#2017_spillway_failure https://www.constructionequipmentguide.com/kiewit-leads-phase-ii-of-oroville-dam-spillway-repairs/41036	

036 Mossyrock Dam and Mayfield Dam

Plant name		Mossyrock Dam and Mayfield Dam						
Operation start		1968 & 1963		**Work completion**		2015		
Owner		Tacoma Power						
Country		The United States						
Max output	**kW**	300,000 & 162,000		**After work**		Not changed		
Max generation discharge	**m³/s**	Not specified				Not changed		
Effective head	**M**	Not specified				Not changed		
Type of decision making		**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)								○
Time of decision making		2003						
Target structures		Salmon hatchery						
・Driver(s)		External factors (compliance)						
・Phenomena (caused by Driver)		Operation permit revoked due to license violation						
Risk		Avoidance						
・Risks for plant operation		Operation permit revoked due to license violation						
・Specific risk management		Reconstruction of salmon hatchery						
(1) Current status (before decision making)								
1) General status		For the commissioning of the dam and power plant, a salmon hatchery was constructed in 1968. Salmon hatchery was added to the regulatory criteria of the new 35-year plant operation license issued in 2003 by Federal Energy Regulatory Commission.						
2) Operation status		Before the reconstruction, the hatchery built in 1968 was used.						
3) Risks		**Potential risk in case of no decision making** Operation permit revoked due to license violation						
		Potential risks when implementing decision-making items Increase in construction and design cost for new facilities						
(2) Priorities		Compliance with license conditions (not specified)						
(3) Strategy		**Against potential risk in case of no decision making** To reconstruct the hatchery in compliance with the license conditions						
		Against potential risks when implementing decision-making items No descriptions						
(4) How decision-making was implemented and technologies adopted		No specific methods were provided. The technical knowledge regarding the hatchery was possessed already as the aged facility was also the property of Tacoma Power. As a technology used for refurbishment, a temperature control tool was introduced to better simulate the natural condition for the fish. A water way was constructed to allow the fry to leave the hatchery following their instinct instead of at the timing imposed by humans.						
Reference documents / sources https://www.renewableenergyworld.com/2012/07/01/fish-protection-upgrading-the-cowlitz-salmon-hatchery/								

037 Nisqually River Project

<table>
<tr><td>Plant name</td><td colspan="8">Alder Dam & La Grande Dam</td></tr>
<tr><td>Operation start</td><td colspan="2">1945 & 1912</td><td colspan="2">Work completion</td><td colspan="4">(continuous correspondence)</td></tr>
<tr><td>Owner</td><td colspan="8">Tacoma Power</td></tr>
<tr><td>Country</td><td colspan="8">The United States</td></tr>
<tr><td>Max output kW</td><td colspan="2">50,000 & 64,000</td><td colspan="2" rowspan="3">After work</td><td colspan="4">Not changed</td></tr>
<tr><td>Max generation discharge m³/s</td><td colspan="2">(Not specified)</td><td colspan="4">Not changed</td></tr>
<tr><td>Effective head m</td><td colspan="2">(Not specified)</td><td colspan="4">Not changed</td></tr>
<tr><td>Type of decision making</td><td>O&R</td><td>R&E</td><td>Refurbishment</td><td>Extension</td><td>Redevelopment</td><td>Abolition</td><td>Other</td><td></td></tr>
<tr><td>(○ where it applies)</td><td></td><td></td><td></td><td></td><td></td><td></td><td>○</td><td></td></tr>
<tr><td>Time of decision making</td><td colspan="8">2016</td></tr>
<tr><td>Target structures</td><td colspan="8">Dam, salmon hatchery</td></tr>
<tr><td>・Driver(s)</td><td colspan="8">External factors (maintenance of license)</td></tr>
<tr><td>・Phenomena (caused by Driver)</td><td colspan="8">Penalty for license violation</td></tr>
<tr><td>Risk</td><td colspan="8">Avoidance</td></tr>
<tr><td>・Risks for plant operation</td><td colspan="8">Operation permit revoked due to license violation</td></tr>
<tr><td>・Specific risk management</td><td colspan="8">Reconstruction of salmon hatchery, financial support for local aboriginal tribe, increase in dam discharge</td></tr>
<tr><td>1) General status</td><td colspan="8">A set of conditions were added to the license renewal by Federal Energy Regulatory Commission for La Grande Dam and Alder Dam on Nisqually River to maximize the effects of fishery deregulation, protection and enforcement in the Nisqually River Project, such as construction of Kokanee hatchery, increased dam discharge, and funding for Clear Creek Hatchery by Nisqually Tribe.</td></tr>
<tr><td>2) Operation status</td><td colspan="8">Operation was continued without meeting the above conditions</td></tr>
<tr><td rowspan="2">3) Risks</td><td colspan="8">Potential risk in case of no decision making
Operation permit revoked due to license violation</td></tr>
<tr><td colspan="8">Potential risks when implementing decision-making items
Increase in construction and design cost for new facilities</td></tr>
<tr><td>(2) Priorities</td><td colspan="8">Compliance with license conditions (not specified)</td></tr>
<tr><td rowspan="2">(3) Strategy</td><td colspan="8">Against potential risk in case of no decision making
To increase dam discharge, construct the hatchery and provide financial support in compliance with the license conditions</td></tr>
<tr><td colspan="8">Against potential risks when implementing decision-making items
No descriptions</td></tr>
<tr><td colspan="9">No specific methods were provided. No specific technologies were used.</td></tr>
</table>

038 Nathaniel Washington Power Plant Overhaul Project

<table>
<tr><td colspan="2">Plant name</td><td colspan="7">Grand Coulee</td></tr>
<tr><td colspan="2">Operation start</td><td colspan="2">1941
1974(Plant No.3)</td><td colspan="2">Work completion</td><td colspan="3">Undecided</td></tr>
<tr><td colspan="2">Owner</td><td colspan="7">US Bureau of Reclamation</td></tr>
<tr><td colspan="2">Country</td><td colspan="7">Washington, USA</td></tr>
<tr><td>Max output</td><td>kW</td><td colspan="2">690,000 (Overload)</td><td colspan="2" rowspan="3">After work</td><td colspan="3">770,000</td></tr>
<tr><td>Max generation discharge</td><td>m³/s</td><td colspan="2">623.00</td><td colspan="3">Not specified</td></tr>
<tr><td>Effective head</td><td>m</td><td colspan="2">95.10</td><td colspan="3">Not specified</td></tr>
<tr><td colspan="2">Type of decision making</td><td>O&R</td><td>R&E</td><td>Refurbishment</td><td>Extension</td><td>Redevelopment</td><td>Abolition</td><td>Other</td></tr>
<tr><td colspan="2">(○ where it applies)</td><td></td><td>○</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Time of decision making</td><td colspan="7">Not specified</td></tr>
<tr><td colspan="2">Target structures</td><td colspan="7">T/G unit</td></tr>
<tr><td colspan="2">・Driver(s)</td><td colspan="7">Aging</td></tr>
<tr><td colspan="2">・Phenomena (caused by Driver)</td><td colspan="7">Troubles, addicents</td></tr>
<tr><td colspan="2">Risk</td><td colspan="7">Avoidance</td></tr>
<tr><td colspan="2">・Risks for plant operation</td><td colspan="7">Unexpected troubles, accidents, declining output of T/G</td></tr>
<tr><td colspan="2">・Specific risk management</td><td colspan="7">Repair</td></tr>
<tr><td colspan="9">(1) Current status (before decision making)</td></tr>
<tr><td colspan="2">1) General status</td><td colspan="7">The project targets Plant No.3 (G19-G24) which has been in operation for more than 40 years since the commissioning. Overhaul was to be conducted to continue to use recyclable parts and implement modernization refurbishment.
The overhaul results indicated that if large amounts of water leak occurs due to the cavitation damage and aging from a long-term use, oil containing polychlorinated biphenyl (PCB) will flow into the river.
Some spare parts were no longer available after a long time since the installation.</td></tr>
<tr><td colspan="2">2) Operation status</td><td colspan="7">Due to the commissioning in the 1970's, the facilities were old and spare parts were difficult to be procured.</td></tr>
<tr><td colspan="2" rowspan="2">3) Risks</td><td colspan="7">Potential risk in case of no decision making
Unexpected troubles, accidents of T/G</td></tr>
<tr><td colspan="7">Potential risks when implementing decision-making items
Repair cost, loss of water resources due to delayed work</td></tr>
<tr><td colspan="2">(2) Priorities</td><td colspan="7">No descriptions</td></tr>
<tr><td colspan="2" rowspan="2">(3) Strategy</td><td colspan="7">Against potential risk in case of no decision making
To enhance the facility reliability by conducting repairs and modernization refurbishment</td></tr>
<tr><td colspan="7">Against potential risks when implementing decision-making items
Not specified</td></tr>
<tr><td colspan="2">(4) How decision-making was implemented and technologies adopted</td><td colspan="7">For G19~G21, it was decided to replace the main components instead of repairing them.
As per the overhaul results, the runner, shaft, stator, guide vane and other degraded parts will be replaced.
An inspection was conducted for the head covers, thrust brackets, top overs, rotors and other aged parts to check any issues after being used for over 40 years, while electrical wiring and piping are to be refurbished. The overhaul was completed in 2019, and a modernization refurbishment was being planned.</td></tr>
<tr><td colspan="9">Reference documents / sources

https://www.usbr.gov/pn/programs/ea/wash/tpp/TPPG1921final.pdf https://www.usbr.gov/pn/grandcoulee/tpp/overhaul.html</td></tr>
</table>

