ANNEX 11 Renewal and Enhancement of Hydroelectric Installations

Format for the 2nd Round Data Collection (Definition of Case Histories)

Category and Key points

Main: 2-b) System and Reliability Improvements in Protection and Control (P&C)

Project Name:

The renewal project of the control and monitoring system of the Okawachi Hydropower Station

Name of Country (including State / Prefecture):

Japan, Hyogo Prefecture

Implementing Agency / Organization:

Kansai Electric Power Co., Inc.

Implementation period:

From 2008 to 2015 (plan)

Trigger Causes for Renewal and Upgrade:

(A) Degradation due to aging and recurrence of malfunction

Keywords:

Improvement of reliability, Adoption of the standard system, Simplification of the system

Abstract:

The control and monitoring system in the Okawachi Hydropower Station is composed of a totally digital system which shares data between the upper dam and lower dam, the switchyard on the ground, and the underground powerhouse through the control LAN. As several decades have passed since the commencement of operations, so trouble and failures from aging have been increasing. Furthermore, when one piece of control equipment stops operating or goes down, there is a fear that the whole power station system will be affected by the interruption of information exchange. In this renewal project, our basic policy is to not allow any impact on the whole power station system even if the control system is stopped or interrupted by service requirement or failure, while taking advantage of the merits of the total digital system. So, the full renewal of the control systems such as the powerhouse, switchyard and dam system was conducted with this in mind in the design.

1. Outline of the Project (before Renewal/Upgrading)

The Okawachi Hydropower Station was planned with a view to supply peak electricity so as to respond to the increase of power demand, and with a view to effectively operate an electricity system to resolve an expansion of the difference of power demand between day and night. So, in 1988, the construction work of the Okawachi Hydropower Station was started. In 1995, the Okawachi Hydropower Station was completed as a pumped-storage hydropower station (No. 1, 2: constant speed type machines, No. 3, 4: adjustable speed type) with a maximum output of 1,280 MW (320 MW×4 machines). Even now this hydropower station contributes greatly to the effective operation and quality maintenance of the electricity system as an adjustable speed type pumped-storage hydropower station with automatic frequency control (AFC) function in pumping operation, besides, having a quick start-and-stop control function and output control function as a hydropower station. The location and specifications of this hydropower station are shown in Fig. 1 and Table 1.

As a control and monitoring system, the total digital system was the first adopted for the pumped-storage hydropower station owned by the Kansai Electric Power Co., Inc.. By this system, information is shared and exchanged between the upper and lower dams, switchyard on the ground and underground powerhouse through the control LAN interconnected with fiber optics. The system architecture of the control and monitoring system before renovation is shown in Fig. 2.

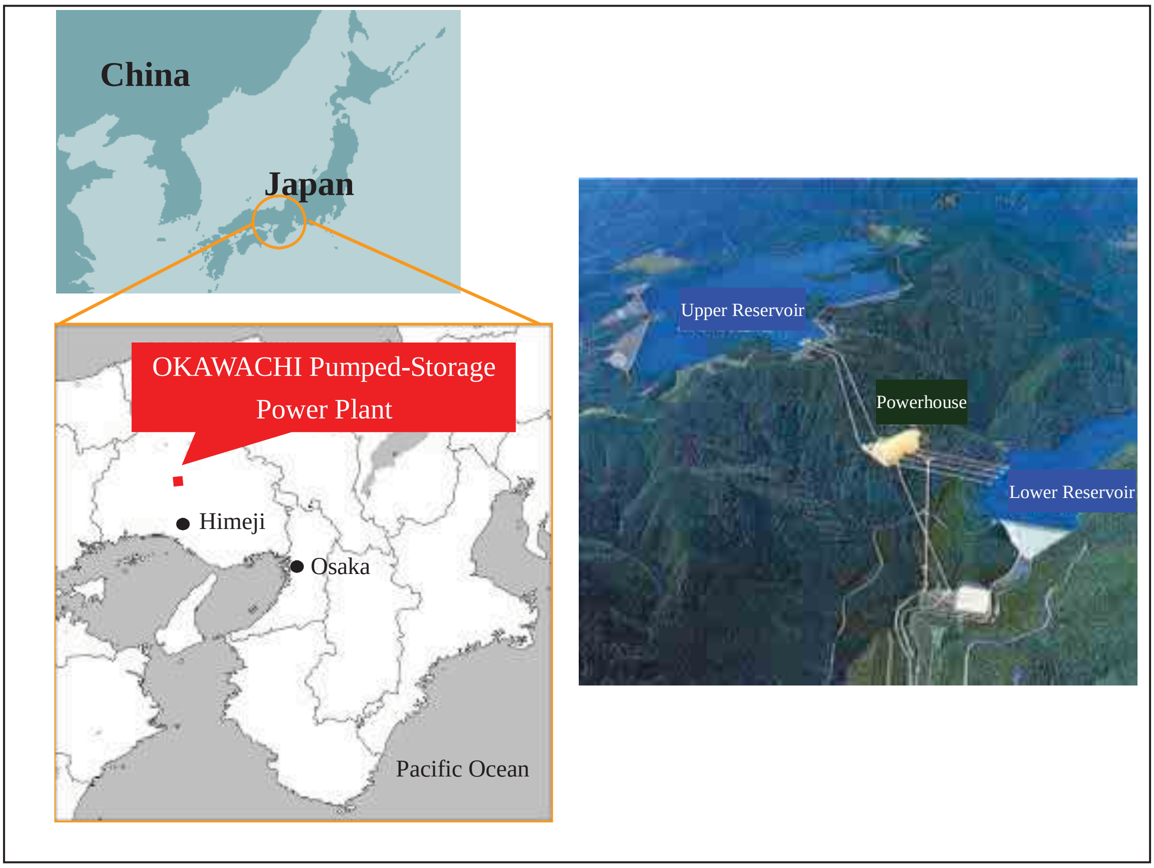


Fig. 1: Location map of the Okawachi Hydropower Station

Table 1: Specifications of the Okawachi Hydropower Station

Item		Specifications	
		No. 1, 2 units (Constant speed type)	No. 3, 4 units (Adjustable speed type)
Pump-turbine	Type	Vertical Francis pump-turbine	Vertical Francis pump-turbine
	Turbine output Pump input	Turbine output: 329 MW Pump input: 340 MW	Turbine output: 331 MW Pump input: 392 MW
	Discharge (maximum)	94.9 m^3/s	95.5 m^3/s
	Effective head (maximum)	411.2 m	411.2 m
	Rated rotational speed	360 min^{-1}	360±30 min^{-1}
Generator-motor	Type	DC excitation Three phase, synchronous generator-motor	AC excitation Three phase, synchronous generator-motor
	Machine type	Revolving-field, totally-enclosed, self- ventilation type	Revolving-field, totally-enclosed, self- ventilation type
	Capacity	350 MVA	395 MVA
	Rated rotational speed	360 rpm	360±30 rpm
Name of river		Odawaragawa tributary, Ootagawa River, Inumigawa River	

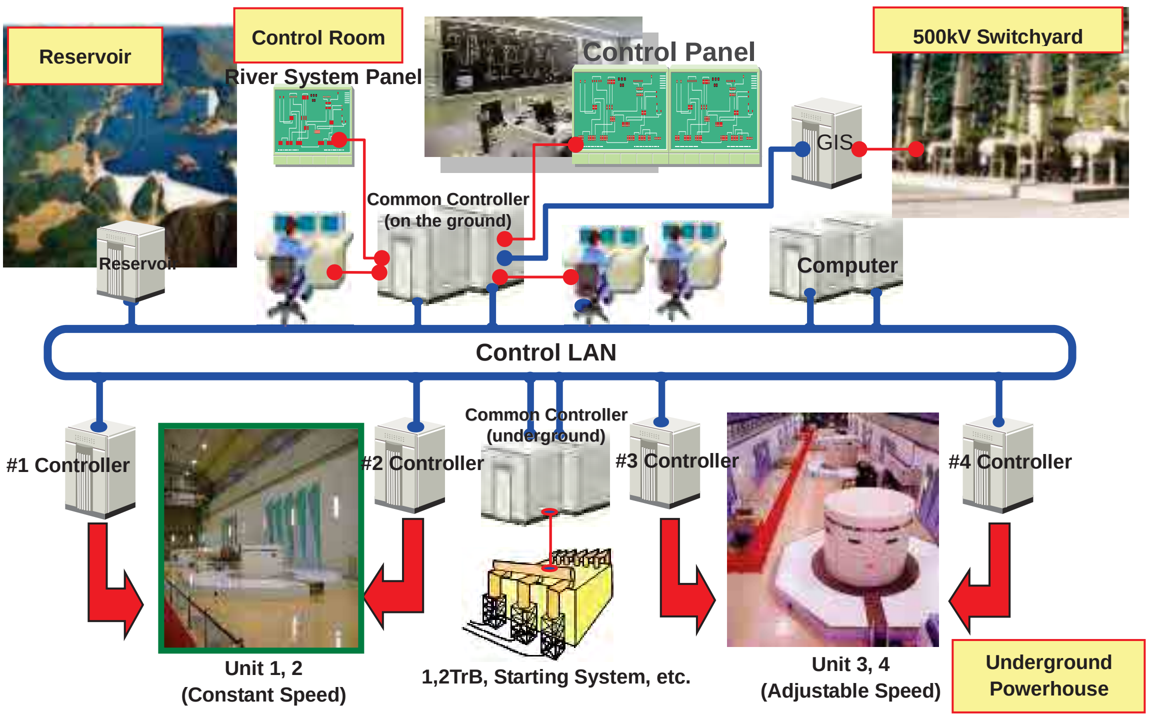


Fig. 2: The system architecture of the control and monitoring systems (before renovation)

2. Description of the Renewal and Upgrading of the Project

2.1 Trigger Causes and Drivers for Renewal and Upgrading

(1) Condition, capability, influence of risk and others

(A)- (b)(c) Degradation due to aging and recurrence of malfunction **---** improvement of durability, safety and reliability, and lower cost

The control and monitoring system has been operated for several decades since the commencement of hydropower station operations, and a variety of problems have been occurring recently. Maintenance is a problem because of the difficulty obtaining repair parts, and the risks for continued safe operation of the power station are increasing.

(2) Improvement of value (functions)

(Not applicable)

(3) Necessity in market

(Not applicable)

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

1995: Operation of all units of the Okawachi Hydropower Station began
2006: Study of this project was started
September, 2008: Construction work of this project began
September, 2010: Scheduled outage of No.2 unit began
November, 2010: Scheduled outage of No.1 unit began
March, 2011: Work on the renewal target part of the No.1 control system was completed.
April, 2011: Work on the renewal target part of the No.2 control system was completed.
October, 2012: Scheduled outage of the 500kV switchyard began
December, 2012: Work on the renewal target part of the 500kV switchyard was completed
November, 2015: The total project is planned to be completed

2.3 Description of Work Undertaken (detail)

2-b) System and Reliability Improvements in Protection and Control (P&C) System and Reliability Improvements in Protection and Control (P&C)

<u>Renewal Policy</u>

The Okawachi Hydropower Station adopted a total digital system for the control and monitoring system at the start of the operation and all data have been shared and exchanged between each control system through the LAN. However, due to this configuration, once any equipment was stopped for service or down due to a failure, control information was interrupted, giving an adverse impact on the whole hydropower station system and temporary action for each such case was required. In this renewal project, our basic policy is to not allow any impact on the whole hydropower station system even if the control system is stopped or interrupted by service requirement or failure, while taking advantage of the merits of the total digital system.

Renewal content

In this project, of the control and monitoring system the following parts are to be renewed. The points of their improvement are shown in Table 2. The system architecture is shown in Fig. 3:

a. System architecture which separates the Dam systems
b. Switchyard was separated and the standard system for Kansai's in-house substations was adopted.
c. System architecture which separates the operating system and maintenance system
d. Projectors were adopted in place of a system monitoring board
e. Operations are conducted by clicking on a LCD monitor and there is no operation console
f. Renewal so as to be applicable of remote control

Table 2: Control and monitoring system, Points of improvement

Item		Outline
Improvement of system reliability	System decentralization of the whole power station systems	- Prevent impacts caused by failure, etc. from reaching the whole power station by separating systems of the powerhouse, switchyard and dams.
	Change of information exchange configuration between individual units	- Add a hard wired circuit for information exchange between units, and between stator and each unit.
	Change of the CPU devices, etc. configuration	- Doubling of information transmission between each CPU and each piece of equipment.
	Other system configuration changes	- Minimize the impacted area when failures of a piece of equipment in the controller occur by optimizing the divided functions of each controller - Doubling of important circuit outputs (common controller, etc.).
Improvement of the maintainability of the hydropower station	Improvement of maintainability for maintenance service	- Minimize impacts on the operating system of the maintenance function by separating the operation system and the maintenance system.
	Accuracy improvement of the condition-based maintenance	- Develop an optimum maintenance system for the condition-based maintenance. - Develop a system which enables the transmission and sharing of the maintenance information to and with other places.
	Prevention of human error	- Add the operation interlock checking software. - Add the functions of simulation of operation on piping system and preparing operation procedure sheet.
	Improvement of other monitoring functionality and operability	- Improvement of monitoring and supporting (measurement, measurement status monitoring, operation guide, system monitoring, etc.). - Adoption of LCD monitors in place of the ground remote operation console and underground direct operation console. - Elimination of a system monitoring board and adoption of the VDP which enables to select several status displays.

Future applicability	Corresponding to remote control	- Reduction of the remote control system cost by adoption of a server which is compatible with remote control operation in the future.
Reflection of the past troubles	Adoption of optical transmission for trip signal between ground and under ground	- Permanent measures against malfunctioning of trip circuit due to thunder.

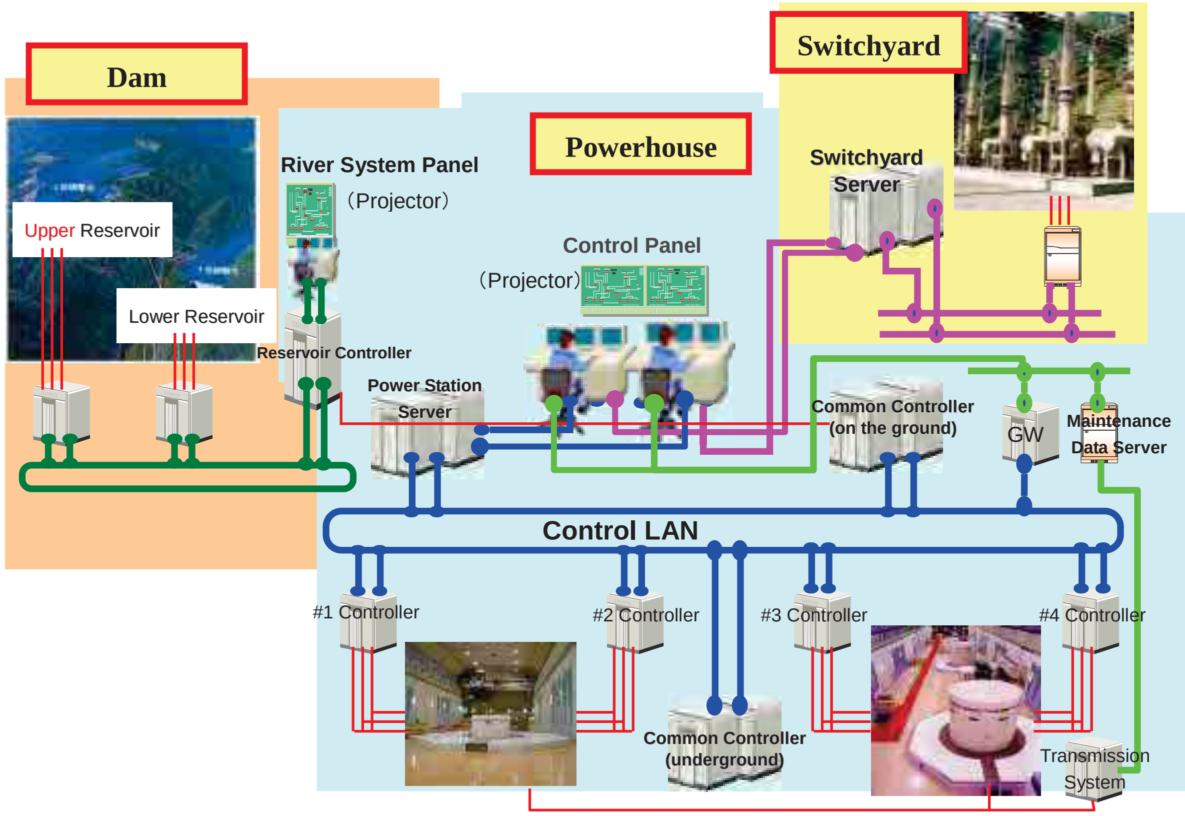


Fig. 3: Control and monitoring system architecture (After renewal)

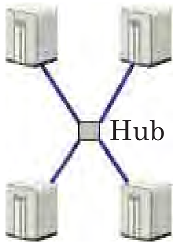
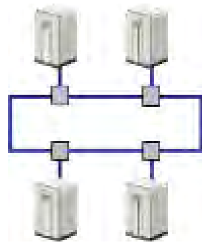
<u>Adopted technologies</u>

In this hydropower station system, since high speed cyclic communication of data for automatic control (sequence control, feedback control) is required between multiple pieces of equipment, a ring type network is adopted.

On the other hand, for the switchyard system, since only monitoring of operation data is required and high speed data transmission (which is required for powerhouse system) is not required, a star type network was adopted because this network system won't have any impact on other equipment even when system trouble occurs.

The characteristics of each control LAN are shown in Table 3.

Table 3: Characteristics of the control LAN

Topology	Star type (substation)	Ring type (pumped-storage)
Block diagram Characteristics	 - Connected by hub to all equipment. Has a common part of hub. - Secure reliability by doubling of LAN - Simple to control the communication route with a LAN failure	 - Systems are connected by ring. No common parts. - Reliability is secured by ring configuration and without common parts. - Complicated to control the communication route with a LAN failure
Adopted place	Extra-high voltage substation	Large scale power station (Thermal power station, Nuclear power station, Pumped-storage hydropower station)
Transmission medium	Twisted-pair cable or optical cable	Optical cable
Transmission speed	10 – 100 Mbps To and from: less than 1 s	100 Mbps, 1 Gbps 1 cycle: less than 100 ms
Protocol	Ethernet 1:N two-way communication; TCP/IP, UDP/IP	RPR(Resilient Packet Ring) Cyclic: H/W control Conversation: UDP/IP
Transmission method	Event (SV), Cyclic (TM)	Cyclic, Conversation
Data conflict	Possible (recovered by resend function)	None
Data loss	Possible (recovered by resend function)	Very rare possibility
Maximum distance	200 m, 2 km when optic repeater is used	2km, 20km when a long distance optic repeater is used
Reliability improvement method	By doubling network. Resend function by serial number control	Optic bypass when system failure occur High speed fault detour while line disconnected
Note	(Substation facility information) Only monitoring and operation information is handled. When some change (event) of information happens between server (or: TC) and each RS (1:N), information is processed.	(Power station facility information) Not only monitoring and operation information but automatic control information between each controller (N:N) is frequently exchanged. Cyclic transmission with less transmission error is adopted so as to respond quickly when information exchange occurs.

3. Feature of the Project

3.1 Best Practice Components

Improvement of reliability by separation of the systems of a powerhouse, switchyard and dam.

3.2 Reason for Success

The Okawachi Hydropower Station has a total digital system facilitating the exchange and sharing of necessary information for the operation control of the dam and other systems between each unit and sites through the control LAN. Consequently, with regard to separation of the system for the powerhouse, switchyard and dam, even the renewal of one piece of control equipment may have an impact on other facilities which are running. Besides, in the process of changing the system into a new control LAN, for a long period of time, both the old control LAN and the new control LAN exist, therefore a well-considered renewal plan is required so as not to negatively affect the operation of the power station.

Therefore, the following switch over process was adopted so as not give an adverse influence on the unit which is being operated. As certain footage in the renewal process, the image diagram of the No.1 and 2 units in 2011 is shown in Fig. 4.

Switch over flow:

(1) Build a new control LAN at other spaces

(2) Using the existing control system as a gate way, the new control system was connected to the existing control LAN, and temporarily is used with the existing control LAN (monitoring and operation are conducted with the existing system).

(3) Whole system will be changed to the new control LAN along with the renovation of common system.

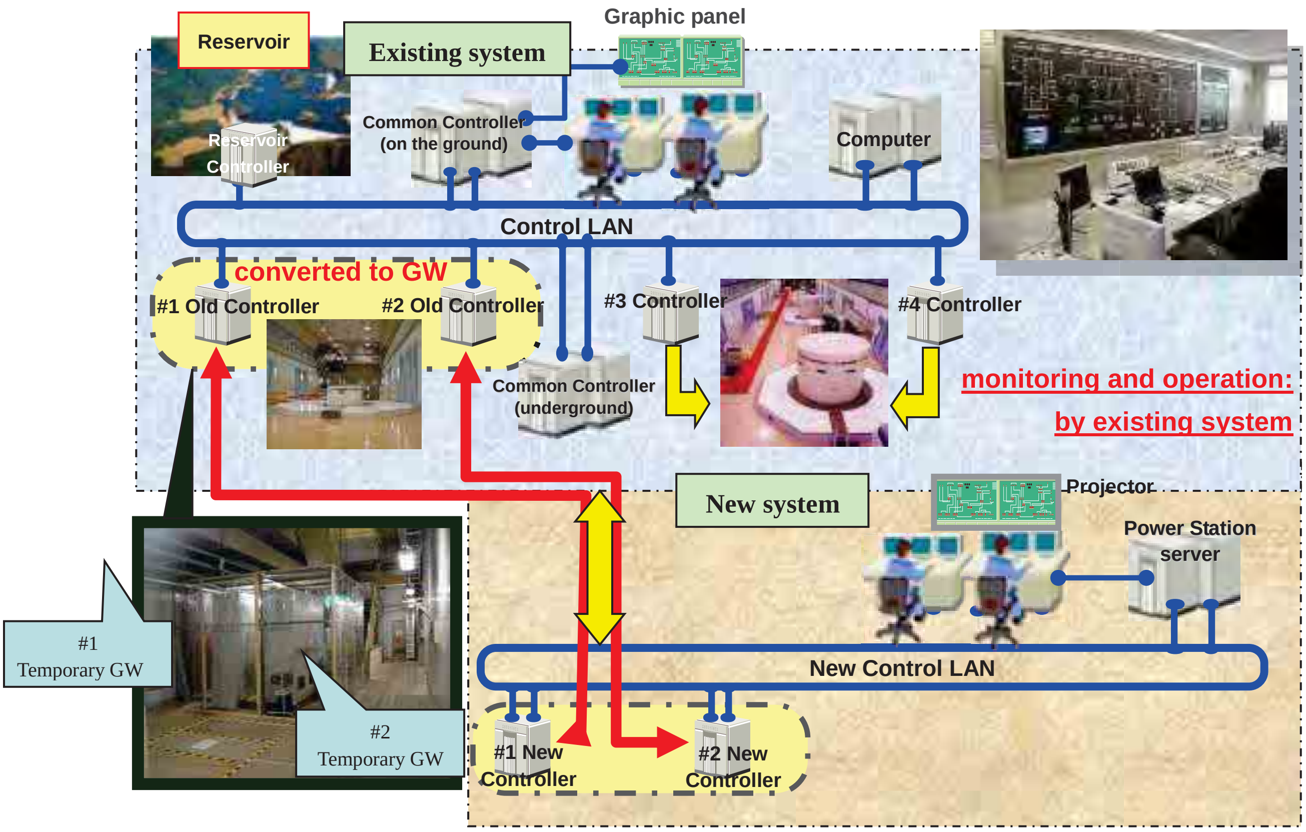


Fig. 4: Image diagram of the renewed No. 1 and 2 units (2011)

4. Points of Application for Future Project

This project is to refurbish the entire control system of a large capacity pumped-storage hydropower station, therefore, it is necessary to determine the optimum timing for renewal in cooperation with other work taking place in our company such as an overhaul of the pump–turbine and generator-motor in the same hydropower station and a large construction project on the other pumped-storage hydropower station.

When all hydro turbines and generators are controlled by one common controller like this hydropower station, to renew the common controller system, it is necessary to stop all hydro turbines and generators. In order to minimize the down time of the whole hydropower station, it is necessary to develop the system architecture and the divided functions of each controller suitable for each hydropower station.

5. Others (monitoring, ex-post valuation etc.)

(Not applicable)

6. Further Information

6.1 Reference

(Not applicable)

6.2 Inquiries

Company name: Kansai Electric Power Co., Inc.
URL: http://www.kepco.co.jp/

ANNEX XI Renewal & Upgrading of Hydropower Plants

Format for the 2nd Round Data Collection (Definition of Case Histories)

Category and Key Points

Main: 2-b) System and Reliability Improvements in Protection & Control (P&C)

Sub: 1-b) Investment incentives (Feed-in-Tariff (FIT), Renewable Portfolio Standard (RPS), subsidies, financial assistance, tax deductions, etc.)

Project Name:

The expansion project of the Power Generation Using Ecological Discharge facilities for the Kagehira Power Station.

Name of Country (including State/Prefecture):

Japan, Tokushima Prefecture

Implementing Agency/Organization:

Shikoku Electric Power Co., Inc.

Implementing Period:

From 2009 to 2010

Trigger Causes for Renewal and Upgrade:

(C) Needs for higher performance

Keywords:

Power Generation Using Ecological Discharge, Use Existing Tunnel, Placement for Series Connection of Two Turbines, Constant Water Flow Control

Abstract:

The electric generating facility in the Kagehira Hydroelectric Power Station is a power generation facility with a maximum output of 150kW which started its operation in April, 2010. This power generation facility uses ecological discharge which is discharged and diverted through the existing headrace from the Kominono Dam located up stream from the power station.

As turbines and generators, the less expensive package type two turbines were installed in series in the existing narrow tunnel (the work tunnel at the time when the power station was being constructed). This enabled saving installation space and corresponded to the available high head. This turbine and generator is the first case in Japan which was planned and put to practical use as a constant flow control type in this layout configuration.

1. Outline of the Project (before Renewal/Upgrading)

The Kagehira Power Station is a dam and conduit type power generation with a maximum output of 46,500kW located on the Nakagawa River of the Nakagawa water system in Tokushima Prefecture.

For this power station, when the water rights were renewed in 1996, Ecological discharge was obligated. Accordingly, the ecological discharge facilities (pipework, discharge valve) were installed in the work tunnel (constructed when the power station was built) located 200m downstream of the Kominono Dam, discharging 0.54m^3/s constantly throughout the year to downstream of the dam. (Fig. 1) (Table 1).

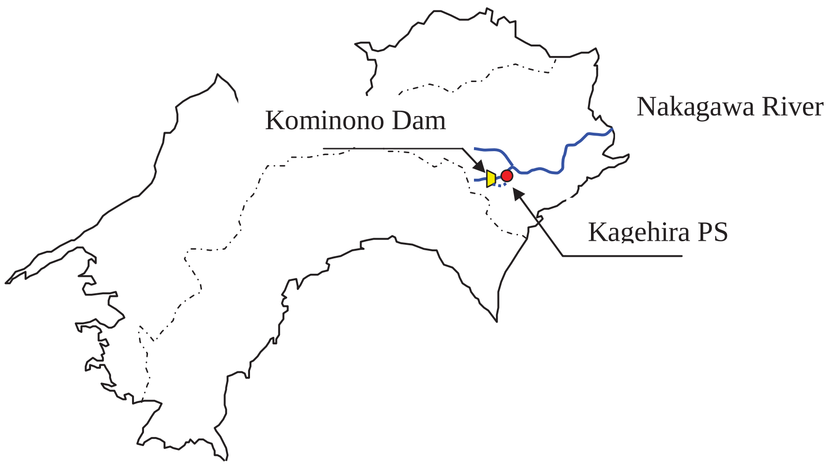


Fig. 1: Location map of the Kagehira Power Station

Table 1: Specifications of the Kagehira Power Station

Items		Specifications
Powerhouse	Name of power station	Kagehira
	Maximum output	46.5 MW
	Maximum plant discharge	60.0 m^3/s
	Effective head	89.7m
Dam	Name of dam	Kominono
	Name of river, water system	Nakagawa, Nakagawa water system
	Type	Arch
	Height of dam	62.5m
	Length of dam crest	151.78m

2. Description of the Renewal and Upgrading of the Project

2.1 Trigger Causes and Drivers for Renewal and Upgrading

(1) Condition, capability, influence of risk and others

(Not applicable)

(2) Improvement of value (functions)

(C)-(a) Neeeds for higher performance – Efficiency improvement , Addition power &energy. Loss reduction

In the Kagehira Power Station, when the water rights were renewed in 1996, ecological discharge was obligated, thus the 0.54m^3/s of water discharged throughout the full year allowed for utilization of the water power.

(C)-(b) Neeeds for higher performance – Role change of hydropower generation. Addition of new functions

To respond to the constrained installation space and a high head, two turbines were installed in series, and it was necessary to generate energy with a constant water flow even when water level changed.

(3) Necessity in market

(Not applicable)

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

May 2008:	Full-scale study of the project began
September 2009:	Civil engineering work began
December 2009:	Electrical work began
January 2010:	Main civil engineering work was completed
February 2010:	Installation of the electric facilities was completed
March to April 2010:	Electric facilities test was conducted (including 2 machines in series control test)
April, 2010:	Construction was completed, and operation was started

2.3 Description of Work Undertaken (detail)

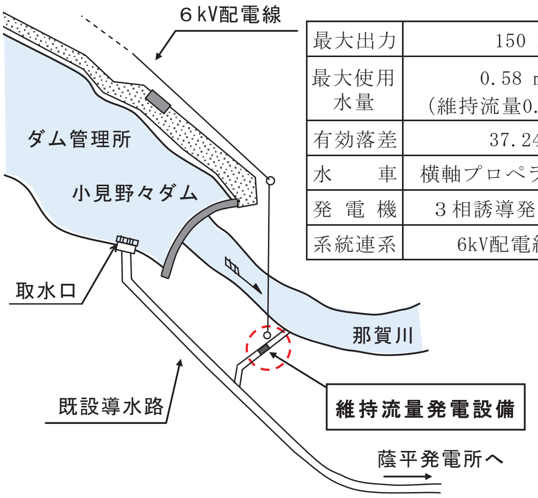
1-b) Investment incentives (Feed-in-Tariff (FIT), Renewable Portfolio Standard (RPS), subsidies, financial assistance, tax deductions, etc

As for a hydropower station with an output of less than 1,000kW, from 2007, ecological discharge power generation by a dam type power station and a dam and conduit type power station has been subject to RPS law, and the government policy to promote small and medium size hydropower stations has been applied by expanding the subsidy system.

Under such a situation, when water rights for the Kagehira Power Station were renewed in 1996, Ecological discharge has been obligated and since then a Ecological Discharge of 0.54 m^3/s has continued. Consequently, the power generation plan using this ecological discharge was studied. As a result, the following findings were obtained:

- Able to contribute to reduced fuel cost.
- Able to contribute to achievement of the RPS obligation amount.
- Able to reduce the amount of carbon dioxide emissions

Thus, it was assured that economic efficiency could be achieved. Therefore, power generation facilities with a maximum output of 150kW, (annual generated energy of 970 thousand kWh) was installed by remodeling the existing ecological discharge facilities (parts which were not used due to a pipe diameter were removed). (Fig. 2)



最大出力	150 kW
最大使用水量	0.58 m^3/s (維持流量0.54 m^3/s)
有効落差	37.24 m
水　車	横軸プロペラ水車２台
発 電 機	３相誘導発電機２台
系統連系	6kV配電線連系

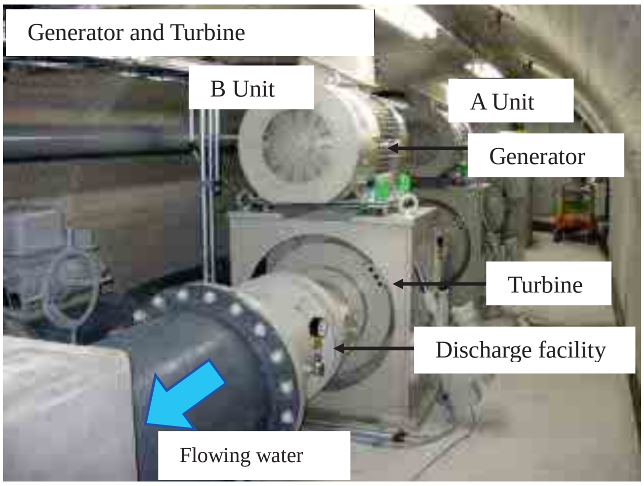


Fig. 2: Location and Photo of the power station

2-b) System and Reliability Improvements in Protection & Control (P&C)

For a turbine, generally the application range is for a Francis turbine, but since the existing tunnel was narrow (tunnel for construction work built at the time of the construction of this power station), it would have been necessary to expand the tunnel diameter so as to install a Francis turbine. Besides, since the scale of the power generation was small, it was necessary to restrain the investment money.

Therefore the package type turbine which meets the following conditions was surveyed:

- able to install in the existing tunnel (3.2m width ×2.4m height ×64.2m total length) without expanding its size and able to allow maintenance work.
- able to regulate constant water flow responding to the fluctuation of normal water level without an operation stoppage, and able to discharge continuously the committed Ecological discharge for power generation.

However, as a single machine, there wasn't any machine type which met these requirements and be able to respond to the planned head (37.24m).

Therefore, in order to enable to apply an existing package type of turbine, two horizontal propeller type turbines were installed in series and the configuration for a head sharing configuration was adopted. Thus, we have developed a constant flow control method using this type of system configuration and put it into practical use for the first time in Japan. (Fig. 3)

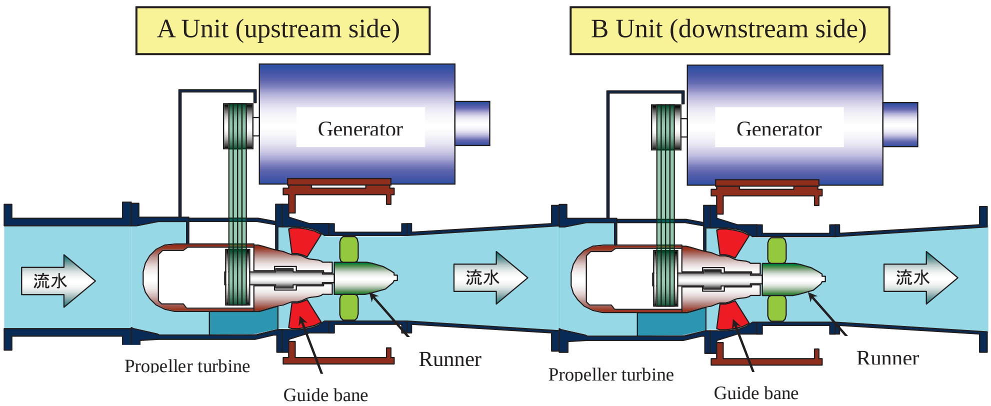


Fig. 3: Cross-section view of the turbine

With regard to the flow control by a series configuration of turbines, it is difficult to regulate an output balance because flow volume changes by opening and closing of the guide vanes. Also, output fluctuates irregularly due to the change of the head sharing rate of each turbine. (Fig. 4)

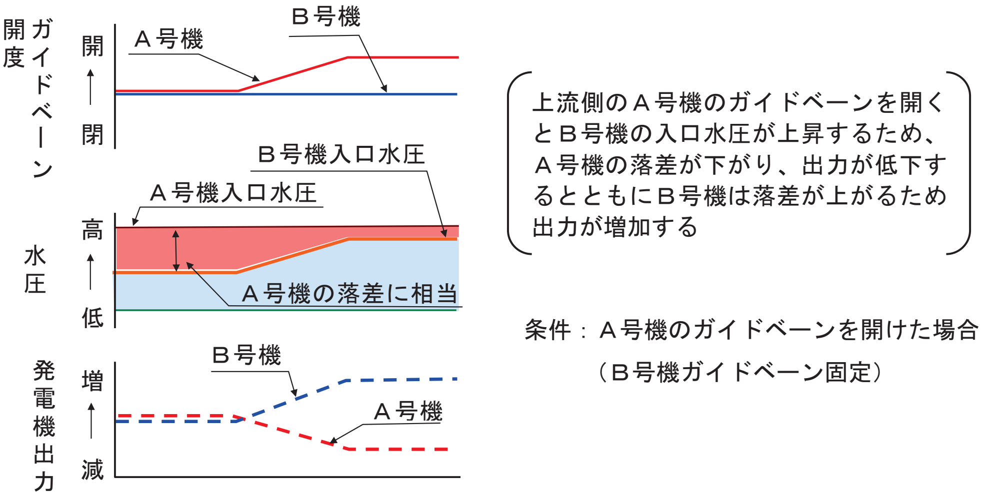


Fig. 4: The relationship between output and opening level of guide vane

Accordingly, various methods were investigated to balance the output of the two turbines in a short period of time. As a result, by adopting the method in which Machine A (upper stream) is controlled and letting Machine B downstream to follow Machine A (follow-up control), it became clear that the hoped output regulation is able to be achieved.

Normally, in the follow-up control, guide vanes are opened or closed so that the output of Machine B downstream corresponds to Machine A up stream. However, if the opening level is changed greatly, water pressure between the two machines changes greatly, and output of Machine A which is the standard, fluctuates greatly. Therefore, since it is necessary to control Machine B in small increments so as to follow Machine A, it takes a long time for the output of two machines to reach a balanced level.

Consequently, we have developed a method in which the output of Machine B is to be synchronized: to Machine A by the following process: first, set the opening level of guide vanes of machines A and B the same so as to roughly balance their output. Then, adjust the guide vane opening level of Machine A little by little. We tried this method by actual machine regulation tests at the site, and by testing the opening timing of the guide vanes, opening level, and the control conditions to find out the proper setting values, and we finally found the conditions which enabled controlling a stable output in a short time of period. (Fig. 5)

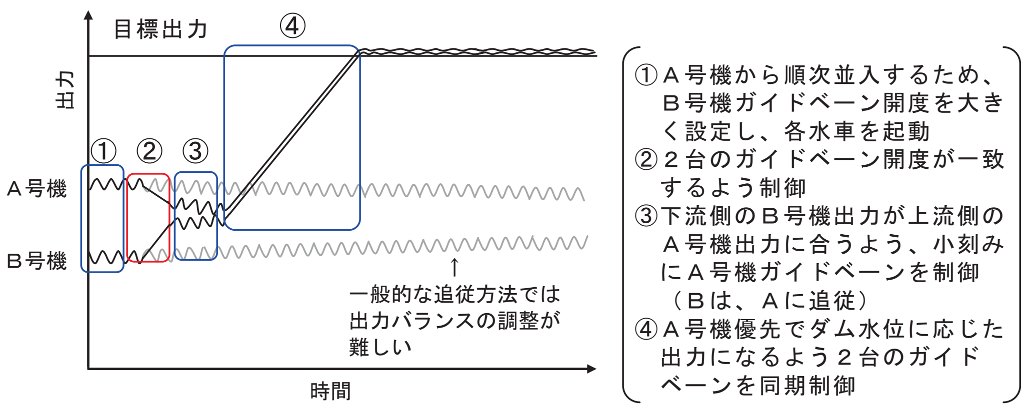


Fig. 5: Image of the follow-up control

3. Feature of the Project

3.1 Best Practice Components

- By adopting the package type horizontal propeller turbines in series, we were able to overcome the installation space constraint and utilize a high head. (Fig. 6)
- Development and practical realization of the constant water flow control method by the installation of the turbine in series.

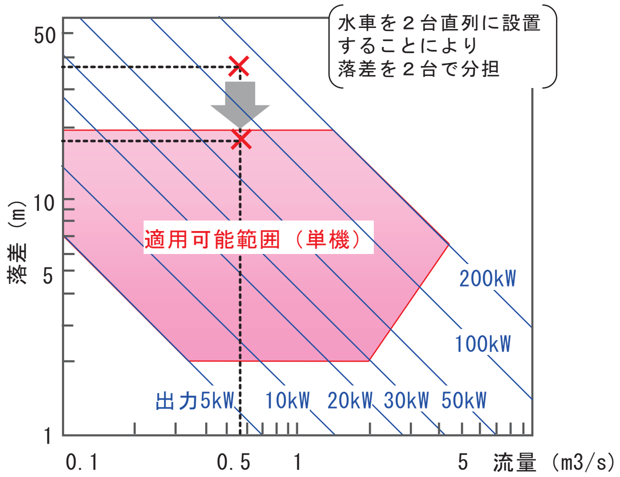


Fig. 6: Application range of the horizontal propeller turbine

3.2 Reasons for Success

The reasons why this project has succeeded are as follows: adopted the less expensive package type turbine which enabled controlling water flow; installed 2 turbines in series so as not expand the tunnel size; accommodated a high head. Besides, the control method for flow control for the series installation configuration was developed, and based on the test results obtained by the actual machines, the proper setting values for guide vane opening/closing timing, etc. were found. These things were also an important reason for success.

4. Points of Application for Future Project

(Countermeasures to water immersion)

- It is necessary to take countermeasures against water immersion when the electric facilities such as turbine generators are to be placed in a lower position than flood level. In this project, since the flood level is higher than the tunnel cope level, the tunnel entrance was closed with a concrete wall, and a vertical shaft was constructed for the connection to the inside of the tunnel. On top of that, the Distribution box was placed on the newly constructed rising space. (Fig. 7, 8)

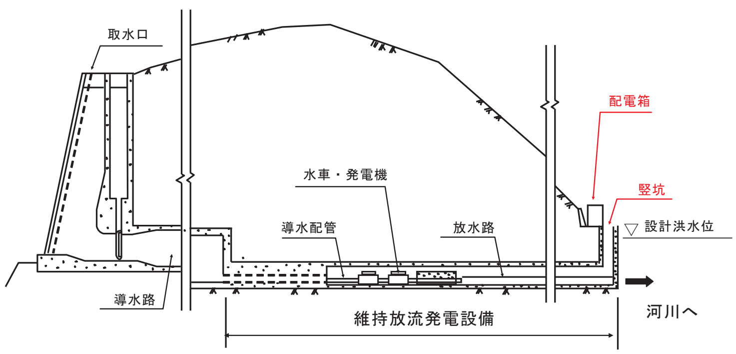


Fig. 7: Installation position of the turbine, the generator, and the distribution box

Fig. 8: Installing status of the distribution box

(Securement of the Ecological discharge)

- As for the power generation facilities using Ecological discharge, it is necessary to assure that Ecological discharge continues even when the generation facilities are inspected and/or stopped due to failure. Consequently, in this project, by installing the bypass pipe, the facility configuration was established so that when generation stops, water discharge is to be switched automatically. (Fig. 9)
- In addition, as for the control and driving power source for the inlet valve and discharge valve, in consideration of a blackout by a distribution line accident, the countermeasure to supply power from the permanent power supply has been arranged.

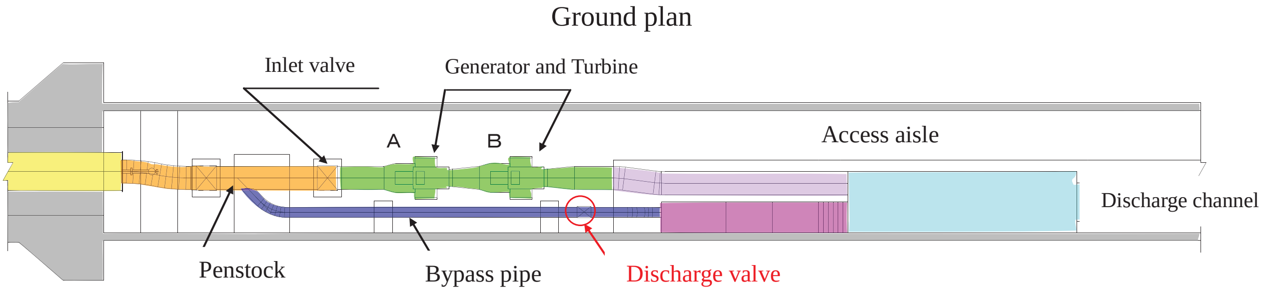


Fig. 9: Bypass pipe and discharge valve

5. Others (monitoring, ex-post valuation etc.)

Since the commencement of the operation, this Ecological Discharge Power Generation facility has generated energy almost as planned, but water inlet screens are shared with the existing facility (maximum plant discharge: 60.0 m^3/s), and since the screen mesh is wide, trash has frequently clogged the screens.

Accordingly, when trash clogged the turbines, an automatic sequencer which manipulates the start and stop of the turbines several times for trash removal was added and maintenance labor has been saved. (Fig. 10, 11)

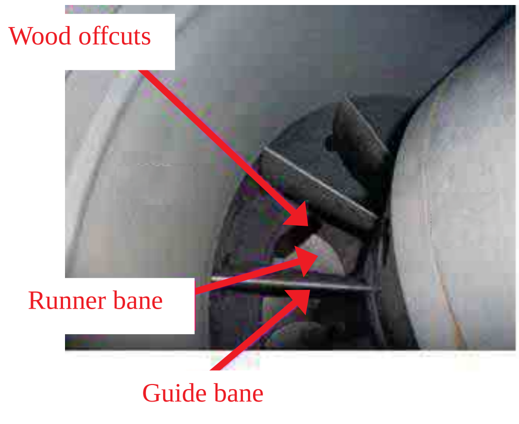


Fig. 10: View of trash clogging the inside of the turbine

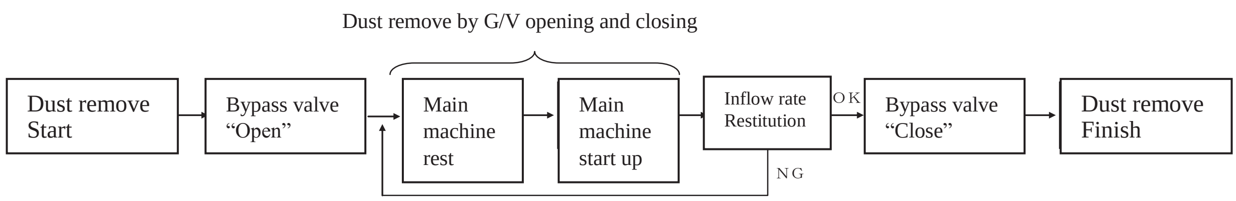


Fig. 11: Sequence circuit of Automatic trash elimination

6. Further Information

6.1 Reference

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3) T. Nakatsuji et. Al., “Plan, design and construction of the Kagehira Power Station No. 2 system”, *Text for the 95th workshop for the small and medium-sized hydroelectric power station,* July, 2012

6.2 Inquiries

Company name: Shikoku Electric Power Company

URL: http://www.yonden.co.jp/

ANNEX XI Renewal & Upgrading of Hydropower Plants

Format for the 2nd Round Data Collection (Definition of Case Histories)

Category and Key Points

Main: 2-c) Technological innovation, deployment expansion and new materials used for civil and building works

Project Name:

The construction project of the Shin-Onagatani No.1 Hydroelectric Power Station

Name of Country (including State/Prefecture):

Japan, Toyama Prefecture

Implementing Agency/Organization:

Toyama Bureau of Enterprise

Implementing Period:

From 1997 to 2001

Trigger Causes for Renewal and Upgrade:

(A) Degradation due to aging and recurrence of malfunction

(C) Needs for higher performance

Keywords:

Tunnel boring machine, Increase of output, Spillway

Abstract:

Since the headrace tunnel and the generators were aging, redevelopment using some parts of the existing facilities was conducted so as to increase maximum output. For the tunnel construction, new technology, that is, an integrated lining type tunnel boring machine (TBM) was adopted.

1. Outline of the Project (before Renewal/Upgrading)

The old Onagatani No.1 Hydropower Station started its operation in June, 1955 as the first hydropower station operated by the Prefecture after the Second World War.

Old Onagatani No.1 Power Station

Item	Specification
Water intake river	First class river, Jintsugawa water system Idagawa River
Generating type	Run of river (waterway)
Effective head	Maximum 146.61m Normal time 148.60m
Plant discharge	Maximum 3.25m^3/sec Normal time 1.51m^3/sec
Output	Maximum 4,000kW Normal time 1,700kW

2. Description of the Renewal and Upgrading of the Project

2.1 Trigger Causes and Drivers for Renewal and Upgrading

(1) Condition, capability, influence of risk and others

(A) - (d) Degradation due to aging and recurrence of malfunction – Easy maintenance with less labor

The previous Onagatani No.1 Power Station started its operation in 1955 as the first hydropower station operated by Toyama Prefecture after the Second World War, and experienced serious aging for the generation facilities such as the headrace tunnel and others due to degradation over time.

(2) Improvement of value (functions)

(C) - (a) Needs for higher performance – Efficiency improvements. Addition power & energy .Loss reduction

By reviewing the water flow data, an increase of plant discharge and maximum power output were pursued. For the construction work of the headrace tunnel, new technology, an integrated lining type tunnel boring machine was adopted.

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

1955: Operation of the Onagatani No.1 Power Station (existing power plant) began

1992: Study of the construction project of the Shin-Onagatani No.1 Power Station was started.

1996: The construction project of the Shin-Onagatani No.1 Power Station was approved by the local government.

1997: Construction work on the Shin-Onagatani No.1 Power Station began (construction road)

1998: Construction work on the headrace tunnel began

1999: The excavating work by the integrated lining type tunnel boring machine was started

2000: The headrace tunnel was completed

2001: Operation of the Onagatani No.1 Power Station (existing power plant) stopped (for 3 months)

2001: Construction work on the Shin-Onagatani No.1 Power Station was completed (Operation began in September)

2.3 Description of Work Undertaken (detail)

2-c) Technological innovation, deployment expansion and new materials used for civil and building works

The Onagatani No.1 Power Station is the run-of-river power plant with a maximum output of 4,000kW. This power station was the first power station operated by the Prefecture after WWII, but since the commencement of its operation, 40 years have passed. Consequently, aging of the facilities such as the headrace tunnel and others were progressing and a redevelopment plan was studied.

Though the old power station used a maximum plant discharge of 3.25m^3/sec which is equivalent to 180 days discharge, the new power plant has adopted 6.0m^3/sec (equivalent to 60 days discharge) which makes construction cost the cheapest, and has increased maximum output to 7,500kW. The new intake weir was constructed upstream of the existing intake weir (doubles as an erosion control weir), and almost all facilities from headrace to the power station were newly constructed. However, by placing the head tank adjacent to the existing facility, and by utilizing the existing hydraulic steel pipe as a spill pipe, construction costs were reduced.

Fig. 1: Location map

Table 1: Onagatani No.1 Power Station

Item	Specification
Water intake river	First class river, Jintsugawa water system, Idagawa River
Generating type	Run 0f river (waterway)
Effective head	Maximum 152.00m, Normal time 154.80m
Plant discharge	Maximum 6.00m^3/sec, Normal time 1.15m^3/sec
Output	Maximum 7,500kW, Normal time 1,000kW

For the construction of the headrace tunnel, the integrated excavation-lining type boring machine (TBM) was adopted.

Generally, in a conventional TBM method for a small diameter tunnel, it is very difficult and troublesome to spray on the inside wall immediately after TBM excavation. This is because of a very small and narrow working space, poor working conditions and application difficulty. Therefore it is common practice to spray concrete or other materials after excavation of the entire tunnel was completed.

As a result, by leaving an excavated tunnel untreated for a long time, various problems occur such as ground weathering, cave-ins, dust and reflection caused by manual nozzle application, and unevenness of the sprayed layer.

The new excavation lining integrated TBM had been studied and developed so as to respond to such problems of the conventional TBM construction by the New Energy Foundation which was required by the Agency for Natural Resources and Energy.

In this new method a spray robot, attached after the TBM, sprays concurrently with the TBM excavation work, and applies an even concrete lining very quickly. Thus, compared to the conventional TBM construction method, this method can not only resolve problems of the conventional TBM construction method but also contributes to cost saving by reducing the construction period and reflected materials.

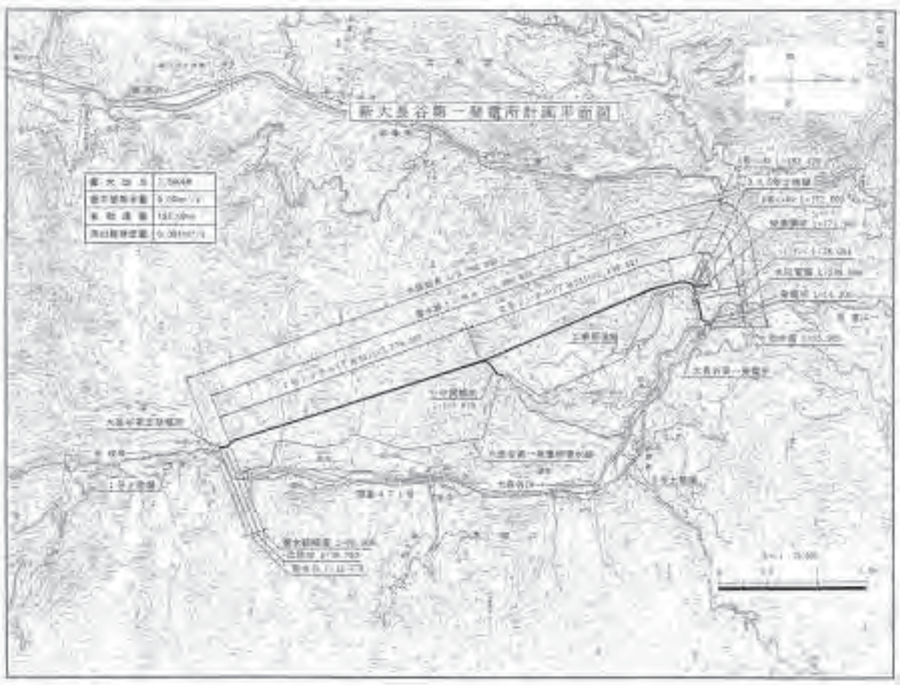


Fig. 2: Plan view of the power station plan

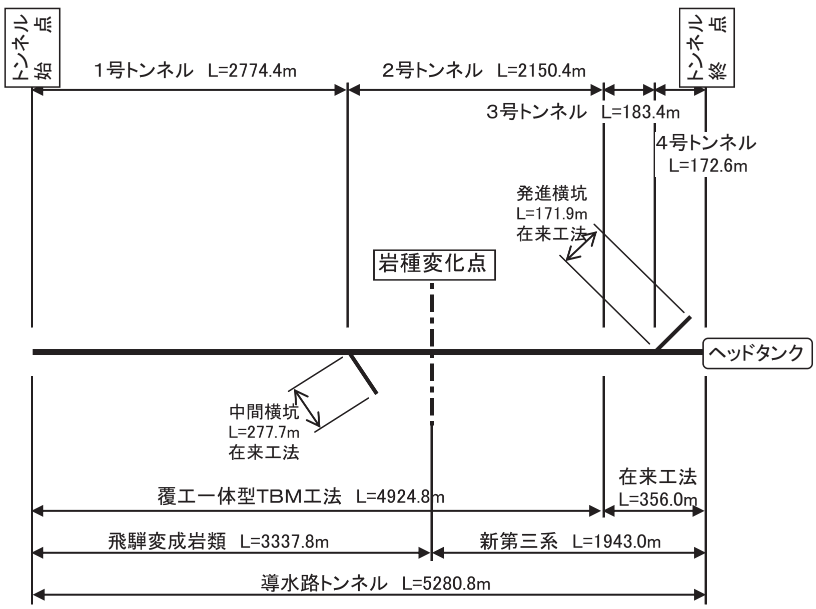


Fig. 3: Route diagram of the headrace tunnel

Table 2: Headrace tunnel; rock support and lining

Type			Type of lining	Design thickness of fiber mortar (cm)	
				At point of support	At middle between supports
(First class)			-	-	
2 class			-	-	2
3 class			-	-	4
4 class	4 class	4class a, 4class b	Tunnel 75×40×5×7	4 - 6	4 - 6
	4 class (1)	4class, 4class c, 4class d	Tunnel 150×75×6.5×10	8	4 - 8
5 class			Steel segment	-	-

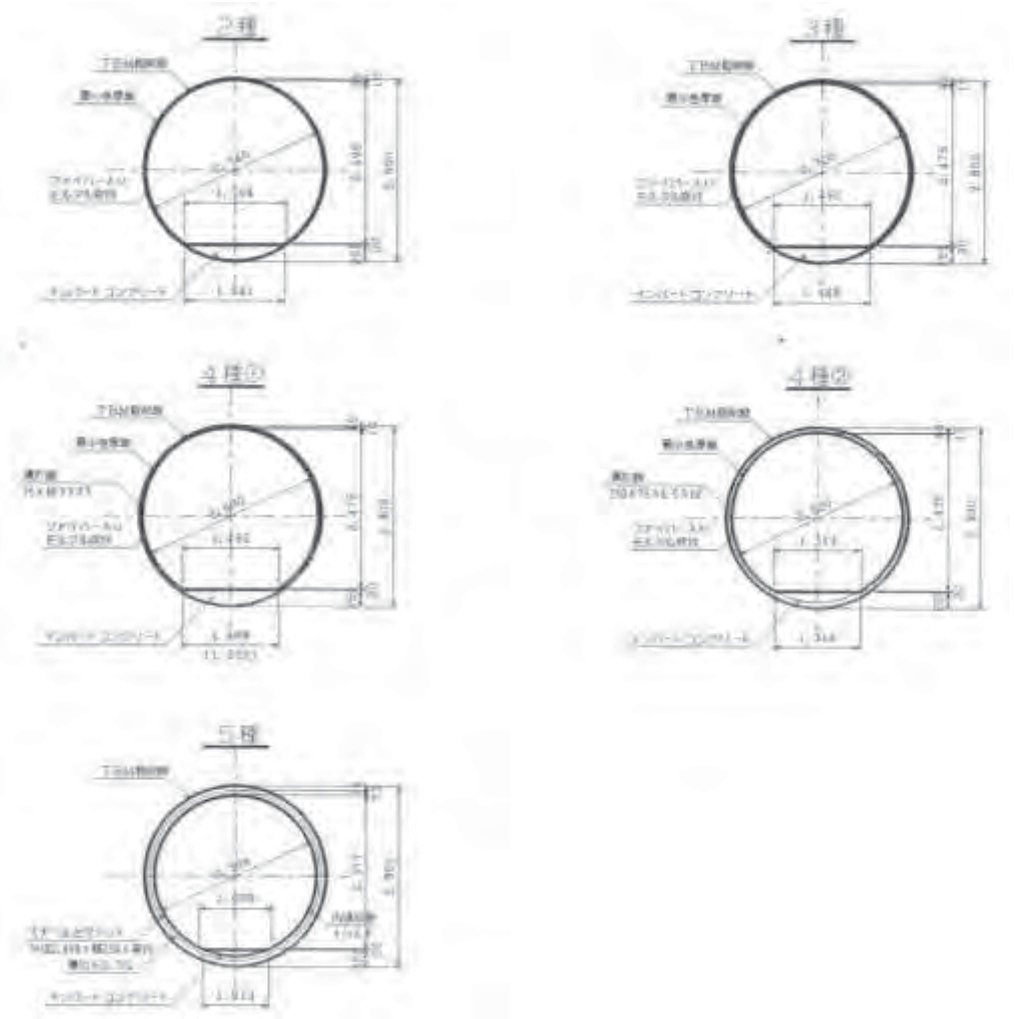


Fig.4 : Headrace tunnel; rock support and lining

Fig. 5: Tunnel boring machine (TBM)　　**Fig. 6: Shotcrete Robot behind TBM**

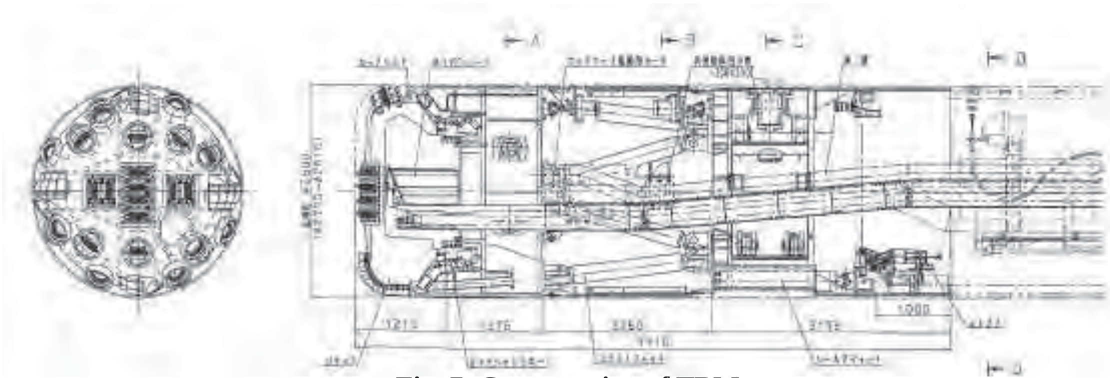


Fig. 7: Cross-section of TBM

3. Feature of the Project

3.1 Best Practice Components

- Excavated ground is stabilized early
- Improvement of working environment
- Improvement of quality of the construction
- Construction work period is shortened
- Cost saving

3.2 Reasons for Success

This integrated excavation lining TBM was adopted for this project as a technical reliability actual experiment for the small-medium hydropower station system. This construction method was studied and developed by the New Energy Foundation which was required to do it by the Agency for Natural Resources and Energy of Ministry of Economy, Trade and Industry.