039 Salto Grande Hydropower Complex Refurbishment

<table>
<tr><td colspan="2">Plant name</td><td colspan="7">Salto Grande Hydropower Plant</td></tr>
<tr><td colspan="2">Operation start</td><td colspan="2">1979</td><td colspan="2">Work completion</td><td colspan="3">2019-2023 (1st Stage)</td></tr>
<tr><td colspan="2">Owner</td><td colspan="7">Argentina & Uruguay</td></tr>
<tr><td colspan="2">Country</td><td colspan="7">Argentina & Uruguay</td></tr>
<tr><td>Max output</td><td>kW</td><td colspan="2">1,890,000</td><td colspan="2" rowspan="3">After work</td><td colspan="3">Undecided</td></tr>
<tr><td>Max generation discharge</td><td>m³/s</td><td colspan="2">(Not specified)</td><td colspan="3">Not changed</td></tr>
<tr><td>Effective head</td><td>m</td><td colspan="2">(Not specified)</td><td colspan="3">Not changed</td></tr>
<tr><td colspan="2">Type of decision making</td><td>O&R</td><td>R&E</td><td>Refurbishment</td><td>Extension</td><td>Redevelopment</td><td>Abolition</td><td>Other</td></tr>
<tr><td colspan="2">(○ where it applies)</td><td>○</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Time of decision making</td><td colspan="7">2013</td></tr>
<tr><td colspan="2">Target structures</td><td colspan="7">T/G</td></tr>
<tr><td colspan="2">・Driver(s)</td><td colspan="7">Aging</td></tr>
<tr><td colspan="2">・Phenomena (caused by Driver)</td><td colspan="7">Decline in frequency control capability for the power system</td></tr>
<tr><td colspan="2">Risk</td><td colspan="7">Avoidance</td></tr>
<tr><td colspan="2">・Risks for plant operation</td><td colspan="7">Decline in stable supply capability</td></tr>
<tr><td colspan="2">・Specific risk management</td><td colspan="7">Risk avoidance by facility renewal</td></tr>
<tr><td colspan="9">(1) Current status (before decision making)</td></tr>
<tr><td colspan="2">1) General status</td><td colspan="7">Salto Grande Power Plant is a hydropower plant located over two countries. Due to its scale, the plant is paying an important role such as the frequency control in the power systems of both counties. The operation has been in good condition at a low trouble rate. At the same time, the operation has been continuing over 40 years.</td></tr>
<tr><td colspan="2">2) Operation status</td><td colspan="7">The operation status is fine</td></tr>
<tr><td colspan="2" rowspan="2">3) Risks</td><td colspan="7">Potential risk in case of no decision making
Discontinuation of power generation due to facility troubles</td></tr>
<tr><td colspan="7">Potential risks when implementing decision-making items
Decline in stable power supply capability</td></tr>
<tr><td colspan="2">(2) Priorities</td><td colspan="7">Not specified particularly</td></tr>
<tr><td colspan="2" rowspan="2">(3) Strategy</td><td colspan="7">Against potential risk in case of no decision making
To select appropriate renewal methods and timing</td></tr>
<tr><td colspan="7">Against potential risks when implementing decision-making items
To manage the plan and necessary funds by preparing a step-wise refurbishment project</td></tr>
<tr><td colspan="2">(4) How decision-making was implemented and technologies adopted</td><td colspan="7">The key to success in this project is to manage the plan and necessary funds by preparing a step-wise refurbishment project. Currently implemented Stage 1 is to perform diagnosis of each component in Extension to partial replacement and repair. The future refurbishment stages will be decided according to the investigation results of Stage 1.</td></tr>
<tr><td colspan="9">Reference documents / sources
https://www.saltogrande.org/rsg.php#navproyecto_es</td></tr>
</table>

040 Technical Renewal of Hydro Power Plant: Itaipu P/S

Plant name		Itaipu Hydropower Plant						
Operation start		1905/6/13		**Work completion**	(not yet implemented)			
Owner		(Not specified)						
Country		Brazil & Paraguay						
Max output	**kW**	14,000,000		**After work**	(Not given) Up rate (-%)			
Max generation discharge	**m³/s**	(Not specified)			Note) renewal is not yet implemented (plann			
Effective head	**M**	(Not specified)						
Type of decision making		**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		(Not specified)						
Target structures		Detector, motor unit, monitoring panel, control panel, protective system of T/G and devices related to centralization of monitor / control						
・Driver(s)		Asset optimization & Review of operation						
・Phenomena (caused by Driver)		Higher efficiency of maintenance management						
Risk		Reduction						
・Risks for plant operation		increased cost, Reduction of profit						
・Specific risk management		Digitalized control of T/G, integration of control systems						
(1) Current status (before decision making)								
1) General status		For the aging of electric facilities, the turbine generator control system and other facilities are to be refurbished to maintain and optimize their functions. Report on technical renewal, issues, and basic design specs of Itaipu Hydropower Plant. 18 of the 20 turbine generator units of analogue control are aging, and the other 2 are controlled digitally but the functions are out of date.						
2) Operation status		Average annual energy generation: 9.3 TWh						
3) Risks		**Potential risk in case of no decision making** The functions are out-of-date						
		Potential risks when implementing decision-making items Itaipu Hydropower Plant supplies for 75% of the demand in Paraguay and 15% of that of Brazil, an important energy source. Therefore, upgrading to the new facilities needs be planned in detail in order to minimize the impact on the power generation.						
(2) Priorities		The technical renewal of the plant is a complicated and difficult project. Most of the existing plant was installed in the 1970's and 1980's, consisting of individually independent processes, operated by independent teams. The integration therefore of the processes shall be implemented in consideration of the characteristics of each operating team while maintaining and improving the processes and the workforce quality. This is the largest issue that Itaipu Power Plant has been facing.						
(3) Strategy		**Against potential risk in case of no decision making** To configure the individually independent systems into an integrated system, and to assess its effects from a technical and operational standpoint						
		Against potential risks when implementing decision-making items 2 basic preconditions were determined for the sequence of technical updating: ・Only one unit is to be upgraded at a time to the maximum extent ・In case the upgrading affects the operation safety and personnel, it is impossible to conducted the work simultaneously for different systems and facilities. In case of being connected with the outside through the integration of digital technology, the security needs to be reinforced.						

(4) How decision-making was implemented and technologies adopted	By configurating the individually independent systems into an integrated system, the capacity for information collection, analysis and processing can be significantly upgraded and improvement in power generation efficiency can be expected. Introducing a new control system which enables multifunctionality and standardization, only one operator can perform various tasks including speed control or exciter control. This renewal project will introduce information management tools which automate various work operations and expand the scope of mutual cooperation between teams. The system will allow access to more information and facilitate the speedy information update. Such an advanced information system will enable to collaborate with asset management. Basic designing will be performed for technical renewal. The scope of basic designing was detectors, motor units, monitor panels, control panels, protective system, centralizing units of monitor, control and protection. The basic designing will be implemented in 2 years. The first year is for the generation facilities, central control room, auxiliary facilities and GIS of switching station. The second year is for the switching station, dam and spillway of Margen Derecha Plant.

Reference documents / sources

Itaipu hydropower plant technological update: Challenges and main aspects of the basic design

https://www.forbes.com/sites/jamesconca/2017/08/10/the-biggest-power-plants-in-the-world-hydro-and-nuclear/#f679f5c2c887

041 Estreito P/S Refurbishment - Synchronous Phase Modifier Project

Plant name		Estreito Power Plant						
Operation start		1969		**Work completion**		2012		
Owner		ELETROBRAS FURNAS						
Country		Brazil						
Max output	**kW**	1,050,000		**After work**		(Not given)		
Max generation discharge	**m^3/s**	1839.60						
Effective head	**m**	65.00						
Type of decision making		**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)		○						
Time of decision making		2007						
Target structures		Turbine, governor, air compressor with control unit						
・Driver(s)		Aging						
・Phenomena (caused by Driver)		Decline in generation efficiency / operating rate, higher efficiency in maintenance management						
Risk		Reduction						
・Risks for plant operation		Reduction of profit, increased cost						
・Specific risk management		Restoration / renewal of plant functions, prevention of wear / improvement in wear resistance, renewal / refurbishment of electric facilities						
(1) Current status (before decision making)								
1) General status		For the aging of electric facilities, the turbine blades and other parts were repaired and refurbished. Due to the degradation and aging, the main unit and auxiliary system malfunctioned repeatedly. The turbine was operated in the condition wherein the speed in non-load or upper limit load modes always deviated from the hill-chart cavitation limits, and thus the runner blades could be easily damaged by the cavitation. Until a new maintenance method was adopted, the turbine was repaired every 34,000 hours of operation						
2) Operation status		Estreito Power Plant was one of the plants with the lowest cost per kW in the world (when commissioned). With 6 turbine units of 1,050 MW in total, it supplies to the demand of 20 medium-sized cities.						
3) Risks		**Potential risk in case of no decision making** Aging, frequent troubles Measures to stabilize the power system						
		Potential risks when implementing decision-making items (Not specified)						
(2) Priorities		To improve turbine resistance to cavitation so as to reduce the maintenance cost To operate continuously playing extremely important role as synchronous phase modifier for the stabilization of the power system						
(3) Strategy		**Against potential risk in case of no decision making** Repair of turbine, unit working as synchronous phase modifier						
		Against potential risks when implementing decision-making items (Not specified)						

(4) How decision-making was implemented and technologies adopted	New materials and welding methods were studied for the cavitation repairs of the turbine blades. The cost of using "Cavitalloy" material was 30% higher than the conventional stainless steel, but the repair intervals could likely be extended by 50%, and thus the unit performance was expected to improve with enhanced cavitation resistance and reduced maintenance cost. The new refurbishment enabled to extend the maintenance intervals up to 50,000 hours of operation. Moreover, "pressurized air system" which lowers the draft tube water level was installed so that the unit operates as a synchronous phase modifier. This eliminates the operation in the "no-load speed" mode, and thereby the turbine cavitation would be mitigated.
Reference documents / sources IEA Hydro ANNEX 11 Renewal & Upgrading of Hydropower Plants Case Portfolio No.2 (detailed data) Br.01_ Estreito https://www.nef.or.jp/ieahydro/contents/pdf/4th_a11/br/01.pdf	

042 1 Dam Upstream Face Restoration: (Not specified) Studena Dam

<table>
<tr><td>Plant name</td><td colspan="7">(Not specified) Studena Dam</td></tr>
<tr><td>Operation start</td><td colspan="2">(Not specified)</td><td colspan="2">Work completion</td><td colspan="3">2018</td></tr>
<tr><td>Owner</td><td colspan="7">Local municipality</td></tr>
<tr><td>Country</td><td colspan="7">Bulgaria</td></tr>
<tr><td>Max output kW</td><td colspan="2">(Not specified)</td><td colspan="2" rowspan="3">After work</td><td colspan="3">(Not given) Up rate (－%)</td></tr>
<tr><td>Max generation discharge m³/s</td><td colspan="2">(Not specified)</td><td colspan="3"></td></tr>
<tr><td>Effective head m</td><td colspan="2">(Not specified)</td><td colspan="3"></td></tr>
<tr><td>Type of decision making</td><td>O&R</td><td>R&E</td><td>Refurbishment</td><td>Extension</td><td>Redevelopment</td><td>Abolition</td><td>Other</td></tr>
<tr><td>(○ where it applies)</td><td>○</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Time of decision making</td><td colspan="7">2004</td></tr>
<tr><td>Target structures</td><td colspan="7">Dam</td></tr>
<tr><td>・Driver(s)</td><td colspan="7">Aging</td></tr>
<tr><td>・Phenomena (caused by Driver)</td><td colspan="7">Declined facility function, reduction of generation discharge</td></tr>
<tr><td>Risk</td><td colspan="7">Reduction</td></tr>
<tr><td>・Risks for plant operation</td><td colspan="7">increased cost, Reduction of profit</td></tr>
<tr><td>・Specific risk management</td><td colspan="7">Restoration / renewal of plant functions, recovery / restoration of strength / safety level</td></tr>
<tr><td colspan="8">(1) Current status (before decision making)</td></tr>
<tr><td>1) General status</td><td colspan="7">For the aging of the dam (water leak from the joints), refurbishment was performed with special impermeable sheets.
Report on the use of impermeable sheets for the recovery (repair) of the underwater sections on the upstream side face of Studena Dam. After 50 years since the commissioning, the dam and related structures were deteriorating remarkably. Although there was no water leakage, the upstream face of the dam weir was outstanding with seepage from the joints into the dam body.</td></tr>
<tr><td>2) Operation status</td><td colspan="7">55-m concrete double-wall buttress dam for industrial water, drinking water, power generation and farm land disaster prevention</td></tr>
<tr><td rowspan="2">3) Risks</td><td colspan="7">Potential risk in case of no decision making
Currently, the dam body is table with no water leak, but the water supply may not be ensured and large repair cost may incur.</td></tr>
<tr><td colspan="7">Potential risks when implementing decision-making items
There should be no interference with drinking water supply during the work</td></tr>
<tr><td>(2) Priorities</td><td colspan="7">(Not specified)</td></tr>
<tr><td rowspan="2">(3) Strategy</td><td colspan="7">Against potential risk in case of no decision making
To perform overall renewal project for the dam boy upstream face using impermeable sheets</td></tr>
<tr><td colspan="7">Against potential risks when implementing decision-making items
The work was to be conducted between November and February (coldest season) when underwater work is less. SIBELON geo-composite is highly flexible and adaptable to complicated shapes, and prefabricated by combining multiple sheets supplied by the manufacturer, and thus contributes to reduction of man-hours underwater.</td></tr>
</table>

(4) How decision-making was implemented and technologies adopted	We used "SIBELON CNT 3750 geo-composite" as an impermeable sheet which was adopted by the US Army Corps of Engineers in their underwater project. The geo-composite was fixed on the dam surface with stainless steel metal fixtures. Due to its high flexibility, SIBELON geo-composite does not need base treatment using grinder and mortar and can be applied only after removing the section of surface flaking. The construction cost was reduced as the material was highly adaptable to the uneven dam surfaces and the underwater drilling work was reduced. SIBELON geo-composite is resistant to temperature changes due to its connective property at relatively low temperatures. In Mongolia, SIBELON geo-composite is used in the condition of -50 to 40℃. SIBELON geo-composite is designed to keep its function even under long-term UV exposure. In one case spanning from 1980 to 1997 wherein it was used in the Alps in Italy (at elevation of 2,000 m), it was still maintenance-free at the time of 2014.

Reference documents / sources

Underwater rehabilitation of the Studena dam with an upstream geomembrane

—

043 Renewal, Upgrading, Capacity Expansion of 125-MW Kaplan T/G at Gezhouba P/S

Plant name		Gezhouba Hydro Power Plant						
Operation start		1981		**Work completion**		2022		
Owner		China Yangtze Power Co., Ltd.						
Country		China						
Max output	**kW**	2,715,000		**After work**		(Not given)	Up rate (-%)	
Max generation discharge	**m³/s**	18600.00				*Up by 1500.0 m3/s after R&E (details unknown)		
Effective head	**m**	18.60						
Type of decision making		**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		2012						
Target structures		T/G (stator iron ore, stator, copper winding)						
・Driver(s)		Aging						
・Phenomena (caused by Driver)		Generation discontinued, declined generation efficiency / operating rate						
Risk		Avoidance						
・Risks for plant operation		Reduction of profit						
・Specific risk management		Renewal / refurbishment of electric facilities, prevention of wear / improvement in wear resistance,						
(1) Current status (before decision making)								
1) General status		For the aging of electric facilities, T/G, were renewed to increase the generated energy. Gezhouba Hydro Power Plant is a readjustment hydro junction for and thus operated together with Three Gorges Power Plant. When Three Gorges Power Plant is operated at full output or for peak control, the discharge far exceeded the full output discharge of Gezhouba Hydro Power Plant resulting in wastewater discharge at Gezhouba Hydro Power Plant. The power generation unit of Gezhouba Hydro Power Plant was in continuous operation for a long time, and thus some parts showed the signs of aging which can seriously affect the safe, stable operation along with unsurfaced safety issues. Particularly, the wear and erosion of the turbine blades were progressing, lowering the efficiency and stability of the turbine operation. Due to the long annual operation hours and short maintenance periods, the operation load was increasing with possible serious safety risks which had not manifested. Gezhouba Hydro Power Plant is supplying power to 4 provinces in the central eastern China. The power transmission network in these 4 provinces was not sufficient for the large power market in the area.						
2) Operation status		The initial design average annual energy generation was 15,700,000,000 kWh at the water utilization rate of about 76%. The average annual operation hours are high, reaching 6,000 hours.						
3) Risks		**Potential risk in case of no decision making** Adverse effects on the peak control capability of Three Gorges Power Plant and total efficiency of combined operation by Three Gorges - Gezhouba Hydro Power Plants						
		Potential risks when implementing decision-making items It was strongly required to upgrade the total installed capacity of T/G units without affecting the existing civil engineering facilities and the reservoir operation.						
(2) Priorities		To renew and upgrade the 125-MW T/G unit (by applying the latest technologies and upgrading methods)						
(3) Strategy		**Against potential risk in case of no decision making** To maintain the T/G units and to renew and upgrade the old facilities to expand the capacity To utilize the new technologies, materials and processes to improve the T/G unit operation performance while extending the flowrate, capacity and efficiency for effective utilization of water resources						
		Against potential risks when implementing decision-making items (Not specified)						