With a view to adopt this method for the construction, this method has been improved so as to improve quality, and to shorten construction time by various measures such as changing the spray material (from the concrete spray to mortar including fiber spray) and doubling of the makeshift racetrack through repeated discussions and investigations with the construction vendors.

4. Points of Application for Future Project

In some fracture zones, due to ground characteristics of swelling and slaking, troubles occurred such as machine clogging during TBM excavation work and/or degrading of the lining property after the lining was completed.

To adopt this construction method, it is necessary to carefully determine excavation and lining patterns in a fracture zone, and also to recognize the geological conditions in every detail

5. Others (monitoring, ex-post valuation etc.)

- Excavated ground was stabilized quickly

By conducting spray lining work immediately after TBM excavation, it became possible to stabilize the excavated ground earlier, and also to be able to conduct lining work by only the spraying process without providing supports such as a lock bolt, metal mesh, ring support and mine timbering which were required for the conventional type of TBM construction method.

Since degradation of excavated ground due to a long time elapsing until lining work was eliminated, the addition of mine timbering was not necessary.

- Improvement of the work environment

By introducing a robot which automatically controls spraying spots and spray thickness, and by adopting a fiber mortar material for spraying, it became possible to reduce dust and reflection materials.

Average dust amount at the spraying work: 1.64 mg/m^3

Reflection rate: 2 – 5%

- Shortening of work periods

Against the monthly progress plan of 322m/month, an actual average monthly progress was 370m/month, and the voluntary monthly progress was recorded at 785m/month. When compared with the conventional TBM method, about 2.2 months (about 13%) were saved. (From the commencement of the excavation work to the completion of the spraying works)

掘削月	作業方数		掘進距離（m）		平均進行（m/方）	
	当月	累計	当月	累計	当月	累計
1月目	32	32	64.2	64.2	2.01	2.01
2月目	50	82	349.9	414.1	7.00	5.05
3月目	52	134	406.6	820.7	7.82	6.12
4月目	34	168	164.1	984.8	4.83	5.86
5月目	49	217	476.4	1,461.2	9.72	6.73
6月目	53	270	284.9	1,746.1	5.38	6.47
7月目	50	320	355.1	2,101.2	7.10	6.57
8月目	20	340	195.5	2,296.7	9.78	6.76
9月目	25	365	164.5	2,461.2	6.58	6.74
10月目	49	414	612.3	3,073.5	12.50	7.42
11月目	54	468	700.7	3,774.2	12.98	8.06
12月目	47	515	296.8	4,071.0	6.31	7.90
13月目	41	556	377.9	4,448.9	9.22	8.00
14月目	49	605	450.1	4,899.0	9.19	8.10
15月目	7	612	25.8	4,924.8	3.69	8.05

Table 3: Actual TBM excavation work

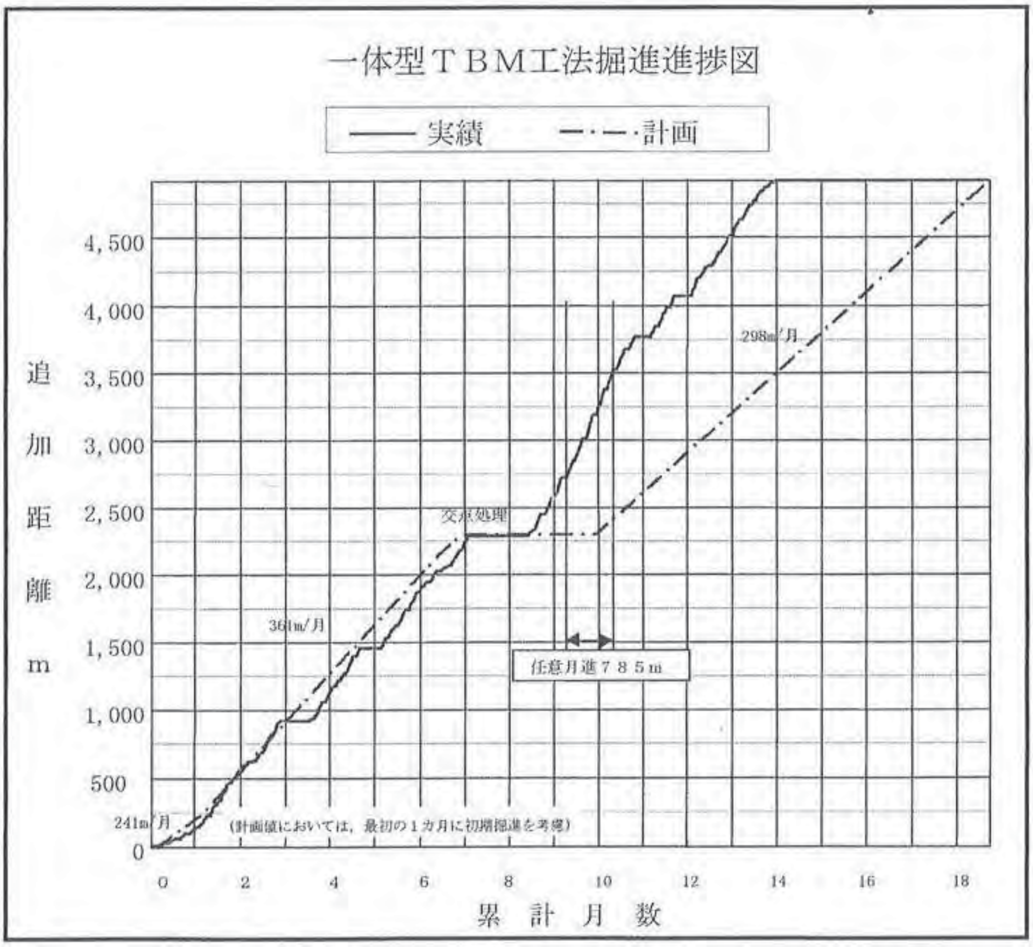


Table 4: Progress diagram of the integrated TBM excavation work

- Cost saving

When compared with the conventional TBM method, by calculation of the costs for the TBM construction sections, it became clear that about 4% of the direct construction costs were able to be saved.

6. Further Information

6.1 Reference

Toyama Bureau of Enterprise, “Records of the construction of the Shin-Onagatani No.1 Hydroelectric Power Station”, March, 2002.

6.2 Inquiries

Company name: Toyama Prefecture
URL: http://www.pref.toyama.jp/

ANNEX XI Renewal & Upgrading of Hydropower Plants

Format for the 2nd Round Data Collection (Definition of Case Histories)

Category and Key Points

Main: 2-c) Technological innovation, deployment expansion and new materials used for civil and building works

Project Name:

The development of the Seismic Upgrading Method of the dam spillway piers using the existing control bridge

Name of Country (including State/Prefecture):

Japan, Shizuoka Prefecture

Implementing Agency/Organization:

Chubu Electric Power Co., Inc.

Implementing Period:

From 2006 to 2011

Trigger Causes for Renewal and Upgrade:

(D) Needs for safety improvement

Keywords:

Spillway gates, Spillway piers, Seismic upgrading method

Abstract:

Though the existing spillway piers meet the seismic capacity required by the current technical standard, it is important to improve the seismic capacity of the spillway piers so as to prepare for large-scale earthquakes like a Tokai Earthquake (hereinafter referred to as level 2 earthquakes) for an improvement of the safety level.

Accordingly, we have investigated the seismic capacity of the spillway piers of the existing dam against level 2 earthquake by dynamic analysis. Based on that data, we have developed the seismic upgrading method for the dam spillway piers using the existing control bridges. By applying this construction method to the spillway piers of the existing dam (actually from 2010), we have improved the reliability of the operation of the spillway gates following a level 2 earthquake, and improved the safety level.

1. Outline of the Project (before Renewal/Upgrading)

1.1 The project site

The dam reported in this report is the power generation dam for which the seismic upgrading method has been applied on the spillway piers of the existing power station. This dam is located midway down the Oigawa River flowing in Shizuoka Prefecture and operated by Chubu Electric Power Co., Inc. Fig. 1 is the location map of the dam, and the external appearance of the Sasamagawa Dam is shown in Fig. 2. The basic specifications of the 4 dams on which in 2010 the seismic upgrading method has been applied are shown in Table 1 (hereinafter the Sasamagawa Dam is referred to as the subject dam).

1.2 The spillway piers of the subject dam

A spillway pier of the dam is a supporting structure which opens or closes a spillway gate, and it is necessary to have a seismic capacity which is able to maintain the flood processing function even when a large-scale earthquake occurs. The basic configuration diagram of the existing spillway of the subject dam is shown in Fig. 3. Unlike the spillway piers installed on both sides, the spillway pier located in the middle of the subject dam is not integrated with the non-spillway structure of the dam, thus the middle spillway pier is to be supported only by its foundations for earthquake loads which swing horizontally. The height and lateral width of the central spillway pier are shown in Table 1. The width of the spillway crest in the upstream to downstream direction is 17.4m. Accordingly, the section modulus of the cross-section of the foundation in a vertical direction is about 1/9 of the section modulus of the cross-section of the sides in the right bank to left bank direction (horizontal direction). Consequently, for the spillway pier of the subject dam, like in the many generations of dams both at home and abroad, when a level 2 earthquake occurs, the main impact by the earthquake comes in a horizontal oscillation in a right bank to left bank direction.

With respect to the upper part of the dam spillway structure which is above water level, in many dams above the spillway pier, a steel control bridge is installed so as to manipulate the spillway gates. As for the steel control bridge, in order to prevent buckling of the main beam and damage of shoe caused by thermal expansion and contraction of the steel main beam, generally, one end of each span is a mobile shoe. The control bridge in which one span is mobile, does not function as a seismic damper structure to restrain the oscillation of the spillway piers.

With a dynamic bearing capacity of the spillway pier of the subject dam, seismic capacity was investigated. As a result, it became clear that the allowable upper limit of the relative displacement of the crest against the spillway pier foundation which doesn’t result in damage to the spillway pier foundation is very small (11mm). Besides, since the watertight part between the spillway pier and spillway gate, that is, the gap between gate sheets is generally about 20mm. When relative displacement of the crest becomes greater than this, there was a fear that the spillway pier may strike the spillway gate.

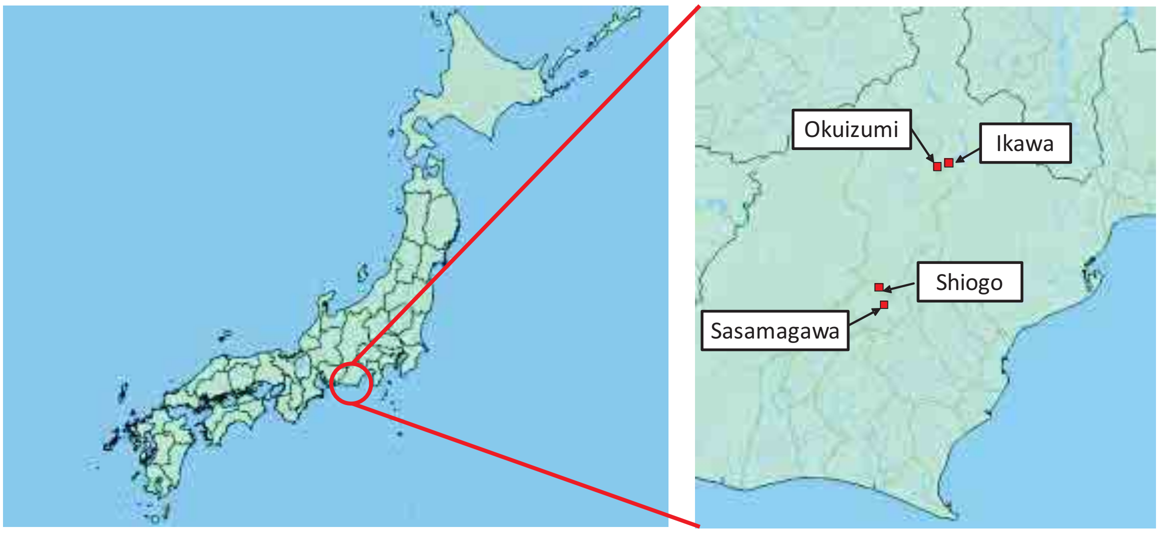
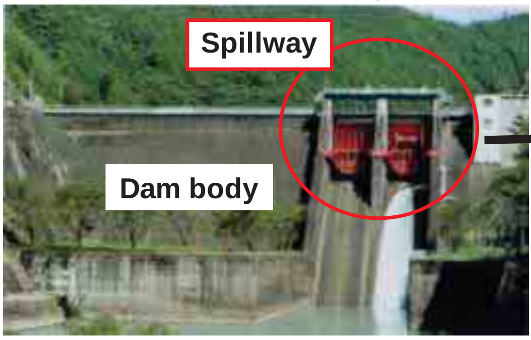


Fig. 1: Dams for which this seismic upgrading method is applied

General view of Sasamagawa Dam



Typical structural outline of the existing spillway

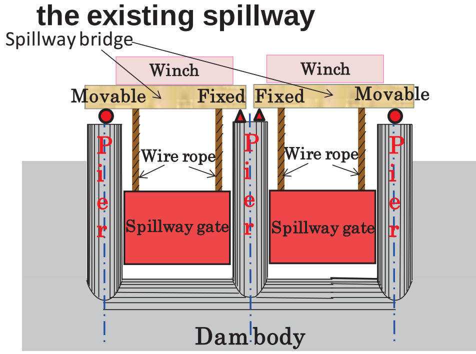


Fig. 2: External appearance of Kasamagasa Dam

Fig. 3: Outline of structure of existing spillway

Table 1: Basic specifications of 4 dams for which the seismic upgrading method was applied on the dam spillway piers in 2010

Dam Name	Gate Type	Dam Body		Spillway Gate, Sediment Flushing Gate							Fiscal Year of Completion
				Central Pier		Edge Pier		Gate			
		Hight (m)	Length (m)	Hight (m)	Lateral Width (m)	Hight (m)	Lateral Width (m)	Hight (m)	Width (m)	The Number (Gates)	
Sasamagawa	Radial	46.4	140.8	16.3	2.0	3.7	1.8	11.8	9.0	2	1960
Okuizumi	Radial	44.5	75.6	17.5	2.3	3.0	2.3	12.3	9.0	3	1955
Ikawa	Radial	103.6	243.0	16.2	3.0	1.6	3.0	12.0	11.0	3	1957
Shiogo	Roller	3.2	146.0	15.0, 18.7	2.5, 2.0	0.0	–	3.5	17.5	8	1960

2. Description of the Renewal and Upgrading of the Project

2.1 Trigger Causes and Drivers for Renewal and Upgrading

(1) Condition, capability, influence of risk and others

(Not applicable)

(2) Improvement of value (functions)

(D) **-** (a) Needs for safety improvement – Improvement of safety

Though the existing spillway piers met the seismic capacity required by the current technical standard, it was important to improve the seismic capacity of the spillway piers to enable them to maintain the flood processing functions so as to prepare for level 2 earthquakes.

(3) Necessity in market

(Not applicable)

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

January, 1956:	Operation of the Okuizumi Dam began
September, 1957:	Operation of the Igawai Dam began
November, 1960:	Operation of the Sasamagawa Dam and Shiogo Dam began
2006:	The project study was started
March, 2010:	The said construction method was applied to Sasamagawa Dam, Ikawa Dam and Shiogo Dam
May, 2010:	This construction method was applied to the Okuizumi Dam
March, 2011:	This construction method was applied to the Ooikawa Dam

2.3 Description of Work Undertaken (detail)

2-c) Technological innovation, deployment expansion and new materials used for civil and building works

This construction method is the seismic upgrading method of the spillway piers using the existing control bridge installed on the upper part of the spillway pier. The structure, as shown in Fig. 4, is as follows: (1) The main beam of the control bridge is connected to the spillway pier at a shoe on one side of the control bridge span by a pin structure, and at the other side of the main beam shoe of the control bridge is connected to the spillway pier by a high damping device (damper) which has a high first phase stiffness. (2) A yield displacement of the above mentioned damper at the time when a level 2 earthquake occurs is set to be lower than the allowable relative displacement of the existing spillway pier top. (3) A yield load of that damper for the earthquake speed is set to be larger than the maximum seismic force applied on the damper by a level 2 earthquake. The developed method is the seismic upgrading method which includes processes (1), (2) and (3) for protecting the spillway pier from level 2 earthquake vibrations as shown in Fig. 4. This method uses the damper in the range of the first phase stiffness before the hysteretic damping property which consists of first phase stiffness and second phase stiffness of the high damping device functions.

The reason why a high damping type damper is adopted for this method is because in general, its first phase stiffness is very high though its second phase stiffness is very low. In fact, out of damping properties of the high damping device which has first phase stiffness and second phase stiffness, in this development, only the damper property in the range of the first phase stiffness ($k_1 = R_{max}/\delta_y$ kN/mm) is used for the earthquake. This is done by setting the maximum reaction force R_{max} kN (high damper capacity) and yield displacement δ_y mm so as to resist seismic force within the allowable relative displacement of the spillway top. While releasing the thermal load in normal times, when earthquakes occur, immediately, by the high first phase stiffness of the damper, oscillation of the spillway pier is suppressed. At that time, the existing control bridge is utilized as a seismic structure for the spillway pier in combination with the damper, and the reliability of the gate operation after a level 2 earthquake is increased so as to have the seismic capacity during an earthquake and so that the spillway pier won't crack causing an opening and won't crash into the gate.

As described above, in this construction method, though a high damping device which has first phase and second phase stiffness is used, unlike the conventional technical application of a damper for the level 2 earthquake, a hysteretic damping property, that is, seismic energy absorption capacity, is not expected to function. This method is the special way to use only the first phase stiffness as elastic behavior of the damper which is the function before a hysteretic damping property is exerted against a level 2 earthquake.

This construction method has actually been applied to 4 dams in Shizuoka Prefecture in 2010, and in 2011 one more dam adopted this method as well. So far, in these 5 dams, the seismic upgrading construction using this method has been completed. Fig. 5 shows the example in which, by utilizing this method, the seismic capability of the spillway piers has been improved. The actual application performances are shown in Table 2.

The benefit of this construction method is that by only conducting modification of the control bridge shoe located above the dam water level, it can achieve the renovation purpose both physical and economic without lowering the dam water level. This method enables continuing to generate energy even during the seismic construction period and not reduce total generated energy. For example, for the subject dam, if this method was not applied, the alternative method, that is, the reconstruction plan of the spillway pier required to drop the water level below the spillway pier's foundation would cause a huge loss of generated energy. The subject dam discharges water to the Kawaguchi Power station with a maximum output of 58,000kW. So, if this alternative method were adopted, it would result in a huge loss of generated energy and, including the cost of this energy loss, the total construction cost became 1,100 million yen. In response, this construction method requires only the modification of the shoe part of the control bridge and doesn't cause any generation energy loss, and the actual construction cost was about 70 million yen, resulting in a savings of about 1,030 million yen (93.3% cost reduction ratio).

In addition, this method is able to improve seismic capability by only modification of the shoe of the control bridge. Thus, it can maintain the original spillway shape without having any impact on the cross-section area of water flow and discharge capability in terms of the designed flood amount of the spillway. Furthermore, the added weight of the pin structure, the dampers and structural metal for installation is very small compared to the weight of the existing dam body and the spillway pier. Therefore, even after this construction was conducted the stability level required by the current technical standard for the subject dam remains satisfied.

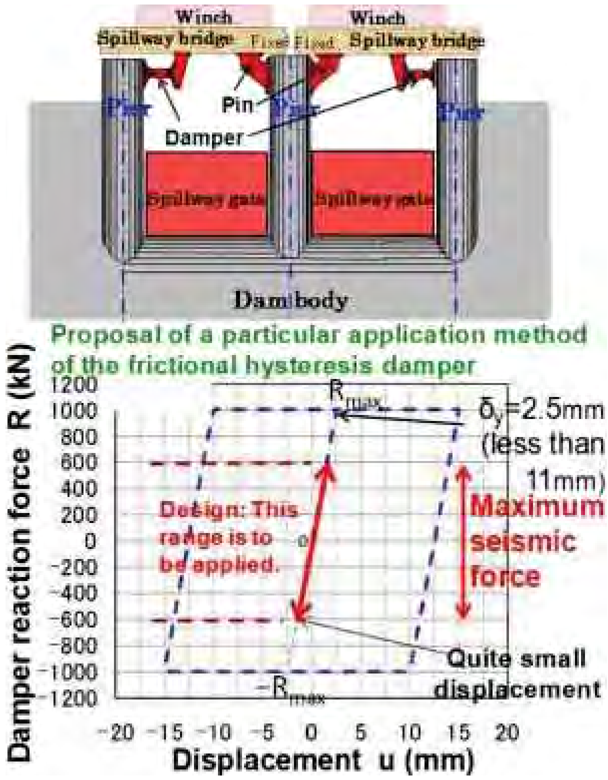


Fig. 4: The outline of the developed construction method and application method of the high damping dampers

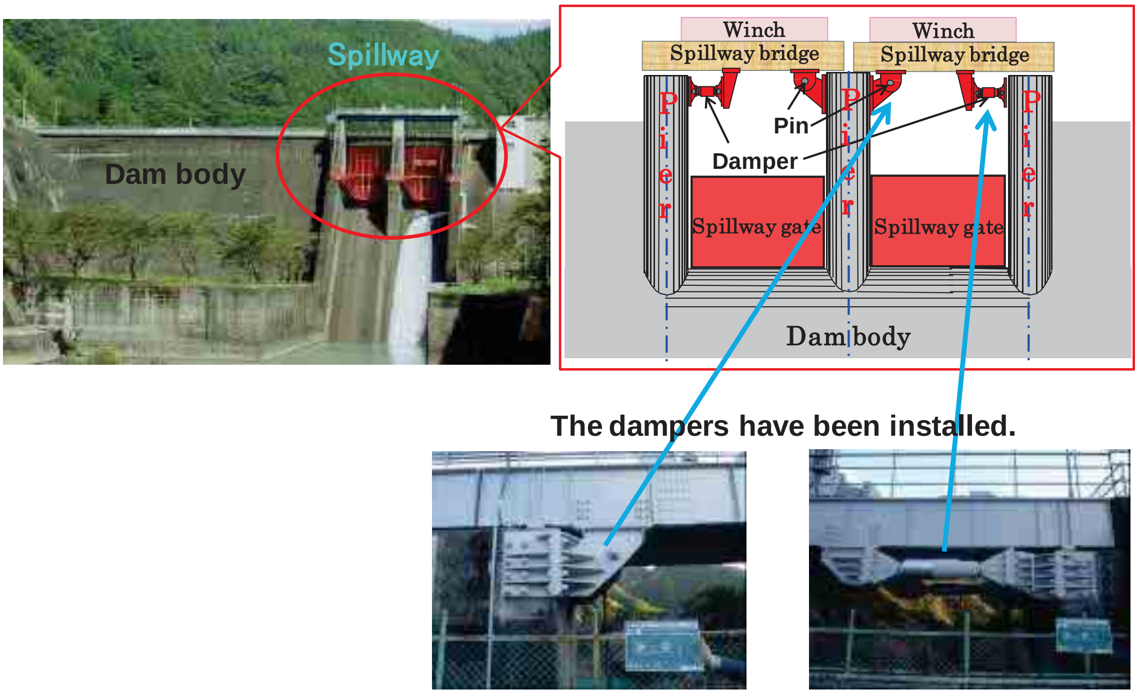


Fig. 5: The structure of the spillway pier of the Sasamagawa Dam after the seismic upgrading construction was applied

Table 2: Actual performance of this construction method in 2010

<table>
<tr><th>Dam Name</th><th>The Number of Bridge Main Girders</th><th colspan="2">Capacity of Damper with High Hysteresis Damping (kN)</th><th colspan="2">First Rigidity of Damper with High Hysteresis Damping (kN/mm)</th><th colspan="2">The Number of Applied Dampers</th><th>Cost Reduction Rate (%)</th></tr>
<tr><td>Sasamagawa</td><td>4</td><td colspan="2">1,000</td><td colspan="2">400</td><td colspan="2">4</td><td>93.9</td></tr>
<tr><td>Okuizumi</td><td>9</td><td colspan="2">1,000</td><td colspan="2">400</td><td colspan="2">9</td><td>96.0</td></tr>
<tr><td>Ikawa</td><td>6</td><td>1,500</td><td>2,000</td><td>600</td><td>800</td><td>3</td><td>3</td><td>94.2</td></tr>
<tr><td>Shiogo</td><td>20</td><td colspan="2">1,500</td><td colspan="2">600</td><td colspan="2">20</td><td>86.1</td></tr>
</table>

3. Feature of the Project

3.1 Best Practice Components

- Seismic upgrading of the spillway piers against a large-scale earthquake by using the existing facility structures
- Retaining the cross-section area of water flow and discharge capability of the spillway piers even after the seismic upgrading construction.
- Minimization of generation energy loss during the seismic upgrading construction period.

3.2 Reasons for Success

This method has succeeded because the steel control bridge, which is commonly installed on the top of the spillway pier in many dams in Japan, was utilized as a seismic structure. In addition, unlike the way of utilizing the conventional dampers which expect the hysteretic damping property of the earthquake energy absorbance as a seismic function, this method atypically utilizes only the first phase stiffness of this damper, that is its elastic behavior, before the hysteretic damping property functions.

4. Points of Application for Future Project

(View point of usage of the existing facilities)

- A steel control bridge of the existing structure needs to have the necessary resistance strength as a seismic structure for the dam spillway pier.
- The location where the high damping device is installed needs to be out of the range of movement of the spillway gate, and even during gate operation, the damper and the gate must not to touch.

5. Others (monitoring, ex-post valuation etc.)

(Not applicable)

6. Further Information

6.1 Reference

I. Kumazaki, Y. Sawai, "The development of the seismic upgrading method for the dam spillway pier using the spillway bridge of the existing facilities", *Journal of Electric power Civil Engineering*, volume 352 (2011.3)

6.2 Inquiries

Company name: Chubu Electric Power Company
URL: http://www.chuden.co.jp/

ANNEX XI Renewal & Upgrading of Hydropower Plants

Format for the 2nd Round Data Collection (Definition of Case Histories)

Category and Key Points

Main : 2-c) Technological innovation, deployment expansion and new materials used for civil and building works

Project Name:

Renovation construction work of the dam of the Saikawa Hydroelectric Power Station

Name of Country (including State/Prefecture):

Japan, Nagano Prefecture

Implementing Agency/Organization:

Chubu Electric Power Co., Inc.

Implementing Period:

From 2000 to 2003

Trigger Causes for Renewal and Upgrade:

(A) Degradation due to aging and recurrence of malfunction

Keywords:

Steel flap gate with rubber bladders, Gate, Gabion dam, Inflatable rubber dam

Abstract:

Before renovation, the dam of the Saigawa Hydroelectric Power Station had a fixed dam of gabion construction and an aging flushing gate. Since the discharge capacity of the flushing gate is small, when a flood occurs, many such gabion dams were lost by the overflow at the fixed dam section. Consequently, a portion of the dam and the steel gate were removed and a large-scale Steel flap gate with rubber bladders (SR dam) was installed.

1. Outline of the Project (before Renewal/Upgrading)

The Saigawa Hydroelectric Power Station owned by Chubu Electric Power Co., Inc. is a conduit type power station with a maximum output of 1,700kW located in Azumino-shi, Nagano Prefecture (see Fig. 1 and Table 1). The Saigawa Dam is the water intake dam for the Saigawa Power Station and had a fixed dam of gabion construction (length 268m, height 5.8m) and flushing gates (width 3m ×2 gates). Photo 1 is an aerial photo before renovation; Photo 2 is the structure of the Saigawa Dam (gabion structure), Photo 3 is during a flood of the Saigawa Dam, and Photo 4 shows the washing out of the Saigawa Dam after the flood.

Table 1: Specifications of the power station

Power station	Saigawa Hydroelectric Power Station
Water system, river	Shinanogawa water system, Saigawa River
Maximum output	1,700 kW
Maximum plant discharge	10.71 m^3/s
Effective head	19.06 m
Start of operation	March 1923

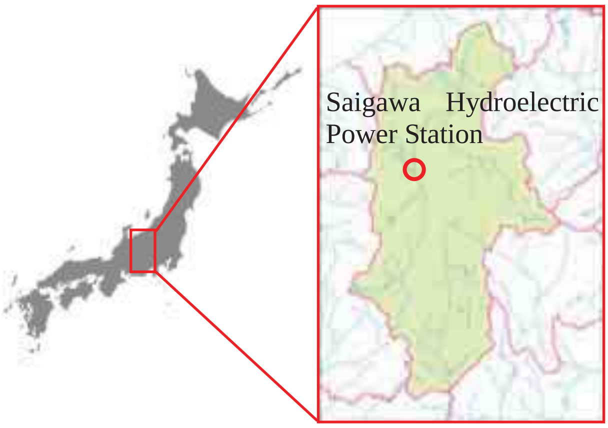


Fig. 1 Location map **Photo 1: Aerial photo (Before renovation of the Saigawa Dam)**

Photo 2: Saigawa Dam (gabion construction)

Photo 3: Flooding at Saigawa Dam

Photo 4: Wash out loss of the dam after flood

2. Description of the Renewal and Upgrading of the Project

2.1 Trigger Causes and Drivers for Renewal and Upgrading

(1) Condition, capability, influence of risk and others

(A)-(d) Degradation due to aging and recurrence of malfunction – Easy maintenance with less labor

Before renovation, the Saigawa Dam had a fixed dam with a gabion structure and an aging small-scale flushing gate. Since the discharge capacity of the flushing gate was too small, when floods occurred, water overflowed the top of the gabion dam and frequently caused dam loss. Therefore, recovery expenditures were required, generation energy loss occurred, and the profits of the power station were deteriorating.

(2) Improvement of value (functions)

(Not applicable)

(3) Necessity in market

(Not applicable)

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

April 1923:	Operation of the Saigawa Power Station began
July 2000:	The study of the renovation of the Saigawa Dam was started
October 2002:	The renovation work of the Saigawa Dam began
March 2003:	The renovation work of the Saigawa Dam was completed, and operation began

2.3 Description of Work Undertaken (detail)

2-c) Technological innovation, deployment expansion and new materials used for civil and building works

As shown in Fig. 2, the SR dam is a shutter weir whose basic structure is to support the steel gate body from its back surface with a rubber bladder. By adjusting the air volume in the bladder, the gate body is moved and the height of the dam is able to be regulated as needed.

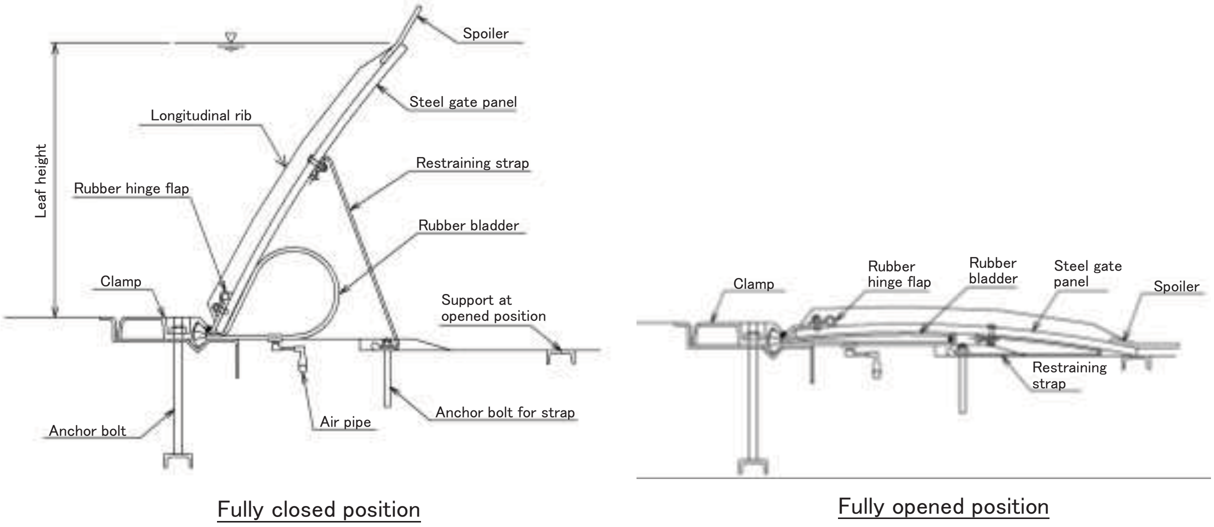


Fig. 2: Basic structure of the SR dam

In this construction work, a portion of the dam and the steel gate were removed, and the SR dam was installed. The SR dam is a new type dam which was developed in the USA, and has excellent characteristics which the conventional dam doesn't have.

(Advantages)

1) Able to control discharge volume and water level
2) Able to install even on long spans by connecting multiple units.
3) Has a higher sediment durability at the time of flood than an inflatable rubber dam
4) Since the side wall of the pier is vertical, it is advantageous to conserve a discharge area.
5) When overflows happen, vibration tends not to occur, and there is no limitation of overflow depth like an inflatable rubber dam has.
6) Even in an emergency (power outage), its structure is able to lay flat, making installation of a backup generator unnecessary.

(Disadvantages)

1) When compared to an inflatable rubber dam, the internal pressure of a bladder is higher, the required capacity of the air compressor is higher and the anchor shape is large.

* Comparison study:

As the dam subject to survey, an SR dam, an inflatable rubber dam and a steel shutter weir were considered. But, the steel shutter weir has a structure to support the gate body by a hydraulic jack from the back surface. Thus, it requires the installation of large-scale facilities in the river bed, and so is not a good method in terms of economic efficiency and maintainability and was eliminated from further study.

Operation image of an SR dam and an inflatable rubber dam at flood time is shown in Fig. 3.

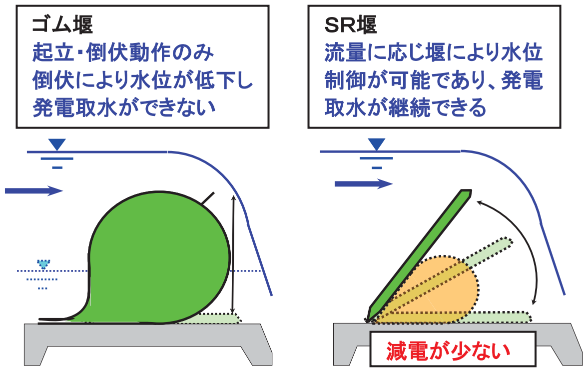


Fig. 3: Operation image at flood time

In the case of the Saigawa Dam, from the view point of the dam wash out loss, for its operation it is necessary to not allow dam water level to reach higher than the top of gabions at flood time. For an inflatable rubber dam, when the overflow depth becomes deeper than a certain level, then it is necessary for the panel to fully collapse, so the water level rapidly drops and water intake becomes impossible for the power station.

On the other hand, depending on water volume, the SR dam is able to control dam height and to regulate water level constantly until the time when gate panel must fall flat completely. Therefore it is possible to continue power generation and power loss is small.

Though there were no large-scale introduction cases in Japan, in this renovation work of the Saigawa Dam, the SR dam was adopted from the view point of water flow regulation, reduction of energy loss and durability.

Outlines of the construction are shown below:

- Removal of the flushing gate (width 3m×2 gates)
- Demolition of a portion of the dam (57m)
- Installation of the protection bed upstream (5m)
- Installation of the protection bed downstream (19m)
- Installation of the Steel flap gate with rubber bladder (1 gate (7 unit), pure span 35m×effective height 2.95m)

Fig. 4: Plan

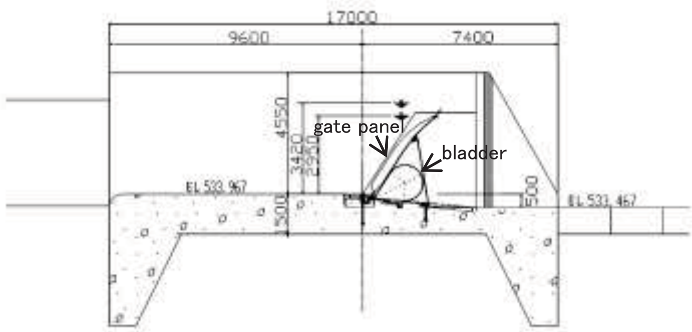
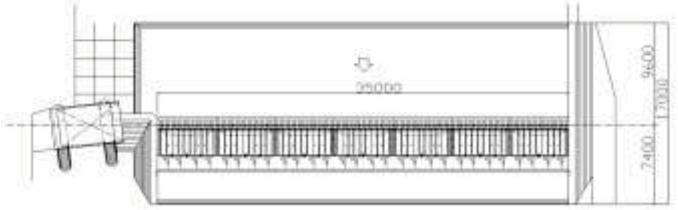
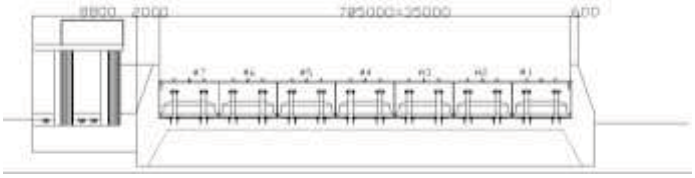


Fig. 5: Cross-section of the SR dam



Ground plan



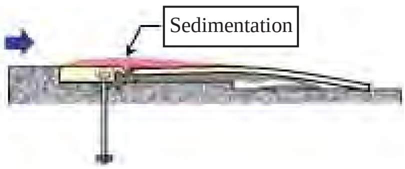
Back view

Fig. 6: General views of the SR dam

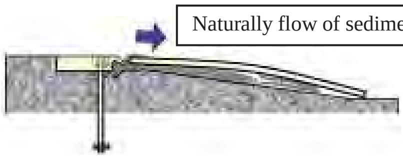
The SR dam has excellent characteristics which other conventional dams do not have. However, when compared with the cases in the USA, the rivers in Japan are rapid flow and have a lot of sediment discharge. Since this was the first case of introduction of the large-scale gate into Japan, the construction work had been conducted adding various improvements.

A. Improvement of the dam gradient at the time when the panel completely falls flat

With a view to prevent sedimentation downstream of dam, and to improve sediment discharge performance at the time when the panel falls flat, about 4° of gradient was put on the shape of the lower part of the dam. The improvement method of the dam gradient at the time when the panel lies completely flat is shown in Fig. 7 and Photo 5.



Before improve



After improve

Fig. 7: Improvement method of the dam gradient at the time when the panels lie completely flat

Photo 5: SR dam lying completely flat

B. Fixing rubber cover

A rubber cover gasket is an important component to protect the gate body. Since there was concern that pebbles would clog in the gaps between the clamping and rubber gasket, the clamp shape was improved and also, improvement was conducted to protect the rubber gaskets by placing rubber gasket covers. The protection methods of the rubber gasket parts are shown in Fig. 8 and Photo 6.

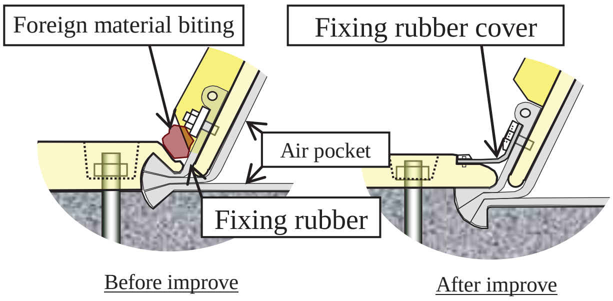


Fig. 8: Protection method for the fixing rubber part

Photo 6: Rubber gasket covers

3. Feature of the Project

3.1 Best Practice Components

- Adoption of the SR dam
- Reduction of the renovation construction work costs and generated energy loss

3.2 Reasons for Success

The completed SR dam (March, 2003) is shown in Photo 7, the back of SR dam is shown in photo 8, and the current status (September, 2012) is shown Photo 9.

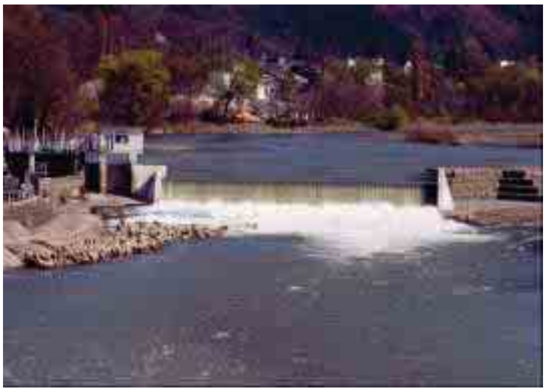


Photo 7: Completion view of the SR dam (March 2003, full view)

Photo 8: Completion view of the SR dam (March 2003, back view)

Photo 9: Current status of the SR dam (September 2012)

Until today, 9 and half years have passed since the dam’s completion. So far there were no troubles with the SR dam and operation has been able to continue. Before completion of the SR dam, since there was not a large-scale gate, once flood occurred, water overflowed the dam and frequently gabions were lost. But after its completion, even at a time of flooding, water overflows of the dam greatly decreased and this SR dam is able to contribute to the power station in terms of profitability.

4. Points of Application for Future Project

When the SR dam is planned to be installed, it is necessary to take proper countermeasures in consideration of the sedimentation amount at that area.

5. Others (monitoring, ex-post valuation etc.)

Since commencement of operations, the SR dam has not had major trouble or failures such as an imperfect panel retraction, and has operated very well.

a. Rubber gasket cover

2 years after operations began a gate inspection was conducted by removing water. No damage or abrasion was found (Photo 10). At the connection area of each unit, peel-off of the naturally vulcanized rubber which was placed on the site was found, and from that gap, fine sand had entered (Photo 11). Then, by opening the rubber gasket cover, the interior of the rubber gaskets was inspected, and no damage by intruding sand and gravel was found, and the conditions were sound (Photo 11). Incidentally, the connection area of each unit was again repaired with naturally vulcanized rubber after removing the sand and gravel inside the fixing rubber cover (Photo 12).

b. ctual record of wash out loss of the gabion dams

For a middle scale flooding which resulted in gabion dams wash out loss before the renovation, the SR dam has a large discharge capacity and is enable to reduce the frequency of loss, and it became clear that it has made a great improvement (Photo 13).

Photo 10: Rubber gasket cover

Photo 11: Inside rubber gasket cover

Photo 12: Repair of the connection area of the rubber gasket cover

Photo 13: Status of SR dam fully retracted at the time of medium scale flooding

6. Further Information

6.1 Reference

Uejima Masaki, Yoshimura Shuichi, Sakurai Hisashi, "The dam renovation work of the Saigawa Hydroelectric Power Station – Adoption of the Steel flap gate with rubber bladders", Japan Electric Power Civil Engineering Association, *Journal of Electric power Civil Engineerin*g, (2003.7)

6.2 Inquiries

Company name: Chubu Electric Power Company

URL: http://www.chuden.co.jp/

ANNEX XI Renewal & Upgrading of Hydropower Plants

Format for the 2nd Round Data Collection (Definition of Case Histories)

Category and Key Points

Main: (2-c) Technological innovation, deployment expansion and new materials used for civil and building works

Project Name:

The Aseismic bearing construction work of Water-tube bridge

Name of Country (including State/Prefecture):

Japan, Shizuoka Prefecture

Implementing Agency/Organization:

Chubu Electric Power Co., Inc.

Implementing Period:

From 2006 to 2008

Trigger Causes for Renewal and Upgrade:

(D) Needs for safety improvement

Keywords:

Water-tube bridge, Seismic assessment, Aseismic bearing

Abstract:

The subject facility is a back siphon type water channel with a pipe diameter of 4.4m installed to go across the river which obstructs the headrace of the Okuizumi Hydroelectric Power Station, and supported with a 60.0m span Lohse bridge. Since about 90% of the total weight of this structure was the water pipe including its contained water weight, there was fear about safety at the time when a large-scale earthquake occurs. Therefore, a Seismic assessment was conducted and Aseismic bearing construction work was implemented.

1. Outline of the Project (before Renewal/Upgrading)

The Okuizumi Hydroelectric Power Station is a dam and conduit type power station with a maximum output of 92,000kW, maximum plant discharge of 60m^3/s, located mid-way down the Oigawa River which flows through the central area of Shizuoka Prefecture from north to south to enter the Pacific Ocean. The operation was started in 1956. (See Table 1 and Fig. 1)

The Sekinosawa Water-tube Bridge, in the back siphon type water channel with a pipe diameter of 4.4m, has been installed to go across the river which cuts across the headrace of the Okuizumi Hydroelectric Power Station, and is supported with a 60.0m span Lohse bridge. Fig. 2 is a photo of the Sekinosawa Water-tube Bridge. Table 2 shows the specifications of the water pipe and bridge, and Fig. 3 shows a side view and cross-section view of the Sekinosawa Water-tube Bridge.

Table 1: Specifications of the power station

Power station	Okuizumi Hydro Power Station
Water system, River	Oigawa water system, Oigawa River, Sekinosawa River, Kurishirogawa River
Maximum output	92,000kW
Maximum plant discharge	60.00m^3/s
Effective head	168.70m
Start of operation	January, 1956

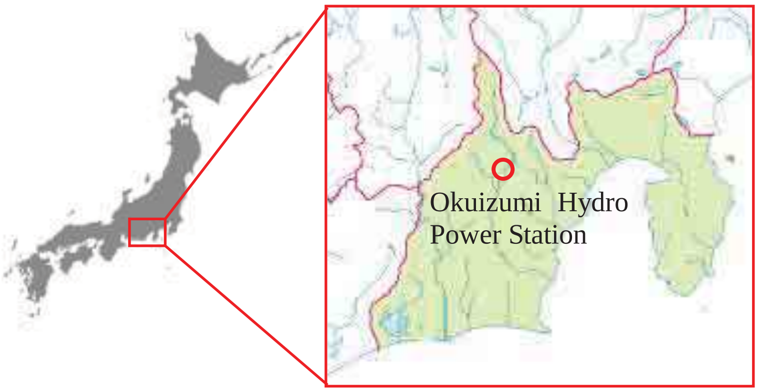
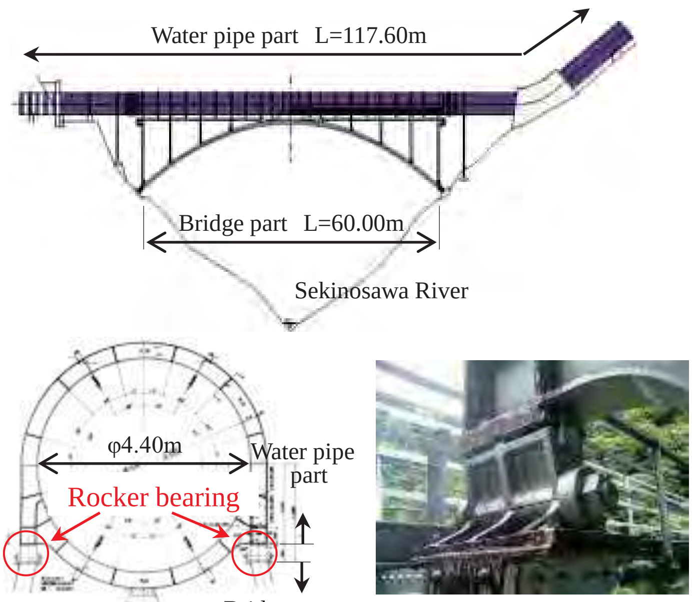


Fig. 1: Location map

Fig. 2: Sekinosawa Water-tube Bridge – Okuizumi Hydroelectric Power Station

Table 2: Specification of the water tube and bridge

Water tube	Length of tube	117.60m
	Inside diameter	4.40m
	Bearing type	Rocker bearing
Bridge	Bridge type	Lohse arch bridge
	Length of bridge	60.00m
Component weight	Water tube	2,093kN
	Bridge	1,460kN
	Weight of water	17,529kN
	Total	21,082kN



Rocker bearing

Fig. 3: Side view and cross-section view of the Sekinosawa Water-tube Bridge

2. Description of the Renewal and Upgrading of the Project

2.1 Trigger Causes and Drivers for Renewal and Upgrading

(1) Condition, capability, influence of risk and others

(D)-(a) Needs for safety improve – Improvement of safety

The main part of the structure is the water tube containing water making up 93% of the total structure weight, and since it is an unstable configuration in which the heavy part is mainly the top part, there was a fear about safety when a large-scale earthquake occurred. In addition, it is said that an event probability of the Tokai mega earthquake happening again within 30 years is 87%. Also it is assumed that the earthquake center area would be the whole Oigawa water system, therefore a Seismic assessment was conducted as to determine the practicality of taking countermeasures against these risks. As a result, it was judged that there would be no impact on the water passing capability, but it would be difficult to repair damaged parts after an earthquake.

(2) Improvement of value (functions)

(Not applicable)

(3) Necessity in market

(Not applicable)

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

January, 1956:	Operation of the Okuizumi Power Station began
2006:	The project design began
November, 2007:	The construction of the Aseismic bearings began
February, 2008:	The construction of the Aseismic bearings was completed

2.3 Description of Work Undertaken (detail)

2-c) Technological innovation, deployment expansion and new materials used for civil and building works

In the planning phase of this project, with the aim of the Seismic assessment for the current structure, 3-dimensional dynamic analysis was conducted. As shown in Fig. 4, analysis was carried out with a 3-dimensional frame model to represent the water tube and bridge, expansion joints, bearings and other parts.

As an earthquake motion input representing an assumed Tokai earthquake, seismic waveforms which were published by the Central Disaster Prevention Council of the Cabinet office were used. Examples of input seismic waveforms are shown in Fig. 5. They were obtained by converting the published waveforms of the Tokai/ East Tokai/ Nankai complex earthquake assumed at the engineering bedrock (Vs=700m/s) into the analysis model in direction of the tube axis and at a right angle to the tube axis.

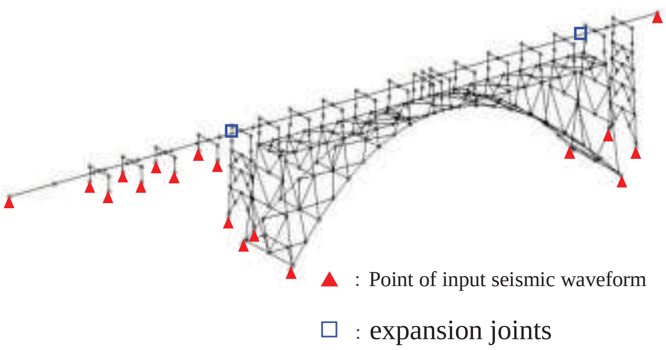


Fig. 4: Analysis model

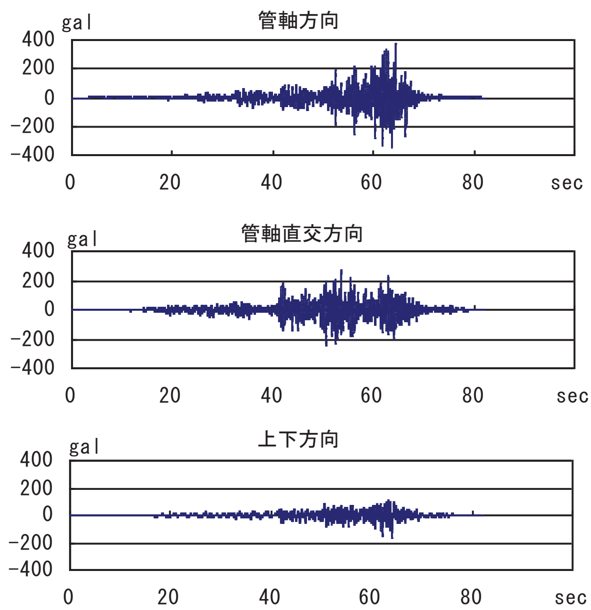


Fig. 5: Examples of the input seismic waveforms

As a result of the numerical analysis, obtained findings are as follows:

- The inertia force which acts on the water tube section at a right angle to the tube axis direction is large, and is transferred to the bridge section through the existing Rocker bearing. At that time, shear fracture of the bearing bolts occurs.

- As a result of the linear analysis, after shear fracture of the bearing bolts, since the inertia force is transferred to the bridge, the developed stress on the bridge arch base became significant.
- The shear fracture of the bearing bolts was simulated with a friction model and analyzed by non-linear analysis, and it became clear that inertia force transferred to the section of the bridge was greatly reduced and, though partial damages are caused, even after the earthquake, the structure body is able to be maintained with the current structure frame. In addition, with a friction model it was confirmed that displacement of the bearing sections was very small.

As a result, it was confirmed that functions of the bridge section were able to be maintained even after a major earthquake, and water was able to pass though the bridge was partially damaged. However, from the view point of an improvement of seismic capability, and also since it was judged that it would be difficult to repair damaged parts after an earthquake, renovation construction work was determined to be implemented. Based on the analysis results, as an improvement method, it was judged to be the most reasonable to reduce the seismic force which is transferred to the water tube and to reduce the dynamic interaction between the water tube and bridge. This would be accomplished by separating the connection between the water tube section and bridge section, and by changing the steel rocker bearings which support the water tube vertically and transfer the horizontal force into Aseismic rubber bearings.

As an Aseismic bearing, the LRB (Lead Rubber Bearing: laminated rubber bearing containing lead plug) shown in Fig. 6 was adopted. The LBR has a structure in which a lead plug at the central area is laminated with alternating layers of steel plates and rubber. This bearing has a high vibration damping effect and excellent decompression capability. Accordingly, it is suitable for this structure. The specifications for the LBR are shown in Table 3.

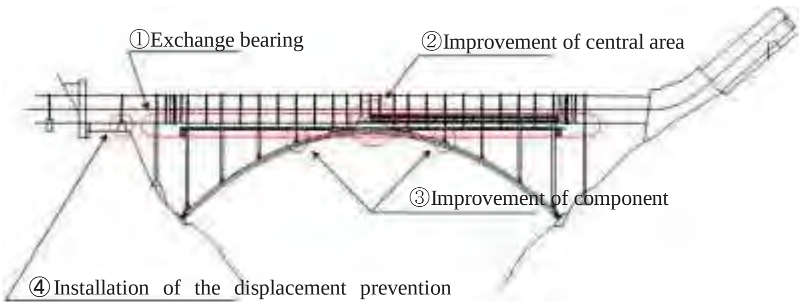
Fig. 6: Model of Aseismic rubber bearing (LRB)

Table 3: Specifications of Aseismic rubber bearing

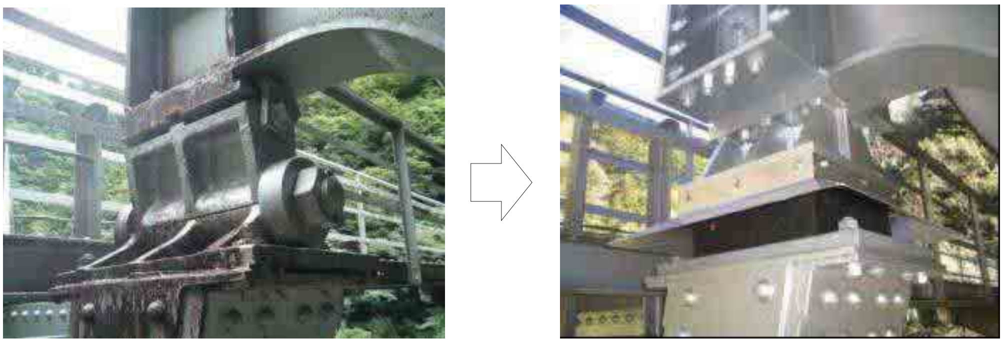
Dimensions	320×320×118mm
Structure of the laminated rubber	Rubber thickness 5mm×8 layers Steel plate 3.2mm× 7 plates
Allowable shear distortion	250%
Vertical reaction force	700kN
Equivalent damping factor	25.6%

The effect of the aseismic measures was analyzed by numerical analysis. By adopting the Aseismic bearing, the stress developed on every component became less than what was considered to be allowable stress. Especially, the safety rate is improved at the arch section which is the important area to maintain the bridge structure. Thus, the effectiveness of the aseismic countermeasures was able to be confirmed.

In addition to the adoption of the Aseismic bearing, improvements such as the installation of the displacement prevention device to prevent collapse of bridge and partial reinforcement of the cross-section of the existing component were conducted. The outline of the construction is shown in Fig. 7.



① Exchange bearing



② Improvement of central area

③ Improvement of component

④ Installation of the displacement prevention

Fig. 7: Outline of Aseismic bearing construction of the Water-tube bridge

3. Feature of the Project

3.1 Best Practice Components

- Facility configuration which emphasizes durability so as to keep seismic functions for the structure for a long period of time.
- Implementation of the water transmission system renovation work which reduces impact on the existing structures without imposing any trouble to power generation and water usage.

3.2 Reasons for Success

The reason for the success of this project is because 3-dimensional dynamic analysis was conducted to quantitatively evaluate the movement of the Water-tube bridge at the time of a large-scale earthquake, and based on that, a renovation plan was established considering the reduction of risks, construction workability and economic efficiency.

In the past, there was not a similar case of such a large-scale aseismic countermeasure for a Water – tube bridge and the experiment in which the construction was conducted while passing water. So, we made a detailed plan emphasizing minimizing the impact on the existing structures, and properly conducted construction work. From these efforts we have been able to achieve good results and we are proud of our success.

On top of that, we collected data from a variety of Aseismic structure construction works on a routine basis, and we have adopted the Aseismic bearing which has been adopted in many cases of road bridges and tall structures. This was one factor for our success.

4. Points of Application for Future Project

- How to determine the damping capability when an Aseismic bearing is adopted.
- Consideration of the degradation of rubber at the installed points

5. Others (monitoring, ex-post valuation etc.)

- The movement of the Water-tube bridge at the time of a large-scale earthquake was quantitatively analyzed.
- It was able to be confirmed that the structures remained sound even after the earthquake
- Based on the numerical analysis, rational countermeasures were selected, and their effectiveness was confirmed (in analysis, the characteristic period was extended by about 20% at a right angle to the tube axis direction).
- Under difficult conditions such as work at a high-place and while passing water, the construction was completed within the planned work period without any accident.

6. Further Information

6.1 Reference

K. Nishizawa, M. Hattori, S. Kondo, "The Aseismic bearing construction of the Sekinosawa Water-tube Bridge of the Okuizumi Hydroelectric Power Station" Electric Power Civil Engineering Association, *Journal of Electric power Civil Engineering*, (2008.11)

6.2 Inquiries

Company name: Chubu Electric Power Company

URL: http://www.chuden.co.jp/

Format for the 2nd Round Data Collection (Definition of Case Histories)

Category and Key Points

Main: 2-c) Technological innovation, deployment expansion and new materials used for civil and building works

Project Name:

The replacement work of the radial gates of the Jinichi Dam, Jinni Dam and Hotokebara Dam

Name of Country (including State/Prefecture):

Japan, Toyama Prefecture and Fukui Prefecture

Implementing Agency/Organization:

Hokuriku Electric Power Co., Inc.

Implementing Period:

From 2009 to 2012

Trigger Causes for Renewal and Upgrade:

(A) Degradation due to aging and recurrence of malfunction

Keywords:

Radial gate, Replacement of a gate, Design standard, Large-scale earthquake

Abstract:

With regard to the design of a radial gate, in 1973 the strength calculation method of the trunnion bearing was defined in detail as a commercial standard for the first time. Based on this standard, Hokuriku Electric Power Co., Inc. conducted stress analysis of the radial gates which were constructed before 1973 while reviewing the corrosion state, measured the actual stresses, and confirmed their safety. As a result of these investigations, we have decided to replace the door body and opening/closing device of the spillway gates of the Jinichi Dam, Jinni Dam and Hotokebara Dam.

For the replacement of the gates, from the view point of how to effectively develop the facilities configuration while assuring the safety of the gates, we have investigated countermeasures against a large-scale earthquake, its construction range, facilities specifications, construction time and other elements. [1).