(4) How decision-making was implemented and technologies adopted	The turbine runner, generator stator iron core, winding of the stator and rotor were replaced to renew and upgrade the generation unit which was aging after 30 years since the commissioning. The overall mechanical performance was restored while removing the unsurfaced safety issues, and thus the service life was extended. The turbine output was increased, the efficiency was improved, and the cavitation resistance was upgraded. A new runner was custom-designed for Gezhouba Hydro Power Plant, remarkably improving the energy characteristics, cavitation performance, stability and other indices. As the flowrate improved, power generation capacity increases, raising the water utilization rate to about 87%, increasing the average annual generated energy to about 700,000,000 kWh.

Reference documents / sources

IEA Hydro ANNEX 11 Renewal & Upgrading of Hydropower Plants Case Portfolio No.2 (detailed data) Ch.01_ Gezhouba
https://www.nef.or.jp/ieahydro/contents/pdf/4th_a11/ch/01.pdf

044 Pirttikoski P/S Renewal

<table>
<tr><td colspan="2">Plant name</td><td colspan="7">Pirttikoski Power Plant</td></tr>
<tr><td colspan="2">Operation start</td><td colspan="2">1959</td><td colspan="2">Work completion</td><td colspan="3">2010</td></tr>
<tr><td colspan="2">Owner</td><td colspan="7">Kemijoki Oy</td></tr>
<tr><td colspan="2">Country</td><td colspan="7">Finland</td></tr>
<tr><td>Max output</td><td>kW</td><td colspan="2">110,000</td><td colspan="2" rowspan="3">After work</td><td colspan="3">152,000 Up rate (38%)</td></tr>
<tr><td>Max generation discharge</td><td>m³/s</td><td colspan="2">250.00</td><td colspan="3">350.0 m3/s</td></tr>
<tr><td>Effective head</td><td>m</td><td colspan="2">(Not specified)</td><td colspan="3"></td></tr>
<tr><td colspan="2">Type of decision making</td><td>O&R</td><td>R&E</td><td>Refurbishment</td><td>Extension</td><td>Redevelopment</td><td>Abolition</td><td>Other</td></tr>
<tr><td colspan="2">(○ where it applies)</td><td></td><td>○</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Time of decision making</td><td colspan="7">2007</td></tr>
<tr><td colspan="2">Target structures</td><td colspan="7">Turbine runner, hydraulic unit, generator, auto control, transformer protective relay</td></tr>
<tr><td colspan="2">・Driver(s)</td><td colspan="7">Aging</td></tr>
<tr><td colspan="2">・Phenomena (caused by Driver)</td><td colspan="7">Reduction of generation discharge, declined generation efficiency / operating rate</td></tr>
<tr><td colspan="2">Risk</td><td colspan="7">Avoidance</td></tr>
<tr><td colspan="2">・Risks for plant operation</td><td colspan="7">Reduction of profit</td></tr>
<tr><td colspan="2">・Specific risk management</td><td colspan="7">Renewal / refurbishment of electric facilities</td></tr>
<tr><td colspan="9">(1) Current status (before decision making)</td></tr>
<tr><td colspan="2">1) General status</td><td colspan="7">For the aging of electric facilities, turbine runner, etc. were renewed to increase the generated energy. The turbines and generators in Pirttikoski Power Plant were over 50 years old, and the generators were upgraded but the output was not improved.
The Kemijoki River Upgrading Project began in 1996, and 20 units have been upgraded until today. Based on the facility upgrading cases of other plants, it was clear that the renewal of the runner in Pirttikoski Power Plant would upgrade the output from 110 MW to 152 MW.</td></tr>
<tr><td colspan="2">2) Operation status</td><td colspan="7">The output of existing plant is 110 MW and the energy generation is 551 GWh.</td></tr>
<tr><td colspan="2" rowspan="2">3) Risks</td><td colspan="7">Potential risk in case of no decision making
It is required for the group of power plants along Kemijoki River to maintain delicate coordination of the max generation discharge of each plant in order to operate in an efficient integrated manner.</td></tr>
<tr><td colspan="7">Potential risks when implementing decision-making items
Risk of crane troubles when hoisting the generator stator and rotor</td></tr>
<tr><td colspan="2">(2) Priorities</td><td colspan="7">In Finland, the hydro power increasingly plays a role of ancillary services, and thus investment for ensuring the reserve margin contributes to frequency control capability and make profit.</td></tr>
<tr><td colspan="2" rowspan="2">(3) Strategy</td><td colspan="7">Against potential risk in case of no decision making
To increase the turbine rated flowrate and to increase the output / energy generation by renewing the turbine runner</td></tr>
<tr><td colspan="7">Against potential risks when implementing decision-making items
To check the reliability of the ceiling crane operation, total inspection / overhaul of the ceiling crane was performed before shutting down the T/G.
When hoisting the generator stator and rotor, other T/G units were shut down.</td></tr>
<tr><td colspan="2">(4) How decision-making was implemented and technologies adopted</td><td colspan="7">This project was designed to perform refurbishment and improvement in combination because of the possible upgrading margin (output increase). The refurbishment extended the life of the generator, reduced the maintenance cost and improved the safety level. The upgrade would increase the plant output and generated energy while providing more technical margin for the power system stabilization. The power system control is increasingly important along with the increase in wind power and other intermittent energy sources.
The turbine designing technologies have remarkably advanced in the past 10 years, and the upgrade project resulted in the increase in the output by over 40%.
The oil-less runner-hub for the turbine runner is friendly to the environment as well.</td></tr>
</table>

Reference documents / sources

IEA Hydro ANNEX 11 Renewal & Upgrading of Hydropower Plants Case Portfolio No.2 (detailed data)   Fi.01_Pirttikoski
https://www.nef.or.jp/ieahydro/contents/pdf/4th_a11/fi/01.pdf

045 Refurbishment of Sisteron Hydro P/S Thrust Bearing and Francis Turbine

Plant name		Sisteron Hydropower Plant					
Operation start		1975		**Work completion**	2014		
Owner		EDF (French power utility)					
Country		France					
Max output	**kW**	244,000		**After work**	(Not given) Up rate (-%)		
Max generation discharge	**m³/s**	(Not specified)					
Effective head	**m**	110.00					

Type of decision making	**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)		○					

Time of decision making	2009
Target structures	Thrust bearing, turbine runner, guid vane, and operation unit
・Driver(s)	Aging
・Phenomena (caused by Driver)	Discontinuation of power generation
Risk	Avoidance
・Risks for plant operation	Reduction of profit, lower reliability, impact on stock market price
・Specific risk management	Restoration / renewal of plant functions, recovery / restoration of strength / safety level, renewal / refurbishment of electric facilities
(1) Current status (before decision making)	
1) General status	For the aging of electric facilities, the turbine runner, etc. were renewed to increase the generated energy. After 35 years had passed since the commissioning, the generator unit showed chronically serious signs, and the operation became increasingly restricted and risky. Sisteron Hydropower Plant is located at the edge of a group of run-of-river plants, and not equipped with a control valve or bypass valve, the river water flowing into its dam had to be all used for power generation to discharge downstream. In case a trouble occurred in Sisteron Power Plant, the generation opportunity would be lost in this plant, and other plants would be affected by that, resulting in an enormous energy loss.
2) Operation status	(Not specified)
3) Risks	**Potential risk in case of no decision making** Decline in durability, safety level and reliability
	Potential risks when implementing decision-making items Reduction of loss of generation opportunities durng the renewal work
(2) Priorities	To plan a total refurbishment project to ensure power generation and upgrade the facility performance
(3) Strategy	**Against potential risk in case of no decision making** Repair of thrust bearing and Francis turbine
	Against potential risks when implementing decision-making items To complete the onsite work in a short period (6 to 7 months for each T/G)

(4) How decision-making was implemented and technologies adopted	The thrust bearing and turbine mechanical parts (contacting the water) were replaced. Each of the new thrust bearings had a bearing pad support designed with self-hydraulic adjustment control technology and an oil-feeding system to operate the machine start-up / shutdown at high reliability. The new runner was designed with a new blade shape which proved to be 2-5% more efficient in a model test. The unit was equipped with an air intake system from the unit upper part through the concentric hole at the main shaft to the runner cone in order to reduce the pressure changes in the draft tube for the partial load operation to expected. The guide vane and its operating mechanism was replaced except for the bottom rings and head cover which were repaired for further use. The guide vane operating mechanism was designed with a torque transmission system using the frictional force between each of the guide vanes and operation lever so that when an object is jammed or opening deviations occur, they would not interfere with each other. In the assembly, the shaft line alignment was carefully adjusted for reducing the bearing displacement and vibration level. The refurbishment of the 2 units would increase the annal generated energy by 11,700 MWh.

Reference documents / sources

IEA Hydro ANNEX 11 Renewal & Upgrading of Hydropower Plants Case Portfolio No.2 (detailed data) Fr.01_Sisteron
https://www.nef.or.jp/ieahydro/contents/pdf/4th_a11/fr/01.pdf

046 Indirasagar Dam Spillway Gate Repair

Plant name	Indirasagar Hydropower Plant		
Operation start	2005	**Work completion**	Not specified
Owner	NHDC Ltd, a joint venture of NHPC Ltd and Government of Madhya.		
Country	India		

Max output	**kW**	1,000,000	**After work**	Not changed
Max generation discharge	**m³/s**	(Not specified)		Not changed
Effective head	**m**	(Not specified)		Not changed

Type of decision making	**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)	○						

Time of decision making	2013
Target structures	Spillway gates, apron
・Driver(s)	Disaster
・Phenomena (caused by Driver)	Damage to spillway gates and apron by flood
Risk	Avoidance
・Risks for plant operation	Reduction of generation discharge, delcline in stable supply, restoration of dam functions
・Specific risk management	Repair of spillway gates and apron
(1) Current status (before decision making)	
1) General status	Indirasagar Dam was used since the commissioning of the power plant in 2005, but a flood damaged the spillway gate. The gate remained opened for 45 consecutive days from July 17 to August 30, recording the largest discharge of 34,332 cubic meters on August 23. As a result the gate and apron were greatly damaged in Extension to the wastewater discharge. For this reason, the gate was refurbished.
2) Operation status	No descriptions
3) Risks	**Potential risk in case of no decision making** Dam water level drop and reduction of energy generation due to continuation of ineffective discharge. Extension of damage in the dam apron
	Potential risks when implementing decision-making items Technical issues for gate repair
(2) Priorities	Not specified particularly
(3) Strategy	**Against potential risk in case of no decision making** To repair the gates to normalize the dam functions and stop ineffective discharge. To perform repair of the damaged apron.
	Against potential risks when implementing decision-making items To perform the repair after establishing the technical solutions
(4) How decision-making was implemented and technologies adopted	The decision making was based on the disaster damage, in other words, a case of breakdown management. The damage to the roller bucket of the radial gate was repaired and reinforced by draining the water there with a pump.

Reference documents / sources https://www.projectsmonitor.com/daily-wire/nhdc-to-spend-rs-33-crore-to-repair-indira-sagar-dam/ http://www.nhpcindia.com/projectdetail.htm?CatId=1&ProjectId=19

047 Dhauliganga P/S Repair

Plant name		Dhauliganga Hydropower Plant						
Operation start		2005		**Work completion**	2014			
Owner		Government owned hydropower company (NHPC Limited)						
Country		India						
Max output	**kW**	280		**After work**	Not changed			
Max generation discharge	**m³/s**	-			Not changed			
Effective head	**m**	297.00			Not changed			
Type of decision making		**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)		○						
Time of decision making		2016						
Target structures		Power plant						
・Driver(s)		Disaster						
・Phenomena (caused by Driver)		Inudcation of power plant						
Risk		-						
・Risks for plant operation		Operation shutdown due to disaster						
・Specific risk management		Repair of the plant after disaster						
(1) Current status (before decision making)								
1) General status		The power plant was commissioned in 2005, and the operation was conducted without any trouble until the flood occurred. The flood disaster which occurred in 2013 clogged the tailbay, and the water with no way out flowed into the plant from the turbine. The flood proved to be a disaster causing great impact on the local communities in Extension to the plant. The plant was thus inundated for a half year, unable to operate.						
2) Operation status		The operation was normally conducted before the inundation, from 2006 to 2013, the average energy generation was 1133 GWh annually.						
3) Risks		**Potential risk in case of no decision making** Long-term discontinuation of power generation due to facility damage and securement of alternative power supply						
		Potential risks when implementing decision-making items Increased work cost						
(2) Priorities		Not specified particularly						
(3) Strategy		**Against potential risk in case of no decision making** To restore the plant quickly to shorten the shutdown period						
		Against potential risks when implementing decision-making items No descriptions						
(4) How decision-making was implemented and technologies adopted		The restoration of the power plant was the measure taken for the inundation. There were no specific technologies used in this project.						
Reference documents / sources Wikipedia https://en.wikipedia.org/wiki/Dhauliganga_Dam https://www2.jica.go.jp/ja/evaluation/pdf/2011_ID-P129_4_f.pdf								

048 Mt. Coffee Hydro P/S Repair

Plant name		Mt. Coffee Hydropower Plant						
Operation start		1966		**Work completion**		2018		
Owner		Liberia Electricity Corporation						
Country		Liberia						
Max output	**kW**	64,000		**After work**		88,000		
Max generation discharge	**m³/s**	(Not specified)				Not changed		
Effective head	**M**	20.00				Not changed		
Type of decision making		**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)						○		
Time of decision making		Not specified particularly						
Target structures		Dam, T/G, etc.						
・Driver(s)		External factors (civil unrest)						
・Phenomena (caused by Driver)		Destruction by the rebel army						
Risk		Avoidance						
・Risks for plant operation		Impossibility to operate the plant						
・Specific risk management		Risk avoidance by repair						
(1) Current status (before decision making)								
1) General status		Mt. Coffee Hydropower Plant which began operating in 1966 was initially outputting 30 MW. After the expansion project, the plant output was upgraded to 64 MW. During the civil war in 1990, the dam and power plant were destroyed.						
2) Operation status		Dam and plant were damaged by the civil conflict, and the operation was impossible.						
3) Risks		**Potential risk in case of no decision making** Continuation of ineffective discharge, Shortage of supply to the domestic power demand						
		Potential risks when implementing decision-making items Necessity for constructino cost, lack of funds						
(2) Priorities		Not specified particularly						
(3) Strategy		**Against potential risk in case of no decision making** The dam and plant were repaired and expanded. The plant output was upgraded to 88 MW.						
		Against potential risks when implementing decision-making items The funds were secured through cooperation by donors in various countries. The United States Trade and Development Agency: investigation The Millennium Challenge Corporation: main donor for refurbishment						
(4) How decision-making was implemented and technologies adopted		After the war, sufficient repair funds were not available, so the refurbishment was funded by other countries and institutions. The investigation on the destroyed facilities and environmental impact, and the cost and refurbishment scope were decided.						
Reference documents / sources https://www.mcc.gov/blog/entry/blog-072318-success-of-mount-coffee-hydropower-plant-helps-liberia https://www.eib.org/attachments/pipeline/20120342_esia_en.pdf								