1. Outline of the Project (before Renewal/Upgrading)

The Jinichi and Jinni dams are located mid-way down the Jintsugawa River which is a first class river in Toyama Prefecture, and their radial gates were operated for 54 years since commencement of their operations. For the radial gate of the Hotokebara Dam located upstream on the Kuzuryugawa River which is also a first class river in Fukui Prefecture, 40 years have passed since its start of operations. A safety evaluation was conducted for these gates. As a result, it became clear that it was necessary to replace the door body and opening/closing devices. Thus since November, 2009, the demolition work of the existing gate was started, and the construction work was completed in June, 2012. The location map, specifications, photos of these dams and radial gates are shown in Fig. 1, Table 1 and Photos 1 to 3.

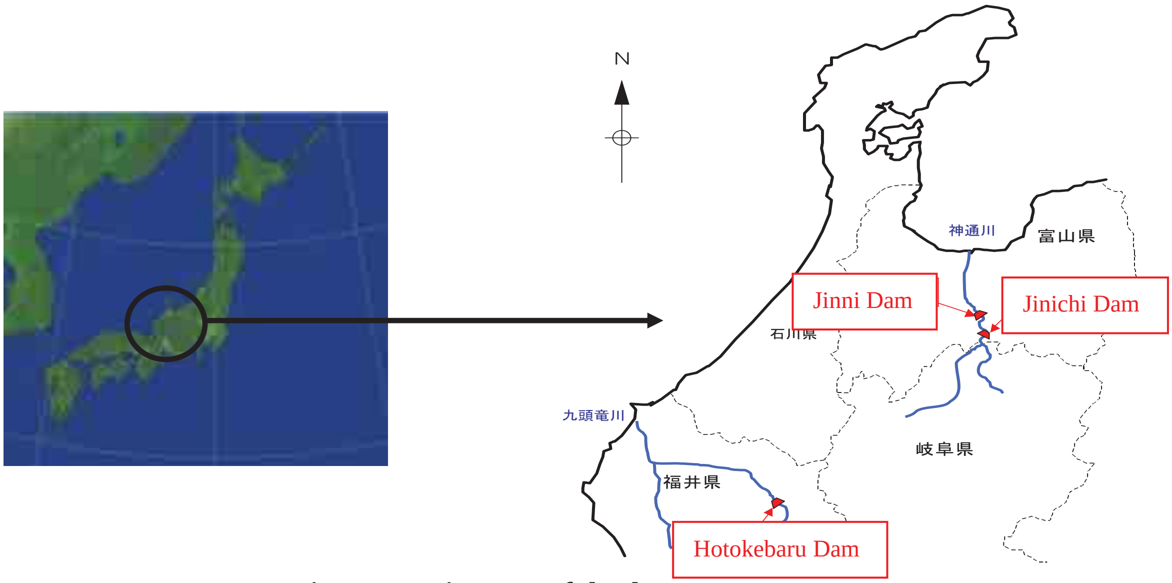


Fig. 1: Location map of the dams

Table 1: Specifications of the dams and gates

		Jinichi Dam	Jinni Dam	Hotokebara Dam
Dam	Name of river	Jintsugawa water system Jintsugawa River	Jintsugawa water system Jintsugawa River	Kuzuryugawa water system, Kuzuryugawa River
	Basin area	1.960.00km^2	2.060.00 km^2	421.92 km^2
	Type	Concrete gravity dam	Concrete gravity dam	Concrete gravity dam
	Height	45.00m	40.00m	48.60m
	Length of dam top	344.40m	336.766m	141.0m
	Dam volume	108,000m^3	107,000 m^3	50,000 m^3
	Total pondage	11,346×10^{3}m^3 (when constructed)	11,265×10^{3}m^3 (when constructed)	4,100×10^{3}m^3 (when constructed)
	Effective pondage	3,494×10^{3}m^3 (when constructed)	3,227×10^{3}m^3 (when constructed)	1,650×10^{3}m^3 (when constructed)
Gate	Type	Radial gate type Wire rope type	Radial gate type Wire rope type	Radial gate type Wire rope type
	Number of gates	9 gates	9 gates	3 gates
	Dimension	Width 9.20m Height 12.35m	Width 9.20m Height 12.35m	Width 9.20m Height 14.85m
	Radius of door body	13.2m	13.2m	14.0m

(1) From upstream

(2) From downstream

Photo 1: Jinichi Dam

(1) From upstream

(2) From downstream

Photo 2: Jinni Dam

(1) From upstream

(2) From downstream

Photo 3: Hotokebara Dam

2. Description of the Renewal and Upgrading of the Project

2.1 Trigger Causes and Drivers for Renewal and Upgrading

(1) Condition, capability, influence of risk and others

(A)-(c), (d) Degradation due to aging and recurrence of malfunction - Cost savings.

Based on "Guidelines for safety evaluation of the spillway gate" defined in our company, a safety evaluation was conducted by measuring the actual stress, corrosion conditions and others, and it became clear that the value of the stresses was almost at the limits of the maintenance management standards. Thus, the replacement plan was determined to be necessary.

The maintenance management standards were prepared by referring to the "The maintenance management standard of steel structures such as gate door, etc."[2)], published: May, 2008.

(2) Improvement of value (functions)

(Not applicable)

(3) Necessity in market

(Not applicable)

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

The history of this project is shown in Table 2.

Table 2: Chronological Events

Item	Jinichi Dam	Jinni Dam	Hotokebara Dam
Content	1954.1: Operation of all gates began 2007.4: Full-scale study of the project began 2009.8 :Construction began 2010.5: First phase (3 gates) construction was completed 2010.10: Second phase (3 gates) construction began 2011.5: Second phase construction was completed 2011.10: Third phase construction (3 gates) began 2012.6: Third phase construction was completed	1954.2: Operation of all gates began 2007.4: Full-scale study of the project began 2009.8: Construction began 2010.5: First phase (3 gates) construction was completed 2010.10: Second phase (3 gates) construction began 2011.5: Second phase construction was completed 2011.10: Third phase construction (3 gates) began 2012.6: Third phase construction was completed	1968.5 :Operation of all gates began 2007.4: Full-scale study of the project began 2009.10: Construction began 2010.4: First phase (1 gate) construction was completed 2010.10: Second phase (1 gate) construction began 2011.4: Second phase construction was completed 2011.10: Third phase construction (1 gate) began 2012.4: Third phase construction was completed

2.3 Description of Work Undertaken (detail)

2-c) Technological innovation, deployment expansion and new materials used for civil and building works

In the design of the new gate, the stationary load was determined based on the current standard "Water gate steel pipe technical standard (Gate door)" [3] and "Dam-Dam facilities technical standard (planned) (Standard description version, Manual version)[4].

In the replacement of the existing radial gate of the hydroelectric power station, for the first time in Japan, the detailed investigation for a large-scale earthquake was conducted, and safety was confirmed. The detailed investigation was conducted by the following conditions referring to the "Aseismic performance investigation guide for a dam during a large-scale earthquake (as proposed)-Description"[5].

(1) Design load

The design load during a large-scale earthquake should include hydrostatic loading, hydraulic pressure load during the earthquake and inertia force during the earthquake (Table 3).

Table 3: The design load on a radial gate during a large-scale earthquake

	Jinichi Dam	Jinni Dam	Hotokebara dam
Hydrostatic loading (top water level)	HWL182.0-EL170.5 =11.5(m)	HWL116.8-EL105.3 =11.5(m)	HWL335.0-EL320.916 =14.084(m)
Hydraulic pressure load during an earthquake time	8.444×10^{3} kN	8.444×10^{3} kN	1.276×10^{4} kN
Inertia force during an earthquake	Door body weight ×0.92	Door body weight ×0.92	Door body weight ×0.92

In this project, the Hydrostatic loading was defined to be the load at the time of highest normal operation water level which would give the largest impact on the dam structure when an earthquake occurs.

For the Hydraulic pressure load during an earthquake, the time when the hydraulic pressure load became a maximum at the compression side was found by conducting a 2-dimentional linear seismic response analysis over time on the dam-reservoir combined system. Then, the Hydraulic pressure load distribution at this time was integrated by the gate pressure receiving area to obtain the Hydraulic pressure load in an upstream to downstream direction. As the input earthquake vibration, the waveforms which conform to the "Lower limit response spectrum for verification" defined in the "Aseismic performance investigation guide for a dam during a large-scale earthquake (as proposed)-Description"[5)] was used.

With respect to the Inertia force during an earthquake, since the 3-dimentional FEM analysis model which was used for the safety evaluation of the previous gates before replacement was available, by using this model, a dynamic analysis was conducted using the response acceleration waveform in an upstream to downstream direction at the trunnion position which was obtained by the above described seismic response analysis. By this means, the maximum value of reaction force from the upstream direction at the trunnion position was obtained. This study was conducted only for the radial gate of the Hotokebara Dam and the ratio of the Hydraulic pressure load during an earthquake against the door body weight was obtained. This same ratio was applied to the Jinichi Dam and the Jinni Dam as well assuming the same ratio would occur on these dams.

(2) Allowable stress

The allowable stress at the time of a large-scale earthquake was determined based on the Article 15 of "Water gate steel pipe standard (Gate door)" [3)] setting a yield point as the baseline.

(3) Verification method

Using the above described design water pressure, the allowable stress and calculated result of the design value based on the current standard were verified. When verification was conducted, the gate was closed completely.

As a result of investigation based on (1) to (3) above, in this case the normal load became the dominant condition. Accordingly, the configuration of the component material was determined.

Items which were considered for the cost saving and future maintenance managements are as follows:

(1) Change the shape of the gate;

The plane structure was changed from portal type to π type so as to make space available for the installation and maintenance management and to reduce the weight. (Fig. 2)

For the cross section structure, pedestal columns were changed from the 3 column type of the statically indeterminate structure to a 2 column type of statically determinate structure so as to simplify its structure and reduce the weight with the aim of cost savings and efficient maintenance management.

For the frame structure, the vertical auxiliary girder-horizontal main girder method was adopted (Fig. 3).

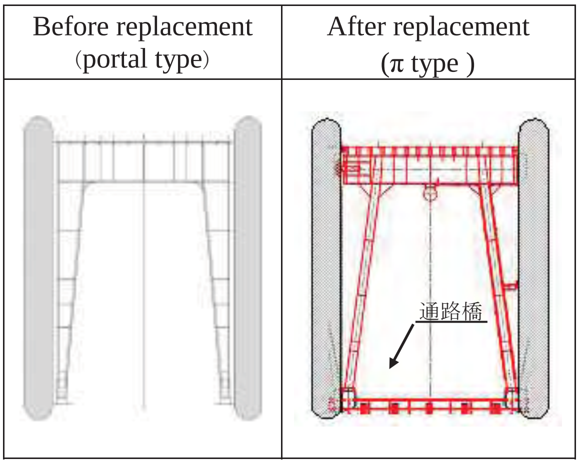


Fig. 2: Comparison of planar structure

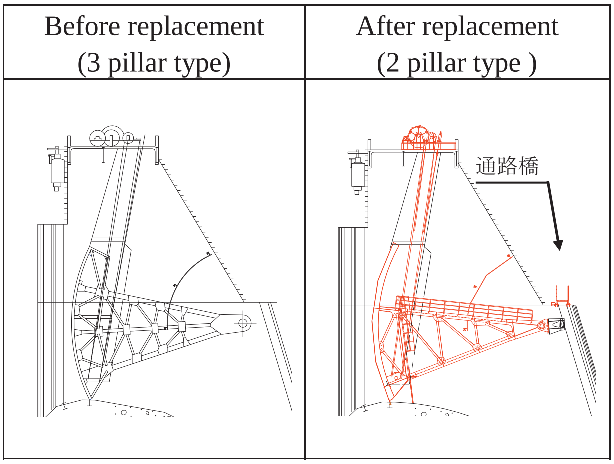


Fig. 3: Comparison of cross section structure

(2) Change of the output of the opening/closing electric motor

When the previous electric motor was installed, a high output motor was adopted because the worm reduction gear used was low in mechanical efficiency, and a large allowance was made in consideration of winter time oil viscosity.

This time, a helical reduction gear of high mechanical efficiency is adopted, and by: maintaining the lubricant oil viscosity during winter time constant with a heater, the output requirement of the electric motor was greatly reduced (Jinichi Dam, Jinni Dam; 22kW→7.5kW, Hotokebara Dam 15kW→11kW) and cost savings were achieved.

(3) Installation of a walkway bridge

Before renovation, in the Jinichi Dam and Jinni Dam, when inspecting the door body, it was necessary to go up and down a ladder from the slab. In this project, before removal of the gate, an inspection walkway (Width 0.98m× length106.2m) was installed on which the inspector is able to walk between piers at the same level as the trunnion girder, and by this means, safety of the installation work and future maintenance management work are improved.(Fig. 2, 3 Photo 4)

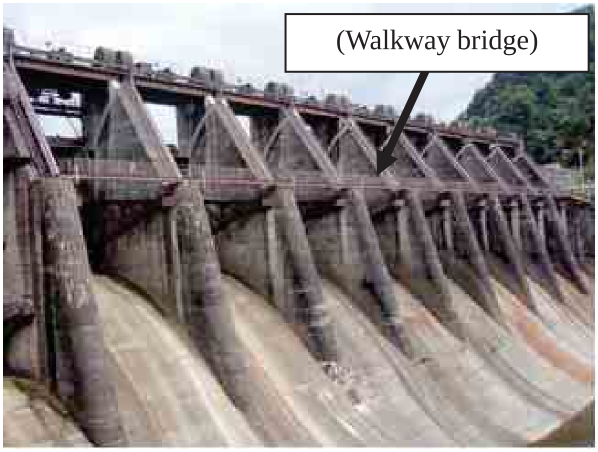


Photo 4: Installation status of the walkway bridge

(4) Reuse of the fixed part and gate sheet

It was confirmed that the fixed part was safe based on the current standard "Water gate steel pipe standard (Gate door)" and "Dam-Dam facilities technical standard (planned) (Standard description version, Manual version)". As for the dam concrete, the concrete properties were confirmed by boring at the pier area to take a sample core and examining it. (Photo 5)

For the concrete properties, compressive strength, static elastic modulus and the ultrasonic wave propagation tests were conducted, and it was confirmed that the allowable values which were to be used for the design calculation (allowable value when constructed) were not a problem.

The gate sheet was slightly rusted, but it was judged to be able to be saved by repainting, and thus cost savings were obtained by reusing the existing facility.

Before replacement

After replacement

Photo 5: The status of the fixed part (Jinichi dam)

3. Feature of the Project

3.1 Best Practice Components

- Countermeasures against a large-scale earthquake
- Facilities configuration which consider cost savings and maintenance management

3.2 Reasons for Success

As a result of the safety evaluation test of the radial gates, it became clear that the stress value was approaching the maintenance management standard level, therefore it was judged that it was necessary to replace them at the earliest possible opportunity.

However, since these gates were the spillway gates to discharge flood water, the River administrator directed us to conduct the renovation work from November to April, that is, during a non-flood period, for the Jinichi Dam and Jinni Dam, and from November to March for Hotokebara Dam.

In the Jinichi Dam and Jinni Dam project, the historical maximum water flow for the past 30 years during the construction period was surveyed, and judging from the discharge capacity by other gates which were renovated, it was determined that 3 gates could be replaced in 6 months, and actually 9 gates were replaced over 3 half-year periods.

The Hotokebara Dam has 3 spillway gates, and while one gate was renovated, if it became necessary to discharge from the gate due to flood, (even one gate went failure by trouble), in order to be able to do backup discharge by one gate, the plan was decided so that one gate was replaced in 4 months, and in fact 3 gates were replaced for 3 terms.

Incidentally, during this construction, dam water level was not restricted, and the rounded corner part for the makeshift cofferdam was inserted on the upstream side of the radial gate and the construction was conducted.

4. Points of Application for Future Project

(1) Countermeasures to a large-scale earthquake

With regard to the verification method for a large-scale earthquake, based on the above mentioned design load, the allowable stress and the design calculation result based on the current standard were examined in detail, but furthermore, it is also possible to compare it with the analysis result obtained by FEM analysis.

Depending on the design load, sometimes the design by FEM analysis can be more economical, therefore, it is necessary to compare the merit and cost from FEM.

(2) Vertical bending stress on the pier

In the ex-post facto evaluation described later in 5., it became clear that the axial force which acts on the truss part of the pier causes a bending moment which was not considered in the previous design, and so, depending on the gate structures, it is necessary to design the piers including the truss axis force.

(3) The maintenance management standard of the gate

In this project, for the maintenance management standard of gates, "The maintenance management standard of steel structures such as gate doors, etc." was referred to, but even after that, in Japan the maintenance management standard was studied and "Consideration of the uncertainty and management standard value about the stress verification of the dam gate " [6)] was published.

5. Others (monitoring, ex-post valuation etc.)

Of the gates which were renovated in the first phase, second phase and third phase construction, one gate from each phase was chosen and for the three of them, a safety verification test of the door bodies was conducted with a view to obtain data for confirming the safety of the door body and for maintenance management.[7].

As safety verification, a stress evaluation, vibration evaluation and buckling evaluation were conducted, and it became clear that all data were within the standard range and evaluated to be safe.
A summary of each evaluation is as follows:

(1) Stress evaluation

In the stress evaluation, static stress and dynamic stress were measured and verifications within the allowable stress were conducted. In addition, from the stress measurement results, the friction factor of the trunnion pin was assumed and the verification with designed value was conducted.

The static stresses were measured for the main components such as girders, skin plate and the truss between piers with strain gages attached to each component, by applying the hydrostatic pressure. (Fig. 4, 5)

As for the dynamic stresses, the stress increment by the actual discharge when the gate was opened was measured with the strain gages which were attached on the points which were selected so as to assume the friction factor of the trunnion pin and to measure the stress change which occurred on the main girder, piers and truss between piers. (Fig. 6, 7)

凡　例
━ ：測定断面
◀ ：単軸ゲージ
● ：３軸ゲージ
■ ：水圧計

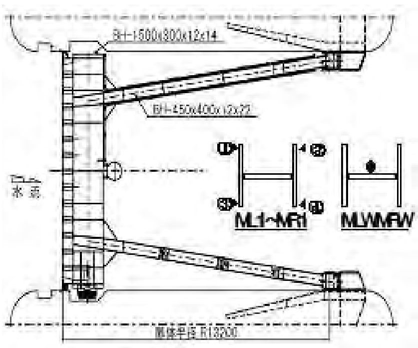


Fig.4: Measurement points of the static stress on the main girder

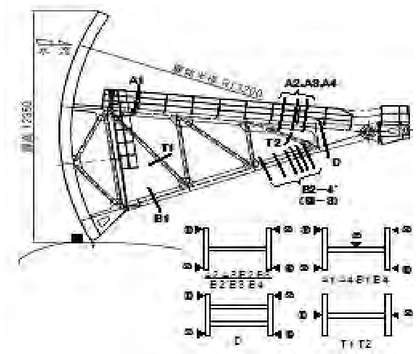


Fig. 5: Measurement points of the static stress on the truss between piers

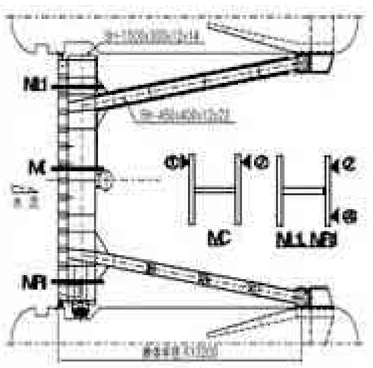


Fig. 6: Measurement points of the dynamic stress on the main girder

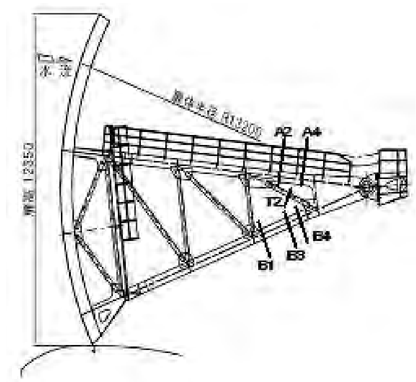


Fig. 7: Measurement points of the static stress on the piers

As a result of the measurement, every static stress and dynamic stress were lower than the allowable stress, thus it was confirmed that there was not any concern about safety.

The friction factor of the trunnion pin was 0.16 at a maximum and satisfied to be lower than design value of 0.2, but the value immediately after replacement was relatively large. This is thought to be because the measurement was conducted under the relatively harsh low temperature condition of winter time, and to be due to the effect of the solidification of the lubricating grease. Therefore, it was determined that it is safe even for future operations by feeding grease into the trunnion bearing.

(2) Vibration evaluation

Together with the dynamic stress measurement, the vibration of the gate caused by discharge was measured by an acceleration meter placed on the gate, and the data were evaluated by the Petricut chart.

The measurement points were 3 directions (water flow direction, left to right direction, vertical direction) for the central part of the lower step main girder, and one direction (vertical direction) for the central part of the lowest auxiliary girder. For all measurement points, the values fell within the "very quiet area" range and lower than "the lower limit which gives an impact on the structures". Thus, it was judged that it was safe (Fig. 8).

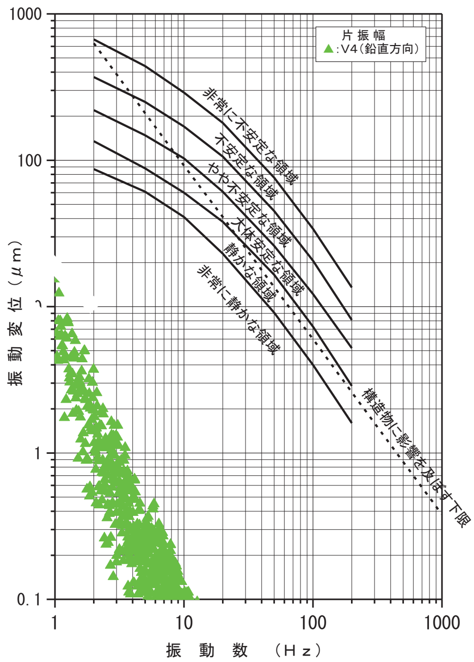


Fig. 8: Vibration evaluation by the Petricut chart when discharged with 3cm opening (Measurement point: the lowest step auxiliary horizontal girder)

(3) Buckling evaluation

When a component which receives both force along its axis direction and a bending moment is designed, it is necessary to conduct a "Verification for stability"[3), 4)] for buckling by the combination of the force and bending moment. Therefore, the pier was examined based on the stress measurement results. There are two verification formulae, that is, the whole buckling equation and local position buckling equation. In this case, the whole buckling equation was chosen because it is much stricter in evaluation. The whole buckling is judged to be safe if the value of formula (1) is less than 1.

$$-\frac{\sigma_t}{\sigma_{ta}} + \frac{\sigma_{bcy}}{\sigma_{bagy}} + \frac{\sigma_{bcz}}{\sigma_{bao}} \leqq 1 \qquad \cdots (1)$$

Here:

σ_t: Tensile stress along the axis direction which acts on the subject cross section which is to be examined (N/mm^2)

σ_{ta}: Tensile stress allowable along the axis direction (N/mm^2)

σ_{bcy}, σ_{bcz}: Bending compressive stress by bending moment which acts on a strong axis and around weak axis (N/mm^2)

σ_{bagy}: Allowable bending compressive stress around a strong axis which doesn’t take into consideration the local stationary position (N/mm^2)

σ_{bao} : The upper limit of an allowable bending compressive stress around a strong axis which doesn’t take into consideration the local stationary position (N/mm^2)

In the evaluation, the actual measured value of the friction factor of the trunnion pin was 0.16, and in consideration of the future increase of the friction factor, the verification was conducted using the design value of 0.2. As a result, equation (1) became “0.98” and was over the design calculation value of “0.835”, but still it met the criteria of “lower than 1”, therefore it was judged to be safe.

The reason why the analyzed value exceeded “0.835” is mainly because the vertical bending stress of the pier was large. On top of that, stress increments by errors from manufacturing and construction also gave some influence.

6. Further Information

6.1 Reference

1) Izumi Mitsuru, Shiraishi Tokumitsu, Osaka Kazuhiro, “Outline of the design and construction for the replacement of the dam spillway gate: Jinichi Dam, Jinni Dam and Hotokebara Dam”, *Journal of Electric power Civil Engineering*, volume 349 (2010.9)

2) “Review session for the maintenance management standard of the steel structures such as gate door, etc.”, *The Water gate steel pipe*, volume 234 (2008.6)

3) “Water gate steel pipe technical standard (Gate door)” Japan Water Gate Steel Pipe Association (2007.9)

4) “Dam-Dam facilities technical standard (planned) (Standard description version, Manual version)” Dam-Dam facility Technical Association (1999.3)

5) “Aseismic performance investigation guide of a dam during a large-scale earthquake (as proposed)-Description”[5)], Land, Infrastructure and Transportation Ministry (2006.3)

6) Shiogama Yuzo, “Consideration of the uncertainty and management standard value about the stress verification of the dam gate”, Central Research Institute of Electric Power Industry, *The Summary Report*, volume 12 (2011)

7) Izumi Mitsuru, Shiraishi Tokumitsu, Jindo Takuya, “Consideration of the design method and the safety verification of after replacement of the radial gate: Radial gate replacement of the Jinichi Dam, Jinni Dam and Hotokebara Dam”, *Journal of Electric power Civil Engineering*, volume 363 (2013.1)

6.2 Inquiries

Company name: Hokuriku Electric Power Company

URL: http://www.hepco.co.jp/

Format for the 2nd Round Data Collection (Definition of Case Histories)

Category and Key Points

Main: 2-c) Technological innovation, deployment expansion and new materials used for civil and building works

Project Name:

The conservation measures construction of the Taishakugawa Dam

Name of Country (including State/Prefecture):

Japan, Hiroshima Prefecture

Implementing Agency/Organization:

Chugoku Electric Power Co., Inc.

Implementing Period:

From 2003 to 2006

Trigger Causes for Renewal and Upgrade:

(C) Needs for higher performance
(D) Needs for safety improvement

Keywords:

Dam body conservation measures, Deteriorated dam, cast concrete, Elevation of stability

Abstract:

Since its commencement of operations in 1924, the Taishakugawa Dam has contributed to not only one part of a stable energy supply but also tourism resources. However, the discharge capacity of its tunnel type spillway is small and this dam had been given a restriction on reservoir usage during the flooding season. Furthermore, since there was about 35m of unused head at a maximum, and about 80 years have passed since its completion, this dam was not meeting stable conditions. Therefore, the Taishakugawa Dam body conservation measures construction (Structural reinforcement and improvement of the flood processing capacity) was conducted to modify the dam into a modern dam and to utilize the water resource more effectively. In this report, the case in which a concrete structure was built on the downstream side of the existing dam so as to improve stability is reported.

1. Outline of the Project (before Renewal/Upgrading)

The Taishakugawa Dam is a water intake dam for the Taishakugawa Hydroelectric Power Station (maximum output 4.4MW, full-scale construction started June, 1923, operation began March, 1924) located downstream on the Taishakugawa River which is a tributary of the first class, Takahashi River, flowing in the northeast part of Hiroshima Prefecture. The surrounding area of the dam-reservoir has been designated as a national sightseeing spot and a Class 1 special district of the Hiba-Dogo-Taisyaku Seminational Park. This dam is located in the center of the "Taisyakukyo Gorge " which is a leading tourist attraction. The location map and the specifications of the power station and dam are shown in Fig. 1 and Table 1.

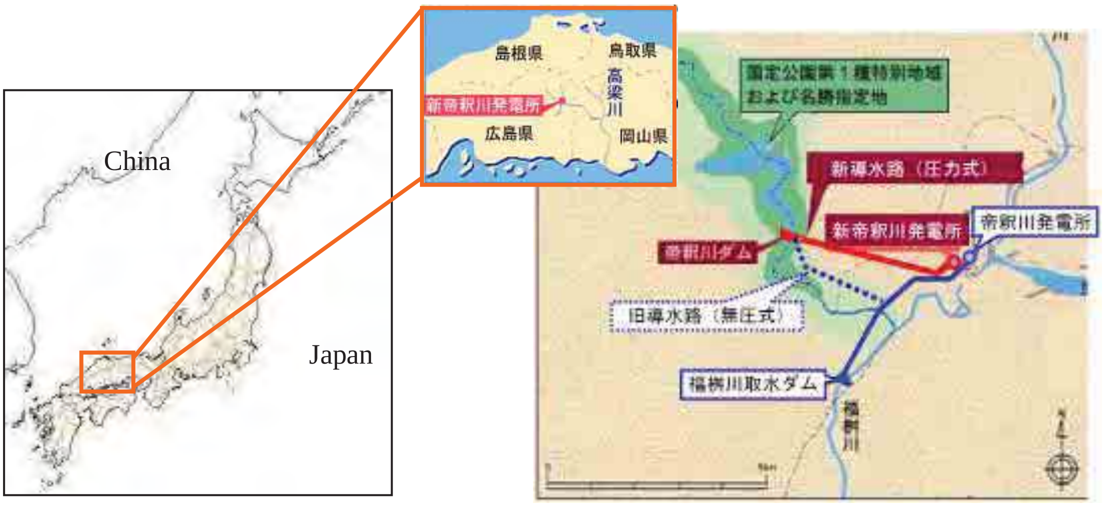


Fig. 1: Location map of the Taishakugawa Dam

Table 1: Specifications of the power station (before and after renewal)

Item		Specification	
		Before renewal	After renewal
Powerhouse	Name of power station	Taishakugawa Power Station	Shin-Taishakugawa Power Station
	Maximum output	4.4 MW/unit	11 MW/unit
	Maximum plant discharge	$5.7m^3/s$	$10.0m^3/s$
	Effective head	95.17m	129.0m
Dam	Name of dam	Taishakugawa Dam	
	Name of river	Takahashigawa water system, Taishakugawa River	
	Basin area	$213.2km^2$	$120km^2$
	Type	Concrete gravity dam	
	Height	62.10m	62.43m
	Length of dam top	35.15m	39.50m
	Dam volume	$31{,}000m^3$	$45{,}000m^3$
Reservoir	Total pondage	$14.278\times10^6m^3$	
	Effective pondage	$12.995\times10^6m^3$	$7.490\times10^6m^3$
	Used water depth	34.39m	13.94m

2. Description of the Renewal and Upgrading of the Project

2.1 Trigger Causes and Drivers for Renewal and Upgrading

(1) Condition, capability, influence of risk and others

(Not applicable)

(2) Improvement of value (functions)

(C)- (a) Needs for higher performance – Efficiency improvement, Addition power &energy. Loss reducation

By changing the headrace from a non-pressure tunnel type to a pressure type tunnel to utilize the unused head (35m), the Shin-Taishakugawa Power Station of 11MW was expanded. The old Taishakugawa Power Station stopped intaking water from the Taishakugawa River, began intake from only the Fukumasugawa River and was downsized. In total, an increased output of 9MW was achieved (Table 2).

Table 2: Maximum output of the Taishakugawa P.S. and Shin-Taishakugawa P.S.

	Maximum output (MW)		Change output(MW)
	Before renewal	After renewal	
Shin-Taishakugawa Power Station	－	11.0	＋11.0
Taishakugawa Power Station	4.4	2.4	－2.0
Total	4.4	13.4	＋9.0

(D) – (a) Needs for safety improvement – Improvement of safety

The Taishakugawa Dam was designed and constructed in the Taisho era, about 80 years ago, and does not meet the necessary stability conditions according to the current design standard.

(3) Necessity in market

(Not applicable)

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

1924:	Operation of the Taishakugawa Power Station (existing power station) began
July 1995:	Survey approval was requested to the local government, and a full-scale study of the project began
June 2003:	Civil engineering work began
March 2004:	Concrete construction work of the dam body began
December 2005:	Concrete construction work of the dam body was completed.
June 2006:	Commercial operations began (11 MW)

2.3 Description of Work Undertaken (detail)

2-c) Engineering innovation, application expansion and new materials in the field of civil engineering and construction

The Taishakugawa Dam was designed and constructed in the Taisho Era (1912-1926) and according to the current design standard it did not meet the necessary stability conditions, therefore along with the expansion, so as to meet the stability requirements, the concrete reinforcement construction was implemented. (Fig. 2)

(Before restoration countermeasures) (After restoration countermeasures)

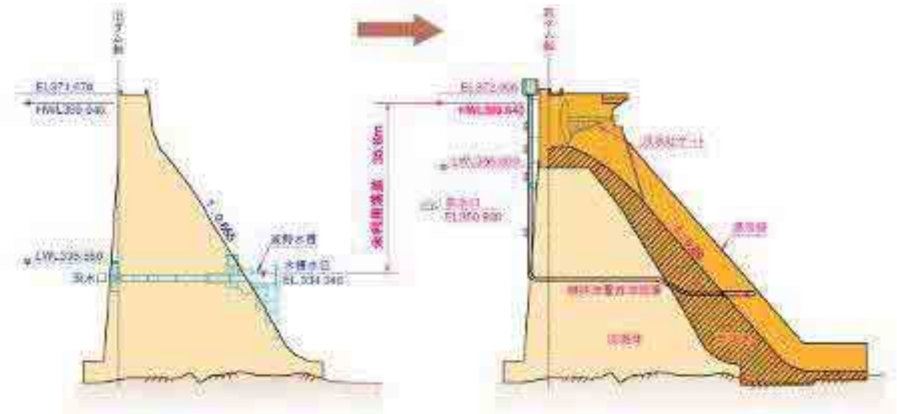


Fig. 2: Cross-section view of the Taishakugawa Dam (before and after the restoration countermeasures)

In this project, dam height was not increased; instead, concrete was added on the downstream part of the existing dam. The technical challenge accompanied with this construction was the same as with the case of a dam height increase. The structural issues associated with a dam height increase are mainly the following 3 items:

(1) Stability of the dam
(2) Integration of the old dam body and the new dam body with respect to (1)
(3) Thermal stress caused by hydration heat developed by the added new concrete work on the back face of the old dam body (especially the impact on the old dam body)

a. Stability of the dam (1), Integration of the old and new dam body (2)

In consideration of the fact that the reservoir is an important sightseeing spot, this construction was conducted while maintaining a full pool. In this project, dam height was not increased, and the construction was conducted based on the idea of the “Dam height increase formula by Kakitani (hereinafter refer to as the Kakitani formula)” which is able to consider the water level during the construction.

The Kakitani formula is based on the Rigid body theory, and using the basic idea that “the load during construction is supported by the old dam body, and the new added total load after completion of construction is supported by the integrated dam body of old and new dams”. In Japan, the majority of the height increase dams were designed by this formula.

The Kakitani formula premise is that the integrated dam body of the old and new dams needs to resist external force, it is necessary to understand the relationship between the stress and the strength acting on the joint face of the old and new dams, and it is necessary to confirm the integration of the old and new dams. Consequently, by measuring the shear stress and tensile stress which develop on the joint face by the hydration heat from new concrete and/or by external forces such as water pressure and seismic inertia force by thermal stress analysis and other methods, and by comparing them with the strength at the joint face which was confirmed by the original position shear test, its safety was confirmed.

In the actual construction, from the view point of assuring the integration of the old and new dam body, along with the demolition work of the stone pitching over the old dam body surface, by a large jack hammer, pitting work of the old concrete was conducted (Photo 1)

Photo 1: Pitting status of the old dam body

b. Countermeasures to the thermal stress (3)

When the new concrete is added to the existing dam body which was already at thermal equilibrium, the existing dam body would then have a huge thermal load on its back surface. It is recognized that this thermal change associated with this thermal load causes specific thermal stresses such as a tensile stress on the upper stream surface of the existing dam body. Therefore, so as to understand these phenomena, thermal stress analysis was conducted, and countermeasures were studied.

As one example of the analysis results, the maximum tensile stress distribution chart is shown in Fig. 3. Zones with a large tensile stress were found in two areas, one on the lower elevation and another on the higher elevation of the new dam body. It is thought this is because the concrete pouring construction was conducted in the summer time and influenced by this. At the vicinity of the border between the old and new dam bodies, on the old dam body and at the upstream side of the old dam, zones with a high tensile stress were found. This phenomenon is thought to occur because the height increased dam specific tensile stress which is developed by cooling contraction of the heat generating new concrete acted in this dam as well.

As a result of analysis, it became clear that the tensile stress of the new concrete associated with the summer concrete pouring work, and the tensile stress appearing on the upstream side of the new and old dam bodies were both within the concrete tensile strength range, and it was judged that special countermeasures were not necessary. However, with a view to improve waterproof performance, on the upstream surface of the old dam, grouting was applied. (Fig. 4) On the other hand, the vicinity of the border between the old and new dam bodies on the old dam body was reinforced by reinforcing steel and also waterproof plate was inserted into the dam axis direction. Thus, countermeasures were conducted so that nothing would happen to the waterproofing.

As for the concrete production, since the total usage for the concrete pouring construction was small at 15,600m^3 and in order to greatly save costs, it was decided to partially modify the ready mixed concrete manufacturing plant and use it. For the modification the plant, so as to meet the dam construction specifications (large maximum aggregate size, low slump, special cement, etc.), at the order stage, a large-scale modification such as to the aggregate plant, etc. was considered but after all, by conducting a small-scale modification such as an improvement of the performance of the mixer unit, cost savings were achieved.

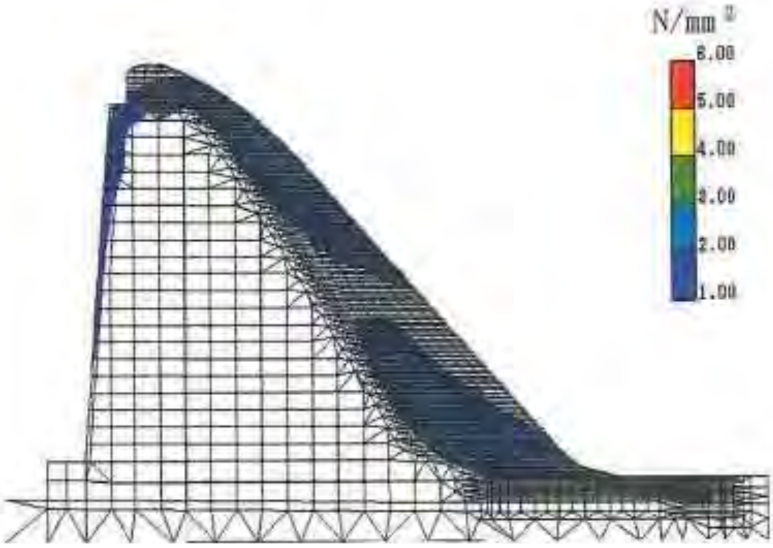


Fig. 3: Thermal stress analysis results

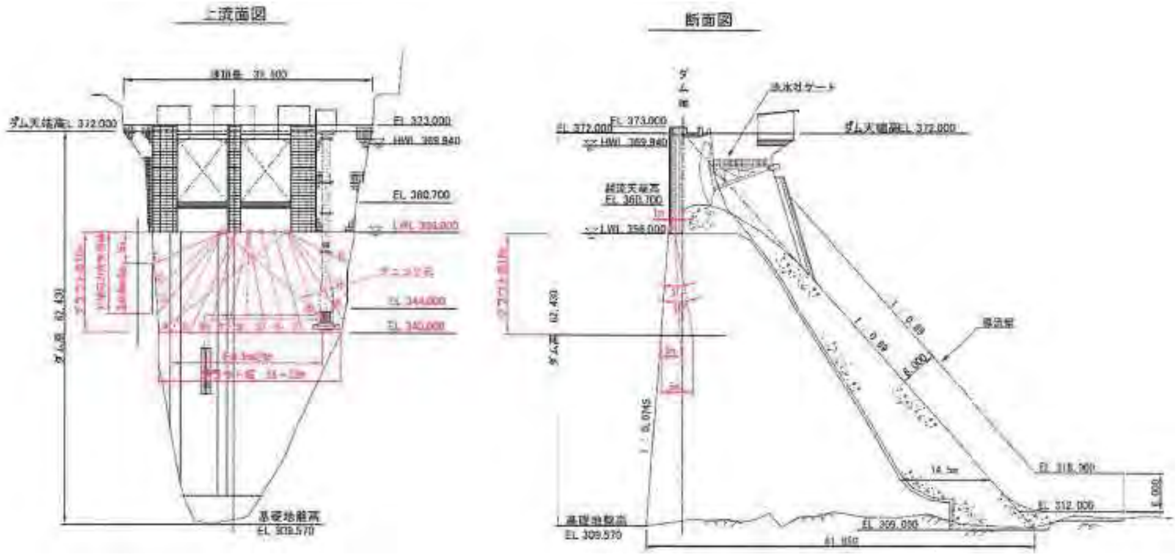


Fig. 4: Grouting work status on the dam body (red marked part)

As a result of analysis, it became obvious that there was a fear of an impact of a temperature increase accompanying concrete pouring construction in the summer during daytime. Therefore, pre-cooling treatment of the concrete by liquid nitrogen (LN_2) was conducted. For the pre-cooling method, two methods, that is, the plant mixer input method and the truck mixer site input method were considered, and the former was adopted because it was easy to control temperature at the time of input (Photo 2). From the result of the temperature analysis, an injection temperature for pre-cooling was targeted to be 20 °C, and from 2004 to 2005 (June to September) this process had been followed. The cooling basic unit of liquid nitrogen which shows the concrete temperature reduction efficiency was set to be 13kg/m^3 °C, and until the temperature dropped to around 10°C, the assumed effect was confirmed. On top of that, in order to decrease the rise of the concrete temperature during transport, heat insulation was installed on the external surface of the concrete mixing vehicle (Photo 3).

The monitoring results of such as the temperature during the concrete pouring construction and others are shown in “5. Others”.

Photo 2: Liquid nitrogen (LN_2) plant facility installation status
(In the ready mixed concrete manufacturing plant)

Photo 3: Mixer vehicle with heat insulation material attached

3. Feature of the Project

3.1 Best Practice Components

- Implementation of the dam stability examination
- Implementation of the thermal stress countermeasures

3.2 Reasons for Success

The reason why this project has been successful is because in this conservation countermeasure construction, the stability consideration of the dam was surely conducted. In the height increase construction, the structural problems were studied first in the project at our Odomari Dam (completed in 1935, and height increased in 1959), then next for the Kuroda Dam owned by Chubu Electric Power Co., Inc. (completed in 1934, and height increased in 1978) and the Shin-Nakano Dam owned by Hokkaido Electric Power Co., Inc. (completed in 1960, and height increased in 1983). From these investigations, we had examined and confirmed the safety regarding the subjects which were extracted from these survey results, and took countermeasures as necessary.

4. Points of Application for Future Project

(View point of increase of the construction costs)

- Consideration for whether or not to adopt ready-mixed concrete

(In this project, since the total usage for the concrete pouring construction was small at 15,600m^3, and in order to greatly save costs, it was decided to partially modify and use the ready mixed concrete manufacturing plant. In advance, the manufacturing capacity for the concrete, the conveying time from production to the pouring construction and the impact on the other general construction by concrete supply were surveyed in detail, and it was confirmed that quality was fully able to be assured.)

(View point of operation)

(Not applicable)

5. Others (monitoring, ex-post valuation etc.)

With a view to monitor the behavior of the old and new dam bodies during the concrete pouring construction and after concrete work, as shown in Table 3, buried measurement devices have been installed. As of today, no problematic displacements or other problems were found.

Table 3: Number of buried measuring devices

Type	Number	Place to be installed
Heat gauge	26	New dam body:18, Old dam body :8
Strain indicator	30	New dam body: 26, Old dam body:4
Joint meter	7	Joint face between old and new dams
Shear displacement indicator	7	Joint face between old and new dams

6. Further Information

6.1 Reference

1) S. Okita, I. Yoshioka, S. Ichihara, "Outline of the construction work of the Shin- Taishakugawa Power Station", *Journal of Electric power Civil Engineering*, volume 309 (2004.1)

2) S.Ichihara, J. Hayashi, Y. Shimizu, "Construction of the conservation countermeasure project of the Taishakugawa Dam", *Journal of Electric power Civil Engineering*, volume 324 (2006.7)

3) I. Yoshioka, "The conservation countermeasure construction of the Taishakugawa Dam", *The Dam Digest*, volume 728 (2005.6)

6.2 Inquiries

Company name: Chugoku Electric Power Company

URL: http://www.energia.co.jp/

Format for the 2nd Round Data Collection (Definition of Case Histories)

Category and Key Points

Main: 2-c) Technological innovation, deployment expansion & new materials used for civil and building works

Sub: 1-f) Environmental conservation and improvement

Project Name:

The installation project of the fence to countermeasure of muddy water

Name of Country (including State/Prefecture):

Japan, Kochi Prefecture

Implementing Agency/Organization:

Shikoku Electric Power Co., Inc.

Implementing Period:

2005

Trigger Causes for Renewal and Upgrade:

(B) Environmental degradation

Keywords:

Lengthening period of muddy water, Fence as a countermeasure to muddy water

Abstract:

In recent years, it has been reported that by installing an “opaque” fence (fine mesh screen, hereinafter referred to as the “Fence”) in a stratification type reservoir as a countermeasure to reduce a lengthening period of muddy water in the reservoir, muddy water flows out from under the lower layer of the Fence resulting in an early discharge of the inflowing muddy water. Also by discharging under the clear water layer on the surface held by the Fence, the turbidity is able to be reduced. Until recent years, in the Nagasawa Dam, reduction of a lengthening period of muddy water had been pursued by installing a selective water intake facility. So as to furthermore reduce a lengthening period of muddy water, a Fence as a countermeasure to the muddy water was installed in March, 2005 by a newly established design.

So far, for the medium-scale flooding, the effect of the Fence installation was confirmed, continuous monitoring will be conducted and the Fence effect for the wide range of flood scale is planned to be verified.

1. Outline of the Project (before Renewal/Upgrading)

The Nagasawa Dam is a concrete gravity dam with a height of 71.5m, total pondage of 31.9 million m^3, which was constructed for the Nagasawa Hydroelectric Power Station (Dam type power station, maximum output 5,200kW, generation was started in 1949) located at the most upstream part of the Yoshinogawa River, Yoshinogawa water system in Shikoku. The location map and specifications of the power station and dam are shown in Fig. 1 and Table 1.

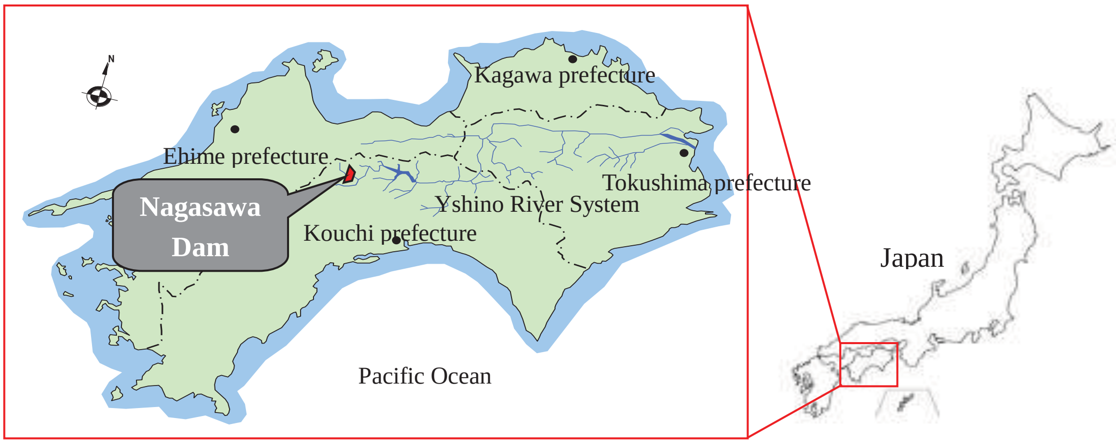


Fig. 1: Location map of the Nagasawa Dam

Table 1: Specifications of the Nagasawa Power Station

Item		Specifications
Powerhouse	Name of power station	Nagasawa Power Station
	Maximum output	5,200 kW
	Maximum plant discharge	9.50 m^3/s
	Effective head	64.940 m (when maximum plant discharge used)
Dam	Name of dam	Nagasawa dam
	Name of river	Yoshinogawa water system, Yoshinogawa River
	Basin area	91.52km^2
	Type	Concrete gravity dam
	Height	71.5m
	Length of dam crest	216.6m
	Dam volume	235,000m^3
	Total Storage Capacity	31.9×10^6 m^3

2. Description of the Renewal and Upgrading of the Project

2.1 Trigger Causes and Drivers for Renewal and Upgrading

(1) Condition, capability, influence of risk and others

(B)- (b) Environmental degradation – Improvement of river environment

In the early 1970’s, for the Nagasawa Dam, lengthening periods of muddy water became a social problem, thus the reduction of the muddy water periods was pursued by taking actions such as placing the selective water intake facility and others. However, since it had not been successful to reduce the muddy water with only these facilities, additional countermeasures have been taken since then.

(2) Improvement of value (functions)

(Not applicable)

(3) Necessity in market

(Not applicable)

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

April 1949:	Operation of the Nagasawa Power Station began
July 2003:	The study of the project was started
February 2005:	The installation work of a Fence to counteract the muddy water began
March 2005:	The installation work on the Fence was completed

2.3 Description of Work Undertaken (detail)

1-f) Environmental conservation and improvement

In the Nagasawa Dam, from the early 1970's, since the lengthening periods of muddy water became a social problem, as a countermeasure, in 1978, a selective water intake facility was installed, but even after its installation, the fundamental problem was not solved.

Under such conditions, in recent years it has been reported that the reduction of muddy water downstream was able to be achieved by installing a Fence to reduce surface muddy water because it quickly discharged the muddy water from the lower layer under the Fence. Also it discharged the muddy water under the Fence away from the clear water layer on the surface. Accordingly, with regard to the installation of the Fence as a countermeasure to the muddy water in the reservoir of the Nagasawa Dam, a hydraulic model test and numerical simulation were conducted. Applicability for the dam was confirmed and the Fence was installed at the site.

2-c) Technological innovation, deployment expansion and new materials used for civil and building works

So far, it was confirmed that the Fence as a countermeasure to the muddy water had a qualitative performance, but its quantitative evaluation was not sufficient. Consequently, the flow control phenomenon by the installation of the Fence was analyzed quantitatively, and based on that, the Fence design method was developed.

First, using a hydraulic model test (model scale: 1/50), the factors were analyzed by quantitatively studying the change of the muddy water phenomena by installing the Fence. As a result, it became clear that the boundary face of the lower part under the Fence, which is the indicator of the change of the flow phenomenon, changes according to inlet flow, height of the Fence, water depth at the position of the Fence installation and density difference between the clear water and muddy water (Fig. 2). In addition, the high relationship was identified between the Fence height and the flow conditions into the reservoir (inlet flow of muddy water, density difference with reservoir water), and between the raising of the density interface and the Froude number, which is calculated based on the cross section of the flow at the position of the Fence installation. Thus, the clear water holding effect at the lower flow surface part of the Fence was evaluated by assuming the raising of the density interface from the Froude number (Fig. 3). By means of this, it became possible to easily determine the general specification of the Fence by using the density interface rise which is assumed from the Froude number.

Based on the knowledge obtained by the hydraulic model test, a 3-dimentional simulation model of the turbulent phenomenon at the time when muddy water in flow was developed. Then, based on the Fence outline specifications, installation positions and height of the Fence were investigated in detail by numerical simulation. Accordingly, the method which enables determining the optimum Fence specifications, which are able to achieve the clear layer holding effect and the early discharge effect of the muddy water mass, were developed in a rational and effective way.

Finally, the optimum Fence specifications were determined by applying the developed design method to the reservoir of the Nagasawa Dam. (Table 2, Fig. 4, Photo 1)

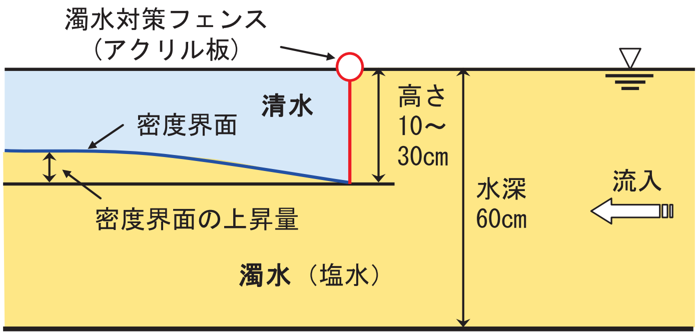
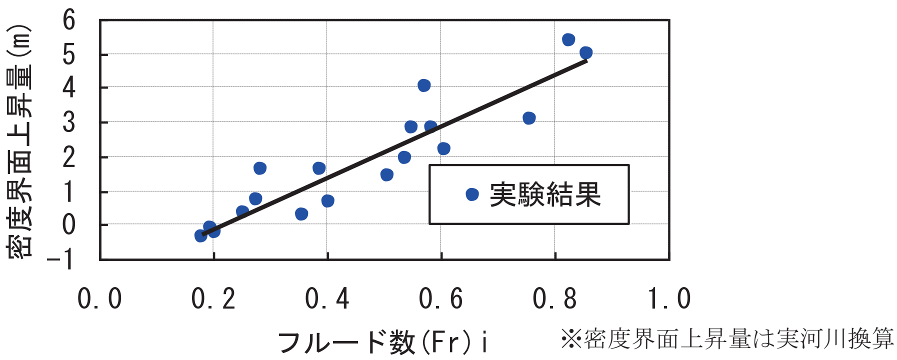
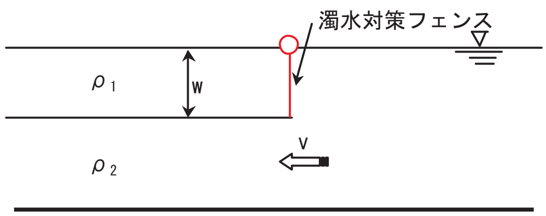


Fig. 2: Outline of the hydraulic model test



【Definition of Froude namber】



$$(F_r)_i = \frac{v}{\sqrt{g\frac{\rho_2 - \rho_1}{\rho_2}w}}$$

Fig. 3: Relationship between the Froude number and the rising of the density interface

Table 2: Specifications of the Fence as a countermeasure to muddy water

Impermeable sheet	Dimension	(standard part) L=20m, length of curtain h=10m, 10 curtains (edge part) L=10m, length of curtain h=10m, 2 curtains
	Sheet	Polyester, N500 Strength: more than 5,000N/3cm
	Float	φ400mm, foam polystyrene Ascending force: more than 23,535N/20m
	Float cover	PVC Tarpaulins, thickness=1.0mm Strength: more than 2,941N/3cm
	Main belt	Polyester, width=100mm Strength: 137.2kN/1belt
	Connection part	Metal fitting with a D ring, diameter=19mm (for main belt) Fracture strength: more than 115kN
Ship passing gate	Dimension	Effective width for passing ship : 4.0m Effective water depth for passing ship: 1.5m
	Opening/closing method	Semi-automatic type (Gate is opened for boats, and after boat passage, the gate is closed by a counter weight)
	Frame material	SUS304
	Float	Surface: covered with urethane resin Inside: polystyrene foam

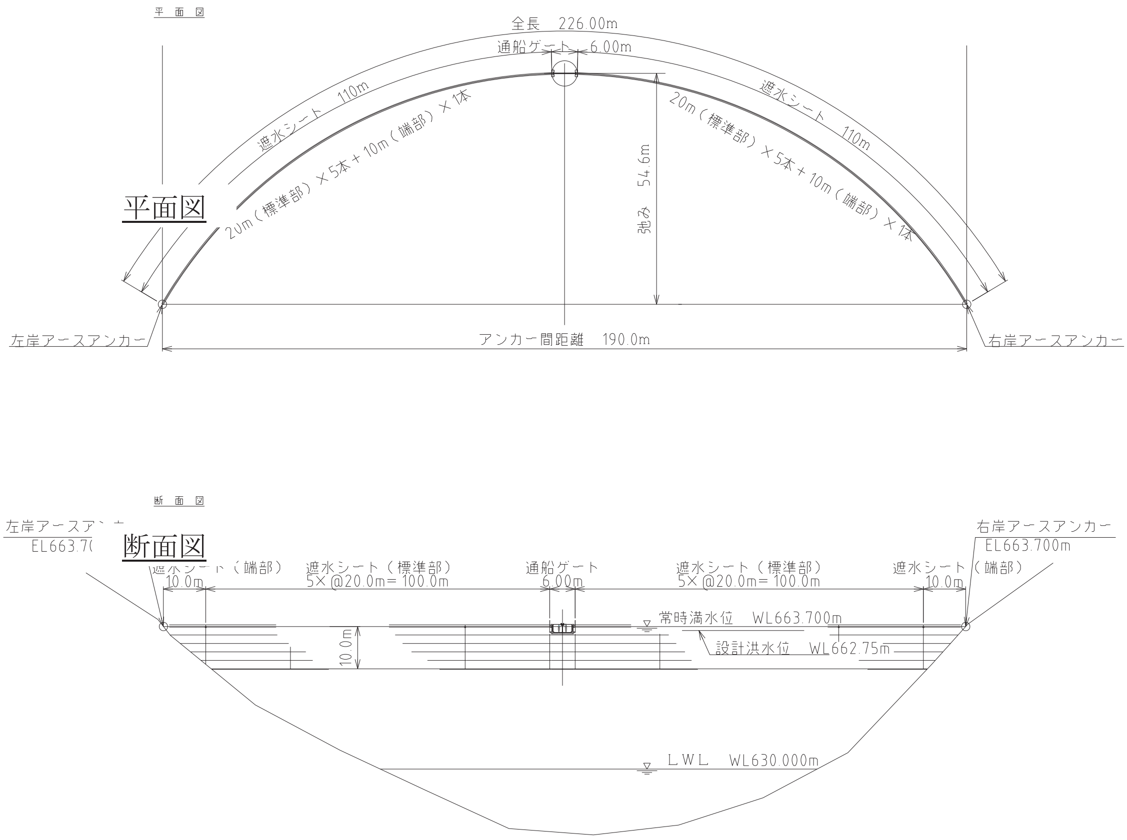


Fig. 4: Fence as a countermeasure to muddy water

Photo 1: Installation status of the Fence as a countermeasure to muddy water

3. Feature of the Project

3.1 Best Practice Components

- The optimum specifications of the Fence as a countermeasure to muddy water was determined rationally by quantification of the relationship between the density interface rising and the Froude number at the time when muddy water flows in.

3.2 Reasons for Success

In the past, a Fence as a countermeasure to muddy water was designed based on empirical rules such as past performance, however in this project the design method which enables quantitatively evaluating the flow control effect by the Fence was developed. To be more precise, by a hydraulic model test, the change of the density interface depending on various conditions such as the Fence height, density differences and flow volumes was found. The relationship between the density interface and Froude number, which is an indicator showing the muddy water control efficiency by a Fence, was then identified, making it possible to determine the general specifications of the Fence (the general Fence height, the installation point). Furthermore by 3-dimensional simulation which enables evaluation of the water flow in the reservoir very precisely, the case was studied based on the general specifications. And by means of these efforts, the most rational and effective method which is able to determine the optimum specifications of the Fence as a countermeasure to muddy water was developed.

4. Points of Application for Future Project

(Applicable range of this countermeasure)

- This was the countermeasure for the lengthening of periods of muddy water which mainly targeted the stratification type reservoirs.

5. Others (monitoring, ex-post valuation etc.)

- To verify the assumed effect of the installation of the Fence as a countermeasure to muddy water, before and after the Fence installation, several similar flooding scales were selected and compared in terms of turbidity distribution. The turbidity distribution in the lake 5 to 6 days after the subject flooding ended is shown in Fig. 5.

- According to the turbidity distribution in the lake, when compared to the case of before installation of the Fence, the turbidity of the surface layer on the downstream side of the Fence is lower than that upstream of the Fence, and was able to hold the clear water layer. Thus, the effect of the Fence installation for reducing turbidity was confirmed.

- Since the Fence was installed, to understand its effect quantitatively, monitoring of the turbidity and water temperature distribution before and after flooding has been conducted and the effect for the middle-scale flooding by the Fence installation was confirmed. From now on, monitoring will be continued, and we will confirm the conditions such as turbidity before and after Fence installation for a large-scale flood. We also plan to verify the Fence effects for a wide range of flooding scales.

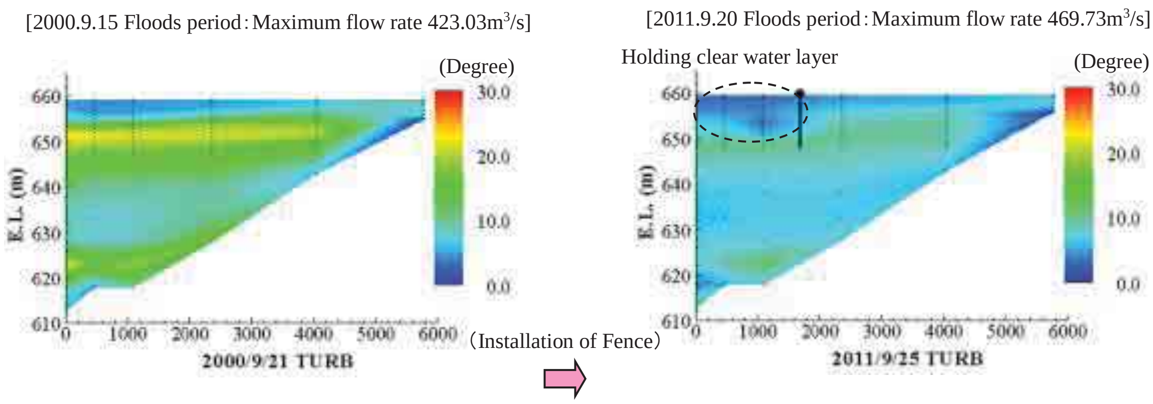


Fig. 5: Turbidity distribution in the lake for similar floods before and after Fence installation.

6. Further Information

6.1 Reference

1) K. Sakamoto, M. Nakahiro, K. Maeda, K. Miki, “The development of the design method for the reduction of the lengthening periods of muddy water in the reservoir by using a Fence as a countermeasure”, *Journal of Electric power Civil Engineerin*g, volume 329 (2007.5)

6.2 Inquiries

Company name: Shikoku Electric Power Company

URL: http://www.yonden.co.jp/

ANNEX XI Renewal & Upgrading of Hydropower Plants

Format for the 2nd Round Data Collection (Definition of Case Histories)

Category and Key Points

Main: 2-c) Technological innovation, deployment expansion and new materials used for civil and building works

Project Name:

The renovation project of the Yusuharagawa No.3 Hydroelectirc Power Station

Name of Country (including State/Prefecture):

Japan, Kochi Prefecture

Implementing Agency/Organization:

Shikoku Electric Power Co., Inc.

Implementing Period:

From 2005 to 2008

Trigger Causes for Renewal and Upgrade:

(A) Degradation due to aging and recurrence of malfunction

Keywords:

Aging, FRPM pipe (Fiber reinforced plastic mortar pipes), Energy dissipator, Increase of output

Abstract:

Since the Yusuharagawa No.3 Power Station has been operated for 75 years and a wide variety of its facilities have deteriorated due to aging, large-scale renovation work was conducted. In this renovation project, for the hydraulic pipe system, the existing steel pipe was replaced with FRPM pipe. And for the supporting structure of the pipe system, a continuous base saddle supporting structure using the existing subgrade was adopted so as to achieve cost saving and minimum maintenance.

1. Outline of the Project (before Renewal/Upgrading)

The Yusuharagawa No.3 Power Station is a dam and conduit type power station with a maximum output of 2,580kW, an effective head of 41.8m and a maximum plant discharge of 7.79m^3/s. The plant is located in Yusuhara-machi, Takaoka-gun, Kochi Prefecture in the west part of Shikoku on the Yusuharagawa River which is a tributary river of the so called last clear water river in Japan, the Shimantogawa River (Fig. 1).

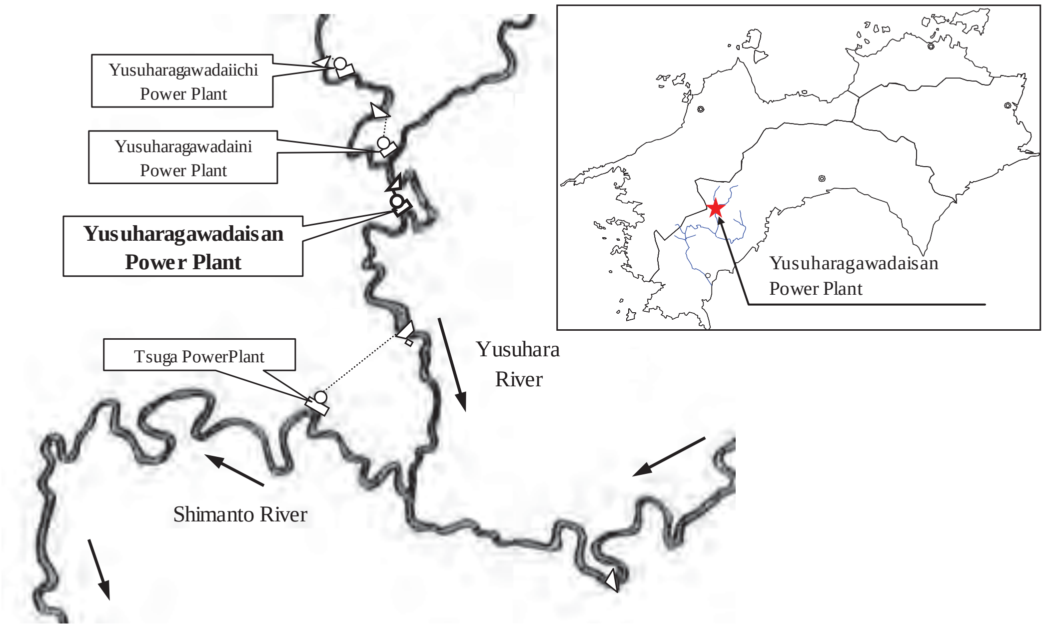


Fig.1 Location of Yusuharagawa No.3 Power Plant

2. Description of the Renewal and Upgrading of the Project

2.1 Trigger Causes and Drivers for Renewal and Upgrading

(1) Condition, capability, influence of risk and others

(A)-(b) Degradation due to aging and recurrence of malfunction - Improvement of durability and safety

The Yusuharagawa No.3 power station began operation in 1930 and until 2005 had been operated for 75 years with only periodical facility inspections, maintenance and necessary repair work. However, various parts of the facilities were found clearly to have deteriorated due to aging. Especially for the hydraulic pipe system and the water turbine and generator, by a remaining life estimation method, it was predicted that they would reach the end of their life around 2007.

For the headrace tunnel, voids which might be created during construction were identified on the back of the lining concrete, therefore there is a fear that the tunnel would be damaged by disintegration of the back rock base during a long period of operation in the future.

This power station, with a site height of EL218.788m, was flooded to the point of EL222.288m caused by a typhoon in 1982. Consequently it was necessary to take counter measures to raise the site height and others so as to protect the major electric facilities. In addition, on the spill channel of this power station, an energy dissipator had not been installed. In order to protect people using the river who increasingly fell victim to flooding recently, it became necessary to install a spill channel energy dissipator.

(2) Improvement of value (functions)

(Not applicable)

(3) Necessity in market

(Not applicable)

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

December 1930:	Operation of the power station began
2001:	Study of the renovation project of the power station was started
February 2005:	Construction work implementation plan was determined.
September 2005:	Construction work began
November 2005:	Power generation was stopped and water turbines and generators were removed.
February 2006:	Construction of the underground building frame of the power station began
March 2006:	The removal work of the old facilities was completed
April 2006:	Replacement work of the hydraulic pipes began (from riveted joint pipe to FRPM pipe)
September 2006:	Repair work on the headrace tunnel began (filling the voids behind the concrete lining)
February 2007:	Replacement work of the hydraulic pipe and construction of the underground building frame of the power station were completed.
February 2007:	Land preparation work for the power station began
March 2007:	Repair work on the headrace tunnel was completed
November 2007:	Installation work of the water turbines and generators began
February 2008:	Installation work of the new water turbines and generators was completed
February 2008:	Land preparation work for the power station was completed.
March 2008:	Renovation work was completed and the operation was started.

(A maximum output has been increased to 2,800kW from 2,580kW by utilizing the latest high efficiency runner)

2.3 Description of Work Undertaken (detail)

2-c) Technological innovation, deployment expansion and new materials used for civil and building works

(1) Adoption of a FRPM pipe

In Yusuharagawa No.3 Power Station, the existing hydraulic pipe was riveted joint pipe which was used for 75 years and not replaced, greatly exceeding its standard replacement life (40 years). Rust and pitting corrosion of 2 to 4mm depth was identified on the steel pipe fixed band, fixed base and contact areas with saddles. Based on past plate thickness tests, the service life of the hydraulic pipe was studied and it was estimated that by 2007 the effective plate thickness would have been reduced locally to 5.87mm, reaching its service limit. Consequently, a detailed study for a replacement plan of the hydraulic pipe was conducted, and based on the review of actual records from other companies, it was determined that existing steel pipe would be replaced with FRPM pipe so as to minimize maintenance work by eliminating painting, etc (Fig. 2).

FRPM pipe is a composite material which is composed of glass fiber reinforced layers (FRP layer) as the inner and outer layers, and a resin mortar layer placed between both fiber layers. FRPM is a filament wound pipe (with multiple layered high strength glass fiber in circumferential and axial directions) (Fig. 3). This pipe has the following characteristics: 1) lighter weight than steel pipe, 2) the same level of wear resistance as steel pipe, 3) excellent workability 4) excellent conformity to displacement of the mountain land (stretch properties) 5) excellent water tightness and corrosion resistance, therefore making it possible to reduce construction time and cost. In this project, since the route to the construction site is narrow and has many steep curves, shorter pipe lengths of 4m were used instead of the 6m pipe length generally used.

For the replacement of the hydraulic pipe, it was determined to reuse the 10.8m of existing steel pipe at the upper end (head tank part) which was sound so as to save cost, but there was a problem with securing water tightness at the jointed area between the existing steel pipe and the FRPM pipe. Accordingly, for the resolving this problem, a new connecting tube was developed and adopted for the uneven step at the riveted joint of the existing pipe. The added connecting tube has a steel liner with a taper to create less local stress and was able to secure water tightness (Fig. 4).

With regard to the supporting structure of the hydraulic pipe system, various shapes were compared and studied so as to save cost by reusing the existing facilities. As a result, a "continuous base saddle type" was adopted which combines the subgrade and saddle into an integral structure which reduces the amount of concrete to be removed more than a single saddle base type and which doesn't require concrete removal when exchanging parts of the FRPM in the future (Fig. 5, Photo 1).

The newly constructed hydraulic pipe is confirmed to be fully safe in terms of the design criteria by measurements of stress and vibration and a visual inspection of whether or not water leaks occur at joints when the pipe was filled with water after completion of the installation. Incidentally, in the operation and maintenance of the FRPM pipe, control is planned to be conducted by setting the measured stress and vibration created when filled with water as an initial value.

(2) Development of a flexible, injectable material in which fly ash is mixed, and its adoption to the repair work of the headrace tunnel

Generally the headrace tunnel has maintained a sound condition and so it was planned to use the entire length for the new facilities. However in order to secure long-term soundness, it was necessary to take the countermeasure of filling in the void behind the lining concrete for about 1.1 km which was supposed to have been created when initially constructed. But, since the cross section of the headrace tunnel was small, and it was difficult to convey the construction equipment such as a squeeze pump into the tunnel, it became necessary to use injectable material which enabled long distance pneumatic pressure feeding (Fig. 6, 7).

For this purpose, investigations in the laboratory and trial and error studies by test implementation were repeated, and as a result, an injectable material mixed with fly ash (added amount of fly ash: 450kg/m^3) which is excellent in long distance feeding and has filling and non-leaking properties and necessary strength was developed and adopted on the actual construction site (Table 1).

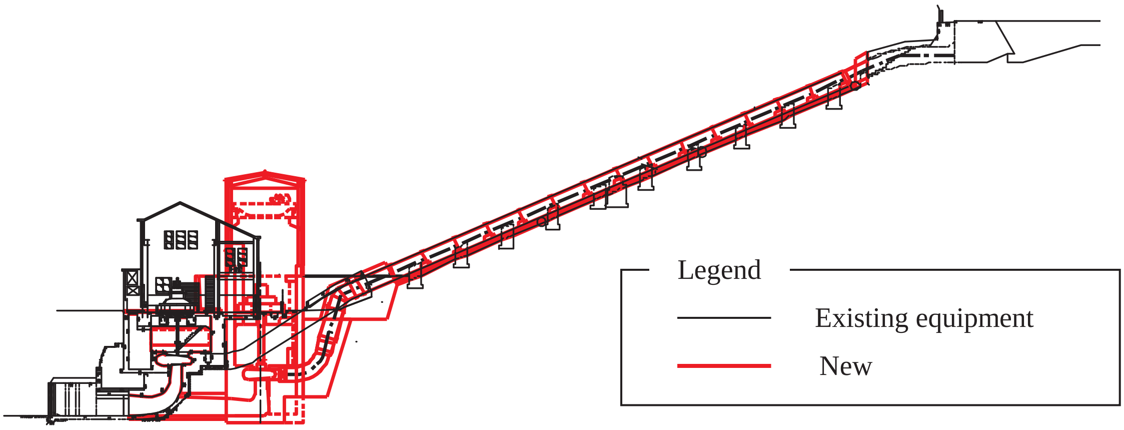


Fig. 2 Comparison of penstock and powerhouse building

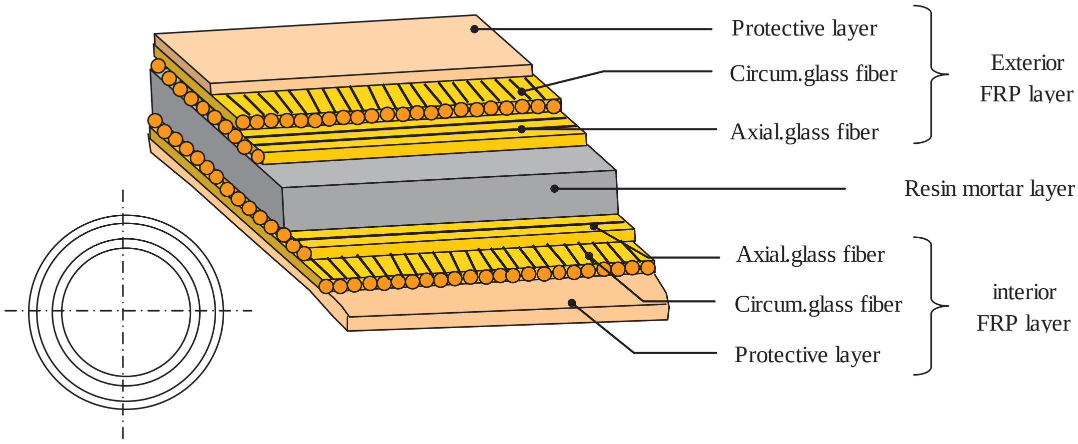


Fig. 3 Cross section structure of FRPM pipes（Filament Winding）

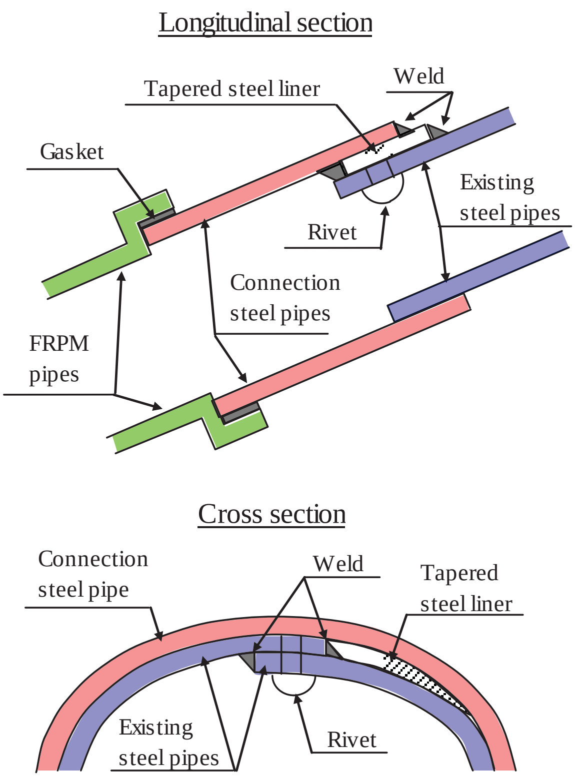


Fig. 4 The connection of existing steel pipes and FRPM pipes

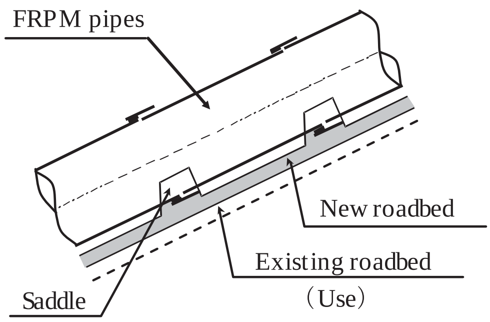


Fig.5 Support type of penstock

Photo 1 View of saddle

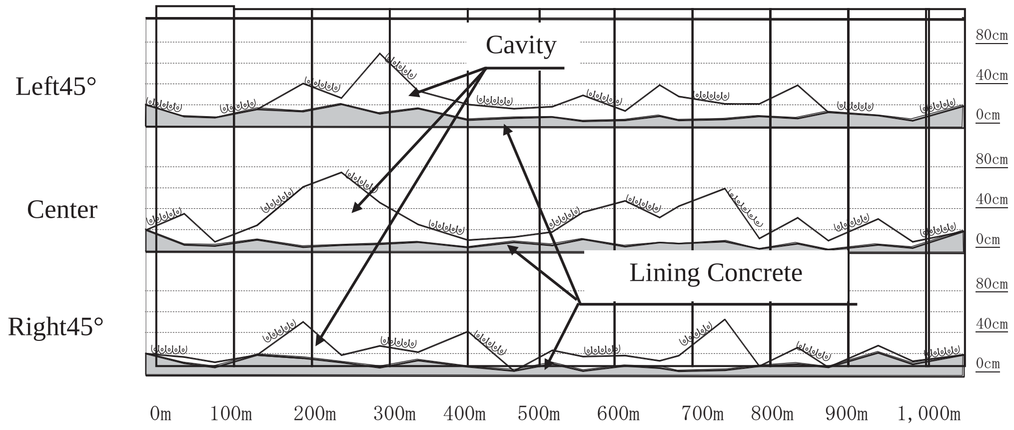


Fig. 6 Cavity of headrace tunnel roof arch

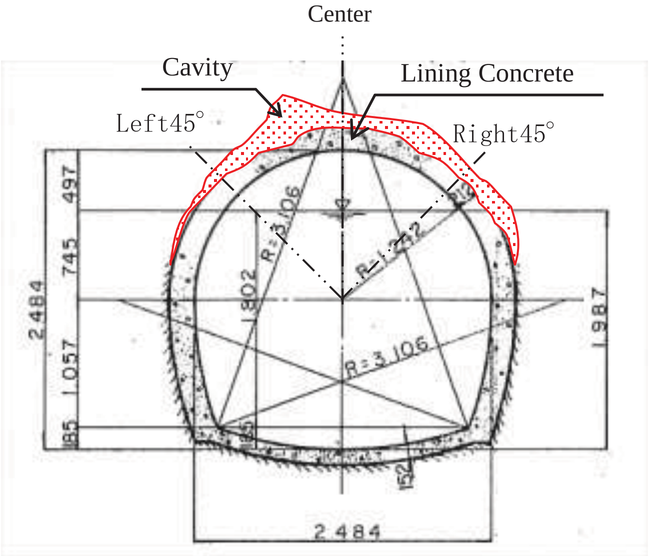


Fig. 7 Headrace tunnel（sectional view）

Table 1 Mixture proportions of filling material

（Unit content：kg）

A-liquid			
Fly ash Class II ※	Stabilizer	Water	Admixture
450	250	280	3. 5

※JIS A 6201

B-liquid		
Plasticizer	Water	Admixture
85	408	0. 9

A-liquid ＋ B-liquid ＝ 1,000 liter

3. Feature of the Project

3.1 Best Practice Components

- Minimum maintenance by adopting the FRPM pipe
- Cost saving by reusing of the existing facilities.
- Development of backfilling materials which were excellent for long distance feeding

3.2 Reasons for Success

Since the renovation project of the power station included a wide variety of improvements to the entire facility and required a huge investment of money and a long generation stoppage, it was therefore necessary to reduce the construction time and cost. In this project, renovation methods for each portion of the facility were studied in great detail so as to reduce cost and down time, new technologies were developed and adopted, and also the existing facilities were reused where possible. These were reasons that this project succeeded.

Particularly, the adoption of the FRPM hydraulic pipe for the first time in our company, by developing and adopting the new method to solve the problem of the step at the joint area so as to secure water tightness between the existing steel pipe and new FRPM pipe contributed to the project’s success.

On top of that, in consideration of improving the flowability of concrete by mixing with fly ash, to improve the pressure filling property of the solidification material (A-liquid), a large amount of fly ash (450kg/m^3) was added, yielded a backfilling injectable material which is excellent for long distance feeding, and put into practical use. This is also one of the reasons why this project succeeded.

4. Points of Application for Future Project

(Adoption of a FRPM pipe)

When an FRPM pipe is designed, it is necessary to consider the various usage environmental conditions such as a high pH of intake river water, acidic water common in volcanic regions and elevated water temperature, and the need to take actions so as to prevent serious deterioration of materials by these conditions.

(Usage of the plastic injectable materials in which fly ash is mixed)

Depending on required specifications, construction work conditions (pressure feed distance, head, filling range, etc.) and the variable quality of fly ash as the main material, composition and mixing conditions need to be adjusted.

5. Others (monitoring, ex-post valuation etc.)

(Not applicable)

6. Further Information

6.1 Reference

1) T. Kaji., et al., "Plan and construction status of the renovation of the Yusuharagawa No.3 Hydroelectirc Power Station", *Journal of Electric power Civil Engineerin*g, volume 332 (2007.11)
2) M. Masuda, et al., "Development of the injectable backfilling material for long distance feeding using fly ash", *Journal of Electric power Civil Engineerin*g, volume 334 (2008.3)
3) T. Kaji., et al., "Plan, design and construction of the renovation of the Yusuharagawa No.3 Hydroelectirc Power Station", *NEF, Text for the workshop for the small and medium-sized hydroelectric power station, second text of 2008 (total 84 times)* ,October, 2008
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6.2 Inquiries

Company name: Shikoku Electric Power Company

URL: http://www.yonden.co.jp/

Format for the 2nd Round Data Collection (Definition of Case Histories)

Category and Key Points

Main: 2-c) Technological innovation, deployment expansion and new materials used for civil and building works

Project Name:

The restoration work of the intake weir and others of the Kawabegawa No. 1 Hydroelectric Power Station

Name of Country (including State/Prefecture):

Japan, Kumamoto Prefecture

Implementing Agency/Organization:

Kyushu Electric Power Co., Inc.

Implementing Period:

From 2008 to 2012

Trigger Causes for Renewal and Upgrade:

(F) Accidents and disaster

Keywords:

Destruction of facilities, Disaster restoration, Sedimentation, Inflatable rubber weir

Abstract:

In June 22, 2008, in our Kawabegawa No. 1 Hydroelectric Power Station, the water intake, sediment discharge gate, fish pass and other facilities were destroyed during the gate discharging associated with the heavy rain from a seasonal rain front. After that, on July 5, the spillway gate of the intake weir was destroyed and some part of the administration bridge collapsed, expanding the damage. Consequently, in 2008, the countermeasure construction work was conducted to prevent the damage to these facilities from expanding. For the restoration work following, in 2009 the work was started and completed in 2012.

1. Outline of the Project (before Renewal/Upgrading)

The Kawabegawa No. 1 Power Station owned by Kyushu Electric Power Co., Inc. is a run-of-river power station with a maximum output of 2,500kW (2,500kW × 1 generator). It is located in Itsuki-mura, Kuma-gun mid-way down the Kawabegawa River which is the largest tributary of the Kumagawa River which flows through the southern district. This power station was constructed in 1937 by the Kumamoto Electric company, and after that was taken over first by the Kyushu Electric company, next by the Kyushu Electric Distribution company, and finally in 1951, by the Kyushu Electric Power Co., Inc. The location map, Photo and the specifications of the power station are shown in Fig. 1, Photo 1 and Table 1.

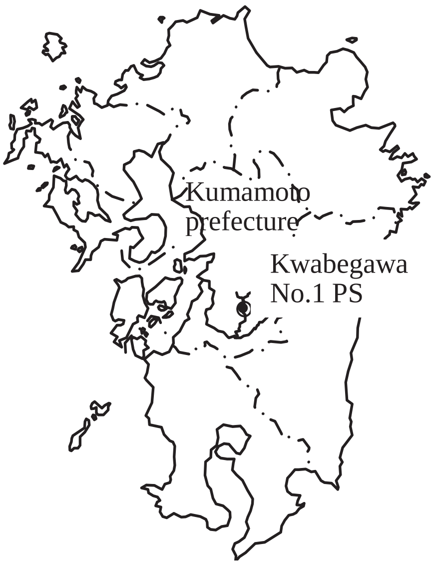

Fig. 1: Location map of the power station

Photo 1: Status of the intake weir before destruction

Table 1: Specifications of the No. 1 Kawabegawa water intake weir

Item		Specifications
Basin area		360.30km^2
Design flood discharge		2,124m^3/s (previous maximum: 1,539ｍ^3/s：2005/9)
Intake weir	Type	Concrete gravity weir
	Dimension	Length of weir top 71.500m, Height of weir 11.500m, Base width 15.000m
	Spillway gate	Radial gate: width 8.000m × height 4.500m × 6 gates (installed in 1937: 71 years have passed)
	Sediment discharge gate	Slide gate: width 4.900m × height 3.035m × 1gate (replaced in 1966: 42 years have passed)
Water inlet	Structure	Concrete
	Dimension	Total length 21.400m × width 7.200m × height 3.200m
	Regulating gate	Slide gate: width 1.900m × height 3.250m × 3gates (replaced in 1963: 45 years have passed)
	Driftwood gate	Slide gate: width 2.100m × height 1.900m × 1gate (installed in 1937: 71 years have passed)
Fish passage	Structure	Made by concrete and stonework, stairway-type, grade 1/12
	Dimension	Total length 90.000m × width 3.000m × height 2.800m
	Regulating gate	Slide gate: width 3.130m × height 2.340m × 1gates (replaced in 1963: 45 years have passed)
	Discharge	0.5m^3/s (discharge period: April.1 to October 31)
Date of the operation start		July, 1937

2. Description of the Renewal and Upgrading of the Project

2.1 Trigger Causes and Drivers for Renewal and Upgrading

(1) Condition, capability, influence of risk and others

(F)- (a) Accidents and disaster - Recovery

On June 22, 2008, during the gate discharge forced by flooding caused by a major storm in a rainy season, the water intake, sediment discharge gate, fish pass and other structures were destroyed. After that, on July 5, the spillway gate of the water intake weir and some part of the administration bridge was destroyed and fell, expanding the damage.

(2) Improvement of value (functions)

(Not applicable)

(3) Necessity in market

(Not applicable)

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

July 1937:	Operation of the Kawabegawa No. 1 Power Station began
November 1963:	Replacement of the regulating gate of the water intake and the regulating gate of the fish pass
December 1966:	Replacement of the sediment discharge gate of the weir
June 2008:	The structures such as the water intake, sediment discharge gate, fish pass and others were destroyed.
June 2008:	Removal of the destroyed structures began
July 2008:	Spillway gate and part of the administration bridge collapsed
January 2009:	Removal of the destroyed structures was completed
June 2009:	Temporary restoration work was completed (countermeasures to prevent damage expansion)
January 2010:	The full-scale restoration work began
June 2012:	The full-scale restoration work was completed.

2.3 Description of Work Undertaken (detail)

2-c) Technological innovation, deployment expansion and new materials used for civil and building works

This facility was constructed before the design standard for dams/weirs had been established. Therefore, the reason why this destruction occurred was as follows; none of the damaged facilities were embedded into the foundation rock, and the seepage control was not installed on the water intake weir body, so the foundation area was locally undermined by seepage water for many years. On top of that, there was a huge rain, so the revetment downstream of the water intake weir was broken down and the embankment was washed out, so it was assumed that the damage then expanded into the upstream side.

For implementing the countermeasures, first, the destroyed water intake weir, intake inlet, sediment discharge gate and fish pass were planned to be restored. This was especially because the intake weir was constructed on the river bed sand and gravel; the foundation supporting force was confirmed by the plate bearing test.

It was planned that the intake weir was to be modified to a rubber cloth type shutter weir (rubber weir) which enabled labor savings for the positive discharge operations, and thus the intake weir was restored. When the adoption of a rubber weir was considered, a rubber bladder support type steel shutter weir (SR weir) was also considered. But the height of the rubber weir which was restored in this project was 5.8m, and there was no similar scale actual construction to compare to and the technology was not yet established. Therefore, it was thought that it would take a long time to design and be difficult to restore at a necessary pace, so the SR weir was not adopted.

For the seepage control work, not only from the view point of assuring creep length but also with a view to prevent sucking by the flow and/or washing out of the structure foundation, it was decided that sheet piling was to be embedded in the foundation bedrock upstream and downstream. As for the water intake and fish pass, with a view to restore them to their original status, reinforcement work was conducted as necessary.

The status of the destruction of the water intake weir is shown in Photo 2, and the specifications after restoration are shown in Table 2, Fig. 2, 3, 4 and Photo 3.

Photo 2: Distant view of the destruction of the water intake weir

Table 2: Specifications of the Kawabegawa No. 1 water intake weir (before and after renewal)

Item		Specification
Water intake weir	Type	Concrete gravity dam
	Dimension	Length of weir top: 72.500m, Height of weir: 13.250m Base width:32.700m
	Rubber weir	Rubber weir: width 24.000 × height 5.800m × 2 gates
	Sediment discharge gate	Roller gate: width 4.500m × height 3.000m × 1 gate
Water intake	Structure	Made by concrete
	Dimension	Total length 22.011m × width 6.450m × height 4.900m
	Regulating gate	Slide gate: width 2.650m × height 2.700m × 2 gates
Fish passage	Structure	Made by concrete, cascade type, gradient 1/12
	Dimension	Total length 129.100m × width 3.000 m × height 0.95-2.45m
	Regulating gate	Slide gate: width 3.000m × height 3.000m ×1 gate
	Discharge	$0.5m^3/s$ (discharge period: April 1 – October 31)

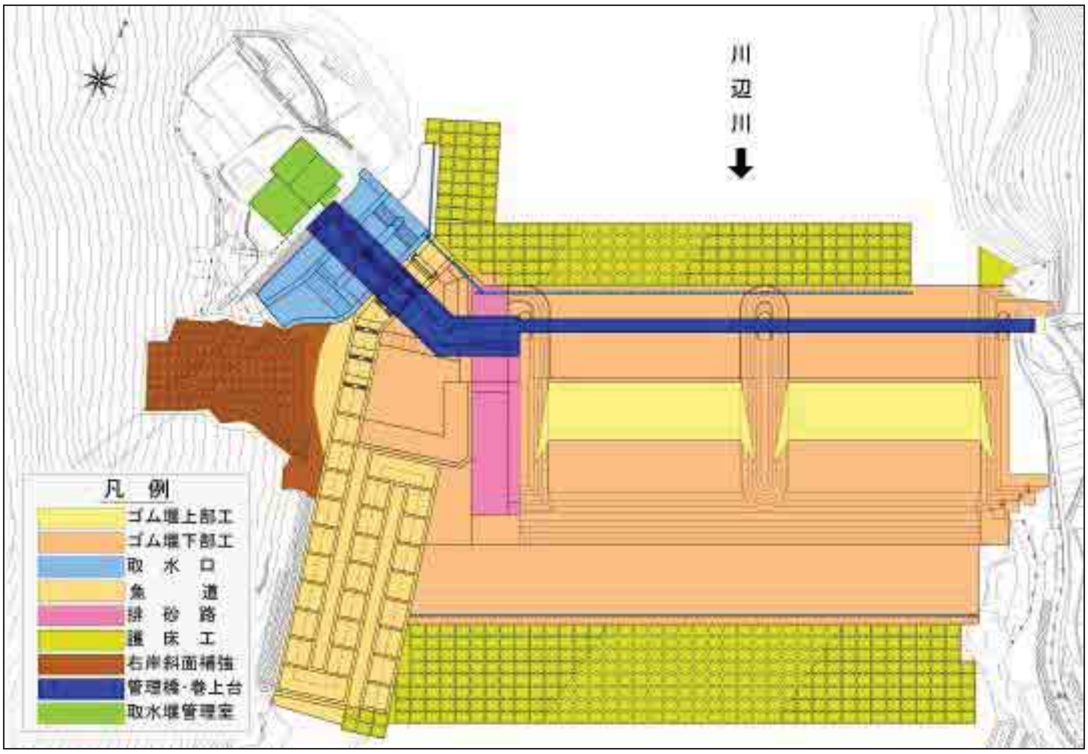

Fig. 2: Restoration plan diagram of the Kawabegawa No. 1 water intake weir

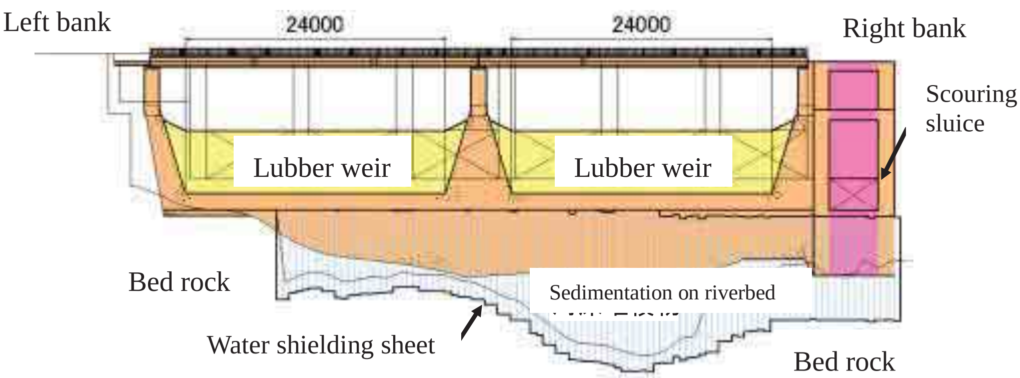

Fig. 3: Diagram of the upstream view of the intake weir

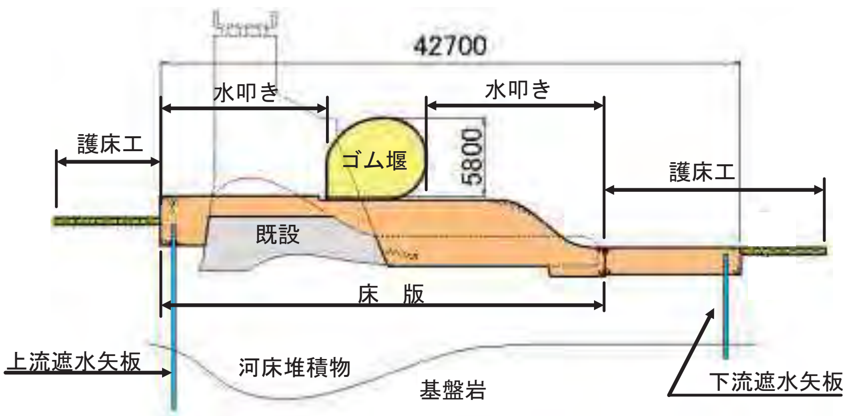

Fig. 4: Cross section view of the water intake weir

Photo 3: Photo of the water intake weir after restoration

3. Feature of the Project

3.1 Best Practice Components

- Countermeasure for water shielding of the foundation of the intake weir

3.2 Reasons for Success

The design of the water shielding is a steel cutoff sheet-pile (III type) structure. Since a large boulder was found in the river bed, advance excavation was conducted before construction using a large diameter boring machine. The inside of the created cavity was filled with sand, and the cutoff sheet-pile was installed. Thus, the following work was able to be quickly conducted such as: the prevention of the occurrence of lateral force to the cutoff sheet-pile, confirmation of whether the cutoff sheet-pile reached the supporting bedrock or not, and confirmation of the excavated length of the foundation (more than 1.2m).

The point where the steel cutoff sheet-pile was embedded was excavated more than 1.2m and injected with liquid shielding material to improve the shielding effect. After construction, the coefficient of permeability was measured with a single hole type permeability test (Tube method) and its effect was confirmed.

4. Points of Application for Future Project

(Prior confirmation of the river bed sand gravel and the foundation line)

In this project, by prior confirmation, a large boulder was found in the river bed, therefore advance excavation work was conducted by a large diameter boring machine. In this manner, it is necessary to investigate every detail on how to conduct construction work depending on the situation of the river bed.

5. Others (monitoring, ex-post valuation etc.)

(Not applicable)

6. Further Information

6.1 Reference

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2) Tsuruoka, Iwata, Terajima, "The design and construction of the restoration work of the water intake weir and other parts of the Kawabegawa No. 1 Power Station", *Journal of Electric power Civil Engineerin*g, volume 357 (2012.1)

6.2 Inquiries

Company name: Kyushu Electric Power Company

URL: http://www.kyuden.co.jp/

Format for the 2nd Round Data Collection (Definition of Case Histories)

Category and Key Points

Main: 2-c) Technological innovation, deployment expansion and new materials used for civil and building works

Sub: 1-f) Environmental conservation and improvement

2-a) Technological innovation & deployment expansion of electro-mechanical (E/M) equipment

Project Name:

Expansion Project for the Okutadami and Ohtori Hydropower Stations

Name of Country (including State/Prefecture):

Japan, Fukushima Prefecture, Niigata Prefecture

Implementing Agency/Organization:

Electric Power Development Co., Ltd.

Implementing Period:

From 1999 to 2003

Trigger Causes for Renewal and Upgrade:

(C) Needs for higher erformance

Keywords:

Waterway Tunnel Expansion, Power Generation Using Ecological Flow, Deep Depth Closure Facility

Abstract:

The expansion project for the Okutadami and Ohtori Hydropower Stations aimed to expand new power generation facilities by using the existing Okutadami Dam and Ohtori Dam, and to increase their peak supply capacity by 287,000kW (Okutadami expansion; 200,000kW, Ohtori expansion; 87,000kW). This was the largest case in Japan in terms of an expansion of a conventional type of hydropower by increasing the peak response capacity of a large-scale reservoir, and also aimed to contribute to the reduction of CO_2 emissions. Along with the expansion of the Okutadami Hydropower Station, Ecological Flow discharge facilities were constructed, and using these facilities, the Power Station Using Ecological Flow (maximum output :2,700kW) was constructed simultaneously.

1. Outline of the Project (before Renewal/Upgrading)

(1) Okutadami Hydropower Station

The Okutadami Hydropower Station is a dam type power station with a maximum output of 360,000kW on the Tadamigawa River of the Aganogawa water system located in Hinoemata-mura, Minami Aizu-gun, Fukushima Prefecture. This power station was constructed so as to respond to the rapid increase of electricity demand after the war. The location is shown in Fig. 1, and a general plan view and the longitudinal profile of the water channel are shown in Fig. 2 & 3.

(2) Ohtori Hydropower Station

The Ohtori Hydropower Station is a dam type power station with a maximum output of 95,000kW on the Tadamigawa River of the Aganogawa water system located in Tadami-machi, Minami Aizu-gun, Fukushima Prefecture. This power station controls the generation discharge from the Okutadami Power Station upstream and utilizes a head from the reservoir of the Tagokura Power Station downstream. The location map is shown in Fig. 1 and a general plan view and a longitudinal profile of the water channel are shown in Fig. 4 & 5.

Fig. 1: Location map (Okutadami Power Station and Ohtori Power Station)

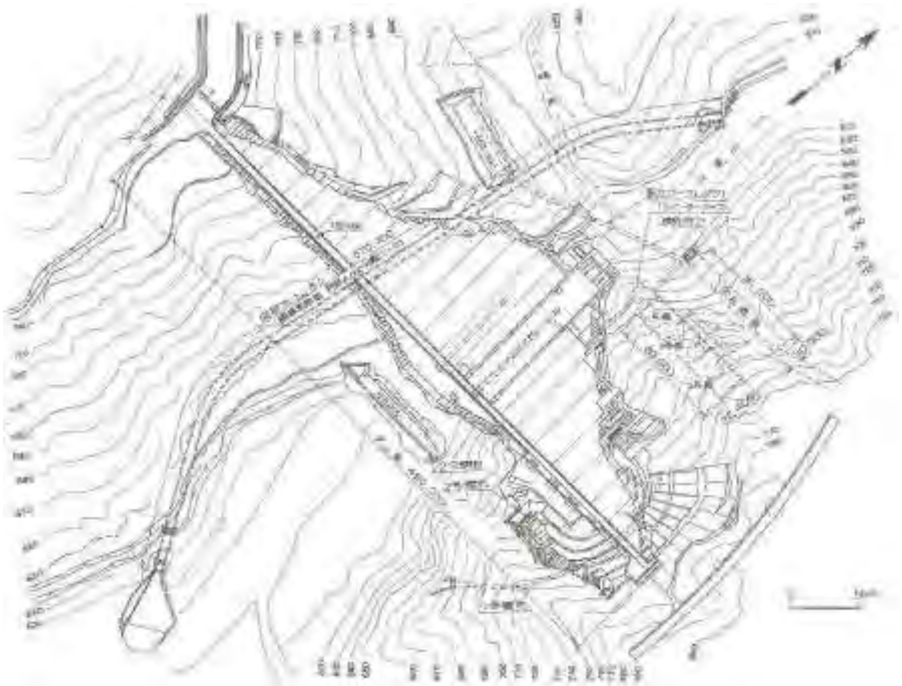

Fig. 2: General plan view (Okutadami Power Station)

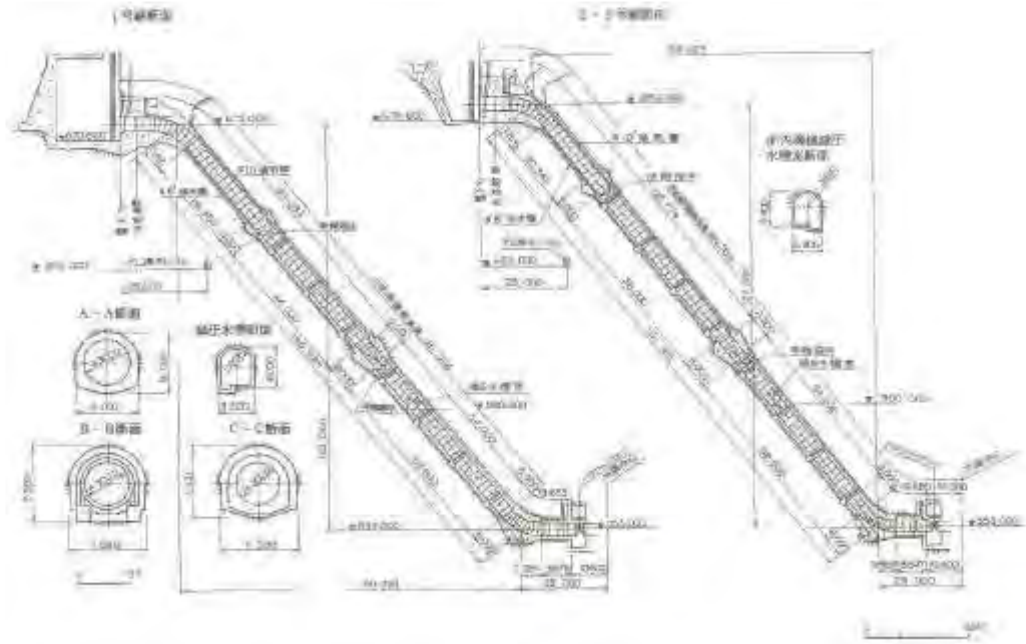

Fig. 3: Longitudinal profile of the water channel (Okutadami Power Station)

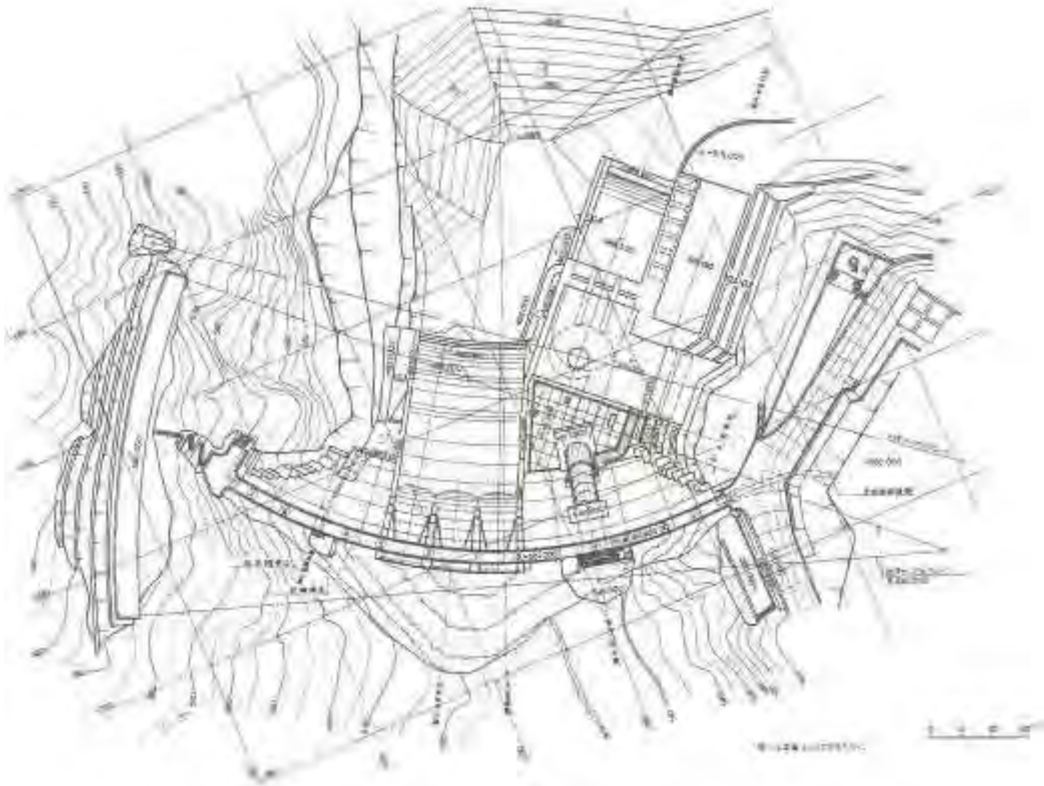

Fig. 4: General plan view (Ohtori Power Station)

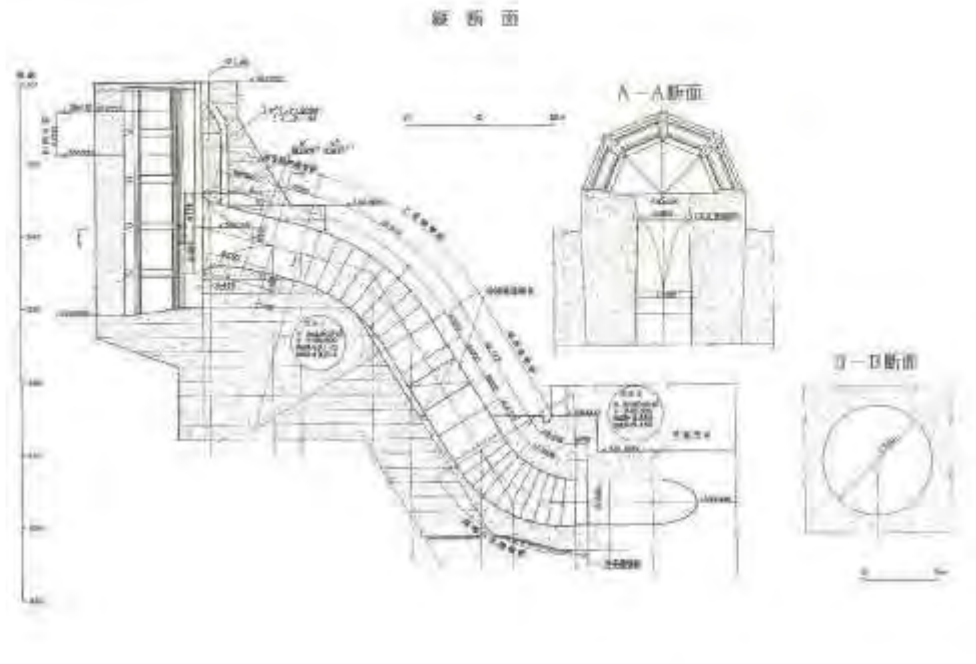

Fig. 5: Longitudinal profile of the water channel (Ohtori Power Station)

2. Description of the Renewal and Upgrading of the Project

2.1 Trigger Causes and Drivers for Renewal and Upgrading

(1) Condition, capability, influence of risk and others

(Not applicable)

(2) Improvement of value (functions)

(C)- (a) Needs for higher performance - Expansion, increase of output per hour

The project site is located on the border between Fukushima Prefecture (right bank side) and Niigata Prefecture (left bank side) upstream on the Tadamigawa River of the Aganogawa water system. The Okutadami Power Station is located in Hinoemata-mura, Minami Aizu-gun, Fukushima Prefecture, and the Ohtori Power Station is located in Tadami-machi of the same. (See Fig.6)

(1) Expansion project of the Okutadami Power Station

This project aimed to increase the plant discharge at the daytime peak by a maximum of 138 m^3/sec, and to generate a maximum output of 200,000kW by obtaining an effective head of 164.2m. The expanded water intake was installed on the right bank side of the existing water intake along with the Okutadami Dam. The hydraulic steel pipe was passed through the dam body, and after that, by a vertical shaft and lower level tunnel, water was to be brought to the underground power station. The power station was expanded in an underground direction, and the tailrace was installed parallel to the existing tailrace. Water is discharged from the new outlet which is located 200m downstream of the existing outlet into the Ohtori regulating reservoir (total pondage; about 16,000,000m^3).

Fig. 7 and Fig. 8 show a plan view of the expanded power station and the longitudinal profile of the hydraulic pipe line.

(2) Expansion project of the Ohtori Power Station

This project aimed to generate a maximum output of 87,000kW by increasing plant discharge by a maximum of 207 m^3/sec by using the added plant discharge from the expanded Okutadami Power Station and by obtaining an effective head of 48.1m. The expanded water intake was installed on the right bank of upstream of the Ohtori Dam. The hydraulic pipe was installed as an inclined shaft and water is delivered to the underground power station. Water used for generation passes through the tailrace which was prepared by expanding the temporary discharge channel made for the expansion of the Ohtori Dam and is discharged into the Tagokura Reservoir from the outlet. The plan view and the longitudinal cross-section of the planned expanded Ohtori Power Station are shown in Fig. 9 and Fig. 10. The specifications are shown in Table 1.

Work on both expansions of Okutadami and Ohtori were started in July, 1999 and their operation began in June, 2003. (Power Generation Using Ecological Flow was also started at the same time)

Fig. 6: Planned location

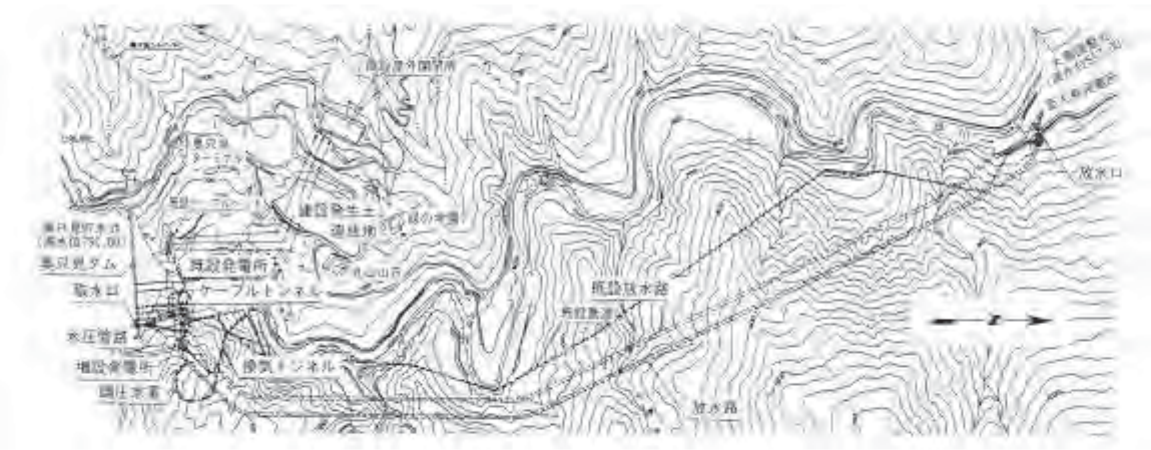

Fig. 7: Plan view of the planned Okutadami expanded power station

Table 1: Specifications of the generation plan

Name of power station	Okutadami Power Station		Okutadami Power Station Using Ecological Flow	Ohtori Power Station	
	Existing	Expansion	New constructed	Existing	Expansion
Basin area (km^2)	595.1		595.1	656.9	
Generation type	Dam and conduit type		Dam type	Dam type	
Used water depth (m)	60	25	60	6	
Maximum output (kW)	360,000	200,000	2,700	95,000	87,000
Maximum plant discharge (m^3/s)	249	138	2.56	220	207
Effective head (m)	170.0	164.2	130.3	50.8	48.1

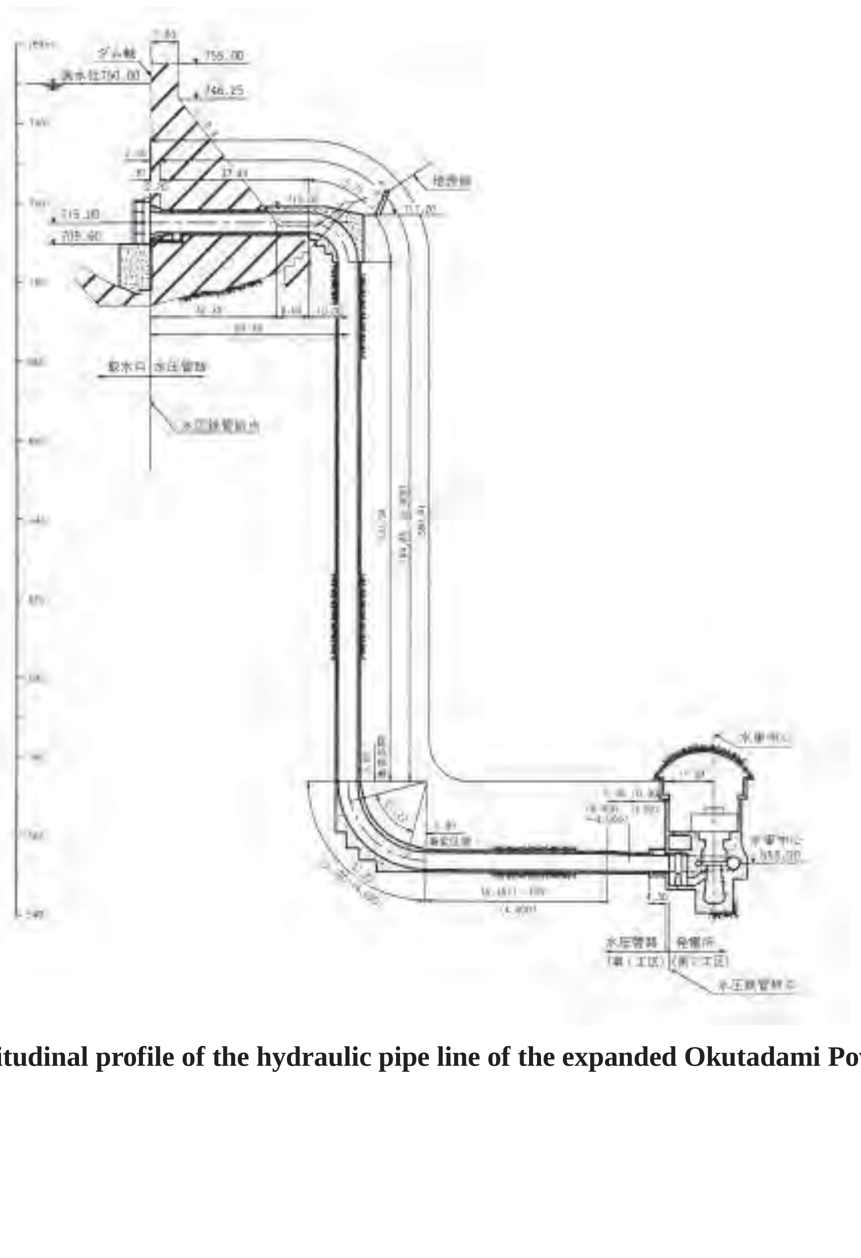

Fig. 8: Longitudinal profile of the hydraulic pipe line of the expanded Okutadami Power Station

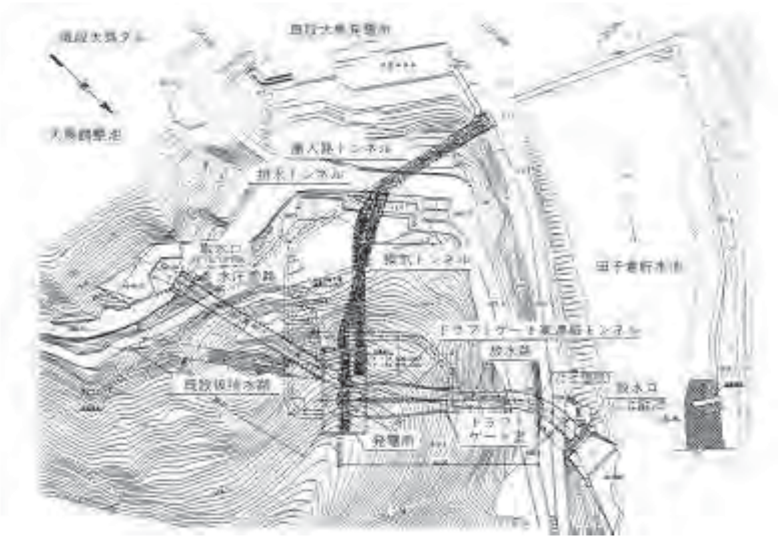

Fig. 9: Plan view of the planned expanded Ohtori Power Station

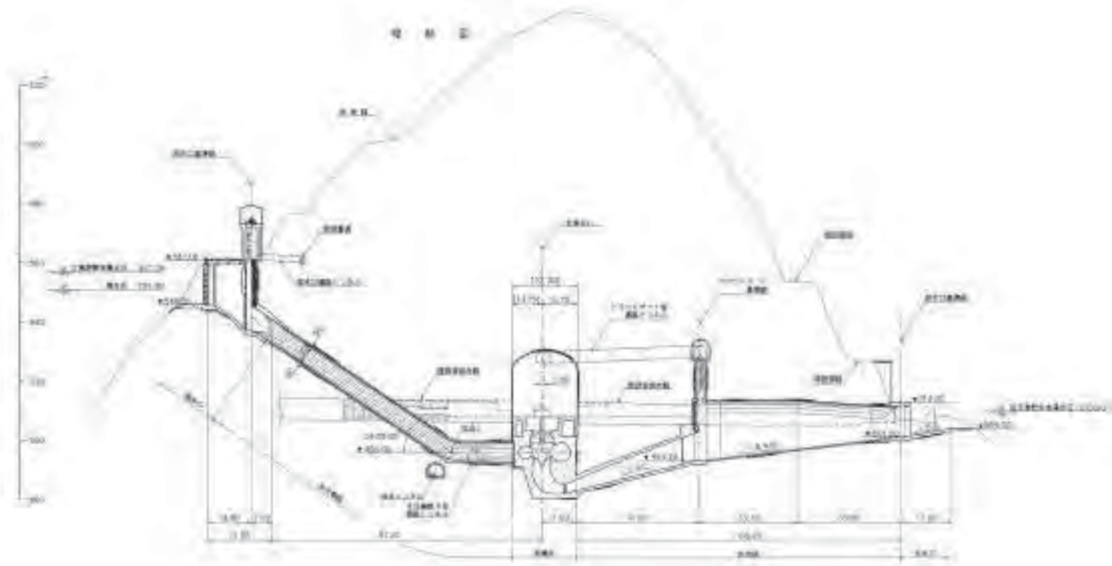

Fig. 10: Longitudinal profile of the hydraulic pipe line of the expanded Ohtori Power Station

(3) Necessity in market

(Not applicable)

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

December 1960:	Operation of the Okutadami Power station (existing power station) began
November 1963:	Operation of the Ohtori Power station (existing power station) began
October 1993:	The study of the project began
June 1994:	Construction of the adit for the survey of the Okutadami Power Station began
July 1994:	Construction of the adit for the survey of the Ohtori Power Station began
July 1999:	The main construction of the expansion of the Okutadami Power Station and Ohtori Power Station began
June 2003:	Commercial operation of the expanded Okutadami and Ohtori Power Station began
October 2003:	Completion ceremony was conducted.