049 Waitaki P/S Refurbishment

Plant name		Waitaki Hydropower Plant						
Operation start		1934		**Work completion**		2017		
Owner		Meridian Energy						
Country		New Zealand						
Max output	**kW**	90,000		**After work**		105,000 Up rate (17%)		
Max generation discharge	**m³/s**	570.00				665 m3/s		
Effective head	**m**	21.30 (design head)						
Type of decision making		**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		2012						
Target structures		Dam, powerhouse building, water gate bridge piers, south side bank, water gate rails and wheels, generator electric protection unit, genarator fire-extinguishing unit, crane, intake screens, T/G						
・Driver(s)		Aging						
・Phenomena (caused by Driver)		Generation discontinued, declined generation efficiency / operating rate, damage / breakage of various structures, environmental degradation						
Risk		Avoidance						
・Risks for plant operation		Reduction of profit, increased cost, impact on the environment						
・Specific risk management		Restoration / renewal of plant functions, recovery / restoration of strength / safety level, improvement in earthquake resistance, renewal / refurbishment of electric facilities						
(1) Current status (before decision making)								
1) General status		For the aging of the power plant and its facilities, T/G, control systems and civil engineering structures including the dam were renewed to increase the generated energy. Waitaki Hydropower Plant had been in operation for over 80 years with most of its turbine and generator components unchanged, but signs suggesting the end of service life were manifested. The generator stator coil of Units 1 and 2 were rewound in 1979 and 1983. The turbine of Unit 3 was renewed in the middle of the 1950's, but the guide vane operating mechanism was broken in 1998, and then the operation was terminated. The turbine of Unit 4 was renewed in the middle of the 1950's, and in 1991, a resin material was injected into the generator stator coil insulation of Units 3 to 7 for extending the service life by 10 years. In Extension, the structural anti-seismic risk assessment for the plant buildings suggested that a large earthquake would cause collapses of the plant downstream side pillars, the roof truss and supporting beam structure between the plant and intake dam.						
2) Operation status		The 6 T/G units are generating about 490 GWh annually. Since the guide vane of Unit 8 had troubles in 1998, the output was reduced from 105 MW to 90 MW. (At the time of commissioning: 15 MW × 7 units ＝ 105 MW)						
3) Risks		**Potential risk in case of no decision making** The stator condition in all units was extremely deteriorated, assessed as having reached the end of service life and estimated to cause troubles in the future by many engineers. 3-D structural dynamic analysis was performed to assess the earthquake resistance of the powerhouse building, and it was pointed out the necessity of relatively small-scale reinforcement against an earthquake of annual exceedance probability (AEP) of 2,500 years.						
		Potential risks when implementing decision-making items						

	(Not specified)
(2) Priorities	To aim at the operation which would level out the flowrate changes of downstream Waitaki River while maintaining the lowest water level agreed on based on the water resources downstream the dam, and to control the change rate of discharge from Waitaki Plant within the agreed range.
(3) Strategy	**Against potential risk in case of no decision making** To perform renewal of the dam and plant, civil engineering refurbishment of water gate bridge piers, south bank, renewal of water gate rails, wheels, generator electric protection unit, generator fireextinguishing unit, renewal and refurbishment of crane, replacement of intake screens, and re-operation of Unit 3
	Against potential risks when implementing decision-making items (Not specified)
(4) How decision-making was implemented and technologies adopted	As part of the Waitaki Refurbishment Project, all assets were evaluated including the technical aspect, operation, environmental impact and potential impact on third parties. A full business plan was prepared, and the preliminary FS investigation and the final FS investigation were carried out for the approval of fund procurement for the project. An early contract involvement (ECI) method was used for the experts and subcontractors to develop practical solutions and calculate a realistic cost quotation in order to clarify the scope and cost of the refurbishment project which was partially complicated and unique. The renewal of turbine and generator is a means to solve the issue of service life termination and produce more profit from energy generation, but it is costly. Based on the status of Waitaki Power Plant having potential of using margin generation capacity, it was confirmed that re-commissioning of Unit 3 would increase the effective generation capacity, and therefore the costly turbine / generator renewal was postponed. After the technical / economic assessment, it was determined to increase the effective generation capacity by re-commissioning of Unit 3. The refurbishment would recovery the total capacity of all 7 power generation units.

Reference documents / sources

IEA Hydro ANNEX 11 Renewal & Upgrading of Hydropower Plants Case Portfolio No.2 (detailed data) NZ.02_Waitaki
https://www.nef.or.jp/ieahydro/contents/pdf/4th_a11/nz/02.pdf

050 Benmore Facilities Refurbishment

Plant name	Benmore Power Plant		
Operation start	1965	**Work completion**	2010
Owner	Meridian Energy		
Country	New Zealand		

Max output	**kW**	540,000	**After work**	(Not given) Up rate (-%)
Max generation discharge	**m³/s**	(Not specified)		
Effective head	**M**	(Not specified)		

Type of decision making	**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)		○					

Time of decision making	2005
Target structures	Turbine runner, excitation system, auto voltage regulator, system interconnection transformer, generator
・Driver(s)	Aging
・Phenomena (caused by Driver)	Generation discontinued, Declined facility function, declined generation efficiency / operating rate
Risk	Avoidance
・Risks for plant operation	Reduction of profit from power generation, increased cost, declined safety of workers
・Specific risk management	Renewal / refurbishment of electric facilities
(1) Current status (before decision making)	
1) General status	For the aging of electric facilities, the turbine runner, etc. were renewed to increase the generation output. Benmore Power Plant is the second largest plant in New Zealand of the power generation facilities utilizing a 100% renewable energy source. The turbine runner suffering cavitation erosion was repaired repeatedly, and therefore, its crosssectional shape had been changed. A 16-kV air-insulated switchgear was installed for emergency protection, but the service life was almost passed, and the reliability was low. Also, the excitation system was malfunctioning due to aging, required more and more maintenance work.
2) Operation status	Benmore Power Plant accounts for about 17% of the energy supplied from the portfolio of Meridian Energy.
3) Risks	**Potential risk in case of no decision making** Decline in efficiency due to repeatedly repaired turbine runner. Increase in time for maintenance work, extension of shutdown time for repair works. Increase in cavitation repair cost. Serious risks for transformers and other equipment of Transpower due to lower reliability of airinsulated circuit breaker. Risks of destructive facility trouble which causes secondary damage to connected plants and physical damage to operating and maintenance staff since the maintenance needs to be performed while the facilities are energized. The excitation system and automatic voltage regulator are built with technologies in the 1950's, and thus troubles in the future may cause long-term unit shutdown due to the shortage of spare parts and maintenance staff workers.
	Potential risks when implementing decision-making items After the decision of removing one unit of HVDC pole, Meridian Energy and Transpower, the grid owner / operator needed to be in close cooperation.

(2) Priorities	To handle the risks at minimum cost by estimating the optimal work scope in consideration of the cost effectiveness and the long-term objectives of Meridian Energy
(3) Strategy	**Against potential risk in case of no decision making** To replace the turbine runner To replace the parts of the excitation system and automatic voltage regulator To modernize the auxiliary components to improve the safety and reliability To newly install 3 units of 225-MVA system interconnection transformer or to change the power system or system interconnection points To perform overhaul of the mechanical parts of all generators
	Against potential risks when implementing decision-making items To review the work scope of the planned grid injection point change as part of the Benmore Refurbishment Project and to carry out the Benmore Final (Electric) Configuration Project which is a new and Extensional capital investment project.
(4) How decision-making was implemented and technologies adopted	The project was designated as a case example of strategic asset management planning process of Meridian Energy. A ranking list was prepared by incorporating the risk management framework, which highlighted the risks requiring alleviation and opportunities for expanding the asset value. An engineering risk review clarified that the basic operation system of Benmore Power Plant was close to the end of design and service life, a possible serious risk. Technical and commercial analyses were performed for various refurbishment options to identify the optimal work scope and timing, to maximize the investment return and to harmonize with the long-term goals and strategies of Meridian. CFD analyses and model testing confirmed that the replacement of the turbine runner and other equipment would recover the lowered efficiency gradually and even gain new increases. As a result, energy generation was increased by about 70 GWh annually without increasing the generation discharge.

Reference documents / sources

IEA Hydro ANNEX 11 Renewal & Upgrading of Hydropower Plants Case Portfolio No.2 (detailed data) NZ.01_Benmore
https://www.nef.or.jp/ieahydro/contents/pdf/4th_a11/nz/01.pdf

051 Kainji P/S Electric Facilities Refurbishment

Plant name		Kainji Power Plant						
Operation start		1969			**Work completion**	Unknown		
Owner		Power Holding Company of Nigeria (PHCN)						
Country		Nigeria						
Max output	**kW**	760,000			**After work**	(Not given)		
Max generation discharge	**m^3/s**	(Not given)						
Effective head	**m**	38.10						
Type of decision making		**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					

Time of decision making	2011
Target structures	Turbine, transformer, control system (DCS), steel structures, etc.
・Driver(s)	Aging
・Phenomena (caused by Driver)	Discontinuation of power generation
Risk	Avoidance
・Risks for plant operation	Reduction in energy generation
・Specific risk management	Risk avoidance by repair and renewal
(1) Current status (before decision making)	
1) General status	Kainji Power Plant constructed between 1963 and 1969 is a dam type power plant with 8 units of 80 MW to 120 MW each, outputting 760 MW in total. After 40 years since then, Unit 5 was shut down for several years while Units 6 and 12 were not able to operate at full capacity and had to be shut down often, and therefore the power plant operated at about 225 MW, less than 1/3 of the total capacity of 760 MW. For this reason, in 2011, renewal and refurbishment were conducted for Units 5, 6, 12, governors, excitation system, transformers, monitor / protection system, cranes, intake / outlet steel structures, etc.
2) Operation status	40 years after the commissioning , Unit 5 was shut down for several years while Units 6 and 12 were not able to operate at full capacity and had to be shut down often, and therefore the power plant operated at about 225 MW, less than 1/3 of the total capacity of 760 MW.
3) Risks	**Potential risk in case of no decision making** Discontinuation of power generation
	Potential risks when implementing decision-making items Increased cost for repair work due to inaccurate knowledge about the plant facility status
(2) Priorities	Not specified
(3) Strategy	**Against potential risk in case of no decision making** Being the plant with the largest output in Nigeria, if shut down, the power supply will be insufficient.
	Against potential risks when implementing decision-making items Planning and implementation of optimal repair project based on accurate status assessment of the existing facilities