2.3 Description of Work Undertaken (detail)

1-f) Environmental conservation and improvement

With the view to protect the natural ecosystem including the protection measures for Golden Eagles and Mountain Hawk Eagles, and to continuously minimize the environmental load caused by the expansion construction, the following environmental countermeasures were conducted:

(1) Protection of rare important birds

During the nest building period (from November to June), within a radius of 1.2km from the bird nests, the structures on the ground were not worked on and vehicle traffic was voluntarily refrained. The makeshift facilities which were used only for construction in the non-nest building period (from July to October) were removed during the nest building period as much as possible. The makeshift facilities necessary for the construction of the underground structures were located more than 1.2km away from the nests, and the necessary materials and machines were brought in during the non-nest building period. Also in the nest building period, vehicle conveyance using the construction road was canceled.

(2) Countermeasures against noise and vibration

To reduce the noise and vibration caused by blasting, the long delay blasting method was adopted and a soundproof door was installed on the tunnel mouth. In addition, the concrete manufacturing facilities and the aggregate production facilities were placed inside of the building to improve sound insulation. On top of that, for the construction machines, low noise types were adopted as much as possible. For the construction vehicles, a self-imposed speed limit and restricted traffic (holding the proper traffic distance) was adopted, and when vehicles stopped, engine idling was stopped.

(3) Countermeasures to maintain water quality

Construction water was recycled as much as possible, and the all construction drainage was cleaned by a turbid water treatment system, and only after confirmation of its quality, was water discharged into the public water area. With regard to the underwater construction (construction of the water intake), dual pollution preventing membranes were installed to prevent muddy water from spreading.

(4) Lighting and color strategy

The range of the night lighting was limited to the minimum necessary for construction safety and high-pressure sodium lamps, which have less impact on insects and plants, were adopted. Windows of the makeshift buildings were covered with shades so that light from the interior wouldn’t leak outside. As for the external color of the makeshift facilities and construction machines, colors which would upset birds (red, yellow) were avoided.

2- c) Technological innovation, deployment expansion and new materials used for civil and building works

In the construction of the Okutadami water intake, it was necessary to not lower the reservoir water level during the construction because of the regular reservoir operation continuing the operation of the existing power station. Consequently, on the upstream side of the dam, a steel concrete semicircle makeshift cofferdam with a maximum water depth of 50m (the first construction case of this size in Japan) was installed so that construction of the water intake, boring of a hole into dam body and installation of the hydraulic steel pipe, intake gate sheet and others were able to be conducted in dry conditions.

This makeshift cofferdam has a structure with a radius of about 8m which resists water pressure by the axis force. Outline of the makeshift cofferdam is shown in Fig. 11. This was a cell type makeshift cofferdam which was made up of 13 box type steel sheet-piles with an arch length of about 8m in the circumferential direction, and 4 steel sheet-piles vertically. The inside of the box type steel was filled with underwater concrete. These actions made it possible for the relatively thin 65cm structure to function as a makeshift cofferdam against the tough pressure conditions of the 50m installation depth.

Fig.11: Outline of the makeshift cofferdam

In the same manner as Okutadami, for the Ohtori, since the construction was to be conducted while continuing operations, prior to the water intake construction, by building the double cofferdam with steel sheet piles in advance, the construction of the water intake and the hydraulic steel pipe line were conducted inside of the makeshift cofferdam without lowering the water level of the Ohtori Reservoir. After the water intake structure was completed and the intake gate was installed and fully closed, then the makeshift cofferdam was removed.

2-a) Technological innovation & deployment expansion of electro-mechanical (E/M) equipment

Along with the expansion of the Okutadami Hydropower Station, Ecological Flow discharge facilities were constructed, and using these facilities, the Power Station Using Ecological Flow (maximum output :2,700kW) was constructed simultaneously.

3. Feature of the Project

3.1 Best Practice Components

By adding to the generation facilities on the existing dam, the peak response capacity of the large-scale reservoir was increased and the increase of the peak supply capability (which was the largest scale in Japan as a case of expansion of the general power station) was achieved.

By adopting new technologies and aggressively planning facilities, construction and design, securement of the work terms and cost savings were achieved. Thus, environmental conservation and development were both successfully achieved without lowering the reservoir water level and without giving any adverse impact on the operation of the existing power station.

3.2 Reasons for Success

The Expansion Project for the Okutadami and Ohtori Hydropower Stations was the case in which the construction was completed in a scheduled period and able to secure the operation start in time under various severe conditions such as being in a heavy snowfall area, necessary environmental preservation measures for precious rare birds, and restricted short work periods due for bird protection

In this project, the latest civil engineering technologies were adopted, such as the large-scale makeshift cofferdam, installation of the expanded water intake by making a hole in the dam body and stability analysis of the existing power station's hollow space accompanying the excavation for the underground power station. By means of these items' consideration, work periods were secured and cost savings were achieved. Generally, the excellent prior design consideration including analysis in every detail and good consideration of the actual site construction plan was thought to be the reason for the success.

4. Points of Application for Future Project

Though a large-scale makeshift cofferdam and hole boring through a dam body are becoming common civil engineering technologies, when adopted, it is necessary to consider the restriction of the reservoir operation and facilities size in every detail and it is important to optimize them.

And since the environmental preservation measures depend heavily on the area specific properties, it is important to conduct an advance environmental survey and to consult with the related supervisory authorities and local governments.

5. Others (monitoring, ex-post valuation etc.)

(Not applicable)

6. Further Information

6.1 Reference

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2) Tobase, Sato, Yoshimura, "Environment conservation measures for the expansion work for the Okutadami and Ohtori Hydropower Stations", *Journal of Electric power Civil Engineering*, (2000.9)

3) Tonomura, Sato, “The construction of the Okutadami and Ohtori Hydropower Stations which considered nature”, Dam Japan (2000.8)

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6.2 Inquiries

Company name: Electric Power Development Company

URL: http://www.jpower.co.jp/

ANNEX XI Renewal & Upgrading of Hydropower Plants

Format for the 2nd Round Data Collection (Definition of Case Histories)

Category and Key Points

Main: 2-c) Technological innovation, deployment expansion and new materials used for civil and building works

Project Name:

Repair and Countermeasure of Kuttari Dam Spillway Gate Damaged by Earthquake

Name of Country (including State/Prefecture):

Japan, Hokkaido

Implementing Agency/Organization:

Electric Power Development Co., Ltd.

Implementing Period:

1993

Trigger Causes for Renewal and Upgrade:

(D) Needs for safety improvement

(F) Accidents and disaster

Keywords:

Anti-seismic Reinforcement, Spillway Gate, Gear Coupling

Abstract:

On January 15, 1993, the Kushiro offshore earthquake occurred with a 5 on the Japanese intensity scale (at the Obihiro district) and damaged the winch of the spillway gate and the fixed part of the operation bridge of the Kuttari Dam Spillway Gate. Correspondingly, this project was planned to examine the restoration of the function of the winch of the spillway gate and to conduct the countermeasure construction work.

1. Outline of the Project (before Renewal/Upgrading)

1.1 Brief overview of the project site

The Kumaushi Hydropower Station which has the Kuttari Dam, is a dam and conduit type power station with a maximum output of 15,400kW, annual generated energy of 97×10^6kWh, located midway down the Tokachigawa River (Shintoku-machi, Shimizu-machi, Kamikawa-gun, Hokkaido). For this power station, a rockfill dam with a height of 21.5m was constructed in Kuttari, Shintoku-machi, about 5km downstream from the Iwamatsu Power Station owned by the Hokkaido Electric Power Co., Inc which is at the lowest point in this river. With this created reservoir with a total pondage of 3.13 million m^3, generation discharge from the Iwamatsu Power Station (maximum; 37.5m^3/sec) and unused water flow are regulated daily, and water of 41.0m^3/sec at a maximum is taken from the intake at the left bank of the dam, and passed through a gravity flow tunnel about 6.3km long into a water tank and then via a pressurized line to the power station. The power station utilizes the head of 44.5m between these places to generate energy, and generation water is discharged by an open conduit about 1km long into the Tokachigawa River. The location of the power stations is shown in Fig. 1 and the planned specifications are shown in Table 1

1.2 Brief overview of the project

The Kuttari Dam has a design discharge of 3,100 m^3/sec and 3 roller gates with an effective span of 12.7m × door height of 13.5m. The overall view of the Kuttari Dam and spillway gates is shown in Fig. 2 & 3, and the main specifications of the spillway gates are shown in Table 2.

The door body is made up of one upper block and one lower block which share the water pressure. The upper block and lower block are connected with a pin at the vertical girder. 7 main rollers are installed on each side, and of them, 3 rollers are the rocker beam type. The material of the main components is SM570C, and for main rollers, SCMnCrM3B is adopted.

The opening/closing winch is a drum end wire rope winding type for which one motor has two drums. So as to secure operations in the winter season, for the No.2 gate sheet, a heater type anti-icing system is installed, and for the front of the door body, an air blow type anti-icing system is installed.

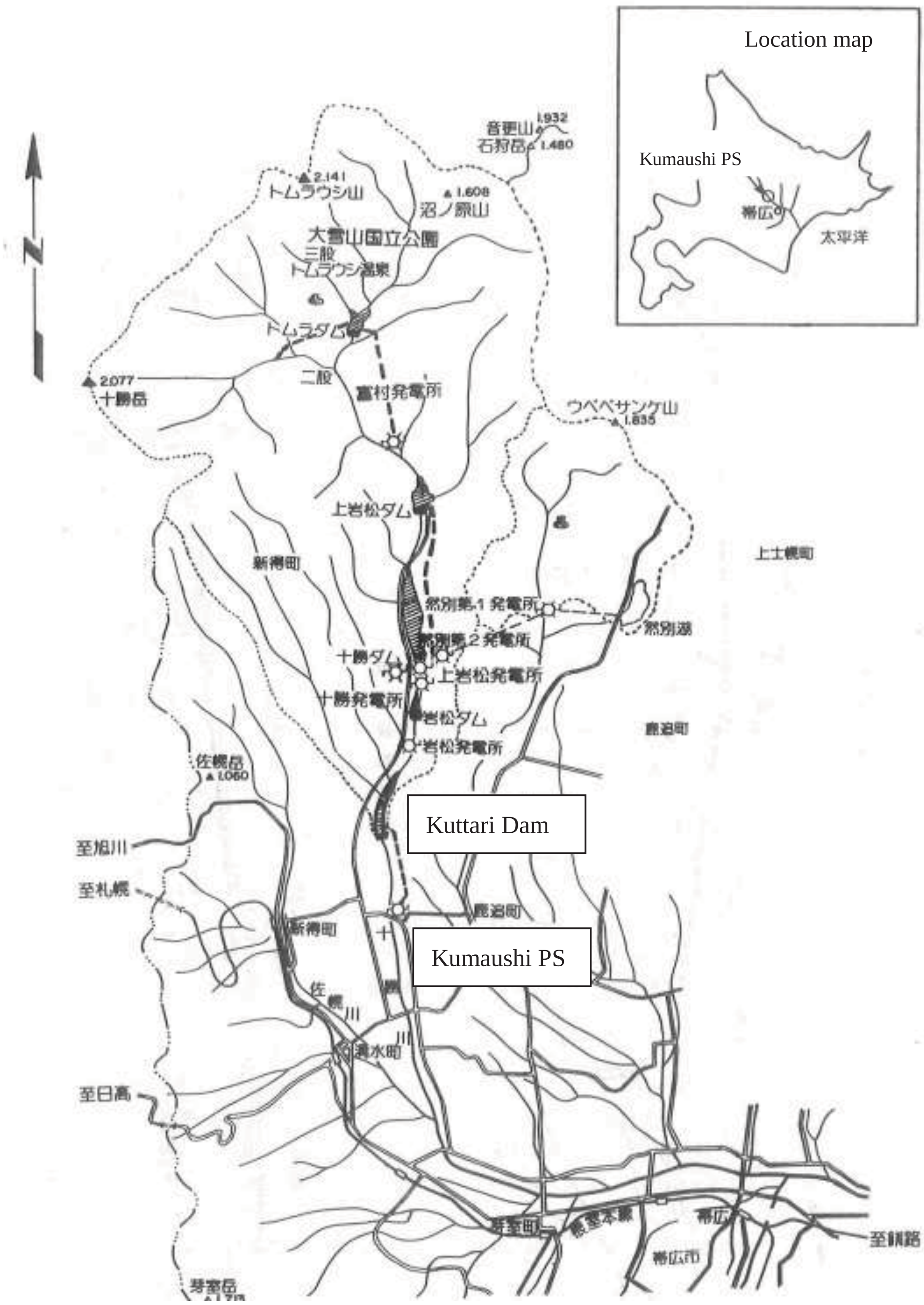


Fig. 1: Location map of the power station

Table 1: Project Features

Dam		Type	Central impermeable wall type, Rock-fill dam	
		Height	27.5m	
		Length of dam top	170.0m	
		Dam volume	173,000m^3	
Spillway		Type	Front overflow type	
		Dimension	Width 12.7 × height 13.5m ×3gates	
		Design discharge	3,100 m^3	
		Regulation mechanism	Roller gate	
Discharge facilities		Type	All duct type	
		Dimension	ϕ1,200 × 1gate	ϕ 500, ϕ 450
		Discharge capacity	10.00 m^3 /s	2.00 m^3 /s× 2
		Regulation mechanism	Jet flow gate	Sluice valve
Intake		Type	Reinforced concrete	
		Dimension	Width 12.0m × height 8.0m	
		Regulation mechanism	Roller gate; width6.0 × height 4.15m ×1gate	
Headrace		Type	Non-pressure tunnel	
		Dimension	Width 4.10m × height 4.15m, Total length 6,319m	
Surge Tank		Type	Reinforced concrete, General water tank	
		Dimension	Width 5.0m × height 3.8 – 6.7m ×length 85.4m	
		Gate	Roller gate; width 4.2 × height 4.2m ×1gate	
Penstock		Type	Hydraulic steel pipe ground type	
		Inside diameter	4.2 – 3.0m	
		Number of lines	1 line	
		Total length	284.34m	
Powerhouse		Type	Semi-underground type	
		Dimension	Width21.5m × height 30.4m ×length40.4m	
		Gate	Slide gate, width 5.0m × height 5.0m ×1 gate	
Tailrace		Type	Culvert, open channel	
		Dimension	Width 5.0 - 20.0m, height 4.0 - 6.0m, total length 1,017.0	
Main Equipment	Turbine	Type	Vertical Kaplan turbine	
		Output	16,000kW	
		Number of machines	1 turbine	
	Generator	Type	Vertical 3-phase AC synchronous generator	
		Volume	16,300kVA	
		Number of machines	1 generator	

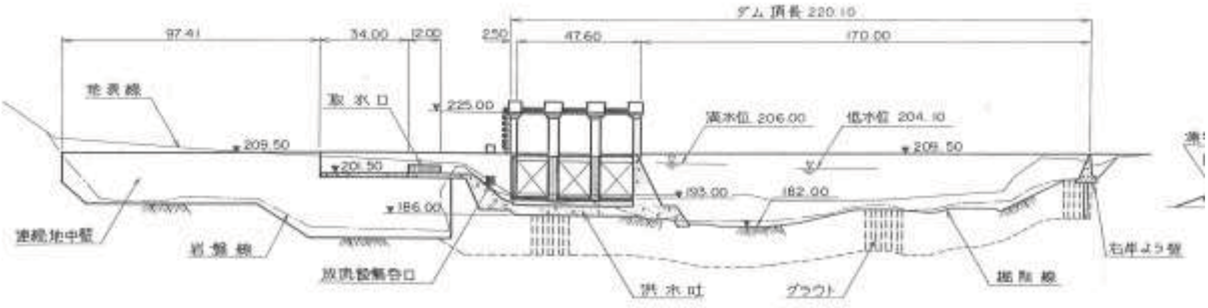


Fig. 2: Overall view

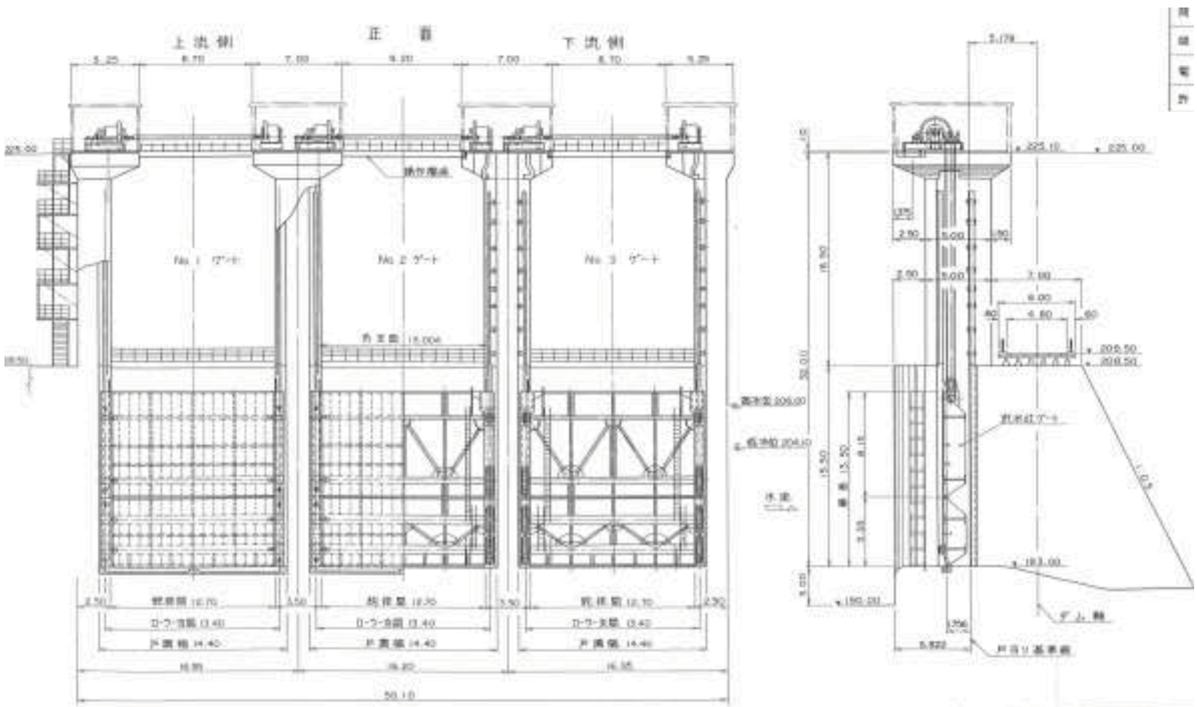


Fig. 3: Overall view of the spillway gate

Table 2: Main specifications of the spillway gate

Gate and guide rail	Type Dimension Numbers Design water level Waterproofing type Distortion of main beam Allowance thickness Seismic load Height of the gate sheet Weight	Steel roller gate Effective span 12.70m × effective height 13.50m (Spillway overflow top; EL193.00 - EL206.50m) 3 gates Normal time; EL 207.20m Earthquake time; EL 207.50m Winter time; EL 206.00m + Ice pressure 3t/1in.m Front 3 face rubber waterproof type Less than 1/800 against the design water depth 1mm against water contact surface Horizontal seismic coefficient 0.15 29.00m (to EL 222.00m) Door body; 114.0t
Opening/closing device	Type Opening/closing speed Head of water Operation method Numbers Opening/closing weight Electric supply Electric motor	Motorized, both end wire rope drum winding type (1 motor, 2 drums type) Motorized, 0.3m/min (engine movement; 0.05m/min) 16.00m Machine side operation and remote operation 1 set for 3 gates 154.5t 210v, 50Hz,3ϕ Outdoor close type, 3-phase AC induction motor with magnetic brake, 15kW
Operation bridge	Type Pure span Width Floor slab Load Seismic load Temperature alteration Numbers	Steel single beam type 9.20m 1 run, 8.70m 2 runs 2.00m Steel floor slab 450kgf/ m^3 Horizontal seismic coefficient; 0.15 - 30°C - +50°C 3 bridges

2. Description of the Renewal and Upgrading of the Project

2.1 Trigger Causes and Drivers for Renewal and Upgrading

(1) Condition, capability, influence of risk and others

(F) - (a) Accidents and disaster – Recovery

- Restoration of the functions of the spillway gate winding machine damaged by the Kushio Offshore Earthquake which occurred in January, 1993.
- It was necessary to conduct the restoration work quickly because flooding caused by snow melting was expected soon in Hokkaido.

(2) Improvement of value (functions)

(D) - (a) Needs for safety improvement – Improvement of safety

- For the main torque shaft, a gear coupling was adopted to increase the allowable movement distance in an axial direction. This was the countermeasure to prevent the failure from repeating.
- The fastening bolts of the operation bridge were all replaced, and a new bridge collapse prevention bracket was installed.

(3) Necessity in market

(Not applicable)

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

On January 15, 1993, the Kushiro Offshore Earthquake occurred with a 5 on the Japanese intensity scale (at the Obihiro district) and since the winch of the spillway gate was damaged, restoration was investigated and the necessary work was conducted.

The damage points and the range revealed by the external site observation are as follows:

- The torque shaft joint (No. 1, No. 3)
- The winch frame transfer bolt and fastening anchor bolts were broken (No. 1, No. 3)
- The operation bridge end section fastening anchor bolts were broken (No. 1, No. 3)

To restore these items as quickly as possible, along with an overhaul and survey, the following countermeasures were conducted.

- No. 1, 3 machines: overhaul and major inspection, alignment and teeth contact
- No. 1, 3 machines: Replacement of the axial joint (gear coupling)
- No. 1, 3 machines: Replacement of all the winch frame fastening anchor bolts
- No. 1, 3 machines: Replacement of all the operation bridge fastening anchor bolts and installation of the bridge collapse prevention bracket

After this restoration work was conducted, in March, 1993 an operation test was conducted and since no abnormality was found, we reported these actions and results to the construction supervisory authority.

2.3 Description of Work Undertaken (detail)

2-c) Technological innovation, deployment expansion and new materials used for civil and building works

Though the allowable slide distance of the previous axis joint was ± 2.75mm, in this restoration, so as to improve the aseismic capacity, a gear coupling joint with a slide distance of ±75mm was chosen and applied. The layout diagram of the winch and the axial joint structure diagram is shown in Fig. 4.

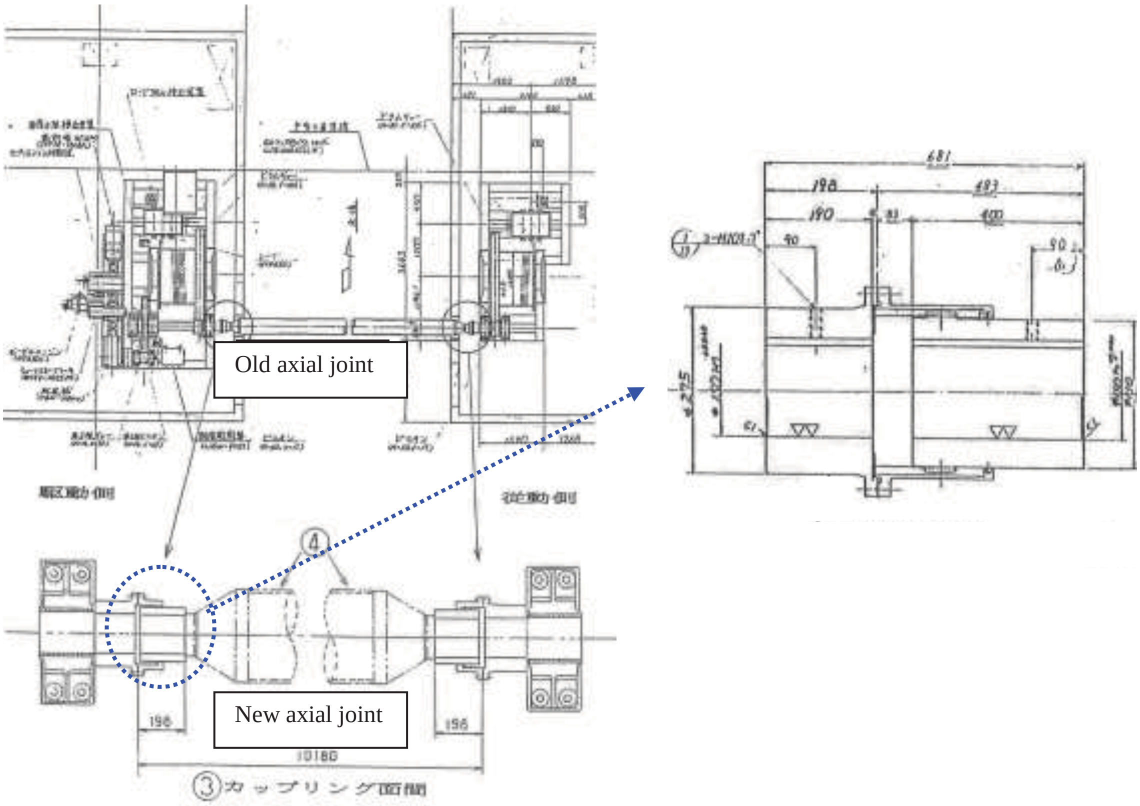


Fig. 4: Layout of the winch and the axial joint structure

In addition, to prevent the operation bridge from collapsing in an earthquake again, a new bridge collapse prevention bracket was installed, expanding the beam contact length and improving the aseismic capacity.

3. Feature of the Project

3.1 Best Practice Components

In this project, the axis joint (gear coupling) with a relatively large allowable movement in an axial direction which are usually not used for a gate raising machine was adopted (see Fig. 5)

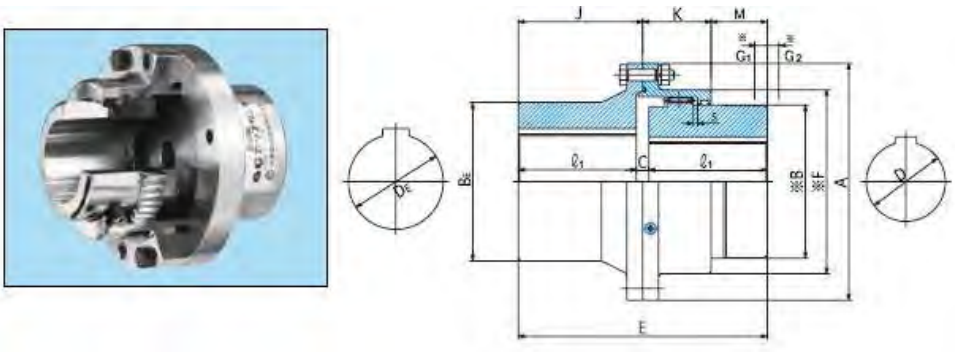


Fig. 5: Gear coupling (From catalog of the Manufacturer: Seisa Gear, Ltd.)

3.2 Reasons for Success

A commercial gear coupling was able to be adopted for the gate winch machine without any modification.

4. Points of Application for Future Project

In this project, the spillway gate winch damaged by earthquake was very quickly restored. However, depending on individual sites and facilities, specifications of the torque shaft of the spillway gate winch may be different, and the relative displacement of the spillway pier which would be caused by an earthquake would also be different. Accordingly, there may be cases in which the commercial product is not able to be used directly, without modification. The axis joint is available made-to-order, but if considering the delivery date and costs, there may be cases to choose alternative options.

5. Others (monitoring, ex-post valuation etc.)

When the Tokachioki earthquake occurred in September, 2003, it was assumed that the oscillation of the same seismic level (Japanese intensity scale 5: Ayoro-machi) occurred, but it was confirmed that this facility remained sound.

6. Further Information

6.1 Reference

1) Minagawa, Yoshimura, "Outline of the plan of the Kuttari Dam gate of the Kumaushi Power Station", *Hydraulic gate & penstock*, volume 153, 2007.12

6.2 Inquiries

Company name: Electric Power Development Company

URL: http://www.jpower.co.jp/

Format for the 2nd Round Data Collection (Definition of Case Histories)

Category and Key Points

Main: 2-c) Technological innovation, deployment expansion and new materials used for civil and building works

Project Name:

Anti-seismic Reinforcement of the Nojiri Waterway Bridge of Totsugawa No. 1 Power Station

Name of Country (including State/Prefecture):

Japan, Nara Prefecture

Implementing Agency/Organization:

Electric Power Development Co., Ltd.

Implementing Period:

From 2009 to 2010

Trigger Causes for Renewal and Upgrade:

(D) Needs for safety improvement

Keywords:

Anti-seismic Reinforcement, Waterway Bridge

Abstract:

In recent years, disaster prevention has attracted great social attention, and electric power utilities are required to take disaster prevention countermeasures in consideration of a large-scale earthquake. For large scale earthquakes assumed to occur such as the Tokai, Minami-Tokai and Nankai earthquakes, so as to prevent public disaster and to prevent business loss, we have been investigating the aseismic capacity of our own facilities, and based on that, we have conducted Anti-seismic countermeasures in rotation through them.

1. Outline of the Project (before Renewal/Upgrading)

The Totsugawa No. 1 Power Station (Operation began in 1960, output of 75,000kW) is located on the Kumanogawa River of the Shingu water system in Nara Prefecture. This power station has generated energy using water introduced from the Kazeya Dam (Dam length: 329.5m, height: 101m, total pondage: 130 million m^3) located midway down the Kumanogawa River. The Nojiri Bridge is a waterway bridge with a length of 217m, with a steel pipe (inside diameter of 4.2m) which passes water taken from the Kazeya Dam into the Totsugawa No. 1 Power Station. This waterway bridge crosses over the Kumanogawa River and National Route 168 in Totsugawa-mura, Nara Prefecture. Photo 1 is the overall view of the Nojiri Waterway Bridge before reconstruction. Fig. 1 is location of the Totsugawa No. 1 Power Station and Nojiri Waterway Bridge, Table 1 shows specifications of the Nojiri Waterway Bridge.

Photo 1: Overall view of the Nojiri Waterway Bridge of the Totsugawa No. 1 Power Station

Fig. 1: Location of Nojiri Waterway Bridge of Totsugawa No. 1 Power Station

Table 1: Specifications of the Nojiri Waterway Bridge

Type	Pipe beam type waterway bridge (some parts are reinforced with Langer beams)
Number of lines	One line
Total length	217m (section of the waterway bridge)
Inside diameter	Ø 4.2m
Design head	66.00m

2. Description of the Renewal and Upgrading of the Project

2.1 Trigger Causes and Drivers for Renewal and Upgrading

(1) Condition, capability, influence of risk and others

(Not applicable)

(2) Improvement of value (functions)

(D)-(a) Needs for safety improvement – Improvement of safety

With regard to aseismic design when constructed, this bridge was designed with a horizontal seismic coefficient of 0.12 by the horizontal seismic coefficient method. However, in this project, especially with the imminent and strong earthquakes, that is, when the Tokai, Higashi-Tokai and Nankai earthquakes are taken into account it is necessary to prepare for them. The data of these earthquakes were made public in "Probability distribution of the case in which earthquakes more than the Japanese lower 6 intensity scale occur in 30 years" (Fig. 2), by the Headquarters for Earthquake Research Promotion of the General Administrative Agency of the Cabinet in 2005.

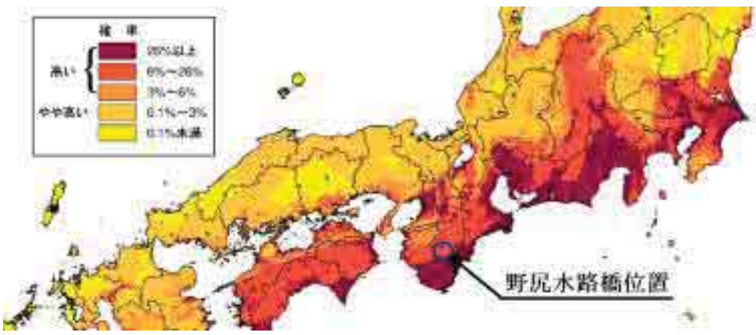


Fig. 2: Probability distribution of the case in which earthquake more than the Japanese lower 6 intensity scale occur in 30 years*

* Abstract of the published data of the Headquarters for Earthquake Research Promotion, added with data of our facilities

(3) Necessity in market

(Not applicable)

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

October 1960:	Operation of the Totsugawa No. 1 Power Station began
October 2009:	Construction work of the Anti-seismic Reinforcement for Nojiri Waterway Bridge began
December 2009:	Reinforcement work of the Langer beam suspension material was completed.
January 2010:	Reinforcement work of the ring garter was completed.
January 2010:	Reinforcement work of the Langer beam arch section was completed
February 2010:	Construction work of the Anti-seismic Reinforcement for the Nojiri Waterway Bridge was completed.

2.3 Description of Work Undertaken (detail)

2-c) Technological innovation, deployment expansion and new materials used for civil and building works

The Nojiri Waterway Bridge of the Totsugawa No. 1 Power Station is a structure which crosses over the national road and river in Totsugawa-mura, Nara Prefecture. If this waterway bridge is damaged by a large scale earthquake, a public disaster occurrence is feared, therefore, a survey of the aseismic capacity was conducted, and for the sections where a countermeasure was required, the Anti-seismic Reinforcement work was conducted. The outline of the Anti-seismic Reinforcement work which was conducted in this project is shown in Fig. 3.

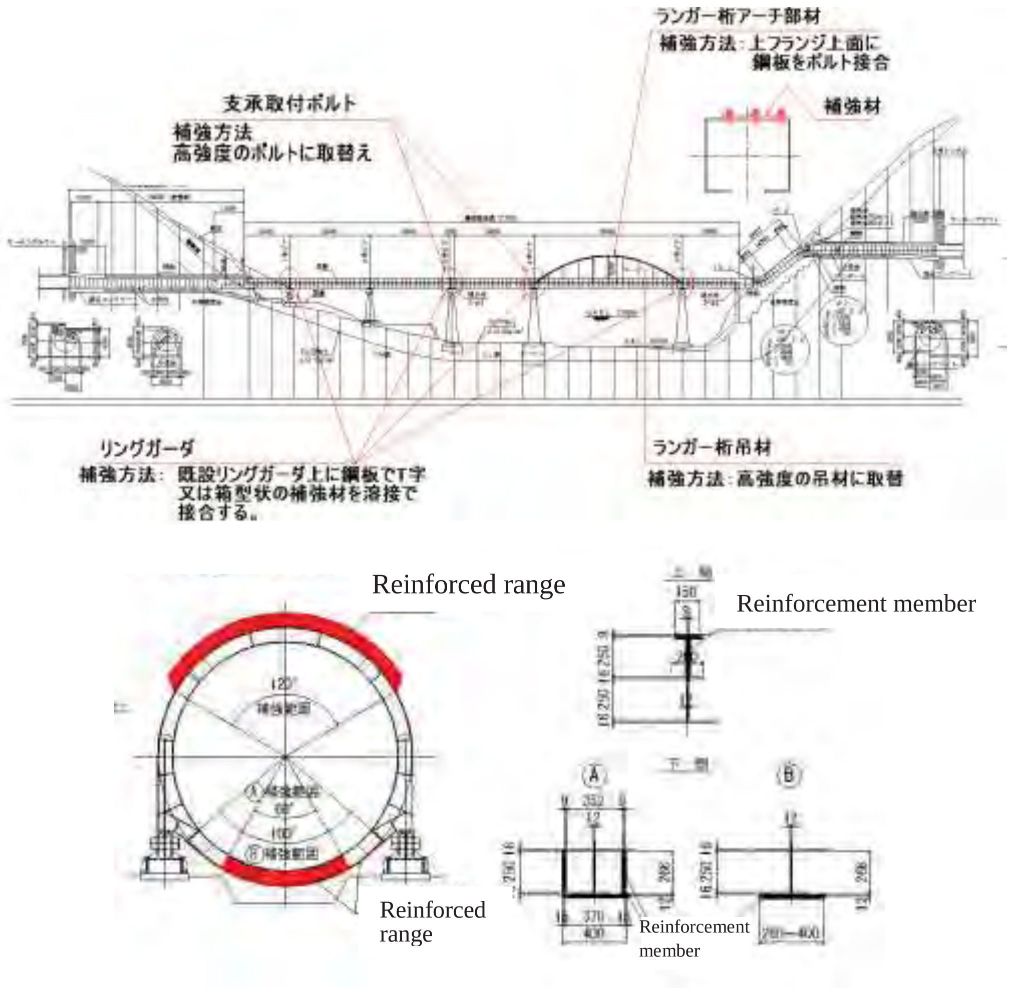


Fig. 3: Outline of the Anti-seismic Reinforcement for the Nojiri Waterway Bridge

(1) Langer girder

For reinforcement of the Langer girder, by joining the steel plates, its cross section strength was increased. Two fixing methods of steel plates, that is, welding and bolt connection were studied, and so as to avoid the change of the stress balance of the suspension materials by the distortion of the existing components caused by heat influence from welding, a high strength bolt (S10T) joint was conducted by installing the reinforcement steel plates on the upper surface of the girder flange. Since it was difficult to remove the existing ancillary materials, they were reinforced by bolt connection on both sides of the steel plate which covers the subject rivet joint area, and by adding a buckling prevention rib.

(2) Reinforcement of the Ring girders

For the ring girders, since their outer edge accumulated force exceeded the allowable value, reinforcement materials were determined to be added. Incidentally, the lower section of the ring girders where the existing structure contacts them was welded with a box type steel plate so as to avoid contact, and the cross section strength was improved.

(3) Suspension material of the Langer girder

As a result of the aseismic capability test, it became clear that the axis stress of the Langer girder exceeded the allowable value. It was therefore determined to replace the Langer girder suspension materials with high strength materials. In fact, to reinforce the Langer girder suspension materials, the alternative method in which a pipe cut in half be welded to the existing suspension materials so as to increase cross section strength was considered. That idea was rejected because there was a possibility that welded parts failed to assure sufficient quality because the existing material was forgings which, when welded, might fail to function. Also it was not certain whether an integrated component composed with a half cut pipe and the existing materials could evenly distribute the load. Thus finally, it was determined that the reinforcement should be conducted by outright replacement of the suspension materials.

(4) Bearing fastening bolt

As for the bearing fastening bolts, as a result of the aseismic capability test, it became clear that at 2 of the 6 bearing locations, the shearing force exceeded the allowable value. Therefore it was determined to replace them with high strength bolts.

In the future, in consideration of the experience of the Great East Japan Earthquake, as appropriate, it is scheduled to improve aseismic capability including re-examination of an assumed seismic movement level.

3. Feature of the Project

3.1 Best Practice Components

The Anti-seismic Reinforcement was conducted without renewal of the main components and while allowing the national road under the bridge to continue to be used.

3.2 Reasons for Success

The reason why this project succeeded was because the optimization of the reinforcement work was able to be achieved by examining the reinforced area based on the seismic capability test and the actual structures.

4. Points of Application for Future Project

When the reinforcement plan of a wide variety of structures such as a waterway bridge is considered, it is essential to make a detailed plan of the reinforcement after fully understanding the characteristics of existing structures.

5. Others (monitoring, ex-post valuation etc.)

(Not applicable)

6. Further Information

6.1 Reference

1) Kawada, Awazu, "Earthquake disaster countermeasures of the J-POWER groups", *Journal of Electric power Civil Engineerin*g, (2008.11)
2) Uemura, Kuwahara, Sakurai, "Construction work of the Anti-seismic Reinforcement for the Nojiri Waterway Bridge of Totsugawa No. 1 Power Station", *Journal of Electric power Civil Engineerin*g, (2011.1)

6.2 Inquiries

Company name: Electric Power Development Company

URL: http://www.jpower.co.jp/

Format for the 2nd Round Data Collection (Definition of Case Histories)

Category and Key Points

Main: 2-c) Technological innovation, deployment expansion and new materials used for civil and building works

Project Name:

Expansion Project for the Okukiyotsu No. 2 Pumped Storage Hydropower Station

Name of Country (including State/Prefecture):

Japan, Niigata Prefecture

Implementing Agency/Organization:

Electric Power Development Co., Ltd.

Implementing Period:

From 1992 to 1996

Trigger Causes for Renewal and Upgrade:

(C) Needs for higher performance

Keywords:

Waterway Tunnel and Powerhouse Expansion, Urgent Development of Power Source

Abstract:

The expansion project of the Okukiyotsu No. 2 Hydropower Station was required to quickly respond to the increase of peak power demand since 1996, and to increase output by 600,000kW while utilizing the existing reservoir of the Okukiyotsu Power Station (maximum output: 1,000,000kW)

1. Outline of the Project (before Renewal/Upgrading)

The Okukiyotsu Power Station is located on the site where 9 electric power companies carried out a joint survey and development, that is, in Yuzawa-machi, Minami Uonuma-gun in Niigata Prefecture. This power station is a recirculating pumped storage power station with a maximum output of 1 million kW using a head of about 470m between the Kassa Dam and the Futai Dam. Kassa Dam was constructed on the most upper site of the Kassagawa River which is a tributary of the Kiyotsugawa River of the Shinanogawa water system, and the Futai Dam was constructed on an upper site of the main river. Their location map is shown in Fig. 1. The general plan view and the longitudinal profile of the waterway are shown in Fig. 2 & 3.

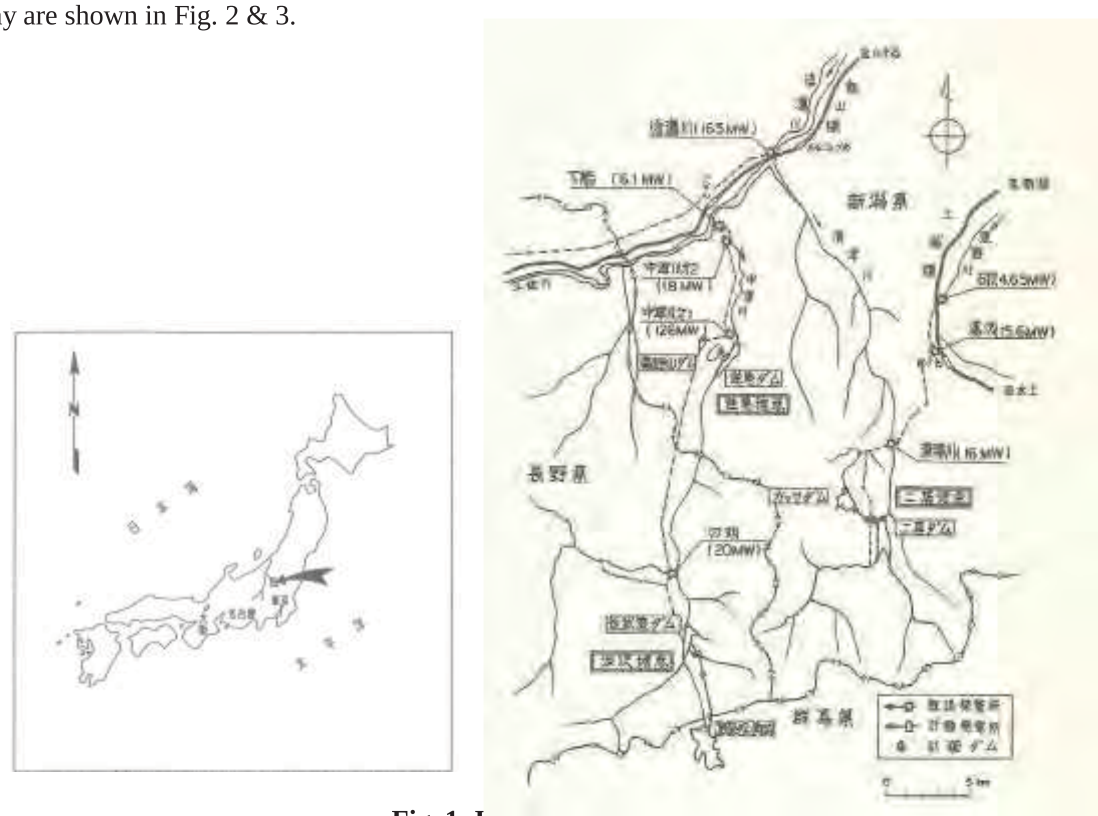


Fig. 1: Location map

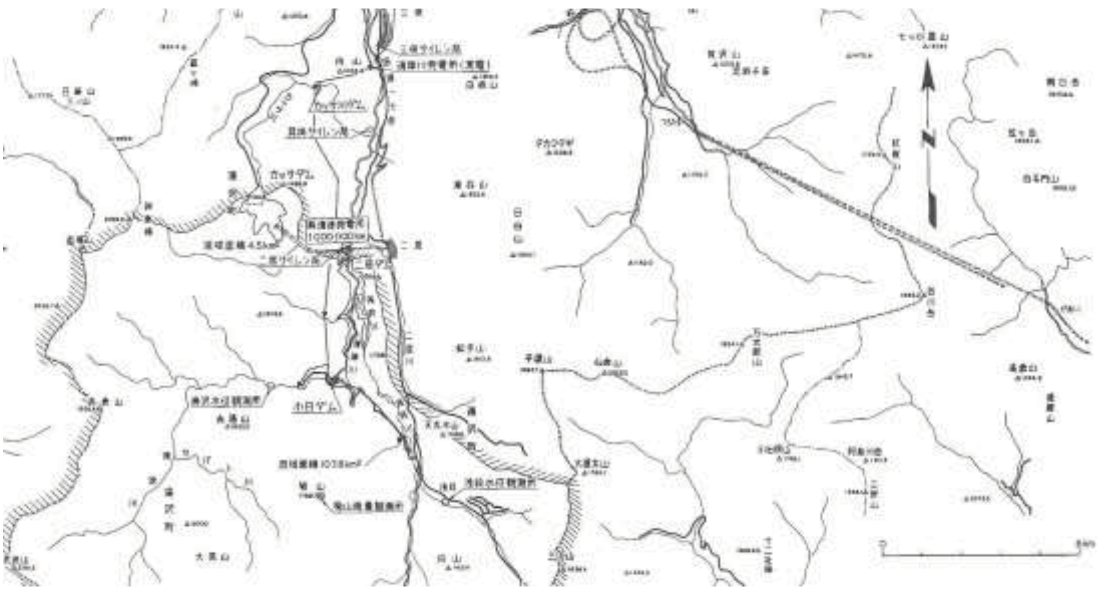


Fig. 2: General plan view

Fig. 3: Longitudinal profile of the waterway

2. Description of the Renewal and Upgrading of the Project

2.1 Trigger Causes and Drivers for Renewal and Upgrading

(1) Condition, capability, influence of risk and others

(Not applicable)

(2) Improvement of value (functions)

(C)-(a) Needs for higher performance – Expansion, increase of output per hour

The Okukiyotsu No. 2 Power Station is a recirculating pumped storage power station with a maximum output of 600,000kW located in Yuzawa-machi, Minami Uonuma-gun in Niigata Prefecture and situated adjacent to the existing Okukiyotsu Power Station (1,000,000kW) located upstream of the Kiyotsugawa River of the Shinanogawa water sytem.　The location is shown in Fig. 4.　For the Okukiyotsu No. 2 Power Station, the water intake was constructed downstream of the upper regulating reservoir side by side with the existing water intake.　From this intake, a maximum of 154m^3/sec of water is taken and introduced to a 700m pressurized tunnel installed parallel to the existing waterway.　Then, through the 1290m pressurized water pipe line, water is passed to the No. 2 Power Station (300,000kW×2generators) located downstream of the existing power station to generate power, and is finally discharged to the lower regulating reservoir by an 880m long tailrace tunnel.　Generated electric power is raised to 500 kV, and sent to the Tokyo metropolitan area through the new Niigata high tension trunk line.　A general plan view and longitudinal profile of the waterway are shown in Fig. 5 & 6, and planned specifications are shown in Table 1.

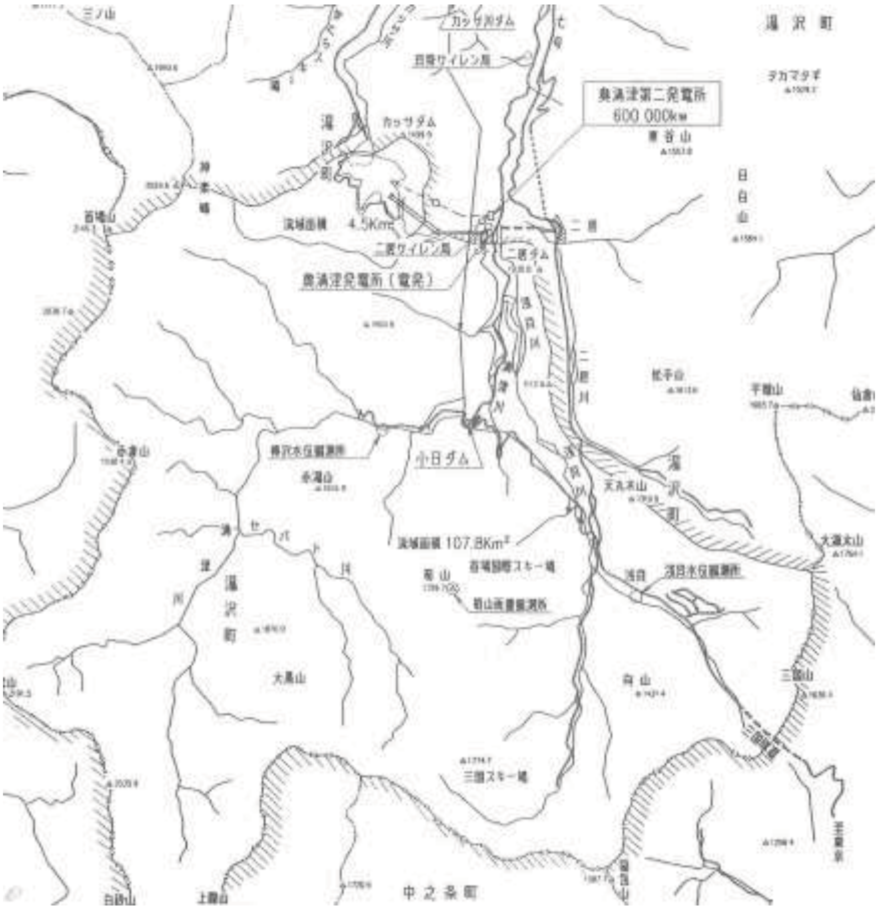


Fig. 4: Location Map

Fig. 5: General Plan view

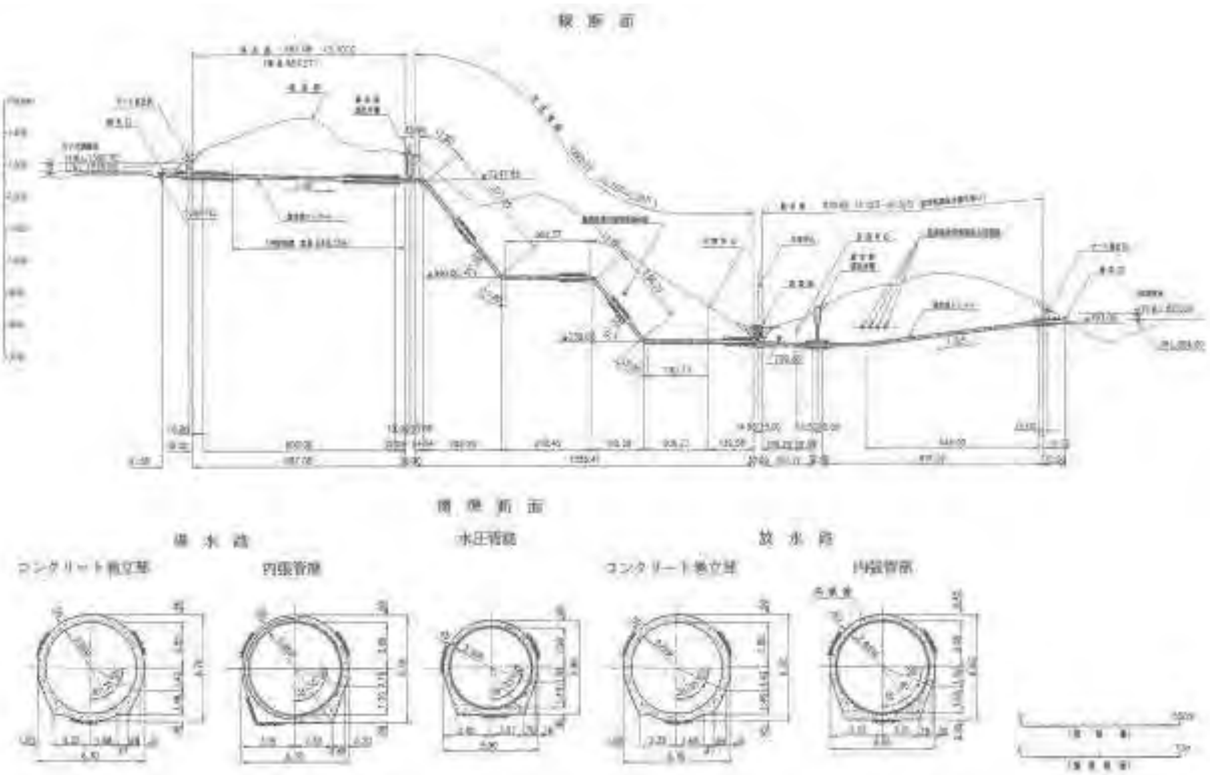


Fig. 6: Longitudinal profile of the waterway

Table 1: Planned specifications

This project was chosen as an urgent development site for the following reasons.

(1) The existing Okukiyotsu Power Station is regarded to be an important peak power supply source because the annual generating hours in terms of the maximum output average was 900 hours of high operation rate when compared to the other pumped storage power stations whose annual generation hours are about 700 hours.

(2) This power station is connected with the Niigata high tension trunk line (500kV) which connects the Tokyo metropolitan area and the Kashiwazaki-Kariwa nuclear power plant owned by Tokyo Electric Power Co., Inc which is an extremely important power source for the Tokyo metropolitan area, and is able to use this trunk line directly.

(3) In this project, as an upper reservoir and a lower reservoir, for both, the existing regulating reservoirs are able to be used as is, therefore what is necessary is only to build an underground waterway and to build the No. 2 power station directly downstream with the existing power station. For construction roads, mainly the existing road is able to be used, so it is possible to minimize the impact on the area geology.

(4) Since the new power station is to be constructed adjacent to the existing power station structures, it is easy to recognize the geotechnical conditions, and be able to refer to actual past construction. Therefore, it was possible to shorten the time period for the survey and construction.

(5) With the effective total pondage of the existing regulating reservoir, the peak power generation was able to be conducted for 12 hours, and even with the 600,000kW increase, it is possible to generate the full maximum for 7.6 hours.

(3) Necessity in market

(Not applicable)

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

July 1978:	Operation of the Okukiyotsu Power station (existing power station) began
December 1990:	The study of the project began
June 1992:	Construction contract of the new Okukiyotsu No. 2 Power Station was signed
October 1993:	Excavation of the inclined adit, heading of upper and lower step of the pressurized water pipe line was completed.
June 1994:	Expansion excavation of the inclined adit of upper and lower step of the pressurized water pipe line was completed
November 1994:	Suspension of the No. 1 pump water turbine runner was conducted
December 1994:	Suspension of the No. 2 pump water turbine runner was conducted
August 1995:	Concrete work of the power station body was completed.
December 1995:	Water filling in the headrace, pressurized water pipe line and tailrace was completed
June 1996:	Commercial operation began
November 1996:	Completion ceremony was conducted.

2.3 Description of Work Undertaken (detail)

2-c) Technological innovation, deployment expansion and new materials used for civil and building works

In the excavation of the inclined adit for the pressurized water pipe line, for the heading excavation of the upper inclined adit where the bedrock was relatively hard, an Alimak climber was used, and for the lower inclined adit where the bedrock was relatively unstable, a raise boring machine was used so as to improve work efficiency. The excavation length was about 400m for upper and 250m for the lower adit respectively. They were the longest excavation records for both machines, and excavation works were completed without any problems.

An overall view of the Alimak climber and the raise boring machine are shown in Fig. 7 and 8.

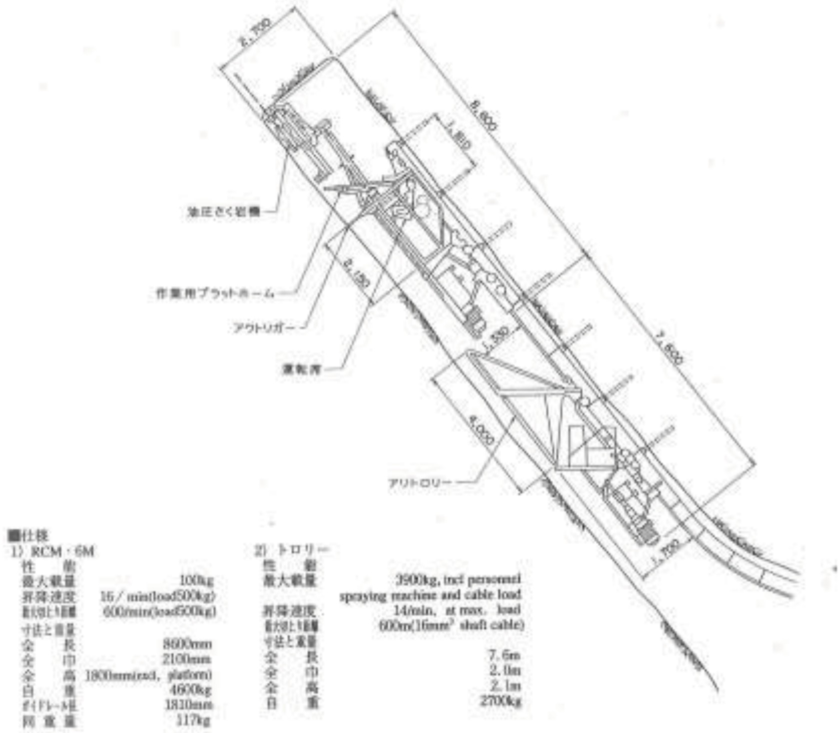


Fig. 7: Overall view of the Alimak climber

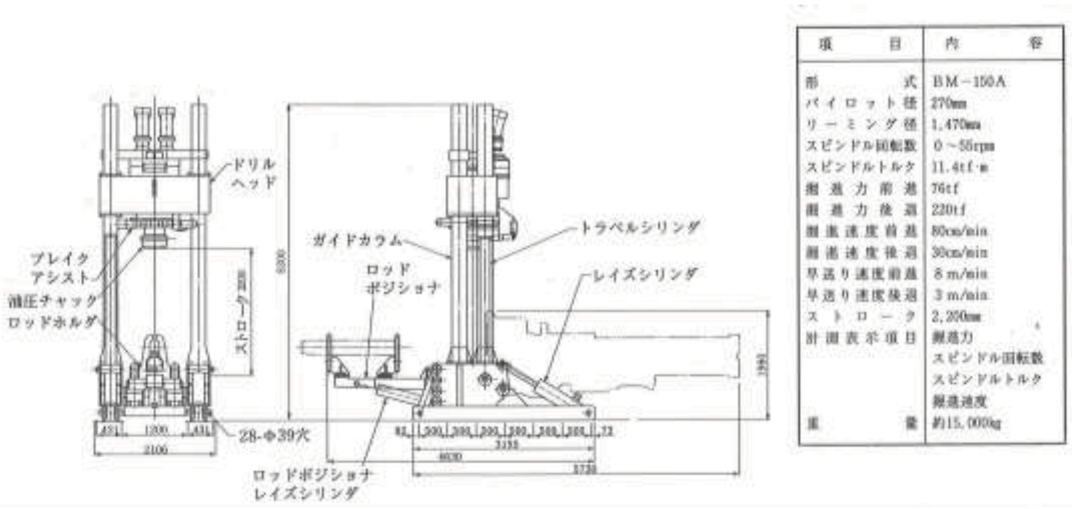


Fig. 8: Overall view of the raise boring machine

(1) Excavation of the heading of the upper inclined adit

The Alimak climber of the Alimak Co., Ltd. was used, and based on the past experiment records, the following improvement was conducted:

- The rock boring machine was changed from one system to 2 systems so as to improve work capability.
- The outrigger was changed from a side extending type to a bottom extending type so as to improve the main body supporting force.
- Made boring operation possible from a driver seat so as to improve safety.
- Reduce the main body weight

(2) Excavation of the heading of the lower inclined adit

With regard to the raise boring machine for the lower inclined adit, there was a fear that with a curve the hole wall might collapse, but by conducting the following countermeasures, it was judged that a hole wall collapse could be avoided.

1) Countermeasures against a hole bend

- Make tool diameter larger so as to improve straightness
- Make the length of the stabilizer longer so as to improve straightness
- Minimize the difference of diameter between the stabilizer and bit so as to eliminate the factors which would cause a bend.

2) Countermeasures against a hole wall collapse

- Immediately before the hole boring was completed, a cementation which injects a cement mortar into a crack was conducted and a hole wall collapse was prevented.
- In order to prepare for trouble in which the lower bit was clogged during the reaming excavation, so as to make it possible to conduct countermeasures against the clogging, blasting wire was installed under the lower reaming bit.

3. Feature of the Project

3.1 Best Practice Components

During the excavation period of the excavation of the heading of the upper inclined adit, the average progress was about 100m/month including periods of failure and for measures against spring water, showing it to be a very fast excavation method. Also, the raise boring method used for the heading excavation of the lower inclined adit was able to be used for the sites with bad geological conditions, and so it was demonstrated that this method was an extremely safe construction method.

3.2 Reasons for Success

There is a space where a new powerhouse can be constructed near to the existing facilities The expansion project of the Okukiyotsu No. 2 Hydropower Station was rapidly: planned as an urgently needed power source development to respond to the rapid increase of peak power demand since 1996, and the securing of the construction work schedule was essential.

Therefore, in consideration of the geological conditions of the site and the improvement of the existing tunnel excavation machines, so as to improve construction efficiency and safety, the latest machinery was introduced. That is, for the critical pass of the headrace tunnel excavation, the combination of the Alimak climber and the raise boring machine were adopted and be able to achieve the planned schedule. This is the main reason for the success of this project.

4. Points of Application for Future Project

Generally, there are not so many projects in which a sufficient geological survey for a tunnel excavation is conducted in advance and all necessary information for the bedrock is obtained and quantified in advance. Even so, it is necessary to select the proper machine type based on the detailed strengths and weaknesses which these machines have.

5. Others (monitoring, ex-post valuation etc.)

(Not applicable)

6. Further Information

6.1 Reference

1) Kanazawa, Hakamatsuka, "Outline of the development project of the Okukiyotsu No. 2 Power Station", *Water gate & penstock*, volume 175, (1993.8)

2) Minagawa, Hakamatsuka, Taguchi, "Outline of the steel structure facilities of the Okukiyotsu No. 2 Power Station", *Water gate & penstock*, volume 189, (1997.1)

6.2 Inquiries

Company name: Electric Power Development Company

URL : http://www.jpower.co.jp/

ANNEX XI　Renewal & Upgrading of Hydropower Plants

Format for the 2nd Round Data Collection (Definition of Case Histories)

Category and Key Points

Main: 1-d) Asset Management, Strategic Asset Management and Life-cycle Cost Analysis

Project Name:

The Survey of the flood disaster of the Nagatono Power Station and its restoration project

Name of Country (including State/Prefecture):

Japan, Nara Prefecture

Implementing Agency/Organization:

Kansai Electric Power Co., Inc.

Implementing Period:

From 2010

Trigger Causes for Renewal and Upgrade:

(F) Accidents and disaster

Keywords:

Flood disaster, Slope failure, Earth dam

Abstract:

The Nagatono Power Station was seriously damaged by the flood caused by Typhoon No.12 that occurred in 2011. The power station building was completely destroyed, the transmission line tower was buckled and the generators were under water; a catastrophic condition. For this disaster, it was thought the reason why the damage became so great was because of not only the major flooding from the record breaking heavy rain but also due to a sudden landslide in which an enormous quantity of earth and sand flowed into the river due to a slope failure on the mountain. The Kansai Electric Power Co., Inc. is now examining the reasons for the disaster and calculating the restoration costs and confirming its economic viability, with a view to restore and recover from this catastrophe. Now they are developing a restoration plan.

1. Outline of the Project (before Renewal/Upgrading)

The Nagatono Power Station started its operation in December, 1935 with a maximum output of 15,300kW and a maximum plant discharge of 9.46m^3/s. The specifications of the power station are shown in Table 1.

Fig. 1: Location map of the Nagatono Power Station

Table 1: Specifications of the Nagatono Power Station

Items		Specifications
Power station	Name of power station	Nagatono Power Station
	Maximum output	15,300kW
	Maximum plant discharge	9.46m^3/s
	Effective head	196.0m

2. Description of the Renewal and Upgrading of the Project

2.1 Trigger Causes and Drivers for Renewal and Upgrading

(1) Condition, capability, influence of risk and others

(F)- (a) Accidents and disaster - Recovery

The Nagatono Power Station was seriously damaged by the flood caused by Typhoon No.12 that occurred in 2011. The power station building was completely destroyed, the transmission line tower was buckled and the generators were under water, resulting in a catastrophic situation. For this disaster, it was thought the reason why the damage became so great was because of not only the major flooding from the record breaking heavy rain but also due to a sudden landslide in which an enormous quantity of earth and sand flowed into the river due to a slope failure on the mountain.

(2) Improvement of value (functions)

(Not applicable)

(3) Necessity in market

(Not applicable)

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

August 30, 2011: At the subject area, rain began to fall accompanying the approaching Typhoon

September 3, 2011: At the measurement point in the vicinity of the site, the hourly rain precipitation reached a peak (about 50mm/h)

September 4, 2011: The sudden landslide occurred because of a huge slope failure on the mountain resulting in an enormous quantity of earth and sand entering the river.

(Incident and time of the disaster was assumed by the Yomiuri News Paper as of 8/31/2012)

September 5, 2011: Rainfall slowed. Accumulated rainfall at the nearby measurement point was 1808mm.

2.3 Description of Work Undertaken (detail)

1-d) Asset Management, Strategic Asset Management and Life-cycle Cost Analysis

Firstly, we examine the mechanism that led to the damage of the power station. Figure 2 shows the status of damage suffered by the power station, and Figure 3 shows the highest level of water marks left. The presence of external force from downstream to upstream is suspected due to the facts that some power poles had fallen toward the upstream side, and that external walls on the downstream side had been found to have moved and smashed upstream. Water mark traces are identified at very high levels in the section 350 – 850 meters downstream from the power station. This corresponds to the area of a large-scale slope failure, indicating that the sand and soil that fell into the river directly gauged riverbanks.

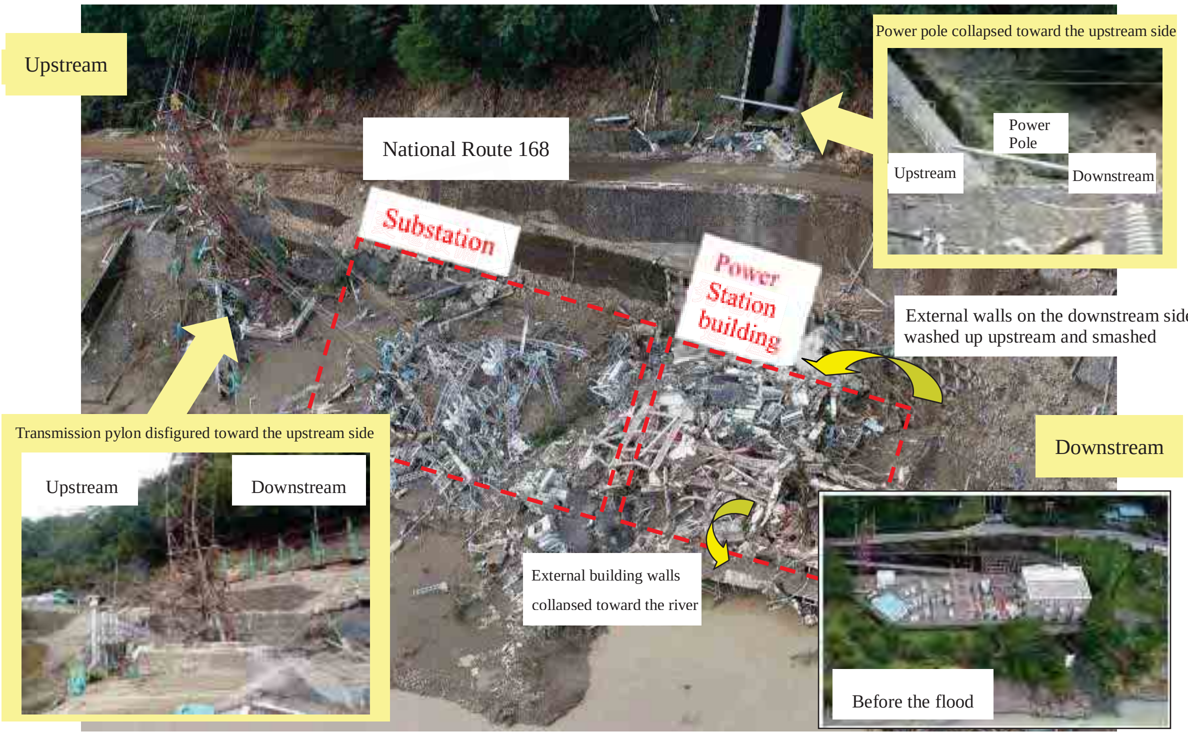


Fig. 2: Damage status of the Nagatono Power Station

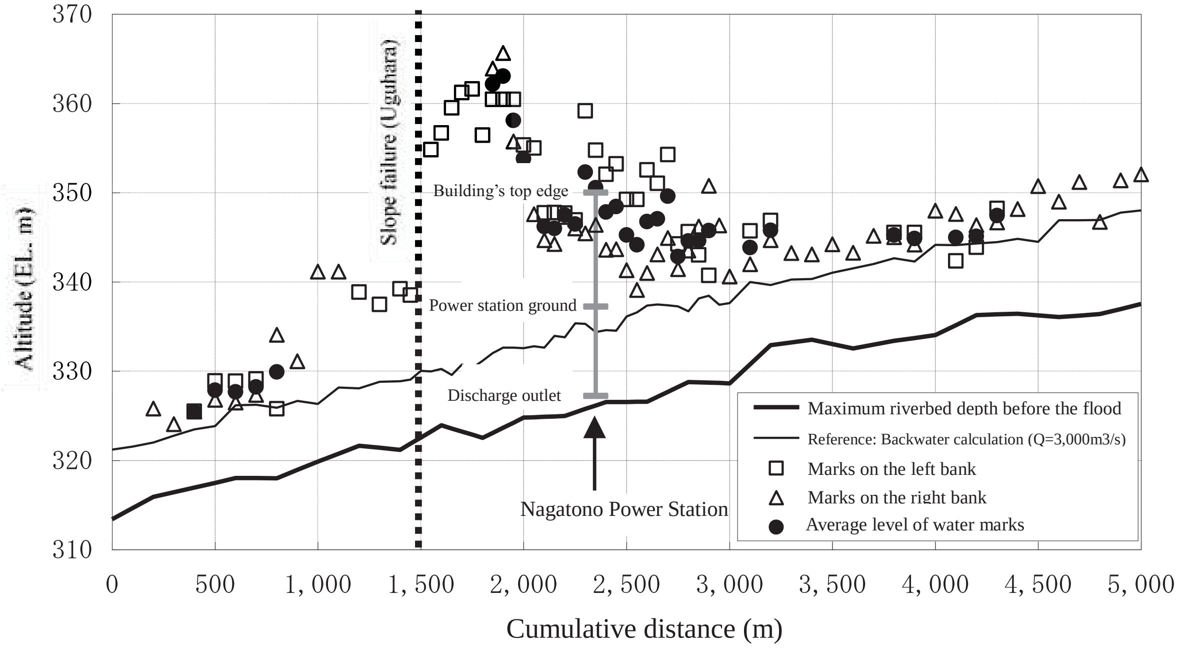


Fig. 3: Results of an investigation into water mark traces

Judging from the collective information, the damage to the power station was magnified not only by the scale of flooding triggered by record-setting torrential rain but also by mountain slope failure, which unleashed a massive amount of soil into the river and generated bores (mountain tsunami). (Fig.4)

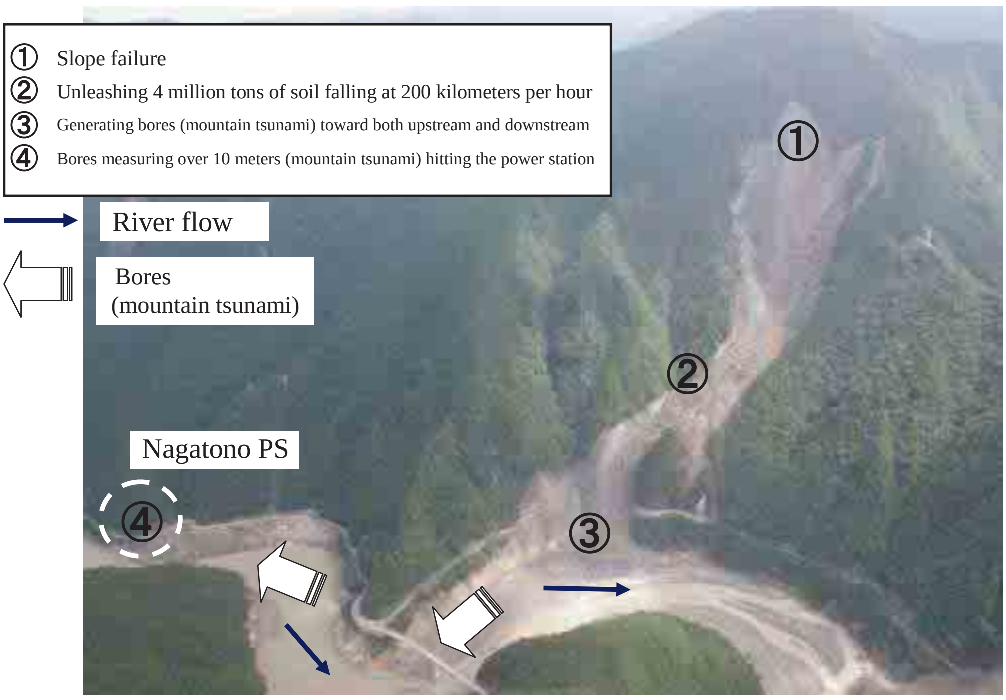


Fig. 4: Estimated mechanism of power station damage

Next, future riverbed changes are examined to assist in restoration design. Riverbed changes over the next 50 years are simulated for four scenarios, incorporating different levels of sediment supply and implementation of riverbed excavation (Fig. 5).

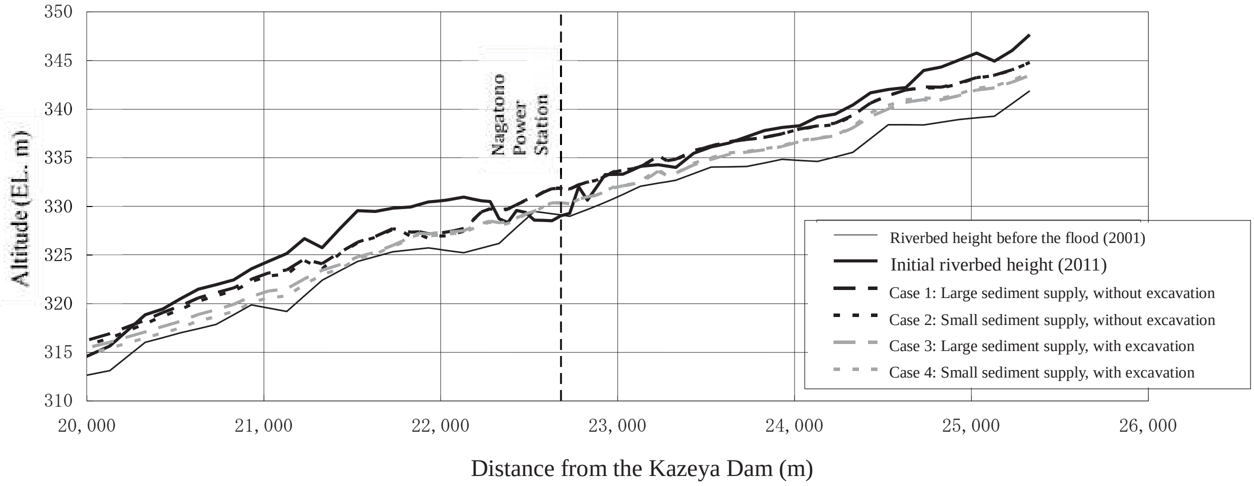


Fig. 5: Comparison of riverbed elevation around the power station

The next graph shows the HQ curve illustrating the results of backwater calculation on the water level in front of the power station (Fig. 6).

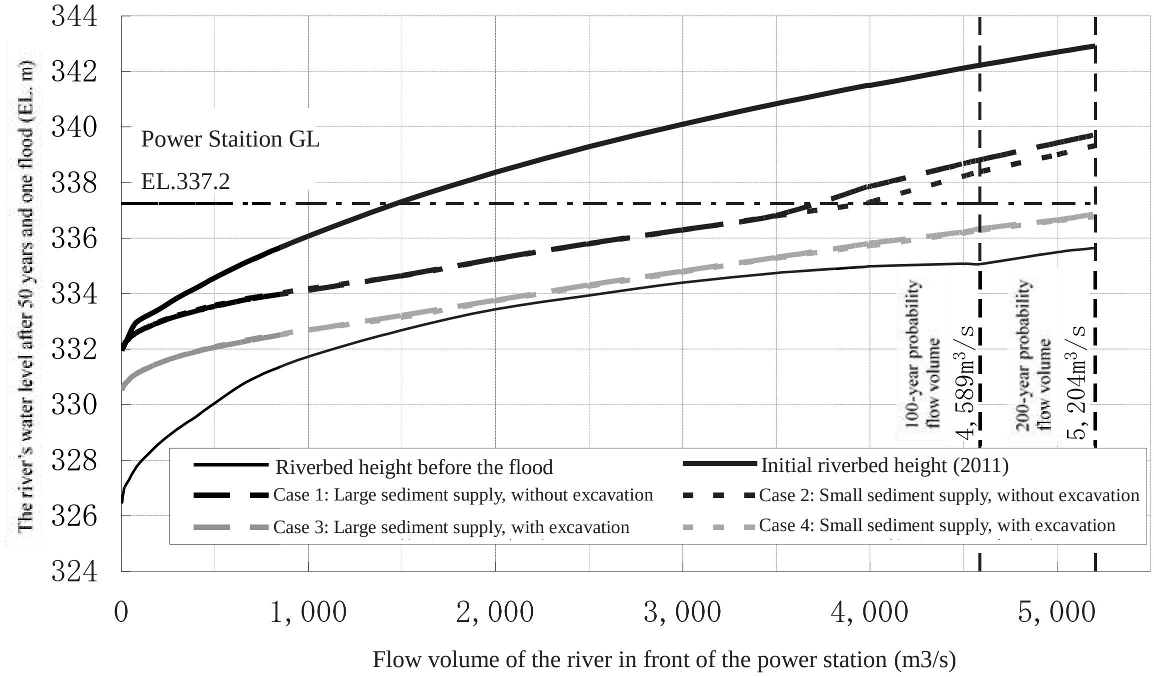


Fig. 6: Comparison of HQ curves at the power station

Due to the fluidity of the riverbed excavation plan at the power station's downstream area as a sediment countermeasure, the scenario without excavation is selected for restoration design. In view of the timing of plant restoration completion, the 100-year probability water level of EL. 340.1m after 5 years has been used as the design-basis flood level. Accordingly, the power station ground is to be raised by approx. 4 meters from the current level. Since the existing discharge outlet is to be buried under riverbed in the future, it will be modified into an after bay structure, surrounded by retaining walls, and raised by approx. 2.5 meters from the current level (Fig. 7).

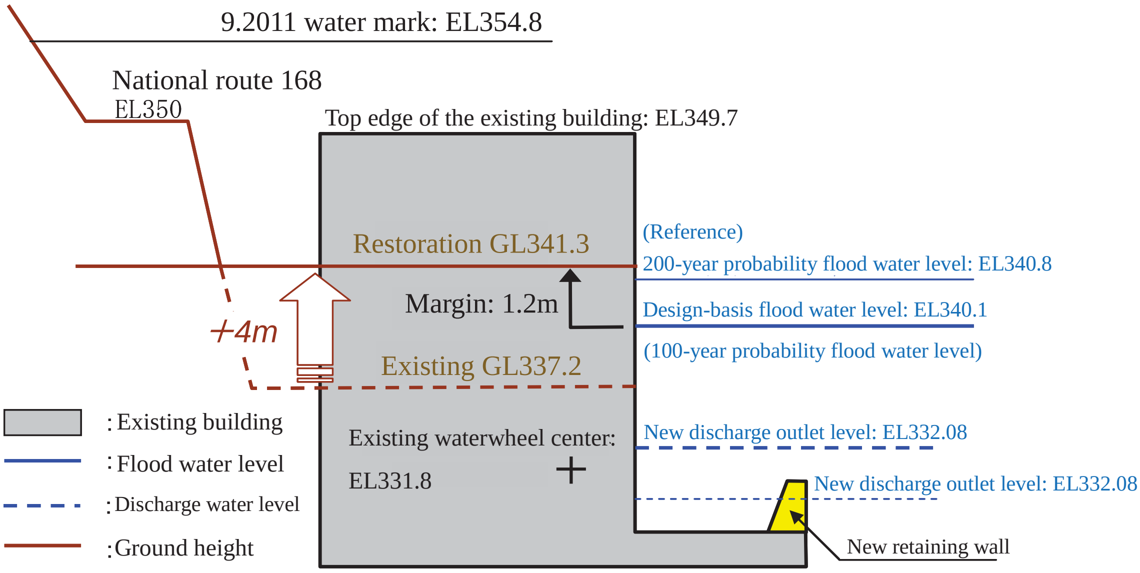


Fig. 7: Design-basis flood water level and plant discharge water level

3. Feature of the Project

3.1 Best Practice Components

- Assumption of the disaster mechanism
- Study the possibility of the same type of a slope failure (Risk assessment)
- Effective utilization of the existing facilities (Cost saving)

3.2 Reasons for Success

Since this power station had been contributing as an important power supply source, it is expected that the power station will be restored as quickly as possible. On the other hand, in the restoration design work, appropriate cost saving is required. Under such conditions, I implement appropriate restoration designing premise of effective application of existing facilities by conduct the early assumption of the disaster mechanism and the riverbed change simulation on future.

4. Points of Application for Future Project

- In applying to the point where the landslide has occurred, it is possible to prevention by possibility of mountain tsunami occurrence and appropriate riverbed change simulation.

5. Others (monitoring, ex-post valuation etc.)

(Not applicable)

6. Further Information

6.1 Reference

(None)

6.2 Inquiries

Company name: Kansai Electric Power Company

URL: http://www.kepco.co.jp/

ANNEX XI Renewal & Upgrading of Hydropower Plants

Format for the 2nd Round Data Collection (Definition of Case Histories)

Category and Key Points

Main: 1-b) Investment incentives (Feed-in-Tariff (FIT), Renewable Portfolio Standard (RPS), subsidies, financial assistance, tax deductions, etc,)

Sub: 1-d) Asset Management, Strategic Asset Management and Life-cycle Cost Analysis

2-c) Technological innovation, deployment expansion and new materials used for civil and building works

Project Name:

The Redevelopment construction project of the Hanakawa Power Station

Name of Country (including State/Prefecture):

Japan, Ibaragi Prefecture

Implementing Agency/Organization:

Tokyo Electric Generation Co., Inc.

Implementing Period:

From 2009 to 2011

Trigger Causes for Renewal and Upgrade:

(A) Degradation due to aging and recurrence of malfunction

Keywords:

Stopped power station, Redevelopment, Conversion of the existing facilities

Abstract:

In 1908, this power station was constructed as a coal mine power supply by the Joban Coal Mine Company (currently: Joban Kosan Co., Ltd.). But in 1971, a huge flood submerged this coal mine resulting in the mine closure, and the power generation was stopped. Under such conditions, the water rights were returned to the Ibaragi Prefecture, and their facilities were given to Kita-Ibaragi-shi free of charge and they have been administering this facility ever since. Even now, the facilities from the dam to headrace are used as common shared facilities for the Takinoe irrigation dam of Kitaibaragi-shi. From this facility water is distributed to the sharing beneficiaries.

This project is to redevelop the old power station by using abandoned existing facilities.

1. Outline of the Project (before Renewal/Upgrading)

(1) Brief overview of the redevelopment of the power station

The Tokyo Hatsuden Co., Ltd. got the facilities from Kitaibaragi-Shi and has redeveloped them.

Fig. 1: Location of the power station

Table 1: Specifications of the power station

Items	Specifications	
	Old power station	Current power station
Output	100kW	130kW
Plant discharge	0.78m^3/s	1.00 m^3/s
Effective head	18.168m	17.35m

2. Description of the Renewal and Upgrading of the Project

2.1 Trigger Causes and Drivers for Renewal and Upgrading

(1) Condition, capability, influence of risk and others

(A)-(a) Degradation due to aging and recurrence of malfunction - Improvement of efficiency

- The old power station used a plant discharge of 0.78 m^3/s, but by reviewing the possible waterway flow, it was found that 1.00 m^3/s of water is able to be passed, and so an output increase of 30 kW could be achieved.

(A)-(b) Degradation due to aging and recurrence of malfunction. Improvement of durability, safety and reliability

- In the existing headrace, at several points, anchor braces were installed, but in consideration of the safety of the facilities, all old braces were removed and new concrete was poured.
- After the power station was stopped, irrigation water was taken from the intake under the existing water rights. In this project, by converting this right into law, new water rights for power generation were proposed. By legislating, water intake administration was able to be properly conducted.

(A)-(c) Degradation due to aging and recurrence of malfunction - Cost reduction

- Cost reduction was pursued by maximum utilization of the existing facilities.
- In this redevelopment, the civil engineering facilities work occupied more than 60% of the project cost, so, by reusing the weir, headrace, water tank, power station foundation, tailrace and other parts, a great cost saving was able to be achieved.
- For the pressurized water pipe, by inserting high density polyethylene pipe into the existing steel pipe to make it a double pipe, great cost savings were able to be achieved without spending funds for removal of the existing pipe.

(A)-(d) Degradation due to aging and recurrence of malfunction - Easy maintenance with less labor

- After the power station was abandoned, the headrace was given to Kitaibaragi-shi and the city had been administering it, but since the facility was transferred to us, we have been conducting maintenance and preservation control, therefore the maintenance condition was improved.

(2) Improvement of value (functions)

(Not applicable)

(3) Necessity in market

(Not applicable)

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

July 2004:	Survey of the sites on the Hanakawa River began.
January 2005:	Project of the Hanakawa Power Station was explained to Kitaibaragi-shi.
March 2005:	Survey for new sites was requested.
November 2008:	Water intake amount and river maintenance discharge amount were determined.
April 2009:	Agreement about the installation of the fish pass on the weir was contracted with the Okitagawa Fisherman's Union.
May 2009:	Compensation agreement for the fishery was contracted with the Okitagawa Fisherman's Union.
June 2009:	Facilities transfer contract was agreed upon with Kitaibaragi-shi.
July 2009:	The subsidy from the New Energy Introduction Promotion Conference was approved.
October 2009:	Converting the Takie Dam irrigation water rights into law was approved.
October 2009:	The construction plan was submitted to the Kanto Northeast Industrial Safety and Maintenance Department.
November 2009:	The construction work on the Hanakawa Power Station began (Construction in FY 2009)
February 2010:	The construction work on the Hanakawa Power Station was completed (Construction in FY 2009)
June 2010:	Approval for the river law was proposed to the River Department of the Civil Engineering Division of Ibaragi Prefecture
August 2010:	The subsidy from the New Energy Introduction Promotion Conference was approved

October 2010:	The construction work on the Hanakawa Power Station began (Construction in FY 2010)
December 2010:	A proposal for the river law was approved by the River Department of the Civil Engineering Division of Ibaragi Prefecture
February 2011:	The construction work on the Hanakawa Power Station was completed (Construction in FY 2010)
February 2011:	Completion test was passed
March 2011:	Management rules were published

2.3 Description of Work Undertaken (detail)

1-b) Investment incentives (Feed-in-Tariff (FIT), Renewable Portfolio Standard (RPS), subsidies, financial assistance, tax deductions, etc,)

With regard to a small scale hydropower station, in general, since cost performance is not good due to a relatively high unit construction cost, development plans are frequently abandoned for many sites. For this site however, the project was to redevelop the abandoned power station, and so, by reusing the existing facilities, a great cost saving of the construction work was able to be achieved. Especially, by reusing the civil engineering facilities such as the weir, intake, headrace, water tank and tailrace, the civil engineering work cost, which made up 60% of the entire construction cost, was able to be reduced to only 30%. In addition, by getting a subsidy from the New Energy Business Support from the Resources and Energy Agency, covering 30% of the whole construction work cost, the construction cost was able to be reduced further. By these measures, the construction cost was able to be reduced to the level which the electrical power supplier who is the recipient of this project wanted.

1-d) Asset Management, Strategic Asset Management and Life-cycle Cost Analysis

After the power station was abandoned, the entire facility was given to Kitaibaragi-shi by the Joban Kosan Co., Ltd. Accordingly we consulted about the redevelopment of the power station with Kitaibaragi-shi. When Kitaibaragi-shi agreed with the redevelopment plan and the city said that they were ready to provide the facilities with no charge, we had certainly investigated the redevelopment.

Since our Hanazonogawa Power Station is immediately upstream of this site, it has been easy to administer and it has been efficient for maintenance work after commencement of the operation.

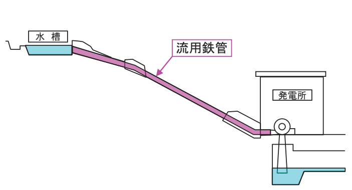
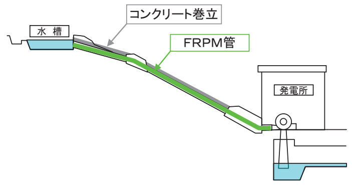
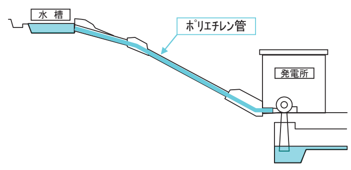
The construction cost was several hundred million yen lower because many parts of the facility were able to be reused, which is within a range for which funds were available for possible financing.

2-c) Technological innovation, deployment expansion and new materials used for civil and building works

- Characteristics of the steel pressurized water pipe construction work.

Though it was determined that the remaining life was 21 years by the survey, in consideration of future maintenance, it was decided to replace the steel pressurized water pipe. For the replacement materials, 1) reuse of the syphon pipe of the other power station, 2) replacement by FRPM pipe and, 3) replacement by polyethylene pipe, were compared and studied.

Table 2: Comparison chart of the materials for the steel pressurized water pipe

材 料 名	水圧鉄管（他発電所鉄管流用）	FRPM管	ポリエチレン管
概 要 図			
工 事 費	△	△	○
材 質	○	○	○
施 工 性	△	△	○
総 合	△	△	○

As shown in Table 2 of the examined result, replacement with a polyethylene pipe is the most beneficial and so a polyethylene pipe was determined to be adopted. The survey results of respective materials are as follows:

(A) Reuse of the water pressure steel pipe

a. By reusing the existing steel pipe, the material cost is able to be saved. However, since the existing shape is not able to be used as is, the existing configuration has to be changed.

b. Cost for the removal of the existing pipe and anchor blocks is necessary.

c. Reuse of the used materials is not subject to the subsidy.

(B) FRPM pipe

a. Less expensive than steel pipe.

b. High in anticorrosion property and abrasion resistance and has excellent durability.

c. Since there is no requirement for painting, economic efficiency is good.

d. FRPM pipe is susceptible to ultraviolet ray and is not able to be used exposed, therefore it is necessary to cover with concrete, resulting in a cost increase.

e. Removal of the old steel pipe line is not subject to the subsidy.

(C) Polyethylene pipe

a. Light and flexible material, and not necessary to worry about abrasion and so, results in good construction workability.

b. High durability because of high anticorrosion property and abrasion resistance.

c. Since there is no requirement for painting, economic efficiency is good.

d. By making it a double pipe system, the removal cost of the old steel pipe was reduced.

(D) Polyethylene pipe construction method

For the installation, the polyethylene pipe was lifted by a 25 ton crane, and after preparing the insert inlet on the steel pipe mouth and anchor block, the polyethylene pipe was inserted into the steel pipe from the anchor block bend section. The end portion was inserted from the end direction of the steel pipe, and while avoiding the bent section, fusion joining was conducted.

After joining, an air leak test was conducted. After insertion, mortar was filled from each opening. The filling status of the mortar was confirmed by making holes in the steel pipe as needed.

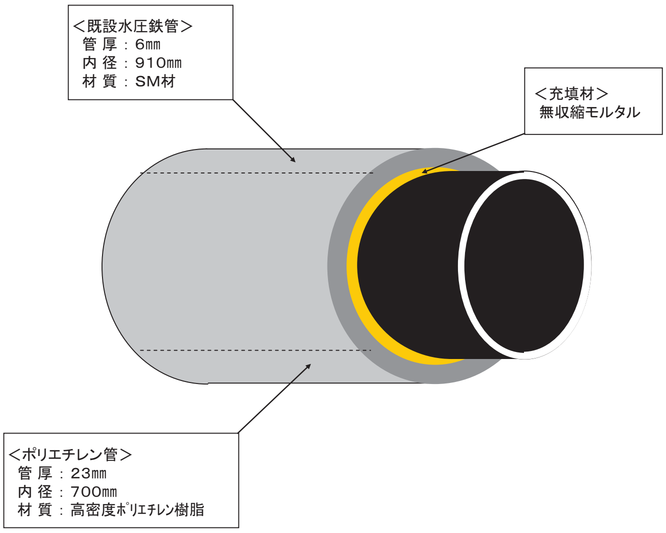


Fig. 2: Cross section view of the pressurized water pipe

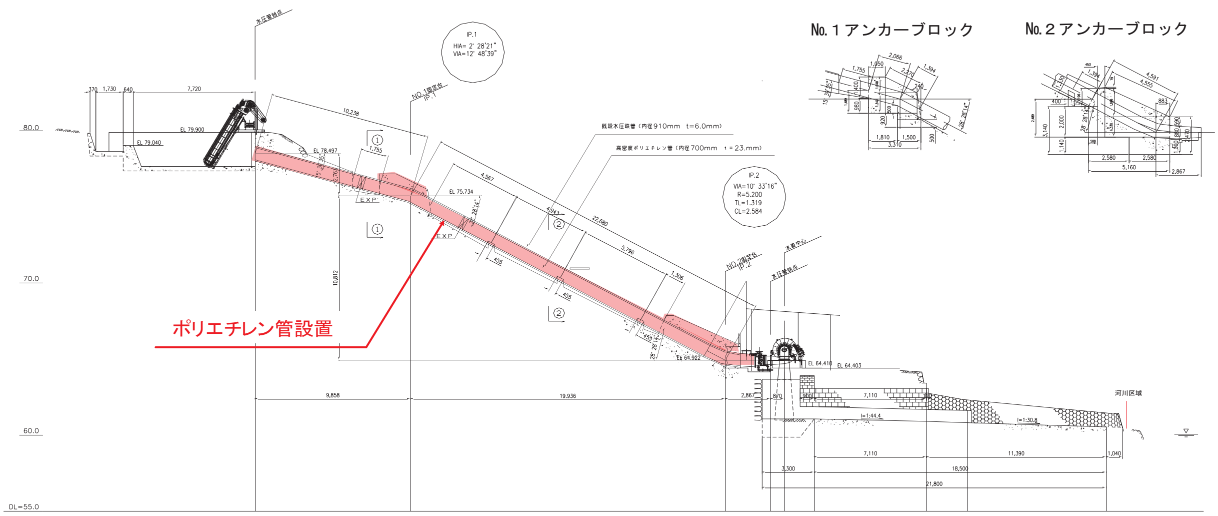


Fig. 3: Longitudinal profile of the pressurized water pipe

3. Feature of the Project

3.1 Best Practice Components

- In the redevelopment project of the abolished power station, by reusing the existing facilities, a great cost saving of the construction cost was able to be achieved.
- By getting the subsidy from the Resources and Energy Agency, the construction cost was able to be reduced even further.

3.2 Reasons for Success

The reason why this project has been successful is because the construction cost was able to be reduced greatly, and to receive the strong cooperation from Kitaibaragi-shi. As a result of the survey, it became clear that the existing facilities were not necessary to be extensively replaced. Consequently economical construction methods which minimized removal costs and others were able to be adopted so as to save cost.

Converting the conventional water rights of the irrigation water into law was able to be achieved in a short period of time due to the support of Kitaibaragi-shi.

4. Points of Application for Future Project

- When reusing the existing facilities, recognition of the soundness of these facilities (Judgment how much of a repair level is required)

5. Others (monitoring, ex-post valuation etc.)

(No monitoring and others)

6. Further Information

6.1 Reference

(None)

6.2 Inquiries

Company name: Tokyo Electric Generation Company

URL: http://www.tgn.or.jp/teg/

Format for the 2nd Round Data Collection (Definition of Case Histories)

Category and Key Points

Main: 1-d) Projects justified by the non-monetary valuation of stabilizing unstable power systems in the up-coming low-carbon society

Sub: 2-c) Technological innovation, deployment expansion and new materials used for civil and building works

Project Name:

Restoration construction project of the earthquake damage of the Ishioka No. 1 Power Station

Name of Country (including State/Prefecture):

Japan, Ibaragi Prefecture, Shizuoka Prefecture

Implementing Agency/Organization:

Tokyo Electric Generation Co., Inc.

Implementing Period:

2011

Trigger Causes for Renewal and Upgrade:

(F) Accidents and disasters

Keywords:

Great East Japan Earthquake, Restoration

Abstract:

Next section reference

1. Outline of the Project (before Renewal/Upgrading)

The Great East Japan Earthquake, which occurred at a depth of 24km under the sea bed offshore from Sanriku on March 11, 2011 at 14:46, was a giant earthquake, magnitude 9, with few equals in history. Along with the earthquake, the concurrent mega Tsunami, also caused huge damage on the area from the Tohoku to Kanto districts.　On top of that, 4 days later, on March 15, 2011 at 22:31, the Shizuoka East Earthquake with a magnitude of 6.4 occurred at a depth of 14km at the Fuji Mountain West Area, and caused serious damage in both Shizuoka Prefecture and Yamanashi Prefecture.

By these earthquakes, the waterway structures owned by Tokyo Generation Co., Inc. were damaged in 11 power stations (Fig. 1 to 3, Table 1-1) to different degrees.　Of all of them, for the following power stations, that is, 1) the Ishioka No. 1 Power Station (Ibaragi Prefecture) which was seriously damaged with the water tank collapse by the Great East Japan Earthquake, 2) the Hananukigawa No. 2 Power Station (Ibaragi Prefecture) in which the waterway piles were damaged and the surge tank was cracked open, and 3) the Kariyado Power Station (Shizuoka Prefecture) which was damaged by the Shizuoka East Earthquake with the surge tank collapse, the damage status, assumption of the cause of damage, plan and schedule of the restoration construction and construction results are described in detail.

Fig. 1: Location map of the Damage status from the Great East Japan Earthquake and the Shizuoka East Earthquake

Table 1: Overview of the power station damage by the Great East Japan Earthquake and the Shizuoka East Earthquake

(**10 power stations damaged in the administrative area of the Ibaragi business office**)

Power station	Output (kW)	Damaged Facilities
Ishioka No. 1 PS	5,500	The water tank partially destroyed and collapsed; The pressurized steel water pipe saddle was damaged, and others
Yokogawa PS	2,500	Inside of the water tank was cracked; Water tank spill channel was damaged, and others
Hanazonogawa PS	2,100	Inside of the water tank was cracked; Some land flowed out from the vicinity of the water tank
Nakazato PS	850	Inside of the headrace was cracked; Headrace had fallen flat, and others
Hananukigawa No. 2 PS	750	Waterway pipe was broken, Surge tank was cracked open, Steel pipe saddle was damaged, and others
Hanakawa PS	130	Inside of the waterway was cracked; Land by the waterway partially collapsed
4 other power stations: Bank protection stone masonry for the water tank failed, and others Output total : 14,810kW		

One damaged power station: In the administrative area of the Mishima business office

Power station	Output (kW)	Damaged facilities
Kariyado PS	1,700	The surge tank was damaged; The steel pipe was damaged

2. Description of the Renewal and Upgrading of the Project

2.1 Trigger Causes and Drivers for Renewal and Upgrading

(1) Condition, capability, influence of risk and others

(F)- (a) Accidents and disasters - Recovery

With the Great East Japan Earthquake of March 11, 2011 and the Shizuoka East Earthquake of March 15, 2011, several power stations ceased to operate. Even under such conditions, early recovery of the power station was strongly required so as to be able to respond to the summer peak power demand from a fear of power shortages after the Great East Japan Earthquake.

(2) Improvement of value (functions)

(Not applicable)

(3) Necessity in market

(Not applicable)

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

March 11 2011: The Great East Japan Earthquake occurred

March 15 2011: The Shizuoka East Earthquake occurred

From late March to early April 2011: Site surveys and designs were conducted

Early April 2011: Access roads to the sites were restored, boring and supporting force examination were conducted at sites, and the protection work on the collapsed slope was conducted.

Late April 2011: Main construction began

Early July 2011: Main construction was completed

2.3 Description of Work Undertaken (detail)

1-d) Asset Management, Strategic Asset Management and Life-cycle Cost Analysis

The Ishioka No. 1 Power Station is a channel type power station which was constructed to meet the increased power demands of the Hitachi Mine Co., Ltd. and started its operation in October, 1911. This power station is very valuable in Japanese industrial technical history as a leading facility for the Hitachi Mine which was renowned as a leading copper mine in modern Japan. This was the first power station in Japan for which for the entire waterway, reinforced concrete technology was adopted. Especially, the main office building was recognized for its value in industrial technical history and designated as a national important cultural property on December 2, 2008, because this main office building was the oldest reinforced concrete class structure which still survived in Japan.

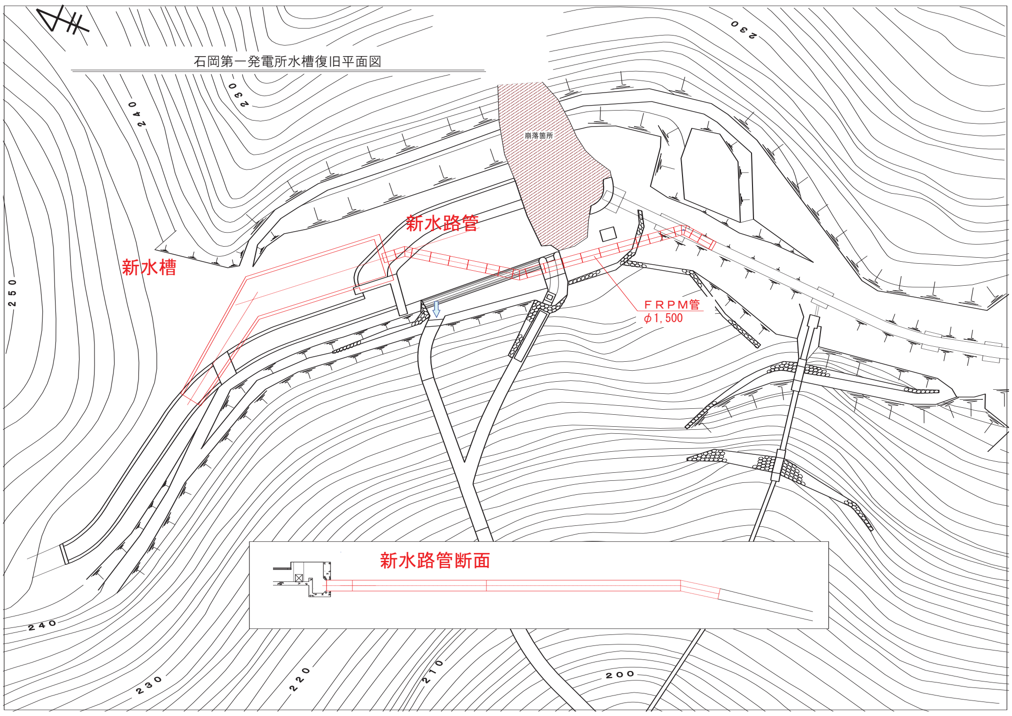
With an output of 5,500 kW, the Ishioka No. 1 Power Station ranks as one of the top 10 power stations owned by the Tokyo Hatsuden Co., Ltd. in terms of its output. Also, since this power station was an important power supply source to respond to the power shortage in the Tokyo Electric Power Co., Inc. administrative area, early recovery of the operation was strongly required to respond to the peak season power demand starting in July, 2011.

2-c) Technological innovation, deployment expansion and new materials used for civil and building works

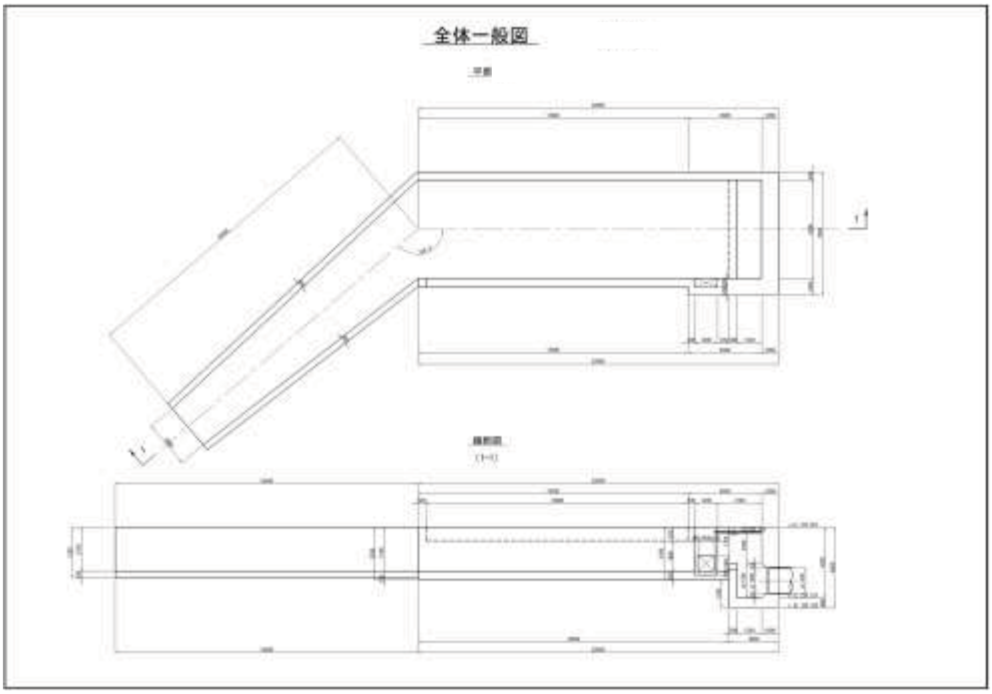
As the first priority work, slope protection work by temporary preservation was conducted and then the upper part of the water tank was to be restored on a priority basis, because it was going to take almost one year to conduct the full-scale restoration of the water tank after the collapse protection work on the lower part of the water tank.

Since the old water tank was only half destroyed, the new water tank was able to be placed only upstream, so it was decided that the tank would be installed by excavation down to bedrock which has sufficient support in that area. As a new water tank, in consideration of the length of construction time, a simple design which has a spill channel without a regulating gate was adopted. For the new water tank, a water tank sediment discharge gate, screen and dust collector were installed. For the spill channel wall, the wall of the old water tank was converted to use. In order to withstand a class 1 level earthquake, for its structure, reinforced concrete construction of the conventional design was adopted.

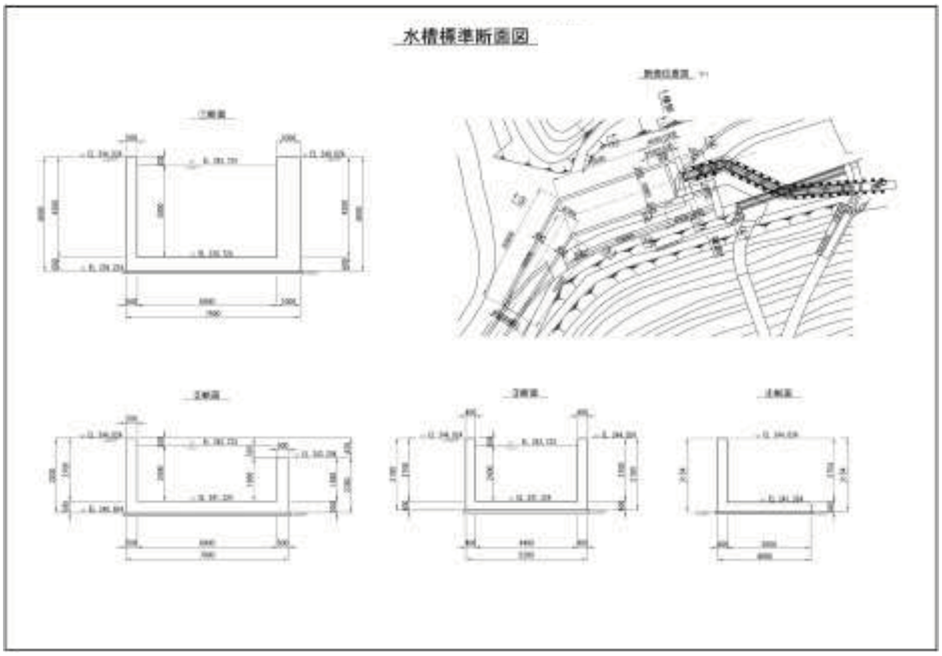
Incidentally, this new water tank is different from the old water tank in its shape as it was impossible to be rebuilt to the unusual original shape. Therefore the designation as a national important cultural property was partially cancelled (only for the water tank).



The restoration design of the Ishioka No. 1 Power Station (overall view)

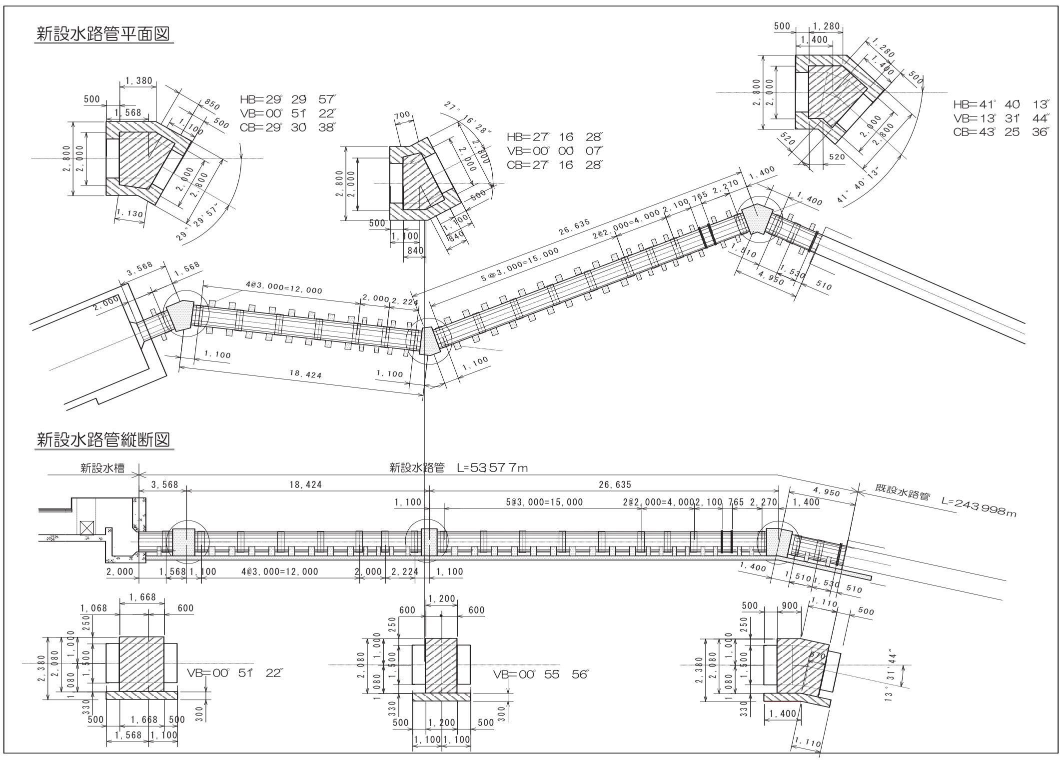


The restoration design of the Ishioka No. 1 Power Station (Water tank - 1)



The restoration design of the Ishioka No. 1 Power Station (Water tank - 2)

As a waterway pipe which connects the water tank and siphon pipe (steel pipe), weatherproof FRPM pipe (ϕ1.5m, inside pressure type) was adopted.　At the outlet of the water tank and at the section of siphon pipe which was not damaged, joints were attached to connect the sections.



The restoration design of the Ishioka No. 1 Power Station (Waterway pipe)

The installation of the new water tank upstream was a critical process for this entire project, therefore this work was started first, and necessary excavation machines, crane and other equipment were transported to the site by helicopter. Since the construction of a bypass road between the upper site and lower site of the collapsed area and installation of the waterway pipe was conducted from the downstream side, the necessary excavation machines and dump trucks were driven to the site on the access road itself.

The construction of the new water tank was conducted in following order of process and a total of 10 concrete pours were conducted, using a total of 220m^3 of concrete: that is, excavation → improvement of foundation cement→ foundation stone breakage→ concrete pour to level→ reinforcement assembly for bottom section→ frame assembly→ concrete pouring→ frame disassembly→ installation of scaffolding for the wide wall→ reinforcement assembly for the side wall→ frame assembly→ concrete pouring→ frame and scaffolding disassembly.

The construction of the 50m length waterway pipe was conducted in the following order: excavation→ improvement of foundation ground cement→ foundation stone breakage→ concrete pour to level→ placing bearing pad concrete (precast concrete) → FRPM pipe (@3.0m) installation→ placement of the seal on the joint area and application of lubricant→ junction connection by wire pulling→ fastening using bands. In addition, the FRPM pipe at the outlet of the water tank was wrapped with water-swelling rubber (chloroprene rubber) so as to prevent leaks, and the joint section with the existing siphon pipe was connected with a special swivel joint ring.

In this entire construction work, the most critical process was concrete placement. For the construction, ready-mixed concrete was used. However, on the access road to the site of the tank, only 4 ton cement mixer trucks could use the road, therefore at the entry to the access road, concrete was transferred to the smaller trucks from 8 ton mixer trucks which came from the concrete plant. By using three 4 ton trucks, concrete was repeatedly transferred to the water tank site on the steep mountain edge which was about 500m away from the approach. By considering the weather, plant status and workers deployment in detail, the concrete pouring work was conducted, and was able to be completed within the required construction work period.

The restoration work including accessory repair work of the pressurized steel water pipe and other parts was completed by June 26. 2 days later, a flow examination, a load dump test and the electric system examination were conducted and it was confirmed that there were no problems so, on June 29, operations of the Ishioka No. 1 Power Station started.

3. Feature of the Project

3.1 Best Practice Components

The restoration work was completed before the summer power demand peak season, and thus was able to contribute to the urgent power demand.

3.2 Reasons for Success

In the entire process, installation of the new water tank at an upstream site was the most critical, and heavy equipment was transported in by helicopter. On top of that, as a decisive factor for the entire construction, concrete placement, concrete was transported from the commercial concrete plant to the access road by 8 ton mixer trucks, and there, concrete was transferred to 4 ton trucks and brought to the site where the concrete pouring was conducted.

4. Points of Application for Future Project

The seismic wave of the Great East Japan Earthquake was recorded in the National Research Institute for Earth Science and Disaster Prevention at Takahagi, (KyoshinNet（K-Net）IBR002). This place is the nearest observation point, only 7.2km away from the damaged Ishioka No. 1 Power Station.

According to this record, the peak ground acceleration was 524.7gals in NS direction, 588.1gals in EW direction and 495.7gals in UD direction. Though the maximum acceleration in EW direction was larger, in all 3 directions, values were almost an equal level. The earthquake duration was very long at 200 to 300 seconds and earthquake intensity was reported to be a lower 6 level.

The water tank is installed on a narrow mountain ridge. The characteristic period of oscillation of the water tank, T, is assumed to be about 0.1 second (from T=0.02H) and based on the fact that the height of the water tank regulation gate H, which is the unstable height, was 5.6m.

In this earthquake, it is assumed that amplified acceleration acted on the water tank. However, since the predominant period of the earthquake wave was 0.4 second and 1.0 second, acceleration was large but the water tank did not resonate and so it is assumed that the direct impact damage was not large. This assumption is confirmed by the fact that the water tank collapsed 4 hours after the occurrence of the earthquake, at the time when the aftershocks were becoming smaller.

As another reason for the collapse of the water tank, it is assumed that because the earthquake duration was very long (200 seconds) and even after, the after quakes continued, therefore the ground where the water tank was installed swayed and gradually land slides were created. On top of that, the overflow caused by sloshing of water in a full water tank accelerated it, and finally the water tank was dragged resulting in the water tank collapse. As a reference, a satellite photograph taken after the disaster shows several new land slides in the vicinity of the water tank. As for the damage in this case by the earthquake, the reason for the collapse is able to be assumed by confirming the earthquake waves.

5. Others (monitoring, ex-post valuation etc.)

(Not applicable)

6. Further Information

6.1 Reference

National Research Institute for Earth Science and Disaster Prevention, K-NET

6.2 Inquiries

Company name: Tokyo Electric Generation Company

URL: http://www.tgn.or.jp/teg/

ANNEX XI Renewal & Upgrading of Hydropower Plants

Format for the 2nd Round Data Collection (Definition of Case Histories)

Category and Key Points

Main: 2-d) Integration of other renewable energies into hydropower systems

Sub: 1-d) Asset Management, Strategic Asset Management and Life-cycle Cost Analysis

Project Name:

Gate control system by hybrid power system at Togagawa No. 2 Power Station

Name of Country (including State/Prefecture):

Japan, Toyama Prefecture

Implementing Agency/Organization:

Kansai Electric Power Co., Inc.

Implementing Period: From

From 2009

Trigger Causes for Renewal and Upgrade:

(C) Needs for higher performance

(E) Needs due to third party factors

Keywords:

Hybrid, Solar cell, Wind power generator

Abstract:

The Kotanigawa Intake Dam is a Tyrolean-type water intake facility which receives water from a mountain stream for the Togagawa No. 2 Power Station. Since this dam was operated with an intake regulating gate full open and fixed, if the water level of the river rose, there was a fear that more than the allowable water would be taken in. Therefore, beginning on April 25, 2007, the intake regulating gate was closed completely and water intake was stopped. In this case, to restart water intake, since it was necessary to adopt an appropriate facility system which enabled controlling water intake within the allowed level, a hybrid power system (solar cell + wind power generator) was adopted as a power source.

1. Outline of the Project (before Renewal/Upgrading)

The Togagawa No. 2 Power Station is a dam and conduit type power station which is located upstream on the Togagawa River in the Shogawa water system in Toga-mura, Nanto-shi, Toyama Prefecture. This power station receives water at a maximum of 11.00m^3/s from the Togagawa River and generates 31,700kW at maximum output and then discharges water to the Shogawa River through a headrace of 5.7km. The intake is located upstream on the left bank of the Senzoku Dam which is installed on the Togagawa River of the Shogawa water system. In addition, a maximum of 1.00 m^3/s of water is received from the Kotanigawa Intake installed on the Kotanigawa River which is a tributary of the Shogawa water system. This occurs at the point of the passage of the main waterway, and is directly discharged into the headrace. The specifications of the power station are shown in Table 1.

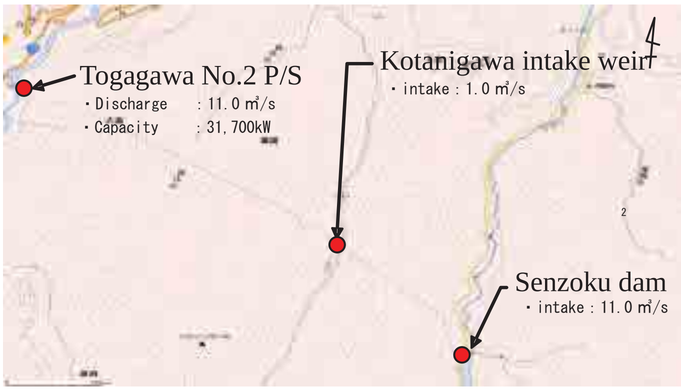


Fig. 1: Location map of the Togagawa No. 2 Power Station

Table 1: Specifications of the Togagawa No. 2 Power Station

Items		Specifications
Powerhouse	Name of power station	Togagawa No. 2 Power Station
	Maximum output	31,700 kW
	Maximum plant discharge	11.00 m^3/s
	Effective head	338.73 m

2. Description of the Renewal and Upgrading of the Project

2.1 Trigger Causes and Drivers for Renewal and Upgrading

(1) Condition, capability, influence of risk and others

(E) - (a) Needs due to third party factors – Sustained operation (sometimes accompanied by power reduction)

The Kotanigawa Intake Dam is a Tyrolean-type water intake facility which receives water from a mountain stream for the Togagawa No. 2 Power Station. Since this dam was operated with an intake regulating gate full open and fixed (opening/closing was operated by an engine), if the water level of the river rose, there was a fear that more than the allowable water would be taken in if the engine should fail. Therefore, from April 25, 2007, the intake regulating gate was closed completely and water intake was stopped.

(2) Improvement of value (functions)

(C) - (a) Needs for higher performance – expansion, increase of output per hour

For the water intake whose operation was stopped, to introduce a system which properly enables controlling water intake within the allowable limits, a hybrid power source (solar cell + wind power generator) was adopted. After installation of the system, water intake was restarted and an output increase was achieved.