(4) How decision-making was implemented and technologies adopted	・The turbines were changed from fixed blade type to Kaplan type to accommodate the large head and variable ranges, while the casings were also replaced accordingly. ・The aging assessment of the transformer was based on the measurement of polymerization of the insulation papers. ・An underwater camera in a clear water tank was used to conduct the underwater inspection even in the turbid water.
Reference documents / sources Hydro2019 Conference Paper https://en.wikipedia.org/wiki/Kainji_Dam	

052 Improvement of Performance / Flexibility of Hydropower Plant: Cabril P/S

Plant name		Cabril Hydropower Plant						
Operation start		1954		**Work completion**		(Not specified)		
Owner		EDP (Portuguese powerutility)						
Country		Portugal						
Max output	**kW**	54,700		**After work**		58,000 Up rate (6%)		
Max generation discharge	**m³/s**	54.00				61.2 m3/s		
Effective head	**m**	108.00						
Type of decision making		**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		(Not specified)						
Target structures		Turbine runner, peripheral equipment						
・Driver(s)		External factors						
・Phenomena (caused by Driver)		Improvement in flexibility for power demand						
Risk		Avoidance						
・Risks for plant operation		Reduction of profit						
・Specific risk management		Renewal of turbine runner and adjustment of peripheral equipment						
(1) Current status (before decision making)								
1) General status		In response to the social request for improving the flexibility of power generation activities, the turbine runner and the peripheral facilities were adjusted and renewed. Improvement in the performance and flexibility of the hydropower plant: Report on the upgrading of Cabril Hydro Power Plant. The existing turbine runner had 11 blades. At the time of test run in 1955, the maximum efficiency of the turbine generator was 89.6% when the output was 49 MW. There were requests for increasing the generation capacity (output).						
2) Operation status		The average annual energy generation is about 300.7 GWh						
3) Risks		**Potential risk in case of no decision making** Not able to respond to requests for increasing generation capacity (output)						
		Potential risks when implementing decision-making items Increased cost						
(2) Priorities		(Not specified)						
(3) Strategy		**Against potential risk in case of no decision making** To implement renewal of turbine runner and adjustment of peripheral equipment						
		Against potential risks when implementing decision-making items						

	To refurbish as a plant which corresponds to digitalization, big data, data analysis, IoT, expanded renewable energy sources, distributed power generation, energy storage, improved flexibility (response to generation opportunities), tighter regulations, intensified competition, etc. To improve the responsivity of the plant and to contribute to the power system flexibility and stability by being able to start up more frequently, increase / decrease the load speedily and operate at low load.
(4) How decision-making was implemented and technologies adopted	The designing of the turbine runner took into consideration the dimensional restrictions and operation modes. Simulations were run for 4 types of operation mode (combinations of generation discharge and head) without considering the water friction, and they confirmed that cavitation would not occur. After the renewal of the turbine runner, visual and non-destructive inspections and behaviour measurements were conducted for the turbine and the peripheral equipment to check if a wider range of operation was possible. Visual inspection and document check were performed for the auxiliary facilities (transformer, circuit breaker, busbar, instrument transducer, etc), and then a test run was carried out. During the test run, acceleration and displacement measuring instruments were installed near the shaft to check the behaviour, and the results showed mostly Zone A (similar to new installation) for ISO 7919-5 standard (mechanical vibration of non-reciprocating machines - measurements on rotating shafts and evaluation criteria), proving their favorable condition. The absolute vibration of the 3 bearing housings also corresponded to Zone A (similar to new installation) for ISO 10816-5 (mechanical vibration - evaluation of machine vibration by measurements on non-rotating parts). Without performing any refurbishment for the generator, connecting wiring, transformer, voltage regulator, etc except for the turbine runner, the maximum output was upgraded to 57 to 58 MW for the head of 108 m. Thus the efficiency was improved by 5.3%. In case some funds are available, the output may be further raised to 60-62 MW by adjusting the unit governor, circuit breaker, measuring instrument transformers (CT, VT), etc. The turbine runner renewal of Cabril Hydropower Plant was a case therein adjustments of peripheral equipment parts can improve the output, etc. through utilization of improved materials, manufacturing technologies, designing, analytic and other technical advancements, without renewing those components.

Reference documents / sources

Increase hydropower plant performance and flexibility: The Cabril hydropower plant repowering case

https://www.waymarking.com/waymarks/WMY24X_Estao_hidroeltrica_do_Cabril_Leiria_Portugal

053 Water pouring like flood inside power house caused by turbine 2 crash with vibration: Sayano-Shushenskaya P/S

Plant name		Sayano-Shushenskaya Power Plant						
Operation start		1963		**Work completion**		2021		
Owner		the Soviet-time Minister of Energy and Electrification Pvotr Neporozhnv						
Country		Russia						
Max output	**kW**	6,400,000		**After work**		No change		
Max generation discharge	**m³/s**	(Not specified)				Not changed		
Effective head	**m**	(Not specified)				Not changed		
Type of decision making		**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		2009						
Target structures		Plant, T/G, etc.						
・Driver(s)		Poor management						
・Phenomena (caused by Driver)		Damage to plant due to troubles in T/G						
Risk		Avoidance						
・Risks for plant operation		Impossibility to operate the plant						
・Specific risk management		Repairs of T/G, plant						
(1) Current status (before decision making)								
1) General status		This accident was caused by the troubles in Unit 2 resulting in a large-scale damage. The following is the background of Unit 2. Installed in 1979, from 1980 to 1983, a number of problems occurred from water sealing, turbine shaft vibration, to bearing. In 2000, the turbine was readjusted, and the runner cracks and cavities were repaired. In 2005, the similar defects were found, and the runner cracks were repaired. In 2009 (January to March), modernization and repair were carried out. Electrical hydraulic servo unit was introduced, and the runner cracks / cavities found again were repaired. In the measurement after the repair, a vibration increase of 0.15 mm was observed at full load, but it was within the permissible range. After restarting the operation, in July, the vibration exceeded the permissible range. On August 17, 2009 at 0345 hours, when the unit was in the process of shutting down after outputting at 600 MW, the bolts on the turbine cover ruptured, the water overflowed from the turbine cover, the turbine generator suffered damage and other machines were damaged as well.						
2) Operation status		Despite the issues arising from degradation, repair was repeated to continue operating						
3) Risks		**Potential risk in case of no decision making** Troubles in T/G causing damage to the plant and ineffective discharge						
		Potential risks when implementing decision-making items Increased labor cost / repair cost						
(2) Priorities		Not specified particularly						
(3) Strategy		**Against potential risk in case of no decision making** To repair the plant / damaged facilities						
		Against potential risks when implementing decision-making items No descriptions						
(4) How decision-making was implemented and technologies adopted		Identifying the case by damage investigation and reporting No new technologies involved						
Reference documents / sources https://en.wikipedia.org/wiki/2009_Sayano-Shushenskaya_power_station_accident								

054 Issues for Secondary System Refurbishment and Control System Renewal: Fala P/S

<table>
<tr><td colspan="2">Plant name</td><td colspan="8">Fala Hydropower Plant</td></tr>
<tr><td colspan="2">Operation start</td><td colspan="2">1905/4/1</td><td colspan="2">Work completion</td><td colspan="4">1905/7/9</td></tr>
<tr><td colspan="2">Owner</td><td colspan="8">DEM-Drava River Power Company</td></tr>
<tr><td colspan="2">Country</td><td colspan="8">Slovenia</td></tr>
<tr><td>Max output</td><td>kW</td><td>60,000</td><td></td><td colspan="2" rowspan="3">After work</td><td>60,000</td><td colspan="3">Up rate (0%)</td></tr>
<tr><td>Max generation discharge</td><td>m³/s</td><td colspan="2">(Not specified)</td><td></td><td colspan="3"></td></tr>
<tr><td>Effective head</td><td>m</td><td colspan="2">(Not specified)</td><td></td><td colspan="3"></td></tr>
<tr><td colspan="2">Type of decision making</td><td>O&R</td><td>R&E</td><td>Refurbishment</td><td>Extension</td><td>Redevelopment</td><td>Abolition</td><td colspan="2">Other</td></tr>
<tr><td colspan="2">(○ where it applies)</td><td></td><td>○</td><td></td><td></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td colspan="2">Time of decision making</td><td colspan="8">(Not specified)</td></tr>
<tr><td colspan="2">Target structures</td><td colspan="8">Secondary system, control system</td></tr>
<tr><td colspan="2">・Driver(s)</td><td colspan="8">Asset optimization & review of operation</td></tr>
<tr><td colspan="2">・Phenomena (caused by Driver)</td><td colspan="8">Higher efficiency of maintenance management</td></tr>
<tr><td colspan="2">Risk</td><td colspan="8">Reduction</td></tr>
<tr><td colspan="2">・Risks for plant operation</td><td colspan="8">Increased cost</td></tr>
<tr><td colspan="2">・Specific risk management</td><td colspan="8">Remote control and total automation of the plant operation</td></tr>
<tr><td colspan="10">(1) Current status (before decision making)</td></tr>
<tr><td colspan="2">1) General status</td><td colspan="8">The power generation system was renewed in response to rapid environmental changes (cyber security, request for distributed power sources, expanded obligations for the maintenance and operation staff by the national and EU regulations).
Report on the issues for the secondary system refurbishment and control system renewal at Fala Hydropower Plant. Correspondence was made to the shortening service life of the plant hardware and software.</td></tr>
<tr><td colspan="2">2) Operation status</td><td colspan="8">Operating staff is necessary for the system operation, and the power plant is 100 km away.</td></tr>
<tr><td colspan="2" rowspan="2">3) Risks</td><td colspan="8">Potential risk in case of no decision making
The secondary system becoming out of date</td></tr>
<tr><td colspan="8">Potential risks when implementing decision-making items
Drop in the plant operation rate during the secondary system refurbishment</td></tr>
<tr><td colspan="2">(2) Priorities</td><td colspan="8">The new technologies entail some issues and cost, but DEM would standardize the infrastructure in order to simplify the maintenance, control and staff training so as to improve the plant performance.</td></tr>
<tr><td colspan="2" rowspan="2">(3) Strategy</td><td colspan="8">Against potential risk in case of no decision making
To refurbish the secondary system
The secondary system includes the plant control system (distributed control), electric protective system, automation unit, power supply unit, and remote-control system.
Currently, the plant is completely automated and controlled remotely.</td></tr>
<tr><td colspan="8">Against potential risks when implementing decision-making items
The connection adjustment between the new system and 25-year-old system had to be carried out by trial and error.</td></tr>
</table>

(4) How decision-making was implemented and technologies adopted	The refurbishment of the secondary system was carried out without having the staff stationed onsite. The system renewal was performed along with the renewal construction of the facilities, the decline in power plant operating rate was minimized. The software of the remote system was adjusted from Maribor. The total remote control was completed in a gradually process starting with the generator in 1990, and then supervisory control and data acquisition (SCADA) system of the plant control room, which are now operated from Maribor. The supervisory control and data acquisition (SCADA) system was independent and isolated initially, but now the system process image can be updated remotely. Being a remotely accessible system, however, it needs periodical system security updates. The renewal cost of the secondary system was about 5% of the construction cost of a power plant of this size. When Fala Power Plant was commissioned in 1918, 260 workers were employed. Today a part of the power plant is maintained as a museum, and the manpower has been reduced by 90% because of the automation and advancement in peripheral equipment, detectors, information processing units, etc.

Reference documents / sources

Secondary systems refurbishment and problems concerning the control system upgrade at the Fala hydropower plant

-

055 Almendra Dam (Right Bank) Asphalt Facing Refurbishment: Villarino P/S (Pumped Storage)

Plant name		Villarino Pumped Storage Hydropower Plant						
Operation start		1970		**Work completion**				
Owner		(Iberdrola; no indication)						
Country		Spain						
Max output	**kW**	810,000		**After work**				
Max generation discharge	**m^3/s**	(Not specified; about 250)				Not changed		
Effective head	**m**	(Not specified; about 400)				Not changed		
Type of decision making		**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)		○						
Time of decision making		2018						
Target structures		Almendra Dam right bank weir asphalt facing						
・Driver(s)		Aging (degradation by UV)						
・Phenomena (caused by Driver)		Expansion and progress of partial cracks						
Risk		Avoidance						
・Risks for plant operation		Decline in dam water storage function						
・Specific risk management		Risk avoidance by repair and renewal						
(1) Current status (before decision making)								
1) General status		The right bank weir of Almendra Dam (arch dam, H = 202 m) is an asphalt facing type rock-fill dam (H = 31 m, L = 1,673m, upstream gradient 1:1.75). About 20 years after the commissioning in 1970, part of the asphalt facing was found to be deteriorating mainly due to UV rays, so it was repaired by spraying bituminous material in 1990. Again in 2018, the surface was partially found damaged. The cracking did not penetrate the facing layer, and thus water leak was very little, but the refurbishment was conducted as planned (in 1991).						
2) Operation status		No particulary problems with the plant operation as the leakage is in slight amounts						
3) Risks		**Potential risk in case of no decision making** Increase in water leak due to progress of cracks						
		Potential risks when implementing decision-making items Increased maintenance cost due to repeated improper repair work						
(2) Priorities		Not specified						
(3) Strategy		**Against potential risk in case of no decision making** Preventive maintenance repair in stages of minor degradation and little leakage						
		Against potential risks when implementing decision-making items Adoption of proper repair work method						
(4) How decision-making was implemented and technologies adopted		work was performed as a systematic / preventive maintenance initiative in the stage where the degradation scope / degree and cost are still not high. The following technologies were employed for the repair: ・Cracking map preparation (with remotely controlled flying equipment), ・Sufficient surface treatment, ・Temperature control of crack repair sections (heating up and material temperatures at cracked sections), ・Appropriate repair equipment and devices (for the work on a steep slope face) and quality management.						
Reference documents / sources Hydro2019 Conference Paper								

056 Nalubaale & Kiira Plants Refurbishment

Plant name		Nalubaale Hydropower Plant / Kiira Hydropower Plant						
Operation start		N: 1954/K: 1968		**Work completion**	N:1996/K:2007			
Owner		Eskom Uganda Limited						
Country		Uganda						
Max output	**kW**	N:150,000 / K:200,000		**After work**	N:180,000 / K:200,000			
Max generation discharge	**m³/s**	(Not specified)			Not changed			
Effective head	**m**	(Not specified)			Not changed			
Type of decision making		**O&R**	**R&E**	**Refurbishment**	**Extension**	**Redevelopment**	**Abolition**	**Other**
(○ where it applies)			○					
Time of decision making		Unknown						
Target structures		T/G						
・Driver(s)		Aging, poor maintenance						
・Phenomena (caused by Driver)		Impossible to perform repairs due to unavailability of spare parts for the aged facilities						
Risk		Avoidance						
・Risks for plant operation		Decline in stable supply						
・Specific risk management		Risk avoidance by equiment renewal						
(1) Current status (before decision making)								
1) General status		Nalubaale Hydropower Plant had the latest turbine and auxiliary equipment between 1954 and 1968. After the operation over a long period of time, the spare parts became unavailable and the equipment repair was difficult. The repairs were not made in time because of the civil unrest. Kiira Hydropower Plant was constructed as an expansion of Nalubaale Hydropower Plant with the latest turbine / generator and auxiliary equipment at the time of 2000 to 2006. After the construction, the plant was named Kiira Hydropower Plant. Due to the rapid technical advancements, however, the spare parts of electronic units became short in supply, and the repair had not been performed.						
2) Operation status		Not specified particularly						
3) Risks		**Potential risk in case of no decision making** Discontinuation of power generation by defective parts, resulting in serious power shortage in the country						
		Potential risks when implementing decision-making items Cost necessary for parts replacement						
(2) Priorities		Not specified particularly						
(3) Strategy		**Against potential risk in case of no decision making** To replace the equipment parts to avoid future troubles						
		Against potential risks when implementing decision-making items To select the parts which need to be replaced to carry out selective replacement						
(4) How decision-making was implemented and technologies adopted		Since many of the facilities and electronic components have aged and thus need to be replaced, replacements are prioritized and carried out. As Extensional information, the refurbishment of Nalubaale Power Plant increased its rated output from 150 MW to 180 MW. No particular technologies were employed.						
Reference documents / sources https://www.hydroreview.com/2020/05/22/eight-om-steps-to-extend-the-longevity-of-hydropower-plants/#gref, https://en.wikipedia.org/wiki/Kiira_Hydroelectric_Power_Station								