(3) Necessity in market

(Not applicable)

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

April 2007: The water intake regulating gate of the Kotanigawa River was closed completely (because there was a fear that intake water might exceed the allowable volume)

November 2009: The construction began at the site (Introduction of this system)

December 2009: Completion test was passed.

February 2010: Water intake was restarted.

2.3 Description of Work Undertaken (detail)

1-d) Asset Management, Strategic Asset Management and Life-cycle Cost Analysis

For the power source for the opening/closing operation of the intake gate, the following methods were studied. The first idea was a power cable on an overhead bridge. It became clear that this idea was impossible because of the various conditions such as the sloppy conditions on the forest road leading to the intake point site on the Kotanigawa River, the number of valleys which have to be crossed, the risk of snow avalanches in the winter season, and the difficulty to obtain the necessary rights of way (Fig. 2). The second idea was a power cable in the headrace. This idea also became clear to be impossible because the confluence of the headrace and inclined adit were at too acute an angle, and the cross-section area of flow is too small to conduct an installation (Fig. 3). Finally, the field operation using natural energy such as solar cells and others (automatic control in response to water volume) was adopted.

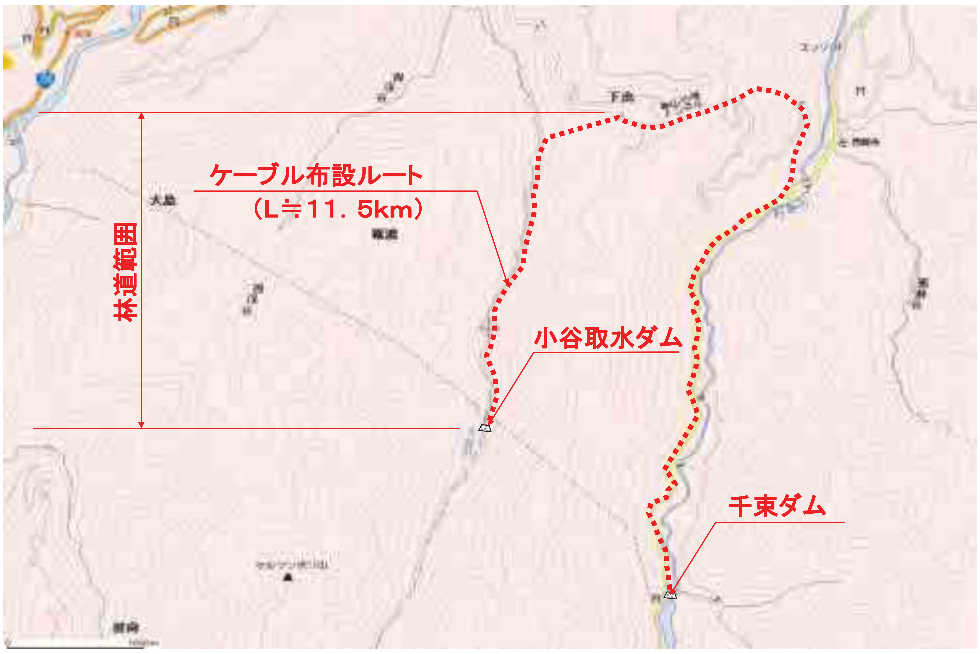


Fig. 2: First idea: plan to install an overhead cable

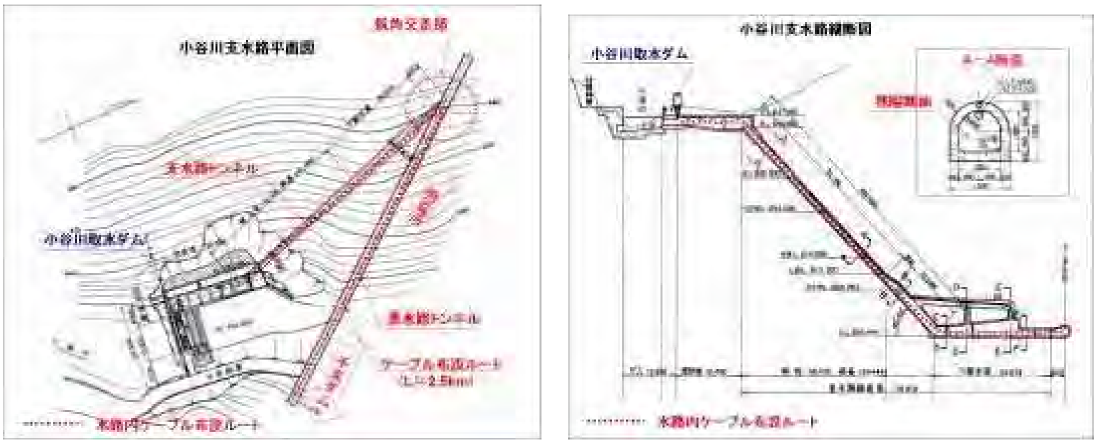


Fig. 3: Second idea: Cable installation in a headrace

2-d) Integration of other renewable energies into hydropower systems

Based on the scale and operation method of the newly installed headrace regulating gate opening/closing system and an automatic control system responding to incoming water volume, the power consumption level was calculated. Based on the calculation, the necessary specifications for the hybrid power system (solar cell + wind power generator) were determined. First, the required numbers of solar cells was calculated and then, assuming the number of days when solar generation is not possible due to rainy weather and other reasons, the required battery capacity was determined. Finally, so as to compensate for a shortage of solar cell output due to snow deposited in the winter season, an appropriately sized wind power generator was selected. The installation status is shown below (Fig. 4 to 7)

Table 2: Specifications of renewable energy

Solar energy	Maximum 336 W
Wind energy	Maximum 3,200 W
Storage battery	105A×8batteries

Fig. 4: View of the installation of solar cells and wind power generator

Fig. 5: Equipment of the automatic control system responding to water volume

Fig. 6: View of the headrace regulating gate

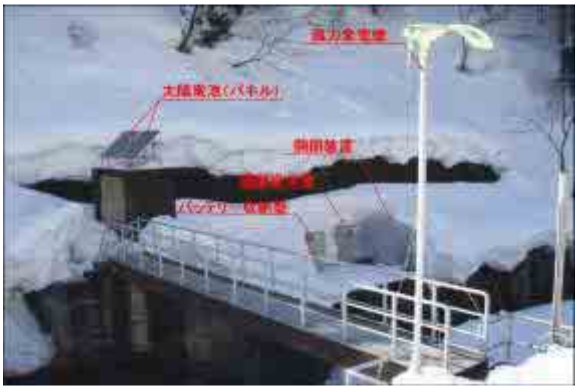


Fig. 7: View of snow accumulation in winter

3. Feature of the Project

3.1 Best Practice Components

In the past, to keep the maximum water volume strictly controlled, the intake gate from the Kotanigawa Intake Dam (weir) was closed completely. However, by integrating other renewable energy sources (solar cell + wind power generator) to the hydropower system, an excess intake of water was able to be avoided, thus water intake was able to be restarted and used for additional power generation.

3.2 Reasons for Success

In this power station, in the past, the usage of the water intake facility was stopped by closing the intake gate completely so as to avoid excess water of more than allowable water volume. Subsequently, low carbon and renewable energies are attracting social attention and in the company, the momentum for effective utilization of water is strengthening. Therefore, on the premise of facilities improvement, the study for the restart of the water intake facility was begun. At this severe natural conditions site, we have studied securing a power source method for the water intake facility control. Based on that, a full-scale investigation about utilization of natural energy (solar cell + wind power generator) at the site was able to be conducted. To be more precise, the following measures were adopted: 1) making it possible to control the gate using natural energy by downsizing and reinstalling the water regulation gate. On top of that, the following various measures were taken: 2) as a method of reducing the required power load, the specification of the system was changed (AC100V→DC24V). For the machine control, power is turned on only as necessary. An alarm sensor was installed which turns on power for the sequencer when water reaches a certain level, and in winter time, since gate opening degree is fixed, control power can be shut down. They are the reasons of success. After all, by these measures, it can be said that the reason for success was that the required energy was calculated very precisely, and the characteristics of the solar energy and wind energy equipment was utilized effectively.

4. Points of Application for Future Project

- Various studies of securing the power source
- Calculation of the necessary power energy and battery capacity based on the study of the scale of the control facilities (gate and others)
- Calculation of the natural energy amount available at the subject area

5. Others (monitoring, ex-post valuation etc.)

(Not applicable)

6. Further Information

6.1 Reference

"Implementation of the gate control using hybrid power system (solar cell + wind power generator)", *Journal of Electric power Civil Engineering*, (2011.5)

"Implementation of the gate control using hybrid power system (solar cell + wind power generator)", 55th Electric Civil Engineering Training Session (February 7 to 8, 2013)

6.2 Inquiries

Company name: Kansai Electric Power Company

URL: http://www.kepco.co.jp/

ANNEX XI Renewal & Upgrading of Hydropower Plants

Format for the 2nd Round Data Collection (Definition of Case Histories)

Category and Key Points Main:

Main: 1-c) Integrated Management of Water Resources and River Systems (General development plan, water rights and others)

Sub: 2-c) Technological innovation, deployment expansion and new materials used for civil and building works

Project Name:

Dam Raising Project (Shin-Maruyama Dam)

Name of Country (including State/Prefecture):

Gifu Prefecture, Japan

Implementing Agency/Organization:

Kansai Electric Power Company

Implementing Period:

2013 onwards

Trigger Causes for Renewal and upgrading

(E) Needs due to third party factors

Keywords:

Dam raising project, Compensation

Abstract

The Kiso River originates from the southern foot of Mt. Hachimori in Nagano Prefecture, merges with its largest tributary, Otaki River, and runs through the gorges of the Kiso region as it joins with numerous other tributaries, before merging with the Hida River at 70km from the estuary, running through the Nobi Plain and pouring into the Ise Bay. It has the total stream length of 227km and basin area of 9,100km^2, with the average rainfall of 2,411mm per annum along the catchment (FY1986). The river, which has one of the largest hydropower potentials in Japan, hosts numerous power plants and dams. The Maruyama Dam is located in the downstream area of the river in the section under the jurisdiction of Kansai Electric Power Company. While this is a multi-purpose dam with flood control capacity, there is also the Dam Raising Project (Shin-Maruyama Dam), which involves dam raise to substantially improve the flood control capacity. Accordingly, the hydropower facilities held by the company need to be upgraded, with details to be worked out in the future.

1. Outline of the Project (before Renewal/Upgrading)

The Kiso River originates from the southern foot of Mt. Hachimori in Nagano Prefecture, merges with its largest tributary, Otaki River, and runs through the gorges of the Kiso region as it joins with numerous other tributaries, before merging with the Hida River at 70km from the estuary, running through the Nobi Plain and pouring into the Ise Bay. It has the total stream length of 227km and basin area of 9,100km^2, with the average rainfall of 2,411mm per annum along the catchment (FY1986). The river, which has one of the largest hydropower potentials in Japan, hosts numerous power plants and dams. The Maruyama Dam is located in the downstream area of the river in the section under the jurisdiction of Kansai Electric Power Company. While this is a multi-purpose dam with flood control capacity, there is also the Dam Raising Project (Shin-Maruyama Dam), which involves dam raise to substantially improve the flood control capacity.

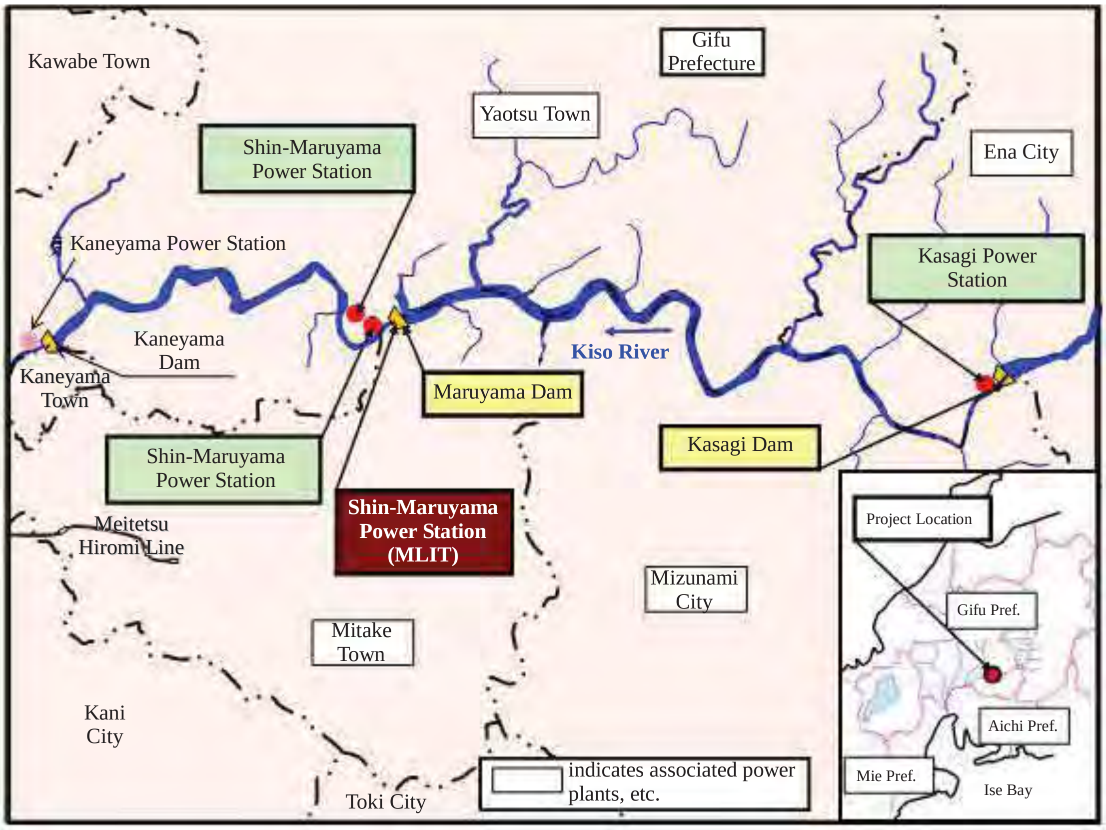


Fig.1 Location of the Shin-Maruyama Dam

2. Description of the Renewal and upgrading of the Project

2.1 Trigger Causes and Drivers for Renewal and upgrading

(1) Conditions, performance, and effects of risks, etc.

(E) - (a) Needs due to third party factor - Sustainable operation (sometimes accompanied by power reduction)

Amidst recent social attention to the need to address flooding resulting from rainstorms, hydropower facilities held by Kansai Electric Power Company must be improved in conjunction with the dam raising project by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) for floodwater control.

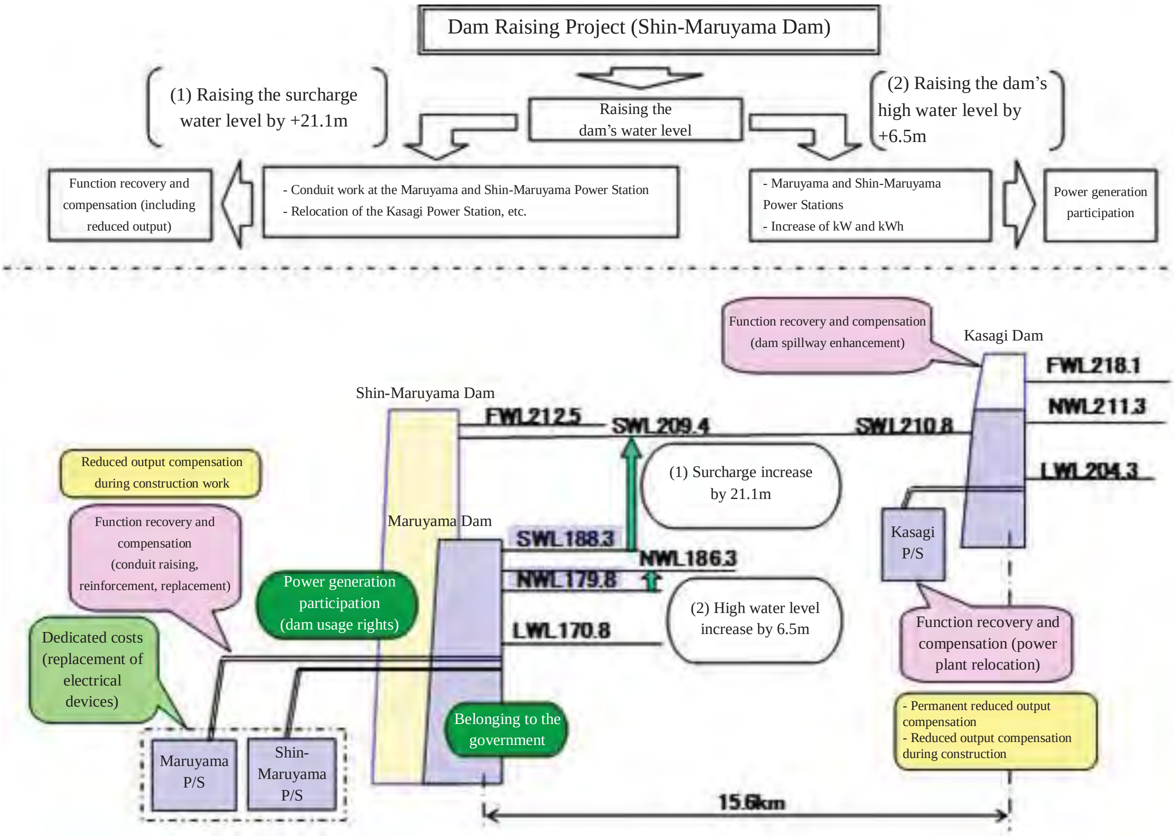


Fig.2 Impact of dam raise on the company's power generation facilities

Kansai Electric Power Company's affected power generation facilities undergo the raising of intake gate / surge tank, reinforcement of conduit and replacement of penstock at downstream power plants, as well as the relocation of power plants and upgrading of spillway gates at upstream power plants, from the perspective of function recovery and compensation. The table below lists engineering works to be carried out (Table 1).

Table 1 Engineering works to be carried out on the company's facilities affected by the project

Overview of performed engineering works

Power plant name	Item	Description	Category	Output increase/decrease
Maruyama P/S	Intake gate	- Raising	Function recovery and compensation	Reduced output compensation during construction
	Conduit	- Reinforcement of surrounding bedrock and lining installation		
	Surge tank	- Raising		
	Penstock	- Replacement		
	Turbine/generator	- Replacement	(Dedicated work)	(Increase of power output effect)
Shin-Maruyama P/S	Intake gate	- Raising	Function recovery and compensation	Reduced output compensation during construction
	Conduit	- Reinforcement of surrounding bedrock and lining installation		
	Surge tank	- Raising		
	Penstock	- Ground reinforcement		
	Turbine/generator	- Replacement	(Dedicated work)	(Increase of power output effect)
Kasagi P/S	Power plant	- Construction for relocation	Function recovery and compensation	Permanent reduced output compensation Reduced output compensation during construction
	Dam	- Regulating gate raising (radial gate to roller gate)		
		- Remodeling of existing intake gate to spillway		

Power generation participation

(2) Improvement of the value (function)

(N/A)

(3) Necessity in the market

(N/A)

2.2 Process to Identify and Define Renewal and Enhancement Work Measure

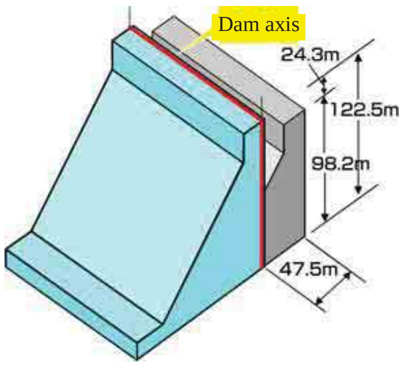
04.1954 Operation of the Maruyama Power Station commenced

05.1971 Operation of the Shin-Maruyama Power Station commenced

2.3 Description of Work Undertaken (detail)

1-c) Integrated Management of Water Resources and River Systems (General development plan, water rights and others)

This project raises a dam with the aim of substantially improving the floodwater regulating capacity.



Dam height	98.2m	122.5m
Floodwater regulation capacity	20,170,000m^3	72,000,000m^3
Capacity for stabilizing the existing water intake and preserving the river environment	0m^3	15,000,000m^3
Power output	188,000kw	210,500kw

Fig.3 Overview of the dam raising project

2-c) Technological innovation, deployment expansion and new materials used for civil and building works

The Shin-Maruyama Dam is to be raised on the largest scale in Japan for a large-scale multi-purpose dam. The existing Maruyama Dam plays an important role in regulating the flooding of the Kiso river's main stream and also in the company's power generation business. Its functionality must be maintained even during the construction work. The project is expected to apply advanced technologies in terms of design and construction methods.

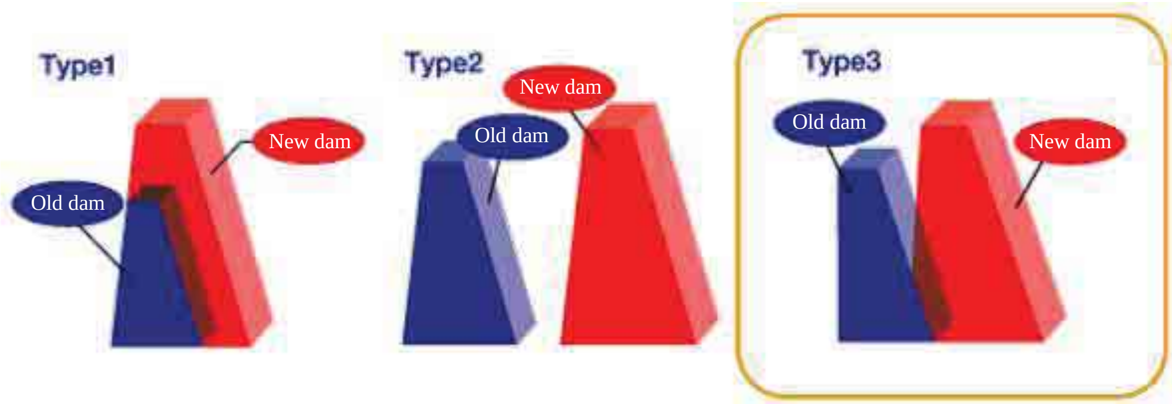


Fig.4 Dam raising methods

3. Feature of the Project

3.1 Best Practice Components

-One of the largest dam raising projects in Japan involving a large-scale multi-purpose dam

-Approach to power plant extension / enhancement

3.2 Reasons for Success

Both parties must reach common understanding about the need for flood control measures. The company extends its cooperation in promoting the dam raising project after carefully examining the impact on its hydropower facilities and necessary compensation.

4. Points of Application for Future Project

-Identifying the appropriate level of flood control capacity

-Identifying the project's impact in all areas including upstream areas, and necessary level of compensation

5. Others (monitoring, ex-post valuation etc.)

(None)

6. Further Information

6.1 Reference

(None)

6.2 Inquiries

Company name: Kansai Electric Power Company

URL : http://www.kepco.co.jp/

ANNEX XI Renewal & Upgrading of Hydropower Plants

Format for the 2nd Round Data Collection (Definition of Case Histories)

Category and Key Points

Main: 1-d) Asset Management, Strategic Asset Management, Life Cycle Cost Analysis

Sub: 2-a) Technical innovation and deployment expansion of electro-mechanical (E&M) equipment

2-b) System and reliability improvements in protection and control (P&C)

Project Name:

Upgrading of the Kumagawa No.1 Power Station

Name of Country (including State/Prefecture):

Gunma Prefecture, Japan (Asia)

Implementing Agency/Organization:

Tokyo Electric Power Company

Implementing Period:

From February 2014 to March 2015

Trigger Causes for Renewal and Upgrading:

(A) Degradation due to ageing and recurrence of malfunction

(C) Needs for higher performance

Keywords:

Sediment abrasion, Maintenance, Running cost

Abstract

It was decided to overhaul the Kumagawa Daiichi Power Station, which commenced operation in 1922, due to severe aging of main facilities. The renewal chose equipment with focus on eliminating auxiliary equipment and achieving a shorter turbine repair period / longer repair cycle after renewal, so as to reduce the power station's life cycle cost.

1. Outline of the Project

Tokyo Electric Power Company's Kumagawa Daiichi Power Station, located in Naganohara Town, Agatsuma County, Gunma Prefecture, is a conduit-type hydropower station with the output of 2,400kW, using water from the Kumagawa River, a tributary of the Agatsuma River (Fig.1). There are the Kumagawa Daini Power Station (1,600kW) downstream, as well as the Kariyado Power Station (1,200kW) and Kariyado Daini Power Station (61kW) upstream.

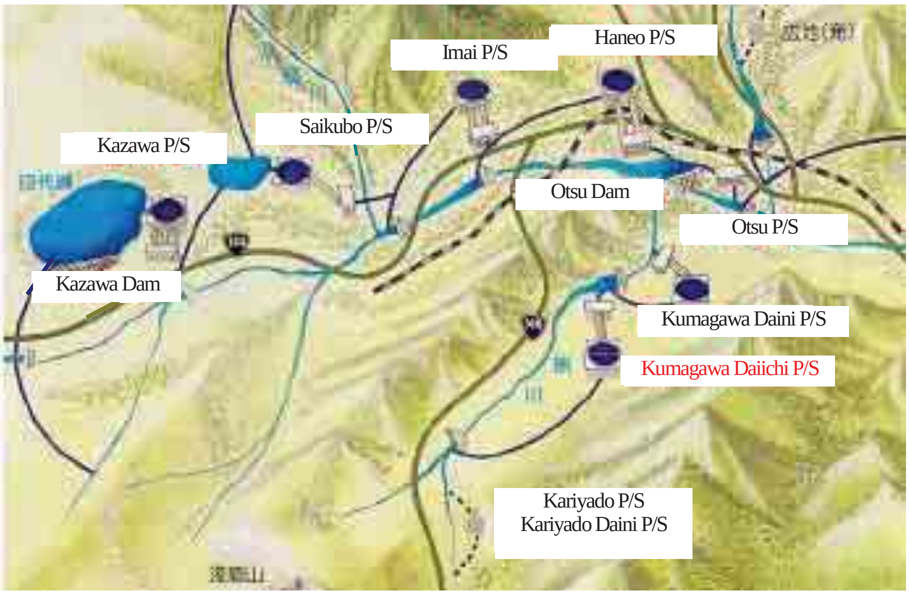


Fig.1 Power stations along the Kumagawa river system

2. Description of the Renewal and Upgrading of the Project

2.1 Trigger Causes and Drivers for Renewal and Upgrading

(i) Condition, capability, influence of risk and others

(A) Degradation due to ageing and recurrence of malfunction

The 90-year-old Kumagawa Daiichi Power Station (Fig.2), which commenced operation in 1922 underwent partial facility renewal to maintain its functions. However, it was decided to renew the entire power station due to a variety of issues including the aging of a majority of the main facilities such as turbine casings, main transformer and power receiving equipment, requiring updating, the existence of numerous auxiliary items requiring maintenance, and seismic safety issues with the power station building.

The extent of facility degradation and administration issues that led to the renewal of the Kumagawa Daiichi Power Station are as follows:

(1) Casing

The casing is 90 years old from the time of its manufacturing and has significant thinning from erosion, corrosion and wear. In the remaining life assessment carried out in 2005, some of the stay vanes were determined to have only around six years in remaining service life. Since it is made of cast iron, it is impossible to repair it with welding, making it necessary to carry out an urgent renewal.

(2) Runners and guide vanes

The high silica content of water causes fast abrasion wear to the water flow areas. The water turbine needs to be repaired at the rate of once every seven years. Every time the turbine is repaired, the runner liners, sheet liners and guide vanes must be replaced.

(3) Inlet valve

The inlet valve is hydraulically operated. Sediment entering into the servo has caused the valve to become non-responsive to operations. Both the valve disc and valve body have suffered significant thinning from corrosion and abrasion, with some of the sections measuring below the required thickness. The valve body also has a linear defect of up to 19.2mm deep.

(4) Main transformer

The main transformer, made in 1960, uses hot rolled silicon steel sheet, and therefore could have an iron-core corner defect. It also contains a minute amount of PCB.

(5) Power receiving facilities and switch boards

The power receiving facilities and switch boards are over 30 years old. Aging has increased the number of faults and is creating issues such as the unavailability of replacement parts.

(6) Power station's main building

The main building is aged and has only about 40% of the seismic strength required.

Fig.2 Kumagawa Daiichi Power Station (before the renewal)

The renewal makes diverted use of civil engineering facilities to cut costs, improves the turbine's efficiency to boost power generation, implements sediment abrasion countermeasures on the turbine's water flow areas to extend the cycle of turbine repair, and eliminates auxiliary equipment to reduce maintenance work. Table 1 shows the specifications of the Kumagawa Daiichi Power Station before and after the renewal.

Table 1 Specifications of the Kumagawa Daiichi Power Station before and after the renewal

Category	Before	After (planned figures)
Power station output [kW]	2,400	2,600
Annual power generation [MWh]	16,900	19,200
Power station type	Conduit type	Conduit type
Discharge for maximum power [m^3/s]	2.230	2.230
Maximum effective head [m]	140.330	139.845

(ii) Improvement of value (functions)

(C) Needs for higher performance

The Kumagawa River, which is the plant's source of water, provides a stable flow volume throughout the year, allowing the Kumagawa Daiichi Power Station to have a very high capacity factor of around 70%. The increased output from enhanced turbine efficiency, and reduced frequency of maintenance shutdown from the turbine's material improvement and auxiliary equipment elimination, are expected to increase the amount of power generation significantly.

This renewal enables more effective| use of water, which is a precious source of renewable energy, cutting CO_2 emissions by around 1,000 tons per year.

(iii) Necessity in market

(Not applicable)

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

1922: Operation of Kumagawa#1 began

2014: Renewable construction work of began

2015: Renewable construction work complete

2.3 Description of Work Undertaken (detail)

Table 2 Comparison of Kumagawa Daiichi Power Station's facilities before and after the renewal

Equipment name	Qty	Before	After
Water turbine	1	Horizontal-shaft single-runner multiple-discharge spiral Francis turbine - Type : VF-1RDS - Output : 3,430kW - Flow volume : 2.780m^3/s - Revolving speed : 600min^{-1} - Specific speed : 50.4m-kW	Horizontal-shaft single-runner single-discharge spiral Francis turbine - Type : VF-1RS - Output : 2,717kW - Flow volume : 2.230m^3/s - Revolving speed : 750min^{-1} - Specific speed : 81m-kW
Pressure regulator	1	Hydraulic pressure regulator	(eliminated)
Inlet valve	1	Main valve: Water-hydraulic sluice valve Bypass valve: Oil-hydraulic sluice valve	Main valve: Electric biplane valve Bypass valve: Electric needle valve
Oil pressure supply system	1	Normal oil pressure: 1.47MPa Scope of supply: Governor, bypass valve, controller Oil pressure tank capacity: 280 L Oil collection tank capacity: 640 L	(eliminated)
Governor	1	Electrical governor Hydraulic guide vane servo	Electrical governor Hybrid guide vane servo
Generator	1	Horizontal-shaft revolving-field three-phase synchronous generator - Capacity : 3,000kVA - Voltage : 6,600kV - Power factor : 80% - Insulation type : B - Revolving speed : 600min^{-1}	Horizontal-shaft revolving-field three-phase synchronous generator - Capacity : 2,770kVA - Voltage : 6,600kV - Power factor : 95% - Insulation type : F - Revolving speed : 750min^{-1}
Bearing cooling method	1	External circulating water cooling	Built-in air-cooling
Exciter	1	Static exciter	Brushless exciter
Main building	1	Two-story reinforced concrete building	Single-story reinforced concrete building
Overhead crane	1	Manual lifter	Electrical overhead crane
Facility configuration (power receiving format)		2LS-1CB (π circuit) Without standby line on site (EG connection)	1LS-1CB (T circuit) With standby line on site (distribution line circuit)

2-a) Technological innovation & deployment expansion of electro-mechanical (E/M) equipment

2-c) Technological innovation, deployment expansion and new materials used for civil and building works

(1) Turbine type and the number of main units

Since the flow volume hardly ever dips below 60% of the discharge volume for maximum power throughout the year and the frequency of low-output operation extremely low, it was determined that the current setup of using single horizontal-shaft Francis turbine is optimum. After comparing performance with revolution count at 600min-1, 750min-1 and 1000min-1, the 750min-1 option was selected as it was the most well-balanced in terms of power generation, initial cost and running cost. The power station output after renewal is expected to be 2,600kW (increase of 200kW) as the use of the latest runner design should improve the turbine efficiency.

(2) Turbine selection based on the ease of dissembling and assembling

In selecting the turbine, the company took into consideration not only turbine efficiency and initial cost but also the ease of dissembling and assembling, which relates to the level of running cost, and chose a turbine that can be dissembled and assembled while having guide vanes kept in the turbine cover. This allows the dissembling / assembling of guide vanes and operation mechanisms at the same time as other operations, reducing the number of days required for dissembling / assembling to repair the turbine by around 15 days compared to the conventional turbine.

(3) Countermeasures for sediment abrasion on the water-flow sections

Sediment abrasion has necessitated turbine repair roughly once every 7 years, at which time the liners and guide vanes were replaced. The company tried thermal-spraying Colmonoy (self fluxing alloy) on the guide vanes, in particular, to make improvement. However, it failed to produce expected results due to the difficulty in thermal processing and the issue of susceptibility to cracking, attributable to internal stress from film thickness difference.

In this renewal, water flow sections such as runner vanes, guide vanes and cover liners, are treated with high-pressure and high-velocity oxygen fuel spraying (hereinafter 'HP/HVOF spray'), using tungsten carbide cermet for corrosion / wear resistance. The HP/HVOF spray can be applied with minimal thermal impact on the base material, creating rigid and fine film. The coating of the water flow sections with the HP/HVOF spray is expected to slow down the abrasion loss of the base materials for existing facilities by at least 50%.

(4) Application of the hybrid servo

Guide vanes were operated hydraulically until now, but this renewal will introduce the hybrid servo for guide vane operation.

The hybrid servo consists of electrical control motor, hydraulic pump unit and hydraulic cylinder, and is attracting attention as a new-generation servo that replaces the conventional hydraulic servo and electric servo. Compared to the mainstream electric servo, it has a simpler structure with a smaller number of components, thereby reducing the initial cost by around 50%. The absence of ball screws, which are the source of the problem for guide vane operation electric servos, extends the repair cycle and eliminates the need for factory overhaul.

The hybrid servo uses a small mount of oil (around 20 liters) for operation, but the oil simply circulates within a short loop directly connecting the hydraulic pump unit and hydraulic cylinder. The risk of oil leak is therefore minimal.

(5) Elimination of auxiliary equipment

The use of the runaway speed unit raises the allowable maximum revolving speed at the time of load rejection. This slows down guide vanes' closing time to reduce the increase of casing's water pressure, enabling the elimination of the pressure regulator. This also eliminates the need for large-capacity hydraulic operation devices, which, in turn, allows the omission of the oil pressure supply unit.

The use of built-in air-cooled bearings means the existing bearing grease circulation unit and grease coolant supply unit can also be omitted.

(6) The use of ICT (Information and Communication Technology)

At un-manned power stations, the company carries out periodical patrols to check the status of individual devices and collect data such as temperature, pressure and oil level. This renewal uses the ICT-based device status monitoring system, allowing remote checking of a wide range of plant data such as bearing temperature, penstock pressure and guide vane openness. This is expected to produce effects including shortening data collection time in walkdowns and reducing the frequency of walkdowns.

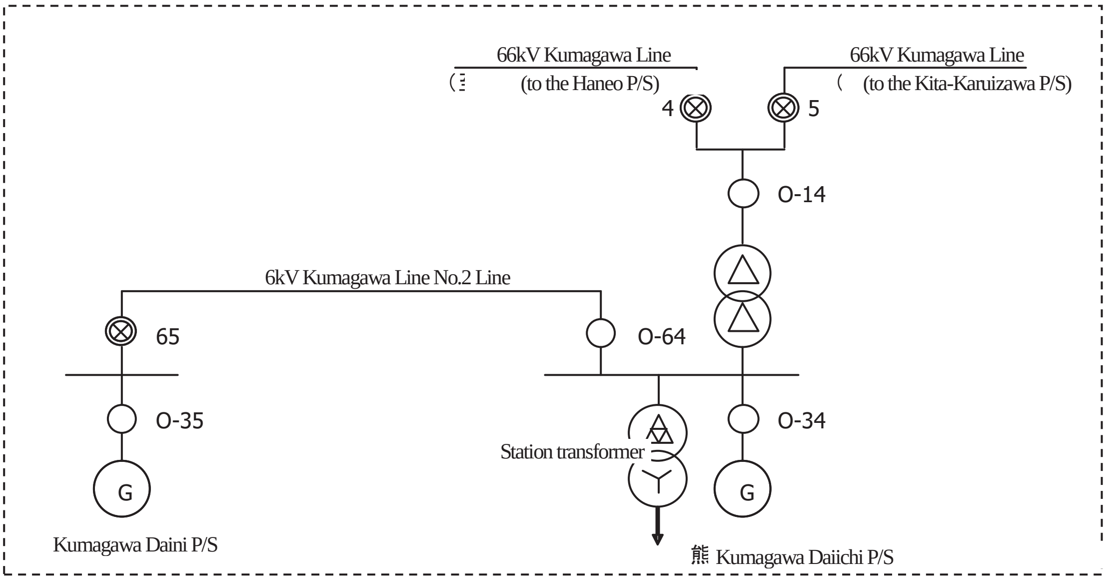
(7) Use of the integrated switch board for a smaller station building

Using an integrated switch board reduces the number of panel faces required and therefore decreases the installation area. This allows the direct installation of the switch board on the elevated section of the turbine operation room, rather than having to set up a separate switch board room in the station building. The space underneath the elevated switch board level can be effectively utilized as part of rotating space for the rotor axis during dissembling / assembling, or as the temporary storage space for dissembled components. This move makes it possible to install the switch board in the turbine operation room without compromising the ease of maintenance work, and reduce the total area of the turbine operation room than before.

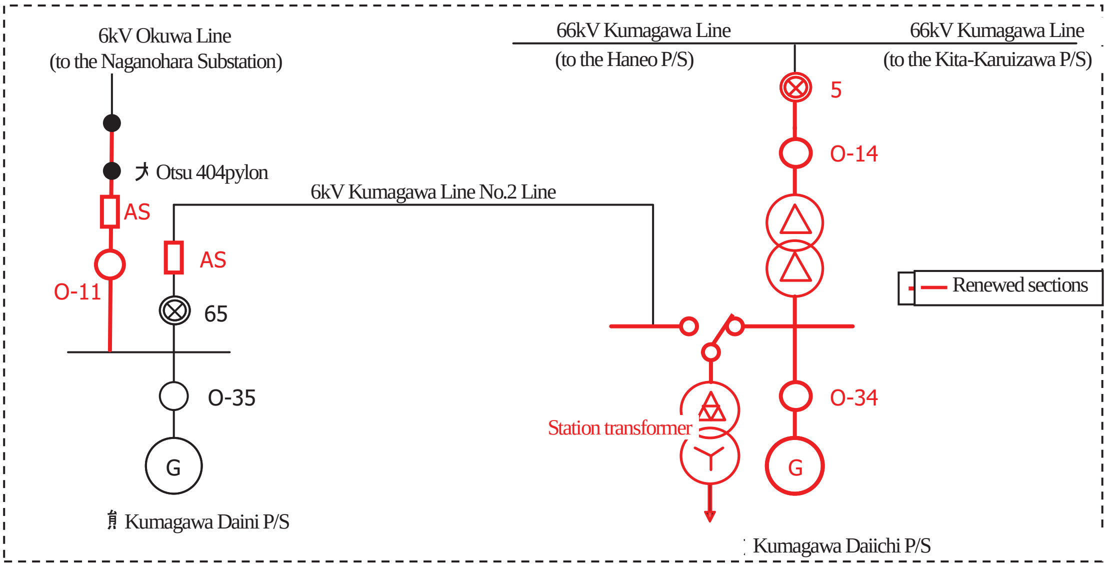
(8) Optimization of transmission / reception facilities

The Kumagawa Daini Power Station, at the downstream of the Kumagawa Daiichi Power Station, uses the 6kV Kumagawa No.2 Line to link to the 66kV Kumagawa Line via the Kumagawa Daiichi Power Station's bus (Fig.3 (a)). For this reason, the Kumagawa Daini Power Station loses the link destination while the bus of the Kumagawa Daiichi Power Station is disconnected. This has been a factor in increasing overflow power.

Carrying out distribution line connection work at the Kumagawa Daini Power Station (Fig.3 (b)) prior to the renewal of the Kumagawa Daiichi Power Station, will not only allow the Kumagawa Daini Power Station to operate regardless of the status of the Kumagawa Daiichi Power Station, but also offers the Kumagawa Daiichi Power Station a standby power supply (Okuwa Line – Kumagawa No.2 Line), enabling stable power station operation.



(a) Current grid connection



(b) Grid connection after the renewal

Fig.3 Renewal of the transmission and receiving facilities at the Kumagawa Daiichi and Daini Power Stations

1-d) Asset Management, Strategic Asset Management, Lifecycle Cost Analysis Initial cost assessment

Fig.4 compares the level of initial cost between that at the initial design stage and that at the stage of design confirmation in the renewal of the Kumagawa Daiichi Power Station. The initial cost is reduced by around 30% from the time of initial design due to factors such as the elimination of auxiliary equipment, use of the hybrid servo to save on the cost of materials and installation for electro-mechanical facilities, and the reduced floor area of the power station's main building to save on the cost of construction.

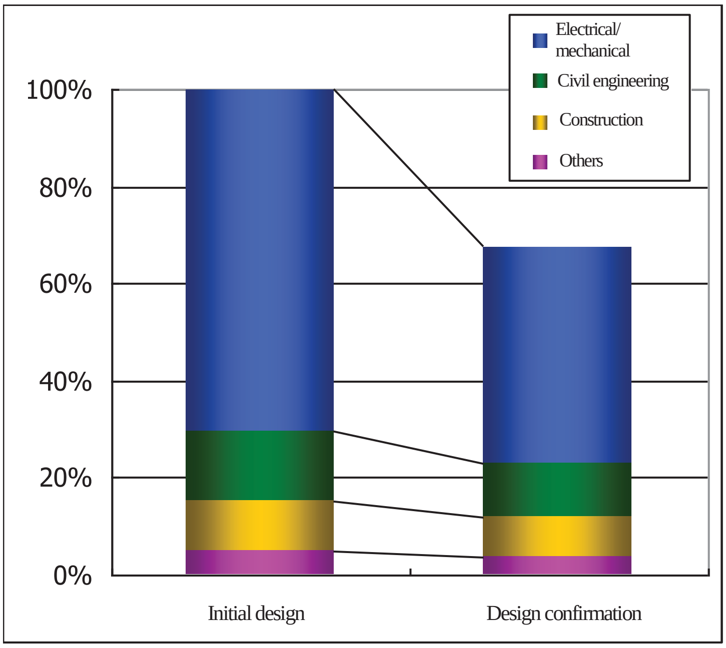


Fig.4 Comparison of initial costs

(1) Running cost assessment

Fig.5 shows the comparison of running cost before and after the renewal.

The use of the structure that allows the integrated dissembling / assembling of guide vanes and turbine cover, shortens the duration of turbine repair and the cost of on-site work. Improved wear resistance at the turbine's water flow sections eliminates the need to replace guide vanes during turbine repair, reducing the cost of materials per turbine repair and extending the interval of turbine repair work itself. Consequently, the annual cost of turbine repair is expected to decrease by over 50% compared to the pre-renewal level.

Furthermore, the use of the hybrid servo and runaway speed unit enables the elimination of a number of auxiliary devices including the pressure regulator, oil pressure supply system, pipes supplying water for inlet valve operation, grease circulation unit and grease cooling unit. The facilities will be substantially slimmed down to offer various advantages, e.g. fewer periodic inspections on auxiliary equipment, reduced walkdown hours, and lower frequency of hardware issues. This saves on the inspection / repair cost as well as associated cost of labor.

The abovementioned cost reduction effects can reduce the running cost by around 25% compared to the pre-renewal level.

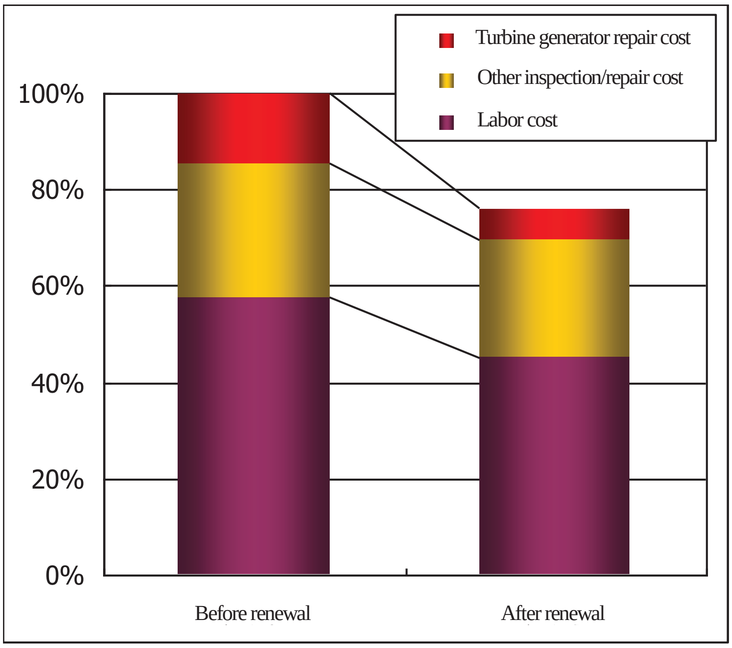


Fig.5 Running cost comparison

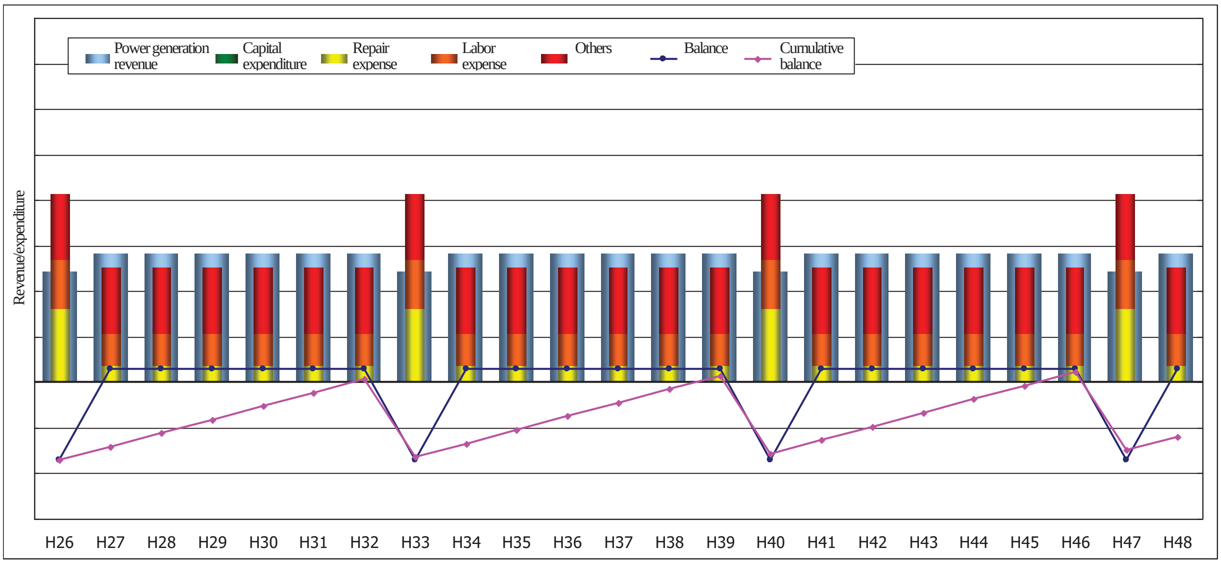
(2) Improvement in annual power generation

The annual power generation is expected to rise by around 13% from the pre-renewal level due to the increased output from higher turbine efficiency, and improved capacity factor thanks to the reduction in the frequency and duration of turbine repair.

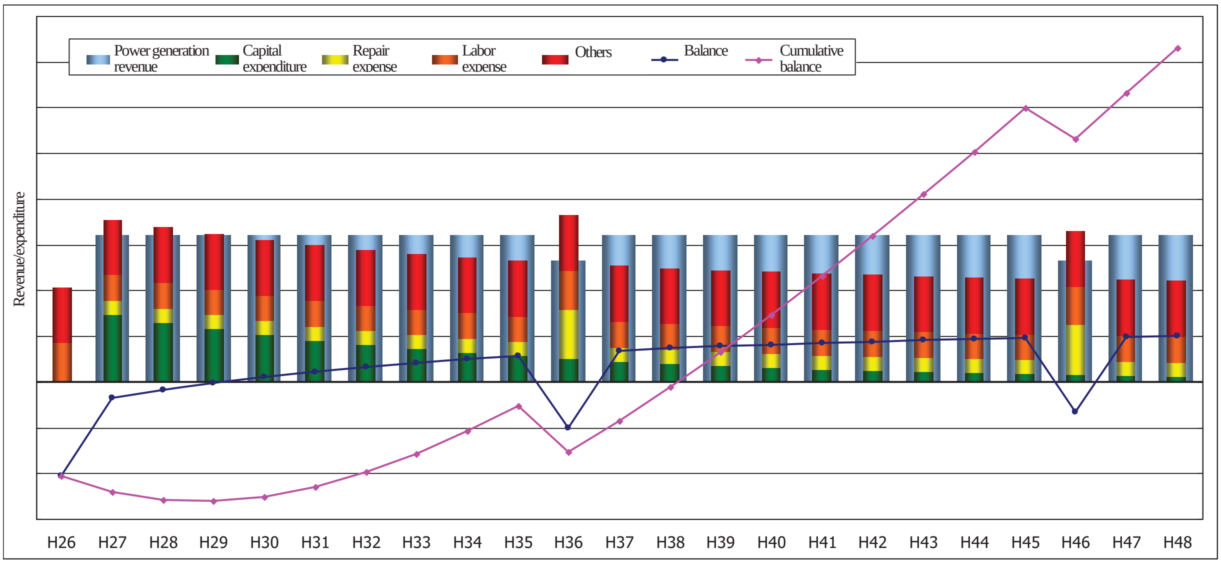
(3) General assessment

Fig.6 compares the annual balance of revenues and expenditures before and after the renewal. Before the renewal, the annual balance was slightly in the positive except in the years requiring turbine repair, when the balance was significantly in the red. If you consider the period from the year of turbine repair to the year before the next turbine repair as one cycle, the financial balance per cycle translated into an extremely marginal profit.

After the renewal, single-year balance will be initially negative due to the high ratio of capital expenses. However, the annual balance turns to the black 4 years after the renewal. The overall balance is expected to become positive 13 years after the renewal. The savings in the cost of turbine repair will reduce the scale of negative balance in the years involving turbine repair. In terms of revenue / expenditure balance per turbine repair cycle, the power station will achieve a sizeable profit from the second cycle onwards. This renewal is therefore expected to dramatically improve the financial balance of the Kumagawa Daiichi Power Station from the pre-renewal level.



(a) Transition in the revenue / expenditure balance of the power station without the renewal
(turbine repair in 2014, 2021, 2028, 2035)



(b) Transition in the revenue / expenditure balance of the power station with the renewal
(turbine renewal in 2014, and turbine repair in 2024, 2034)

Fig.6 Comparison of the power station's annual revenue – expenditure balance with and without the renewal

3. Feature of the Project

3.1 Best Practice Components

(None)

3.2 Reasons for Success

(None)

4. Points of Application for Future Project

(None)

5. Others (monitoring, ex-post valuation etc.)

(None)

6. Further Information

6.1 Reference

(None)

6.2 Inquiries

Company name: Tokyo Electric Power Company

URL : http://www.tepco.co.jp/index-j.html

Nw.01_Embretsfoss #4

Annex XI Renewal & Upgrading of Hydropower Plants

Format for the 2nd Round Data Collection (Definition of Case Histories)

Category and Key Points:

Main: 1-d) Asset Management, Strategic Asset Management and Life-cycle Cost Analysis

Sub: 1-b) Investment incentives (Feed-in-Tariff (FIT), Renewable Portfolio Standard (RPS), subsidies, financial assistance, tax deductions, etc, where it is located)
1-f) Environmental conservation and improvement
2-a) Technological innovation and deployment expansion of electro-mechanical (E/M) equipment
2-c) Technological innovation, deployment expansion and new materials used for civil and building works

Project Name:

Upgrading and Rebuilding of Embretsfoss Hydropower Plant

Name of Country (including State/Prefecture):

Norway, Buskerud County, Modum Municipality

Implementing Agency/Organization:

EB Kraftproduksjon AS

Implementing Period:

2010 – 2013

Trigger Causes for Renewal and Upgrade:

(A) Degradation due to ageing and recurrence of malfunction (a, b, d)
(B) Environmental deterioration (b)
(C) Needs for higher performance (a, b)
(D) Needs for safety improvement (a)

Keywords:

Replacing aged E&M equipment
Increasing production
Increasing flood diversion capacity
Dam safety

Abstract:

The waterfall Embretsfoss in the Drammen River course has been exploited for hydro energy generation since early in the twentieth century. Embretsfoss is located some 75 kilometers west of the Norwegian capital Oslo. The power was earlier used in industrial enterprises close to the power plant. The industry was mainly based on the vast local forest resources, with production of plank, paper and pulp.

Embretsfoss HP system is owned by the Norwegian energy utilities EB Kraftproduksjon AS (50%) and E-CO Energi AS (50%), and are operated by EB.

E-CO is the second largest hydropower production utility in Norway with annually 9.7 TWh. For more details see: www.e-co.no
EB is a large regional hydropower production and power distribution utility, having the tenth largest power production in Norway with annually 2.5 TWh. For more details see: www.eb.no

There were two parallel power stations at Embretsfoss, utilizing the same intake pond and both with the head of approximately 16 metrs. A dam across the river increased the natural head, and provided for a small intake pond.

Embretsfoss II from 1921 was ripe for condemnation regarding civil constructions. Mechanical and electrical equipment were worn, with low efficiency. Embretsfoss III has been running since 1954, and was still well operating and producing to satisfaction. The owner therefore decided to build a new power station Embretsfoss IV to substitute Embretsfoss II. Embretsfoss III is in continued operation.

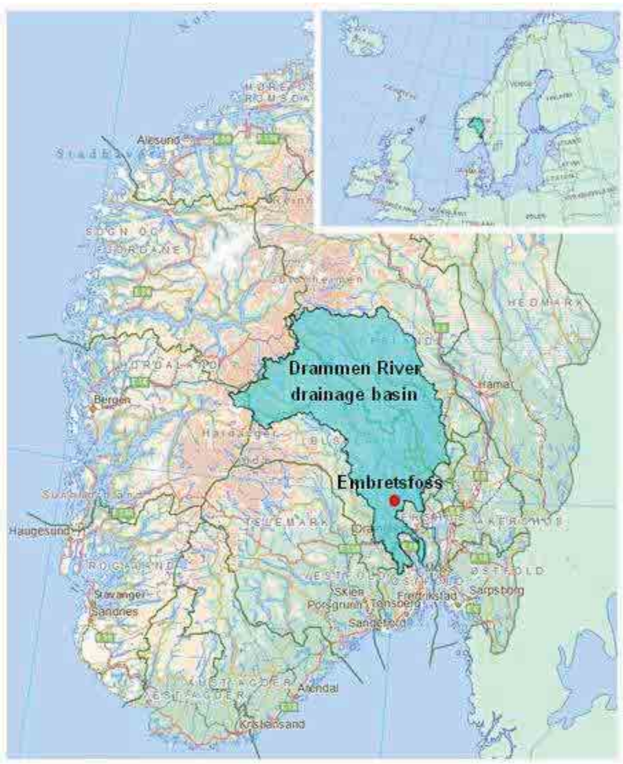
The construction works started in 2010, and the upgraded scheme was commissioned in June 2013. Increased mean annual production at Embretsfoss III and IV is some 140 GWh to 355 GWh in total. The works were obtained within existing licence and at a cost of 745 million NOK (approximately 95 million USD with rate medio June 2015).

The construction works included cleaning up and dismantling old industry and constructions that are not needed any longer, thus contribute to environmental upgrading of the waterfall area. The project also included arrangements for fish (including salmon) to pass by the waterfall.

There were many challenges, and one was to construct the new power station and a new dam while the two existing power stations were continuously in operation. The new power station was built in excavated rock between the old industry area and a nearby railway. A new dam with flood gates and a weir spillway was constructed downstream the old dam, which was then removed.

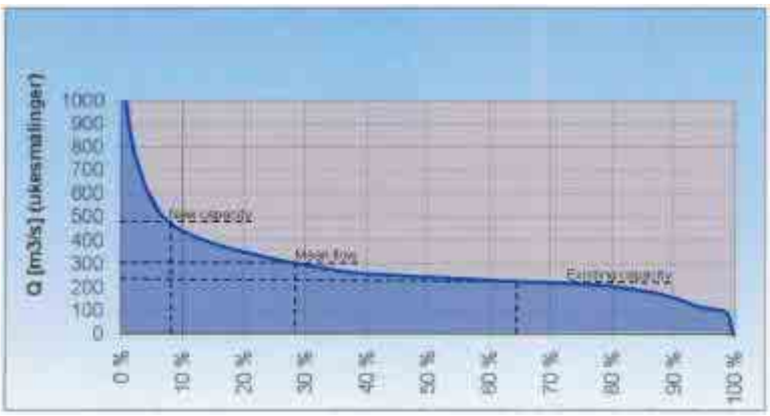
1. Outline of the Project (before Renewal/Upgrading)

Drammen River (Drammenselva) is the third largest river in Norway, with a drainage basin of about 17,000 km^2 and about 300 m^3/s mean flow in lowest part of the river. Approximately 80 power plants are located in the drainage basin, many of them in cascades. Most of the power plants with large storage reservoirs are located in the mountains, in upper part, giving the river quite an evenly flow distribution over the year. In the lower part of the drainage basin mainly run of river power plants are located. Many of the older power plants were built and expanded in several phases. This capacity was according to actual local industrial and public need and not utilizing entire available flow.



Location of Drammen River basin and Embretsfoss hydropower plant (source: NVE Atlas)

Embretsfoss is a rather old run of river hydropower plant without any storage capacity. The existing plant (Embretsfoss II and Embretsfoss III) had an annual production of 215 GWh, utilizing 225m^3/s at 16.3 m head. The system was not optimized with respect to actual river flow and the capacity at other hydropower plants in the cascade. The efficiency was low and there was a challenging infrastructure causing increasing maintenance. Further, the dam did not meet future requirements for flood diversion. Additionally there was an increasing focus on minimizing the environmental footprints.



Flow duration curve at Embretsfoss

There is no storage capacity, only a small intake pond. The dam had been built in several stages, according to different quality standards and having limited documentation. It would not meet future acceptance design criteria, both regarding flood diversion and structural strength. Related to the river at Embretsfoss there have been several dam constructions in connection with industrial activities since mid-eighteen century. These constructions had been expanded or partly replaced in many stages during many decades, according to increased industrial needs.

Parts of existing dam were holdover from the older days, from where we have limited documentation of the foundation, reinforcement and concrete quality. This in combination with a need for new flood gates made it more cost efficient to build a new dam downstream instead of refurbish existing dam in such an order that it meets future design criteria.

Embretsfoss I (E1, east bank) with one 1.2 MW unit, was commissioned in 1916 and closed down in 1954 (after commissioning of Embretsfoss III).

Embretsfoss II (E2, west bank) with 3 x 3 MW Francis units and a total capacity of 75 m^3/s water was commissioned in 1921 and was still in operation. It was more or less in original condition and was closed down in 2013, after commissioning of Embretsfoss IV. The turbine runners were replaced in 1955.

Embretsfoss II, commissioned in 1921 and still in operation in 2012

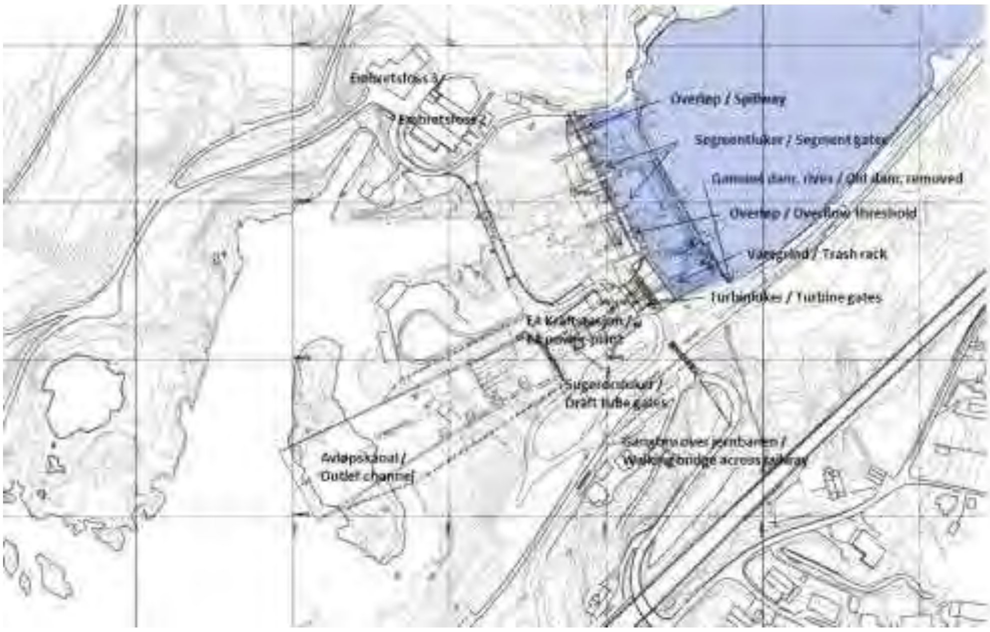
Embretsfoss III (E3, west bank, beside E2) with one 19 MW Kaplan unit having a capacity of 150 m^3/s was commissioned in 1954. This unit is also more or less in original condition. In longer periods over the year it were operated at 20% overload (150 m^3/s versus 125 m^3/s design flow) due to water surplus.

The licence included, and includes still, allowance to utilize all the river flow, with no requirements to have minimum flow in the river (only approximately 50 m dry riverbed). The river had significant water surplus compared to the flow capacity at E2 and E3 in combination. The overload operation impacted increased maintenance need at E3, mainly related to cavitation repair on the runner blades, typically requiring extra stop for 1-2 weeks every second year.

Embretsfoss II, the land at east bank and rights to further develop the hydropower potential were acquired in 2001 from an industry company. Em

When Embretsfoss IV was commissioned in 2013, E3 was changed to low base load operation, potential only as a flood peaking unit. A larger refurbishment is scheduled to be carried out in 2020+.

In recent years the lower part of Drammen River has become one of Norway's better salmon and trout fishing river. This part of the river is also quite dense populated (according to Norwegian Standard). In addition there was an increasing focus on improving the environment for red list of threatened spices, like eel and freshwater pearl mussels.



Powerplant arrangement

2. Description of the Renewal and Upgrading of the Project

2.1 Trigger Causes and Drivers for Renewal and Upgrading

The main rationale for realization of the project was an old power plant which was ripe for condemnation, and in addition, the total capacity was not sufficient to utilize the water flow in the river as much as economic beneficial. The trigger causes appear more thoroughly from Clause 2.3.

(i) Conditions, Performance and Risk Exposure and Others

(A) Degradation due to ageing and recurrence of malfunction (main trigger cause)

(a) Improvement of efficiency

The new E&M equipment has higher efficiency than the equipment in the replaced old power plant Embretsfoss II. In addition, the total capacity has been increased.

(b) Improvement of durability and safety

The E&M equipment in the replaced plant Embretsfoss II was worn, and the plant was ripe for condemnation. Further operation of the plant would have been unsafe and risky. The new equipment will ensure durability and safety for decades.

(d) Easy maintenance with less labor

The maintenance for the replaced plant was already time and resource consuming, and hence pro rata expensive. The new power plant Embretsfoss IV, with new and modern equipment, simplifies maintenance works. Use of time, use of resources and hence costs are reduced considerably.

(B) Environmental deterioration (secondary trigger cause)

(b) Improvement of river environment

Due to almost 100 years of industrial activities parts of the project area were strongly contaminated. The project included transforming the landscape from industrial area to a public recreation area. It was adequate to combine cleaning up pollution and other bad conditions while constructing the new power plant facilities. An additional environmental improvement was passages for fish (salmon and eel in particular).

(ii) Opportunities to Increase Value

(C) Needs for higher performance (secondary trigger cause)
(a) Efficiency improvements, addition power & energy, loss reduction
New equipment (new power plant) gave higher efficiency per m^3 of water. However, the existing power plants were built under other premises than what is relevant today. The total design discharge and installed capacity were therefore relatively low, with a rather high loss of water and production. It was then beneficial to increase the total capacity to reduce water loss, and hence increase total production.
(b) Role change of hydropower generation, addition of new functions
The introduction of the Norwegian - Swedish Electricity Certificate Market in 2012 was an I nvestment incentive for the new power station Embretsfoss IV. The final planning and realization of the project started before 2012, but there were strong and highly trustable indications that a certificate market was in the pipeline. Power plants (renewal and upgrading included) for which construction started after 7th of September 2009 are qualified for the certificate market. Construction works for Embretsfoss IV started in February 2010.

(D) Needs for safety improvement (main trigger cause)
(a) Meet all safety regulatory and operational compliance requirements
The old dam would not meet future criteria for the security class in question, neither with respect to flood diversion capacity, nor structural strength (in some areas), according to updated flood calculations in 2007. A new dam was necessary independent of the result of the power plant solution, but it was anyway useful to plan and construct the new power plant and the new dam as a whole.

(iii) Market Requirements

An investment incentive for new renewable energy production was in place by the establishment of the Norwegian-Swedish Electricity Certificate Market.

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

2001	Acquisition of Embretsfoss II, the land at east bank and rights to further develop the hydropower potential. Embretsfoss III was in EB's ownership from previous
2007	Approval to expand and build new dam and powerhouse, within existing licence
2009	Investment decision in December
2010	Contracted main civil engineering company in January
2010	Contracted main E&M supplying company in January
2010	Construction start at site in February
2012	Establishment of Swedish-Norwegian electricity certificates market (January 1)
2013	Completion and start commercial operation in June

2.3 Description of Work Undertaken (detail)

Category references
1-d) Asset Management, Strategic Asset Management and Life-cycle Cost Analysis
Renewal and upgrading of Embretsfoss had been under planning for many years. Many alternatives had been investigated as a part of a long time strategy for development of EB's hydropower portfolio within profitable limits. This included production and cost estimates, operation costs, remaining technical lifetime for equipment, collapse risks, forecasted future electricity prices, etc. However, a realization was not found profitable before the last years. An important and decisive factor was a new investment incentive, see also Category 1-b) below.

A basis for decision, detailed cost-benefit analyses for several alternatives, was carried out, calculating and comparing Net Present Value (NPV). The model includes project/construction cost, value of potential lost production during works (production stop or reduced production), value of increased production after commissioning, operation and maintenance cost before and after upgrading, value of el- certificates ("green certificates") and taxes (significant importance, since this unfortunately can be a strong incitement to not replace too much equipment, eg. repair the old equipment instead of investing in new equipment). The alternative with highest NPV was selected for implementation.

1-b) Investment incentives (Feed-in-Tariff (FIT), Renewable Portfolio Standard (RPS), subsidies, financial assistance, tax deductions, etc, where it is located.

The plans for a common Norwegian- Swedish Electricity Market (incentive for development of new renewable power), contributed both in the decision of plant capacity and timing for project release.

1-f) Environmental conservation and improvement

It was required to remove contaminated ground, and hence it was adequate to do this as a part of the project execution. Besides this, conservation and even improvement of the landscape and condition for fish took place. Regarding fish, improved conditions were gained through establishment of adequate fish passages.

2-a) Technological innovation & deployment expansion of electro-mechanical (E/M) equipment
and
2-c) Technological innovation, deployment expansion and new materials used for civil and building works

Even there were not developed particular new solutions for the project, it was important to ensure that optimal equipment and materials were obtained. The selections were based on studies and up to date knowledge (state of the art), including types and producers, cost, earlier experience, expert advice, etc.

Supplementary details for category references appear from the text below.

Dam

The existing dam would not meet future criteria for the safety class in question, neither with respect to capacity for flood diversion nor structural strength (in some area), according to updated flood calculations in 2007. Flood diversion capacity was approximately 1 900 m^3/s at flood level 33.8 ASL, with gate capacity 650 m^3/s (at maximum operating headwater level 30.23 ASL). Updated flood calculations in 2007 gave 2 660 m^3/s at flood level 35.86 ASL (Q500 is a 500-year flood, 18% probability for exceeding the flood in next 100 years, referred to Norwegian dimensioning criteria for class 1 dams).

The future required flood capacity had to be met by increasing gate size and fixed spillway capacity. Since the flood gates make up a significant part of the dam, with regard to both size and cost, it was found more cost efficient to build a new dam downstream existing dam. This made it easier to maintain normal production in the existing powerhouses (E2 and E3 during construction). An additional important function of the flood gates is to control and maintain stable headwater level when having surplus water. Due to good experience from a previous project, two 20 x 7 m radial gates were chosen.

Dam under construction (June 2011) and western area with new flood-gates in operation (Oct 2012)

Powerhouse

E2 powerhouse with its three Francis units was at end of its lifecycle. It was worn out after being in continuous service since 1921, with about 750 000 operating hours and producing approximately 4.5 TWh (4 500 000 000 kWh) in accumulated production. The maintenance cost had increased, and the powerhouse did not meet today's standard regarding working environment for operating staff.

Since the site had significant surplus water, it was important to increase the capacity. This could be achieved either by rebuilding E2 powerhouse and replace its existing units, or build a new power plant at the opposite river side.

Rebuilding of E2 would require significant work including possible increase of the headrace tunnel dimensions. It would also give limited capacity increase, anticipated 25% or 19 m^3/s. This would give less than 20 GWh annual increased production, still far away from the potential. A rebuilding would require approximately 1.5 year downtime, estimated to some 100 GWh in lost production. The estimated life cycle for this solution is in the range of 30 years.

Building a new powerhouse at opposite river side gave opportunity to optimize the capacity. The intake could be integrated in the new dam without reducing dimensioning flood capacity. A single large Kaplan turbine (52.5 MW at head 16.3 m with runner throat diameter D2 = 6.7 m and rotational speed 93.75 rpm) was chosen. This gives annual some 140 GWh additional new renewable power production. Two smaller units instead of a single unit were considered, but this is a more costly solution, and existing unit at E3 will be in operation for many years with significant capacity (up to 150 m^3/s). By building a new powerhouse, full operation of E2 without any downtime during construction period was possible. In addition, the new powerhouse more than doubled the capacity and also increased the total plant efficiency with approximately 15% at 250 m^3/s. This is a solution with at least 50 years horizon.

By constructing a new powerhouse, it was possible to optimize and install a state of art turbine with modern flow passages. Especially the draft turbine shape is important since this is a low head power plant. Best efficiency of the old double Francis turbines was 84.8% (before wear). Best efficiency of the new Kaplan turbine is 94.5%.

Arrangement of old (E2 and E3) and new (E3 and E4) power houses

Environment

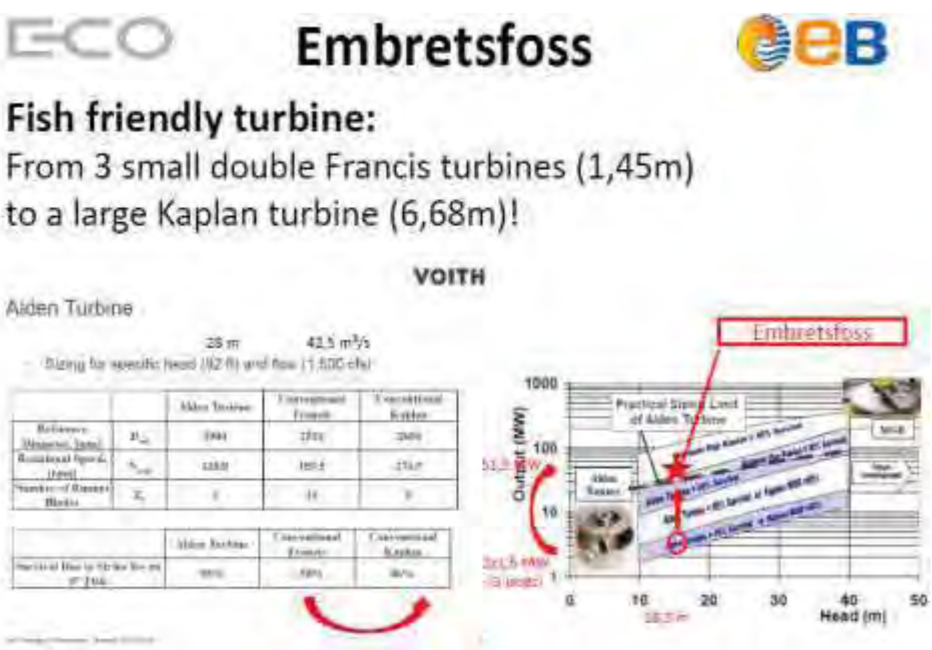
An important objective for this project was to use state of art knowledge and implement solutions in order to reduce and minimize the environmental footprints, even though this was not a controversial topic for the existing plant.

Due to almost 100 years of industrial activities, mainly forest industry, some area of the land at east bank had become contaminated. Several thousand m^3 soil had to be removed and handled as dangerous waste by approved companies.

Drammen River has in recent years become one of Norway's best fish rivers, especially regarding salmon and trout fishing. In order to improve the access for fish going upstream, it has been prepared for future installation of a fish ladder/hoist. By installing a fish flap gate in the dam for seasonally usage, the condition for fish going downstream is improved.

A change from three smaller Francis units to one large and slower rotating Kaplan unit will also improve the fish survival for those passing through the turbine. The positive contribution is made both by increasing the size of the turbine runner and change of turbine type. There are limited information and knowledge available. However, a study has been carried out by Voith Hydro, where field measurements indicate an improvement of from <50% to >90% for a 20 cm long fish (8 inches). Results were presented in a seminar in Norway in March 2014.

The Kaplan turbine is regarded as a fish friendly turbine, which is illustrated in the figure below.



In addition to the figure, the following can be mentioned: The pressure drop gradient for the new turbine is approximately one third (33%) compared with the old (same net head, moving distance increased by 4.6 due to larger size and velocity increased by 1.3 due to modern design, and moving time increased by 3.5). The runner blade passing frequency has decreased from 54 Hz to 8 Hz (from 250 rpm and 13 blades to 93,75 rpm and 5 blades).

At the river east bank, downstream the dam, a fish spawning area was built and the conditions for fish fries were improved.

Eel is today in the red list of threatened species. Passages and seasonal wetted area are important for eel mitigation. In order to improve the access for eel going upstream, the new dam is prepared with an eel flume/channel and a special eel passage. To help safe downstream eel mitigation, it is prepared to use a floating lightening eel barrier in front of the power plant intake, located at east side. This will guide the eel to the seasonal used fish flap gate or the eel passage, located at west side. By relocating the dam downstream existing dam, the drained area is reduced with approximately 30%, also helping eel passage.

A 20.6 kg salmon caught in June 2012 (source: dt.no, photo Arild R. Hansen)

The project included transforming the landscape from industrial area to a public recreation area.

As a documentation of the environmental footprint, a Life Cycle Analysis (LCA) has been carried out and an Environmental Product Declaration (EPD) certificate is acquired. EPD is a brief document whose objective is to sum up the environmental profile of a component, a finish product or a service in an objective standardized manner. EPD is an internationally recognized standard used in both national as well as international contexts.

An EPD shall provide information about the environmental properties of a product and provide its users with the environmental information that they demand and desire. Standardized methods serve to ensure that environmental information provided for products within the same product category can be compared irrespective of region or country.

The content of an Environmental Product Declaration is specified through Product Category Rules (PCR) that are used in Life Cycle Assessment (LCA) of environmental data from raw materials production, manufacture, use and disposal.

The global warming potential for 1 kWh of hydroelectricity generated at the E4 hydropower station is 2.19 g.

Project execution

The investment decision was made by the Board in December 2009. Site work started in February 2010. The new powerhouse E4 was by then scheduled to be put in operation in May 2013.

In brief, the first year (2010) was mainly dedicated to rock excavation (some 350 000 m^3). The second year (2011) was mainly about concrete works (40 000 m^3 and 1 200 metric tons of steel reinforcement). Finally, the third and last year (2012) was mainly about installing the power generating equipment (Kaplan turbine with 6.7 m runner throat diameter and a generator rotor diameter of 7.4 m, giving 410 metric tons of total weight of rotating components). Approximately 450 000 site hours were executed during these three years.

The main challenge for the project execution was a more or less continuous flood period from primo June to primo October in 2011. The flood in this 4 months period was in the range of 700 – 900 m^3/s, peaking to about 1 000 m^3/s from time to time. Normal flow in this period should be 170 – 200 m^3/s. The project was well prepared and had a temporarily flood diversion capacity of 1 400 m^3/s. This seldom summer flood (worst since recording was started more than 100 years ago) caused some shift from summer work to winter work without delaying the project.

Construction of center dam pillar during flood, 2011

The concrete works were carefully carried out in a wide temperature range, from minus 25°C to plus 25°C.

3. Feature of the Project

3.1 Best Practice Components

By replacing the oldest powerhouse (E2), predictable and cost efficient power production with minimized environmental footprints is secured for the next 50 – 100 years. After almost 100 years in service, the run of river hydropower plant was rebuilt to a state of art plant. This gives annually 140 GWh new power production qualifying for electricity certificates in addition to annually 110 GWh replaced production (E2 closed down and a load shift from E3 to E4). This was obtained within existing licence and at a cost of 745 million NOK (approximately 95 million US$ (rate primo June 2015).

3.2 Reasons for Success

- Detailed planning and production simulations for several alternatives
- State of art project management, including process based quality system
- Skilled suppliers with significant experience
- Monitoring of installed equipment
- Commencement of the Norwegian - Swedish Electricity Certificate Market

4. Points of Application for Future Projects

This project will be benchmark for future similar projects with old and outdated equipment and water surplus.

5. Others (monitoring, ex-post evaluation, etc.)

Annual energy production increase is monitored, recorded and analyzed, and meeting expectation (390 GWh in 2014, a year more wet and rainy than a normal year).

6. Further Information

6.1 References

Birger Godal Holt (Head of Project Development and Management, EB Kraftproduksjon AS): “Upgrading and Rebuilding of Embretsfoss Power Plant”, presented at Hydro 2012 Bilbao (Session 17). October 2012

Benjamin Asprusten and Armin Schuh (Voith Hydro): “Enhancing Fish Passage Through Turbine Design”, presented at Gardermoen, Norway. March 2014

6.2 Inquiries

Company name: E-CO
URL: https://www.e-co.no

Company name: EB
URL: https://www.eb.no/

Annex XI Renewal & Upgrading of Hydropower Plants

Format for the 2nd Round Data Collection (Definition of Case Histories)

Category and Key Points:

Main: 1-d) Asset Management, Strategic Asset Management and Life-cycle Cost Analysis

Sub: 2-a) Technical innovation & deployment expansion of electro-mechanical (E/M) equipment

Project Name:

Hemsil 2. Upgrading of Hydropower Plant

Name of Country (including State/Prefecture):

Norway, Buskerud County, Gol Municipality

Implementing Agency/Organization:

E-CO Energi AS

Implementing Period:

2002-2004 Initial studies, contacting and detailed engineering

2005-2006 Major mechanical upgrading

Trigger Causes for Renewal and Upgrade:

(A) Degradation due to ageing and recurrence of malfunction (a, b)
(B) Environmental deterioration (b)

Keywords:

Equipment degradation
Replacing aged E&M equipment
Increasing production
Efficiency improvements

Abstract:

The water fall from Eikredammen to Gol in the Hemsil river has been utilized for hydro energy production since 1960, when the plant Hemsil 2 started delivering power to the city of Oslo. Hemsil 2 HPP is owned by Energi AS, which is a public company, owned by the municipality of Oslo. E-CO Energi is the second largest hydropower production utility in Norway, with mean annual production 9.7 TWh. Total capacity is some 2 800 MW. For more details see: www.e-co.no

Since start-up the control center had been renewed and the generator stators had been rewound (1990-91). Except that, no major upgrades had been executed, and it was decided to do a major upgrade. The turbines were starting to get old. Power efficiency at optimum capacity (best point - BP) for the turbines was 92.7 % when new. Measurements indicated that the turbine efficiency after more than 40 years in service was 1-1.5 % lower than at new state. The guiding vanes were greased, and the spill from this went into the river downstream. In addition, the labyrinth rings were worn out due to humus in the water and the inlet valve control system needed revision. Simulations and calculations were performed, and based on those initial studies project scope was decided. Estimates stated that the capacity could be increased from 41 MW to 48 MW for each generating unit. After the upgrade the capacity of the aggregates were increased from 2x41 MW to 2x49 MW. The mean annual production was raised from 503 to 537 GWh, a production increase of approximately 6.8%. The increase in design discharge was 3 m^3/s.

Old Hemsil 2 turbine runner, now decoration in a roundabout 3 km from the plant.

1. Outline of the Project (before Renewal/Upgrading)

The waterfall from Eikredammen to Gol in the Hemsil River course has been exploited for hydro energy generation since 1960. The power plant Hemsil 2 is located in the valley Hallingdal some 180 kilometers northwest of the Norwegian capital Oslo. The power was earlier dedicated for public use in the City of Oslo. Transmission lines from the Hallingdal region to Oslo were established for this purpose. After the liberalization of the power market in the 1990-ies, the power produced in the plant is sold in the power market.

Location of the Hemsil 2 power plant in Hallingdal.

Hemsil 2 HPP utilizes a water fall with gross head 370 meters in the river Hemsil, from the small intake pond Eikredammen on 566 MASL to the river Hallingdalselva by Gol on 196 MASL. The intake pond is a small artificial lake called Eikredammen. Dam Eikredammen is a concrete dam, 8-12 m high, 500 m long, with two flood gates and spillway.

Photo of Eikredammen (2012)

The intake pond is rather small (0.37 mill. m^3). The catchment area is 913 km^2 with a total inflow of 745 mill. m^3/year. 265 km^2 of the catchment area is regulated with two reservoirs (Flævatn 205 Mm^3 and Vavatn 34 Mm^3). Followingly it is a large unregulated catchment area of 648 km^2. With the weather conditions in Norway this results in quite an evenly flow distribution during wintertime and a rather varying water flow to Eikredammen during spring, summer and autumn. Mean runoff to Eikredammen is 23 m^3/s over the year. .

The reservoir Flævatn is also reservoir for Hemsil 1 HPP upstream Eikredammen. Hemsil 1 HPP was commissioned in 1960, with capacity 70 MW.

The intake pond Eikredammen has limited storage capacity (0.4 Mm^3).

Hemsil 2 power station was built underground in 1959-1960. There were installed two Francis turbines in the power plant, each with capacity 41 MW. Total design discharge was 2 x 14 m^3/s, and mean annual production was 503 GWh (when starting planning for upgrading).

2. Description of the Renewal and Upgrading of the Project

2.1 Trigger Causes and Drivers for Renewal and Upgrading

The main rationale for the realization of the project was equipment which became more and more inefficient caused by wear and tear. An upgrading was planned in order to increase efficiency and hence increased production. Trigger causes appear more thoroughly from Clause 2.3.

(i) Conditions, Performance and Risk Exposure and Others

(A) Degradation due to ageing and recurrence of malfunction (main trigger cause)

(a) Improvement of efficiency

The upgraded E&M equipment has higher efficiency than the old equipment. In addition, the total capacity has been increased, which gave increased production.

(b) Improvement of durability and safety

The old E&M equipment in Hemsil 2 was worn after more than 40 years of operation. Further operation without upgrading would have been more and more unsafe and risky by time (increasing maintenance cost and time, collapse risk). The refurbished turbines will ensure durability and safety for decades.

(B) Environmental deterioration (secondary trigger cause)

(b) Improvement of river environment

There was earlier spill of greasing of guide vanes to the river. The upgrading eliminated this unwanted spill and contamination.

(ii) Opportunities to Increase Value

The upgrading of Hemsil 2 was not directly related to trigger cause (C) or (D). However, the upgrading gave higher production and increased profitability.

(iii) Market Requirements

There were no market requirements. The upgrading of Hemsil 2 was executed before the Norwegian-Swedish Electricity Certificate Market was carried into effect.

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

Planning and execution process:

2002	Initial studies
2003	Contracting
2004	Detailed engineering, order placement
2005	Mechanical works, turbine 2
2006	Mechanical works, turbine 1

2.3 Description of Work Undertaken (detail)

Category references

1-d) Asset Management, Strategic Asset Management and Life-cycle Cost Analysis

These considerations are continually ongoing in E-CO Energi (as in other Norwegian power companies), and was also the case for Hemsil 2. Comprehensive planning and economic and strategic considerations resulted in the decision to renew and upgrade the turbines and the generators. Included were parameters such as cost estimates, expected income and net present value (NPV). Failure probability was taken into account regarding life-cycle costs. The final scope was based on these considerations.

2-a) Technological innovation & deployment expansion of electro-mechanical (E/M) equipment

In general, the old equipment was worn, with decreased efficiency. Other technical tasks were also taken into account in the planning. Even there were not developed particular new solutions for the project, it was important to ensure that optimal equipment was obtained. The selections were based on studies and up to date knowledge (state of the art), including types and producers, cost, earlier experience, expert advice, etc.

Supplementary details for category references appear from the text below.

History

The construction works on Hemsil 2 HPP started in January 1957. When finished the station had two units. Each unit had a vertical Francis turbine made by Voith, Heidenheim in Germany. The generators were from Brown Boveri Baden, Switzerland. The first machine was brought into operation in October 1959, and unit no. 2 was set into service in August next year.

Early in the 1980's one of the generator stators was rewound. Around 1990 the control center was renewed, the generator cooler fans were replaced with new blades with adjustable pitch, and the other generator's stator was rewound. Except that, the machines had no major upgrades since start-up.

Technical state

Datasheets for the existing turbines stated that the efficiency at optimum capacity (best point) was 92.7 % when the turbines were in new condition. The machines had throughout the years faced normal tear. In year 2000 measurements of the turbine runners were performed. The measurements showed a significant reduction of the turbine efficiency at present state, it was measured to 1-1.5% lower than when new. A new turbine would have a considerably better efficiency, due to newer and more efficient design of the turbine wheel. At the same period there were identified a few other maintenance tasks that would have to be taken care of within the next few years, and that would require the generators to be taken out of service for a longer period than during the yearly revisions. Maintenance inspections had shown that the labyrinth rings would be worn out within short time. The inlet valve control system needed revision. There were also other minor upgrade tasks that needed a little more time than available during the yearly revisions. In addition to this, the guiding vane systems that were installed were greased, and the spill poured into the river. Upgrading this system would give a positive environmental contribution.

Decision making

To address the maintenance needs and improve the turbine efficiency, a major upgrade was considered. A consultant (SWECO) was rewarded contract for initial studies. In the initial study simulations and calculations were carried out using Alab, a computer program, and scope of the project was discussed. Cost estimates and net present value (NPV) calculations were carried out for consideration of profitability. Failure probability was taken into account when life-cycle costs were calculated.

Based on these analyses the final scope for the project was decided. It was determined to continue with a project to install new turbine runners, new guiding vanes and expand parts of the tailrace. The generators' new cooling ventilators with upgraded capacity had to be installed due to the increase in turbine capacity, and it was also decided to install new coils with new core insulation. The analysis anticipated an efficiency of 94.5% after the upgrade. Realistic estimates showed that the capacity could be increased from 41 MW to 48 MW for each generator (approximately 17% increase).

The results from the initial analysis were used as a basis for the technical specifications in the tender documents. The tender documents were set up so tenders could offer an improved efficiency if their technology could provide better results. The accepted vendor guaranteed efficiency close to 95%, and capacity of 49 MW for each turbine.

Inspection of one of the new turbines.

Personnel

Dismantling of the machine and the installation of new equipment were executed by E-CO Energi's own work force. Consultants were engaged for engineering.

Measurements and findings

When the upgraded machines were back in service, thermodynamic efficiency measurements were performed. The efficiency was measured to 94.3%, a little lower than guaranteed from the vendor. Reasons for this deviation from guaranteed efficiency were studied, and the reason was found to be more turbulence in the tailrace than excepted. The existing tailrace had a rounder design than used by the new vendor when designing new plants, so the new turbine runners and the existing tailrace design were not optimized together, and this caused some turbulence in the tailrace. This was discovered by detailed computer modeling that was performed past start up to identify the reason for the efficiency deviation. There were not found any design or manufacturing defects. Better computer modeling during the vendor's turbine process for runner selection could have uncovered this issue. Some of the deviation could also be explained due to low accuracy in the thermodynamic measurements. The maximum generator capacity, however, was at guaranteed level.

The efficiency before upgrading can be set to 91.5% (92.7 % as new and 1-1.5% reduction after 40 years in service), while the new efficiency is 94.3%. The increase in efficiency is then approximately 3%.

Summary

After the upgrade, the mean annual production has increased from 503 GWh to 537 GWh.

Technical data	Before upgrade	After upgrade	Increase
Capacity	2 x 41 MW	2 x 49 MW	16 MW
Design discharge	2 x 14 m^3/s	2 x 15.5 m^3/s	3 m^3/s
Mean annual production	503 GWh	537 GWh	34 GWh

When finished the total project cost was 23 MNOK (2006) (about 3 MUSD, with rate May 2015). This gave a development cost of 0.68 NOK/kWh (approximately 0.1 USD/kWh).

Hemsil 2. Power house with generator.

3. Feature of the Project

3.1 Best Practice Components

By renewing old turbine runners with higher efficiency, and perform some modifications on the generators, the production of renewable energy was increased. The design discharge was only increased with 3 m^3/s. This increase had no environmental impacts, and the upgrading could therefore be executed within existing licence.

Computer modeling and simulations were performed in initial studies. It would have been beneficial to use this also in the vendor selection phase, to confirm that new and existing design were optimized towards each other.

3.2 Reasons for Success

- Initial studies with detailed planning and production simulations for several alternatives
- Increased production by utilizing existing resources
- E-CO Energi's own staff with required experience (planning, project management and execution)
- Skilled consultants and suppliers with significant experience
- No environmental impacts
- No landowner permissions needed
- Upgrade obtained within existing licence

4. Points of Application for Future Projects

This project is a benchmark for future similar projects with water surplus and a potential to improve efficiency.

5. Others (monitoring, ex-post evaluation, etc.)

Reference is made to measurements and findings in Clause 2.3.

6. Further Information

6.1 References

Ranveig Jordet, E-CO Energi AS: "Hemsil 2 upgrade project 2004-2006". IEA Hydropower Implementing Agreements, Annex XI, Gol, Norway, June 2013.

6.2 Inquiries

Company name: E-CO Energi AS

URL: www.e-co.no

Annex XI Renewal & Upgrading of Hydropower Plants

Format for the 2nd Round Data Collection (Definition of Case Histories)

Category and Key Points:

Main: 1-b) Investment incentives (Feed-in-Tariff (FIT), Renewable Portfolio Standard (RPS), subsidies, financial assistance, tax deductions, etc, where it is located.

Sub: 1-d) Asset Management, Strategic Asset Management and Life-cycle Cost Analysis

1-f) Environmental conservation and improvement

Project Name:

Hemsil 3: Planning for Upgrading and Extension of Hemsil 2 Hydropower Plant

Name of Country (including State/Prefecture):

Norway, Buskerud County, Gol and Hemsedal Municipalities

Implementing Agency/Organization:

E-CO Energi AS

Implementing Period

2011 - 2015/16 Planning, application, licence and board decision
2015/16 - 2019 (Eventually) Detail planning, construction and commissioning

Trigger Causes for Renewal and Upgrade:

(A) Degradation due to ageing and recurrence of malfunction (a, b)
(B) Environmental deterioration (b)
(C) Needs for higher performance (a, b)

Keywords:

Increasing production (reduction of flow loss)
Efficiency improvements (increasing design discharge and new waterway which reduces head loss)
Introduction of minimum water flow (ecological flow) in river

Abstract:

The water fall from Eikredammen to Gol in the Hemsil river has been utilized for hydro energy production since 1960, when the plant Hemsil 2 started delivering power to the city of Oslo. The hydropower plant Hemsil 2 is located in the valley Hallingdal some 180 kilometers northwest of the Norwegian capital Oslo. Hemsil 2 HPP is owned by E-CO Energi AS, which is a public company, owned by the municipality of Oslo. E-CO Energi is the second largest hydropower production utility in Norway, with mean annual production 9.7 TWh. Total capacity is some 2 800 MW. For more details see: www.e-co.no

Hemsil 2 HPP was upgraded in the period 2004-2006. See also the case “Hemsil 2. Upgrading of Hydropower Plant”. This gave increased capacity, increased production and also ensured durability and safety for decades. Now it is actual also to extend the power plant.

Hemsil 2 HPP was planned and constructed 55 to 60 years ago. Planning and construction were implemented on the basis of premises and requirements by then. Decades later there are other conditions. Economic power was also important. Hence, the design discharge and installation in Hemsil 2 HPP is small in relation to inflow. An extension of Hemsil 2 (named Hemsil 3) has therefore been assessed with different solutions during the last decades. Alternatives were included in the Master Plan for remaining hydropower resources, which were prepared in the 1980s. Since then, the project was in consideration for some years, but was not found profitable.

After planning and later realization of the Norwegian-Swedish Electricity Certificate Market, it is more likely that an extension can be profitable. E-CO Energi therefore started an intensive planning in 2011. This ended up with a waterway and power station system close to and in parallel with the existing scheme. As a maximum plan by now the capacity can be increased from 98 MW to 181 MW, and the mean annual production increases from 537 GWh to 628 GWh. An application for licence was sent to the Norwegian Water Resources and Energy Directorate (NVE). NVE recommends the Ministry of Petroleum and Energy (OED) to grant the licence. If a licence is granted, an investment decision can be done in 2015-16. Site work can start in 2016-17 and will take around 2.5 years. The new power station Hemsil 3 can then be in operation in 2019 or 2020.

The Norwegian-Swedish Electricity Certificate (“green certificate”) Market was launched in 2012. Hemsil 3 will qualify for certificates given commissioning before the end of 2020.

There has been a comprehensive planning with many aspects prior to the current status, but a final scheme is not decided.

Location of the Hemsil 2 power plant in Hallingdal

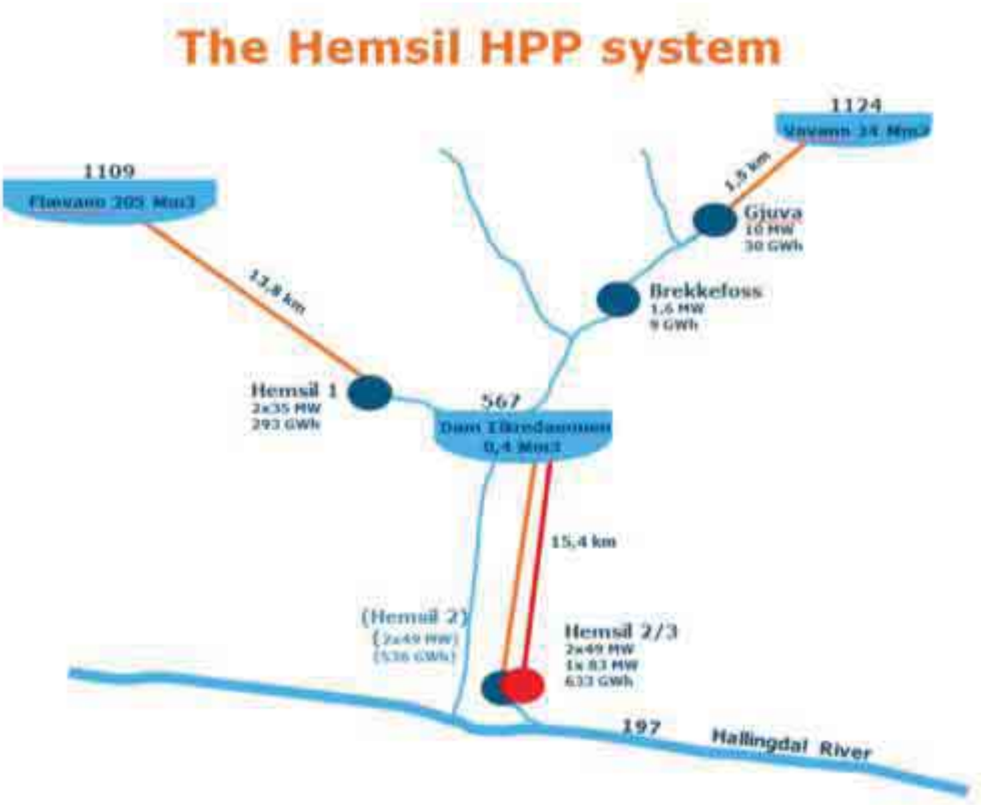
1. Outline of the Project (before Renewal/Upgrading)

The waterfall from Eikredammen to Gol in the Hemsil river course has been exploited for hydro energy generation since 1960. The power was earlier dedicated for public use in the City of Oslo. Transmission lines from the Hallingdal region to Oslo were established for this purpose. After the liberalization of the power market in the 1990-ies, the power produced in the plant is sold in the power market.

The intake pond is a small artificial lake called Eikredammen. Dam Eikredammen is a concrete dam, 8-12 m high, 500 m long, with two flood gates and spillway.

The intake pond is rather small (0.37 mill. m^3). The catchment area is 913 km^2 with a total inflow of 745 mill. m^3/year. 265 km^2 of the catchment area is regulated with two reservoirs (Flævatn 205 Mm^3 and Vavatn 34 Mm^3). Followingly it is a large unregulated catchment area of 648 km^2. With the weather conditions in Norway this results in quite an evenly flow distribution during wintertime and a rather varying water flow to Eikredammen during spring, summer and autumn. Mean runoff to Eikredammen is 23 m^3/s over the year.

The reservoir Flævatn is also reservoir for Hemsil 1 HPP upstream Eikredammen. Hemsil 1 HPP was commissioned in 1960, with capacity 70 MW.



The Hemsil Hydropower Plant System

Photo of Eikredammen (2012).

The existing Hemsil 2 HPP utilizes a water fall with gross head 370 meters in the river Hemsil, from the small intake pond Eikredammen on 566 MASL to the river Hallingdalselva by Gol on 196 MASL. The headrace tunnel is 15.4 km long with a cross section area of 10-18 m^2. The old station with tunnels has low capacity, and there is a significant water loss in the system.

The intake pond Eikredammen has limited storage capacity (0.4 Mm^3)

Hemsil 2 power station was built underground in 1959-1960. There are two Francis turbines in the power station, each with capacity of 49 MW after upgrading in 2004-2006. Total design discharge today is 31 m^3/s. After upgrading, Hemsil 2 HPP's mean annual production is set to be approximately 537 GWh.

Hemsil 2. Powerhouse with generator

The design discharge of Hemsil 2 HPP is not optimal with respect to actual river flow. The utilization is low and additionally there is an increasing focus on minimizing the environmental footprint. There is no licencing requirements for continuous water flow in the river Hemsil downstream Eikredammen. It was a local need for improving the connection between the river and the surroundig landscape. E-CO Energi together with the local community (fishing association and landowners) underwent landscaping of the river in 2009-2011. Since 2011 E-CO Energi has released a voluntary environmental water flow of 25 l/s during winter period and 100 l/s in the summer period. An evaluation conducted in 2012 shows an improved river system regarding fish.

2. Description of the Renewal and Upgrading of the Project

2.1 Trigger Causes and Drivers for Renewal and Upgrading

The main rationale for the project is that the installed capacity is not sufficient to utilize the runoff in the river as much as economic beneficial. The trigger causes appear more thoroughly from Clause 2.3.

(i) Conditions, Performance and Risk Exposure and Others

(A) Degradation due to ageing and recurrence of malfunction

(a) Improvement of efficiency

Malfunction has here the meaning of insufficient utilization of water resources. The utilization can be improved by increasing design discharge and installed capacity. The total capacity will be increased with up to 83 MW, and will give an additional mean annual production of 91 GWh. This refers to the original licence application.

During the handling of the application, E-CO Energi has presented three additional options for a lesser extension. The options have lower design discharge, lower installation and shorter headrace tunnel in parallel with the old tunnel. Briefly, the four alternatives are ranging from 51 MW (48 GWh/y) to 83 MW (91 GWh/y). All alternatives have one unit.

(b) Improvement of durability and safety

The additional turbine (Hemsil 3) will reduce maintenance and downtime in the combined scheme Hemsil 2 and Hemsil 3, and will still more increase durability and safety for decades (the two turbines in Hemsil 2 HPP were upgrades 2004-2006).

(B) Environmental deterioration

(b) Improvement of river environment

Minimum water flow in the river downstream the intake (environmental release) is introduced as a requirement. An ecological water flow was proposed in the licence application, and will be an important prerequisite for the licence. This will safeguard the environmental conditions in and along the river.

(ii) Opportunities to Increase Value

(C) Needs for higher performance

(a) Efficiency improvements, expansion of power & energy, loss reduction

The existing power plant was developed under other premises than relevant today. The total design discharge and installed capacity were therefore relatively low, with a rather high loss of water and production. It was beneficial to increase the total capacity to reduce water loss, and hence increase total production.

(b) Role change of hydropower generation, addition of new functions

The introduction of the Norwegian - Swedish Electricity Certificate Market in 2012 was an investment incentive for the extension of Hemsil 2 HPP. The final planning and realization of the project started before 2012, but there were strong and highly trustable indications that a certificate market was in the pipeline.

(iii) Opportunities to Increase Value

The Norwegian-Swedish Electricity Certificate Market will be important for the project income.

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

Planning and execution process:

2011	Start planning
2012	Introduction of Swedish-Norwegian Electricity Certificates Market
2012	Notification sent to NVE
2012	EIA finalized
2013	Licence application sent to NVE
2014	Recommendation from NVE to Ministry of Petroleum and Energy (OED)
2015/16	Licence decision expected (OED)
2015/16	Planned project management
2016	Expected construction start
2019	Expected completion and start commercial operation

2.3 Description of Work Undertaken (detail)

Category references

1-b) Investment incentives (Feed-in-Tariff (FIT), Renewable Portfolio Standard (RPS), subsidies, financial assistance, tax deductions, etc, where it is located.

A strong incentive for development of new renewable energy production, including hydropower, is the introduction of Norwegian – Swedish Electricity Certificate Market from 2012. The income from new renewable production will both come from power sales and from sale in the electricity certificate market. The extra power production caused by the project Hemsil 3 will qualify for such certificates (given that the new power station is commissioned by 31th of December 2020 as latest).

In this case, certificates will be given for additional production due to:

i) utilizing surplus water,

ii) improvement of efficiency in electromechanical equipment,

iii) reduction of head loss in waterways, and - hopefully

iv) reduction of energy loss during maintenance periods, as the old and the new power plant could be operated separately.

1-d) Asset Management, Strategic Asset Management and Life-cycle Cost Analysis

This project has been in the company's portfolio for many years, but possible profitability was not anticipated before the last years.

Detailed cost-benefit analyses for several alternatives were carried out as a basis for decision. Calculating and comparing Net Present Value (NPV) and Internal Rate of Return (IRR) have been essential. The model includes project/construction cost, value of potential lost production during works (stop or reduced production), value of increased production after commissioning, operation and maintenance cost before and after upgrading, value of electricity certificates ("green certificates") and taxes. Taxes have significant importance, since this unfortunately can be a strong incitement to not replace too much equipment, eg. repair the old equipment instead of investing in new equipment.

The alternative with most profitable NPV and IRR by then was selected for licence application.

New calculations will be carried out if licence is granted. Depending on results, a lesser extension than primarily applied for can be selected for realization. In the investment decision process the following (among other factors) will be considered:

- Licence (conditions and requirements)
- Cost for construction of the new facilities (civil works and electromechanical equipment)
- Power market development (power price, certificate price). The Norwegian-Swedish lectricity Certificates Market (incentive for development of new renewable energy) will be of importance in the decision of plant capacity and timing for project release.

1-f) Environmental conservation and improvement

An objective for this project is to implement solutions in order to safeguard and improve the biodiversity in and along the river.

Due to more than 50 years of energy production without any minimum flow requirements, the EIA process concluded that there still are some species that should be taken care of (rare moss/lichens). A minimum water flow (ecological water flow) will be released from the pond Eikredammen.

The new scheme will give a robust long term solution. Predictable and cost efficient power production with minimized environmental footprints will be secured for the next 50 – 60 years. Supplementary details for category references appear from next.

Status by May 2015

Hemsil 3 HPP can be considered as a capacity extension of Hemsil 2 HPP, and is then a case of Renewal and Upgrading. Hemsil 3 is by now in a final licencing process. Notification of the project was submitted to Norwegian Water Resources and Energy Directorate (NVE) in 2012.

An Environmental Impact Assessment (EIA) on nature, biological diversity and society was carried out by external consultants in 2012. Key issues were:

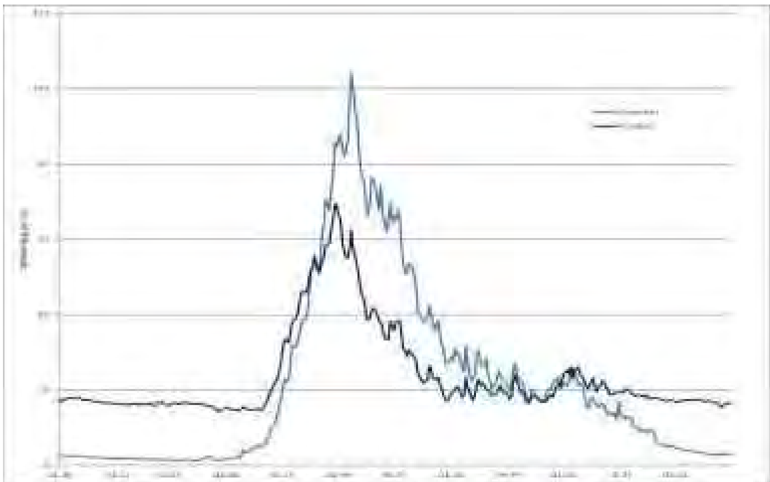
- Environmental issues (environmental water flow, fish and rare plants)
- Landscape (river bed, history and culture, handling of excavated masses)
- Local community (economic impact)

Licence application with EIA-reports was submitted to NVE in 2013. NVE has not the authority to grant a licence, but has recommended a licence to be granted. This authority is assigned to the Ministry of Petroleum and Energy (OED). If a licence is granted, an investment decision can be done in 2015-16. Site work can start in 2016-17 and will take around 2.5 years. The new power station Hemsil 3 can then be in operation in 2019 or 2020.

The investment decision process will consist in an evaluation where licence provisions, construction costs and market development (ordinary market plus sertificate market) are essential factors.

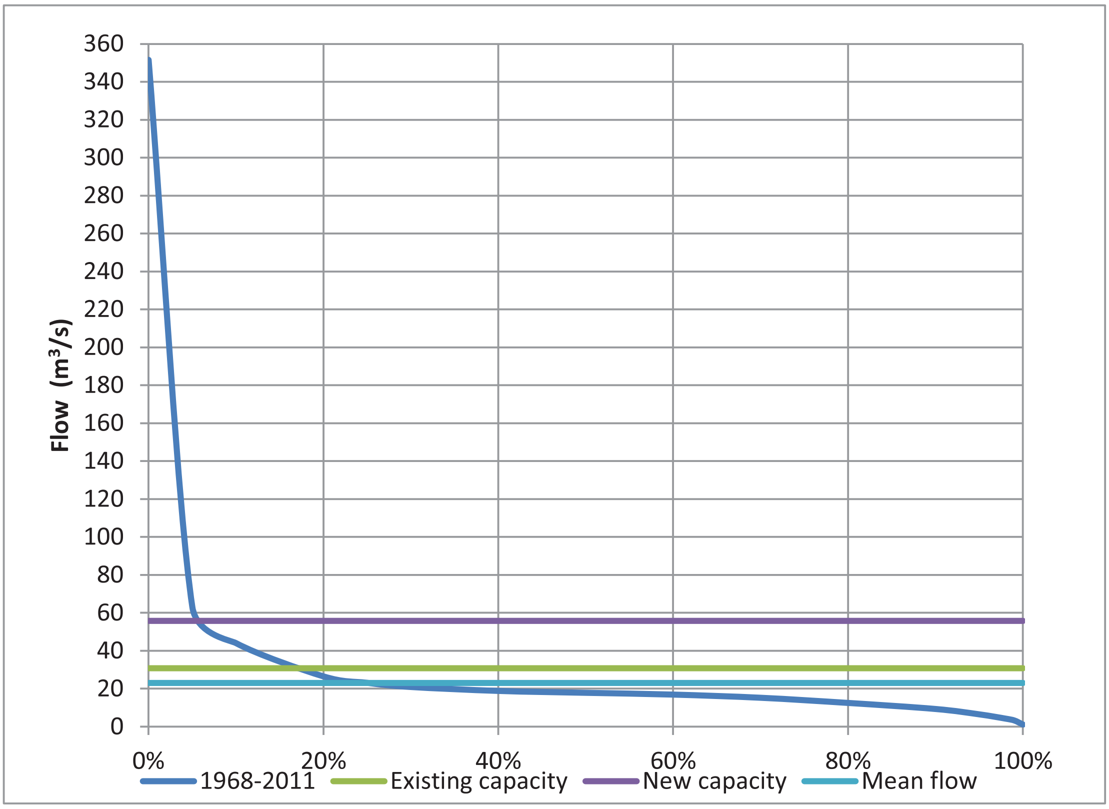
Inflow and flow duration curve

The pond Eikredammen gives only some regulation of the mean inflow. The two upstream reservoirs Flævatn and Vavatn equalaize the water flow over the year. This is shown in the figure below.



Variation in mean inflow (m^3/s) to Eikredammen over the year for regulated and unregulated situation. Unregulated: Light blue. Regulated: Dark blue

The figure below shows the duration curve for water flow at Eikredammen. The summarized capacity of Hemsil 2 and Hemsil 3 (primary alternative) will be 56 m^3/sec, which will be sufficient to exploit a considerable share of the runoff.



Flow duration curve at Eikredammen for Hemsil 2 and Hemsil 3

The duration curve is a simple method to illustrate the selected design discharge. The curve is very steep for water flows larger than about 55-60 m^3/s, indicating that the optimal design discharge likely is in this range. The duration curve gives a rough indication of optimal design discharge, but the production is also calculated by use of more sophisticated simulation models.

Technical layout (primary alternative)

The primary alternative (according to the original application) is to build a new underground power station not far from Hemsil 2 power station, with one new unit of 83 MW with Francis turbine. Design discharge is 25 m^3/s, and minimum discharge is 6.3 m^3/s. The headrace tunnel will be more or less in parallel with the headrace tunnel for Hemsil 2, with length 15.4 kilometers and cross section area 25 m^2. The intake will be located in the same intake basin as Hemsil 2 HPP.

An implementation of the primary project will increase installed capacity from 98 MW to 181 MW. The increased installation will reduce water loss with about 100 Mm^3. Increased production is calculated as total production Hemsil 2 + Hemsil 3 minus current production in Hemsil 2 HPP and minus minimum water flow as proposed by E-CO Energi. Hemsil 3's generating set will be operated as the main unit. Hemsil 2 will be in operation when the inflow is higher than Hemsil 3's discharge capacity.

The Hemsil 3 project gives annually around 91 GWh new power production qualifying for electricity certificates. The power production will increase from a mean annual production of 537 GWh to 628 GWh. The cost is estimated to approximately 740 million NOK (price level 2010; about 100 million US$ with rate May 2015).

	Hemsil 2	Hemsil 3	Sum
Gross head, m	370	370	
Maximum discharge, m^3/s	31	25	56
Capacity, MW	2x49 = 98	83	181
Turbine type	Francis	Francis	
Production, GWh/year	537		628
Increased production, GWh/year			91
In operation, year	1959-60	Planned 2019	

Salient features for Hemsil 2 and Hemsil 3

Some key considerations are described in the next.

Selection of outlet and gross head (main alternative)

Three alternative locations for tailrace tunnel and outlet elevation were considered. The selected solution is a common tailrace tunnel for Hemsil 2 and Hemsil 3. This means that Hemsil 3 will be constructed with the same gross head as Hemsil 2. The two other alternatives had outlet downstream the selected outlet, and then a higher gross head, higher capacity and higher production (same design discharge). However, these alternatives were rejected, mainly due to high costs.

Reduced head loss (main alternative)

There is a significant head loss in existing Hemsil 2 HPP, especially when the power plant is working under full capacity (up to 98 MW). In such situations the head loss in the tunnel is approximately 22 m. When the power plant is working on 2/3 of maximum capacity, the head loss is around 12 m.

When a new parallel tunnel is built, the head loss for full capacity up to 183 MW will be around 18 m for Hemsil 2 and 15 m for Hemsil 3. With 2/3 of this capacity the head loss will be reduced to around 10 m.

Capacity and production (primary alternative)

Since the existing power plant Hemsil 2 HPP has significant surplus water, it is important to increase the capacity. This could be achieved either by total rebuilding of Hemsil 2 powerhouse and replace its existing units, or build a new nearby power station. Rebuilding of Hemsil 2 powerhouse would require extensive works including larger headrace tunnel dimensions. It would also give limited capacity increase. A realization would require about 1.5 year downtime, estimated to +500 GWh in lost production.

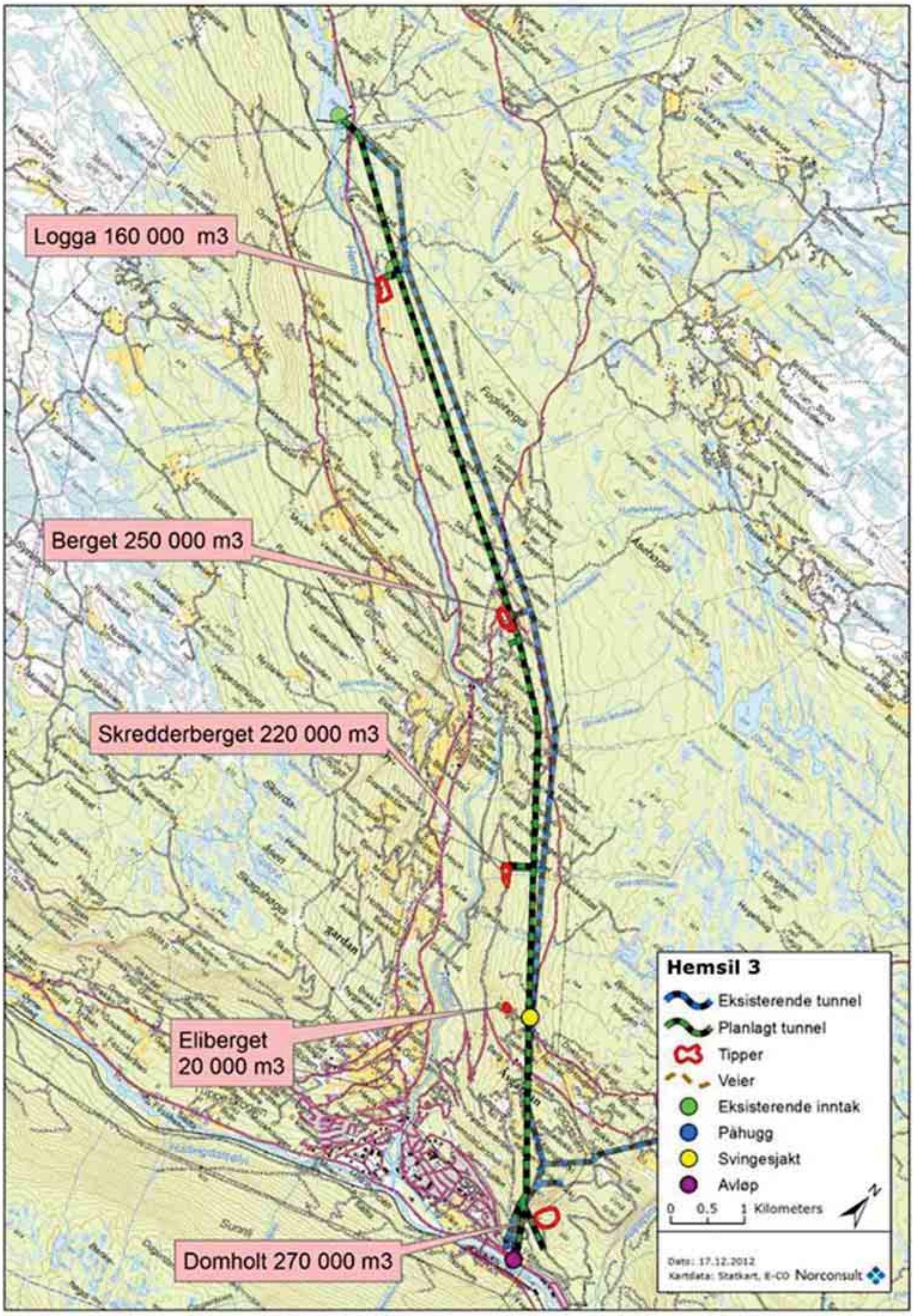
Building a new powerhouse gives opportunity to optimize the capacity. A new intake can be integrated in the intake pond Eikredammen without reducing the flood capacity.

A single large Francis turbine was chosen. Two smaller units instead of a single unit were considered, but this is a more costly solution. By building a new powerhouse, Hemsil 2 will be in operation mainly without significant downtime during construction period. The new powerhouse will in addition to increased capacity also increase the total plant efficiency. The new equipment will at least be of a “state of the art” standard, but it will be left to later phases to consider eventual specific features or innovative technology for E&M equipment.

There are in fact only a few crucial challenges regarding construction works. The new power station and the new waterway will be built while the existing power station is in operation.

Safety

The existing powehouse has only one access tunnel for operating staff and equipment. There should preferably be an additional emergency tunnel to meet today's standard requirements regarding working environment for operating staff. Hemsil 3 will provide an emergency tunnel for both Hemsil 2 and Hemsil 3.



Hemsil 3. Outline of the project. New waterway from Eikredammen to new power station at Gol

Ecological water flow

In the application, E-CO Energi suggested a minimum water flow (ecological water flow) of 200 l/s in summertime (15th of May to 30th of September) and 50 l/s in wintertime (first of October to 14th of May). This is twice the voluntary environmental water flow which started in 2011, and represents a loss of power production of 2-3 GWh compared with no requirements. It is E-CO Energi's opinion that this level of water flow, together with fish-friendly measures in the river bed, will safeguard rare plants and improve fish spawning and living areas.

NVE has recommended a larger minimum water flow, with 500 l/s in summer season and 150 l/s in winter season. This will increase production loss with about 6 GWh/year. Additional production will then be 85 GWh per year in mean.

Improving the water landscape in Hemsil by concentrating the river stream (2010)

Planned project execution

Construction works are expected to start in 2016-17. This will depend on time for granted licence and given an investment decision. Expected construction time is 2.5 years. The new power station Hemsil 3 is scheduled to be in operation in 2019 or 2020.

In brief, the first year will be dedicated to rock and tunnel excavation (approximately 1 mill. m^3). The second year will mainly be about concrete work in the power house and in the intake.

The third and last year is mainly about installing the power generating equipment (one Francis turbine and a generator. About 250,000 site hours will be executed during these 2.5 years.

3. Feature of the Project

3.1 Best Practice Components

By renewing the waterway and the plant and powerhouse, predictable and cost efficient power production with minimized environmental footprint is secured for the next 50-100 years. After almost 60 years in service, the combined regulated and run of river hydropower plant will be renewed to a state of art plant. This gives annually up to about 91 GWh new power production qualified for electricity certificates. This will be obtained at a preliminary enterprise cost of 740 million NOK (100 million US$ with rate per May 2015).

3.2 Reasons for Success

Success will depend on:

- Introduction of Norwegian –Swedish Electricity Certificate Market
- Cost-efficient civil engineering and construction
- Skilled suppliers with significant experience
- State of art project management

4. Points of Application for Future Project

This project can be a benchmark for future similar projects with water surplus and a potential to improve efficiency.

5. Others (monitoring, ex-post evaluation, etc.)

Annual energy production increase will be monitored and analyzed.

Impact on biodiversity and fish population will also be monitored and analyzed.

6. Further Information

6.1 References

Halvor Kr. Halvorsen (Business Manager, E-CO Energi AS): "Planning, economic drivers and decision making for Hemsil 3 HPP – an extension of Hemsil 2 HPP", presented at Hydro 2013 in Innsbruck. October 2013.

Halvor Kr. Halvorsen: "Hemsil 3. Capacity extension of existing HPP Hemsil 2". IEA Hydropower Implementing Agreement, Annex XI, Gol, Norway, June 2013.

6.2 Inquiries

Company name: E-CO Energi AS

URL: www.e-co.no